

Prepared for:
City of Waterloo

**STORMWATER MANAGEMENT MASTER PLAN
(SWM-MP)
MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT**

**Sediment Analysis Memo:
SWM Facilities and OGS Units**



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1 INTRODUCTION

1.1 General

In order to ensure long-term operational effectiveness, it is crucial to remove the sediment accumulated in Stormwater Management (SWM) facilities periodically. The maintenance frequency depends on several variables including type of facility, design storage volume, characteristics of the catchment area and municipal maintenance and operation practices in the contributing catchment area. Sediment accumulation compromises the effective storage volume and the long-term efficiency of suspended solids retention.

This report describes and summarizes the elements involved in the analysis of sediment retention within the Stormwater Management Facilities and Oil and Grit Separator (OGS) Units located in the City of Waterloo.

1.2 SWM Facilities

According to the City's database, there are a total of 59 active SWM facilities currently owned and operated by the City of Waterloo; this includes 45 wet pond facilities and 14 dry pond facilities. Although the City provided original design briefs, Certificate of Approvals, and/or design drawings for these facilities, in many cases, information such as control type of the facility, level of protection, drainage area, impervious area and storage volumes were undefined or unclear. For these cases, whenever possible, data gaps were covered with data gathered using GIS or other studies.

The methodology applied as part of this study was designed to determine the effect of sediment accumulation in City owned and operated SWM facilities. The SWM facilities were grouped according to the facility type. Facility type data was determined from the provided design briefs, Certificate of Approval, GIS data, or design drawing. Dry ponds were analyzed based on the loss of storage capacity, whereas the wet facilities were evaluated based on the minimum SWMF permanent pool volumes prior to maintenance in accordance with the Sustainable Technologies Evaluation Program (STEP) Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands. This approach aims to identify which facilities currently operate under inappropriate conditions.

As part of this analysis, the following should be noted:

- Nine (9) facilities were recently cleaned-out or retrofitted. These facilities were excluded from the analysis. These facilities are identified in **Table 4.2**.
- Six (6) facilities are currently scheduled for retrofit or dredging. These were also excluded from the analysis. These facilities are identified in **Table 4.3**.

- Seven (7) wet facilities were recently assumed by the City from developers. As dredging is part of the assumption process, these facilities were excluded from the analysis. These facilities include: 11, 17, 37, 39, 40, 43, and 65.
- Twelve (12) dry facilities were identified as providing mainly quantity control. In some cases, these facilities also provided an extended detention volume for quality control purposes.
- Twenty-four (24) wet facilities were identified as providing both quality and quantity control (1 provides only quality control and three provide only quantity control), however fourteen (14) of them currently exceed the maximum allowable sediment accumulation as per STEP. In many cases, the permanent pool is almost or completely full of sediment, directly affecting the effectiveness of the facility in terms of water quality.
- Facilities 21 and 64 were removed from analysis due to their tiered drainage system.





In 2015 and 2016, the City of Waterloo undertook an inspection of forty-six (46) of these facilities, examining their existing operational conditions. This information was used to determine the current capacity of each of these ponds and the corresponding maintenance requirements. **Figure 1.1** illustrates all existing SWM facilities within the City of Waterloo.

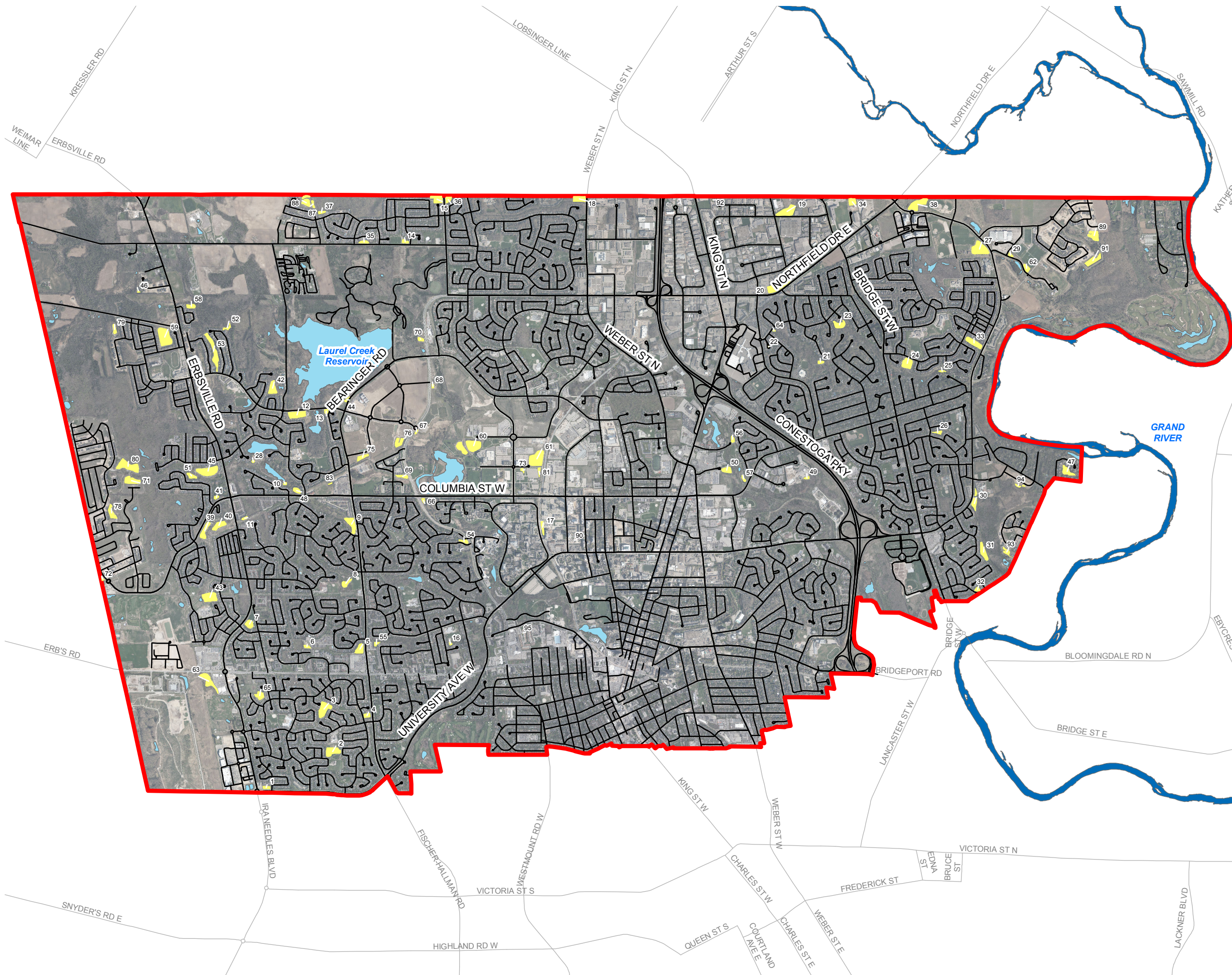
1.3 Oil and Grit Separators (OGS)

According to the City of Waterloo's GIS database, two hundred and forty-one (241) Oil and Grit Separators exist within the City of Waterloo. The City is responsible for the operation and maintenance of sixty-one (61) of these units. In 2016 the City of Waterloo undertook an inspection of forty-seven (47) of these structures, examining their existing operational conditions and structural aspects. The 2016 survey identified immediate service requirements for six (6), and categorized eight (8) additional units under 'Try to Clean'. Following this inspection, maintenance was undertaken for twelve (12) of the most critical units.

Based on manufacturer specifications, this study concluded that eight (8) OGS units require maintenance. Since the reported sediment depths are based on 2016 inspections it is assumed that two (2) additional units have also reached the maintenance threshold. The manufacturer specifies the sediment depth within the OGS when maintenance is required, which corresponds to a drop in OGS capacity of approximately 15%. A standard OGS maintenance practice involves the cleanout of units on a 2-3 year maintenance cycle. Therefore, the twelve (12) units cleaned out in 2016 should also receive maintenance this year as part of a three year maintenance cycle. The study was inconclusive for fourteen (14) structures due to the lack of inspection information with regards to sediment depth. **Figure 1.2** illustrates all OGS structures within the City of Waterloo, separated into those owned, operated and maintained by the City, Region and private entities.

**FIGURE 1.1:
EXISTING STORMWATER MANAGEMENT POND**

-  Roads
-  Stormwater Management Ponds
-  Water Bodies
-  Rivers









0 0.5 1 Kilometers










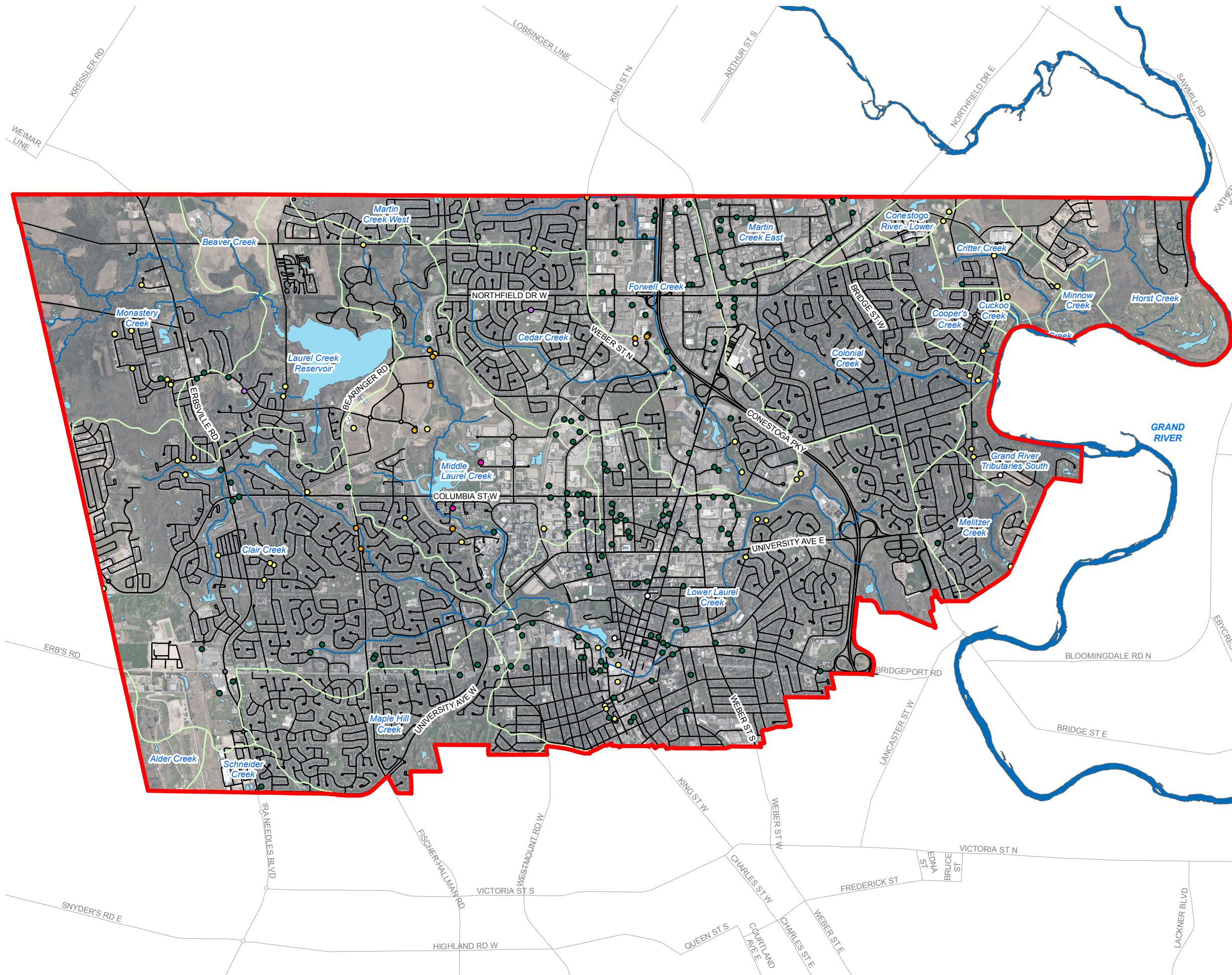
**MUNICIPAL CLASS EA
STORMWATER MANAGEMENT
MASTER PLAN**

**FIGURE 1.2:
EXISTING OGS STRUCTURES**

-  Watercourse
-  Roads
-  Water Bodies
-  Rivers
-  Subwatershed Boundary
-  Study Area

Existing OGS Structures

-  City of Waterloo
-  Region of Waterloo
-  Private
-  University of Waterloo
-  WCDSB
-  WRDSB
-  Null



0 0.5 1 Kilometers



2 Report Structure

The main purpose of this report is to describe the current operational conditions of the SWM Facilities and OGS structures located within the City of Waterloo, analyzing the effect of sediment accumulation in each of them in terms of sediment retention efficiency and storage capacity and identifying which structures should be prioritized for maintenance purposes. This report contains the following sections:

- **Section 1** – Provides an overview of the City of Waterloo’s SWM facilities operational conditions and the purpose of the study.
- **Section 3** – Provides information about the sources of the data used in the sediment analysis.
- **Section 4** – Provides a description of the methodology and analysis used for the City of Waterloo SWM Facilities, including assumptions made and overall evaluations, including maintenance prioritization and estimated service costs.
- **Section 5** – Provides a description of the methodology and analysis used for the City of Waterloo OGS Units, including assumptions made and overall evaluations, including maintenance prioritization and estimated service costs.
- **Section 6** – Provides the summary of the overall conclusions of this report.
- **Appendix 1** – Includes description of sediment loadings calculations as recommended by the MOE 2003 Stormwater Management Planning and Design Manual.
- **Appendix 2** – Includes description of water quality storage volume calculations as recommended by the MOE 2003 Stormwater Management Planning and Design Manual.
- **Appendix 3** – Includes description of maximum allowable sediment accumulation as recommended by the 2018 STEP Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands.
- **Appendix 4** – Waterloo Stormwater Management Facility 2017 Photo Inventory

3 SOURCE OF INFORMATION

The City of Waterloo provided digital copies of the original design briefs and drawings corresponding to most of the existing SWM Facilities, as well as GIS data. OGS data was obtained from the Oil/Grit Separator Database and OGS – Inspection & Cleanout data, both provided to Aquafor Beech Ltd. by the City of Waterloo. Full GIS mapping and data was also provided by the City of Waterloo. Supplemental reports reviewed and included as part of this study included:

- Stormwater Management Facility Assessment – Fifteen Facilities (Ecosystem Recovery, 2017)
- 2015 Stormwater Management Facility Assessment Final Report (Ecosystem Recovery, 2015)

4 SWM Facilities – Analysis & Results

This section contains a description of the analyses procedures, including the data segmentation, initial assumptions, evaluation criteria and details about the calculations performed.

4.1 Data Segmentation

The initial step of the analysis consisted of determining which SWM facilities have recently undergone maintenance processes or are currently scheduled for retrofit, according to data provided to Aquafor Beech Ltd. by the City of Waterloo. The remaining facilities were treated according to their classification and control type.

The primary source of data used in the analyses was the original design brief reports, from which the original features of each facility, including but not limited to:

- Drainage area,
- Impervious area,
- Operational volumes,
- Level of protection,
- Control type,
- Detention requirements and
- Design criteria.

Whenever data was missing from the design briefs, design drawings, Environmental Compliance Approvals (ECAs), and GIS data were used to fill the gaps. For the cases with inconclusive or conflicting data regarding the facility classification and type of control, digital aerial photos served as mean of identifying the characteristic of the facility and normal level protection was assumed for wet pond facilities.

Sediment data was obtained from the 2015 and 2016 Ecosystem Recovery Survey for most of the facilities. For those cases with inconclusive or non-existing sediment information, an estimate of the annual sediment load was developed based on Table 6.3 of the MOE 2003 Stormwater Management Planning and Design Manual, as shown in **Appendix 1**.

4.1.1 Data Gaps

Nine (9) ponds (35, 59, 11, 17, 37, 39, 40, 43, and 65) were not inspected by Ecosystem Recovery in 2015 or 2016; ponds 35 and 59 should be surveyed and inspected to confirm their current condition. The remaining 7 are newly assumed and do not require inspection. Different sources of data related to the SWM Facilities were consulted in order to obtain enough information to complete the analysis. The following table summarizes the facilities with missing information.



Figure 4.1 Pond 35

Table 4.1 – Facility Data Gaps

Facilities Lacking Information	
Design Brief	Bathymetric Survey
2, 8, 9, 10, 18, 21, 23, 25, 32, 41, 48, 50, 58, 64	35, 59

Important information from the design briefs included year constructed, drainage area, impervious area, storage volumes, and control type. Design drawings, Environmental Compliance Approvals (ECAs), and GIS data was used to fill in missing data. The imperviousness of each drainage area was assumed based on GIS land use data. Impervious levels were assigned to each land use using the existing City of Waterloo mapping and applied to each drainage area.

4.2 Sediment Accumulation

Sediment accumulation was determined based on the type of facility and the control provided. The methodology explained in the following sections were utilized to complete the analysis for dry facilities and wet facilities.

4.2.1 Dry Facilities

All facilities not containing a permanent pool were categorized as dry facilities providing mainly quantity control, although some of these are described as also providing quality control due to the inclusion of extended detention storage in the original design. Since the main purpose of these facilities is not the retention of sediment, the effect of sediment accumulation was determined in terms of loss of total storage capacity, calculated as shown in **Equation 1**.

$$\text{Storage Loss (\%)} = \frac{\text{Volume of Sediment in 2015/2016 (m}^3\text{)}}{\text{Total Storage Capacity (m}^3\text{)}} \cdot 100 \quad (1)$$

4.2.2 Wet Facilities

All facilities containing a permanent pool were considered wet facilities. The primary purpose of wet facilities is sediment retention. The permanent pool component of wet facilities is the most important contributor for suspended solids removal, therefore any substantial loss in storage

capacity due to sediment accumulation and lack of maintenance compromises the overall performance in terms of quality control.

The 2015 and 2016 Ecosystem Recovery surveys provided a sediment volume for each facility. As per the 2003 MOE Stormwater Management Planning and Design Manual (SWMPD), the maximum allowable sediment accumulation within a facility is based on a 5% decrease in the target removal efficiency. The TRCA 2018 Inspection and Maintenance Guide for Stormwater Management Ponds and Construction Wetlands provides a table (**Appendix 3**) summarizing the maximum allowable sediment accumulation (m^3/ha) in SWMFs based on the imperviousness of the drainage area.

The 2019 Accumulated Sediment Volumes were determined for each facility by applying sediment loading rates to each facility drainage area. Sediment loading rates reported by Ecosystem Recovery were primarily used; for any facility missing sediment loading rate data Annual Sediment Loadings were determined from the SWMPD (**Appendix 1**). To determine the current reduction in capacity of each facility, the 2019 volumes were compared to the maximum allowable sediment accumulation. The maximum allowable sediment accumulation is determined using the % imperviousness of the drainage area and the level of protection provided by the facility.

4.3 Maintenance Records

4.3.1 SWM Facilities Maintenance Records

Of the fifty-nine (59) facilities listed in the analyzed datasets, nine (9) have received maintenance recently, six (6) are currently scheduled for retrofit, and seven (7) were recently assumed by the City from developers; therefore these facilities were not assessed in terms of sediment accumulation. **Table 4.2** presents the complete list of facilities with maintenance records (previously cleaned-out).

Table 4.2 – List of Facilities Cleaned Out and/or Repaired

SWM Pond #	Year of Construction	Facility Type	Control Type	Drainage Area (ha)	Year Completed
20	1989	Wet Pond	Quality / Quantity	75	2017
30	1996	Wet Pond	Quality / Quantity	7.4	2017
33	1997	Wet Pond	Quality / Quantity	30.9	2017
38	1999/2008	Wetland	Quality / Quantity	54.9	2017
12	1994	Wet Pond	Quality	19.3	2017
52	2002	Wet Pond	Quality / Quantity	6.1	2017
7	2004	Wet Pond	Quality / Quantity	22.1	2017
14	1996	Wet Pond	Quality / Quantity	10.2	2017
55	2000	Wet Pond	Quality / Quantity	4.27	2018

Table 4.3 shows the list of facilities currently scheduled for retrofit in order of prioritization.

Table 4.3 – SWM Facilities Scheduled for Retrofit

Facilities Scheduled for Retrofit				
SWM Pond #	Year of Construction	Facility Type	Control Type	Drainage Area (ha)
53	2003	Wet Pond	Quality / Quantity	19.4
48	1990	Wet Pond	Quality / Quantity	26.5
10	1993	Wet Pond	Quality	10.4
28	1999	Wet Pond	Quality	4
3	1992	Wet Pond	Quality / Quantity	69.8
4	1979	Dry Pond	Quantity	142.9

* - Unavailable data

Table 4.4 shows the list of facilities recently assumed by the City from developers.

Table 4.4 - SWM Facilities Recently Assumed by City

Facilities Scheduled for Retrofit				
SWM Pond #	Year of Construction	Facility Type	Control Type	Drainage Area (ha)
11	1992	Wet Pond	Quality / Quantity	*
17	*	Wet Pond	Quality / Quantity	*
37	1989	Wet Pond	Quality / Quantity	*
39	2001	Wet Pond	Quality	30.4
40	2012	Wet Pond	Quality / Quantity	*
43	2002	Wet Pond	Quality / Quantity	56.43
65	2005	Wet Pond	Quality / Quantity	23.67

* - Unavailable data

4.4 Cost Analysis

Maintenance costs were estimated for the facilities currently operating at less than acceptable efficiency. The calculations were based on the costs of previous sediment removal works completed in the City of Waterloo and surrounding area. Maintenance service costs for all facilities were determined using a value of \$180/m³ of sediment.

Dry pond retrofit costs were determined based on the amount of excavation required to incorporate an enhanced level permanent pool into the facility.

4.5 Maintenance Forecast

Structures that currently do not require any maintenance were analyzed upon their future need for maintenance. For the facilities without sediment data, sediment load estimates, as shown in **Appendix 1**, were used to determine the maintenance forecast.

4.5.1 Dry SWM Facilities Forecast Criteria

For forecast calculation purpose, the maintenance requirement of dry facilities was considered as being a drop of 5% of its storage capacity.

4.5.2 Wet Facilities Forecast Criteria

Wet facilities maintenance forecast was made based on the assumption of 5% loss of performance due to sediment accumulation as being the indication of maintenance requirements.

4.6 SWM Facilities Results

The assessment described in the following sections aims to classify all facilities according to the respective priority for maintenance purposes. The prioritization ranking was based on the amount of sediment within each facility and the effect of this accumulation in terms of loss in storage or decrease in performance. **Appendix 4** contains a photo inventory of every SWM Facility for reference.

4.6.1 Dry Facilities

Since dry facilities focus on quantity control, they were assessed in terms of loss in storage capacity only. In some cases, the design brief reports did not present sufficient information to base the study solely on original data. For these facilities, GIS data had to be introduced so that the calculations could be conducted. Similarly, sediment loads had to be estimated for the facilities that did not have sediment data from the study developed by Ecosystem Recovery in 2015 and 2016. **Table 4.5** consists of an overview of the dry SWM facilities, including the ranking criteria utilized in this report.

Table 4.5 – Dry SWM Facilities Summary

Number of dry SWM facilities analyzed	12
Number of dry SWM facilities with no loss in storage	1
Number of dry SWM facilities with loss in storage	11
1% - 5% loss (small loss)	9
6% - 10% loss (moderate loss)	1
11% - 20% loss (large loss)	1
>20% loss (extreme loss)	0

Table 4.6 displays the list of dry facilities ranked according to their decrease in storage capacity. It also includes sediment load estimates, maintenance requirements, and estimated maintenance costs. **Figure 4.2** shows the locations of the facilities prioritized according to their maintenance priority.

Table 4.6 – Dry Facilities Sediment Analysis Results

SWM Facility #	Year of Construction	Type of Facility	Control Type	Drainage Area (ha)	Imperviousness	Storage Capacity (m ³)	Sediment Load Rate (m ³ /yr)	Volume of Sediment in 2016 (m ³)	Decrease in Storage Capacity	Subwatershed Name and Priority	Maintenance Priority	Estimated Maintenance Cost
36	1988	Dry Pond	Quantity	12.86	0.57	3,800	25.78	Vegetation	2%	Martin Creek West - 3	High Priority*	\$ 13,920.20
8	1991	Dry Pond	Quantity	78.4	0.45	13,900	97.27	Vegetation	2%	Clair Creek – 2	High Priority*	\$ 52,525.64
16	1994	Dry Pond	Quantity/Quality	2.94	0.42	1,231	2.99	75	7%	Maple Hill Creek – 2	Moderate Priority	\$ 15,116.02
22	1997	Dry Pond	Quantity	1.18	0.57	61	2.37	0	12%	Colonial Creek - 2	Low Priority*	\$ 1,277.28
13	1995	Dry Pond	Quantity/Quality	5.5	0.64	2,501	13.30	95	5%	Laurel Creek Reservoir - 3	Low Priority	\$ 24,282.25
18	1986	Dry Pond	Quantity	84	0.51	12,660	136.30	8	3%	Forwell Creek- 1	Low Priority	\$ 75,041.27
6	2014	Dry Pond	Quantity/Quality	62.25	0.47	8,867	85.16	0	3%	Clair Creek – 2	Low Priority	\$ 45,985.02
2	1987	Dry Pond	Quantity	37.9	0.52	7,000	63.91	0	3%	Maple Hill Creek – 2	Low Priority	\$ 34,510.92
32	1992	Dry Pond	Quantity	4.3	0.69	2,400	11.90	19	2%	Melitzer Creek - 3	Low Priority	\$ 9,848.12
26	1989	Dry Pond	Quantity	17.91	0.58	4,700	37.04	0	2%	Colonial Creek - 2	Low Priority	\$ 20,002.14
9	1985 ¹	Dry Pond	Quantity	81.5	0.51	48,535	132.24	65	1%	Clair Creek – 2	Low Priority	\$ 83,110.76
23	1992	Dry Pond	Quantity	4.3	0.57	11,000	8.62	11	0%	Colonial Creek - 2	Low Priority	\$ 6,634.50
											Total Cost	\$ 464,573.93








1 - Based on design drawing date

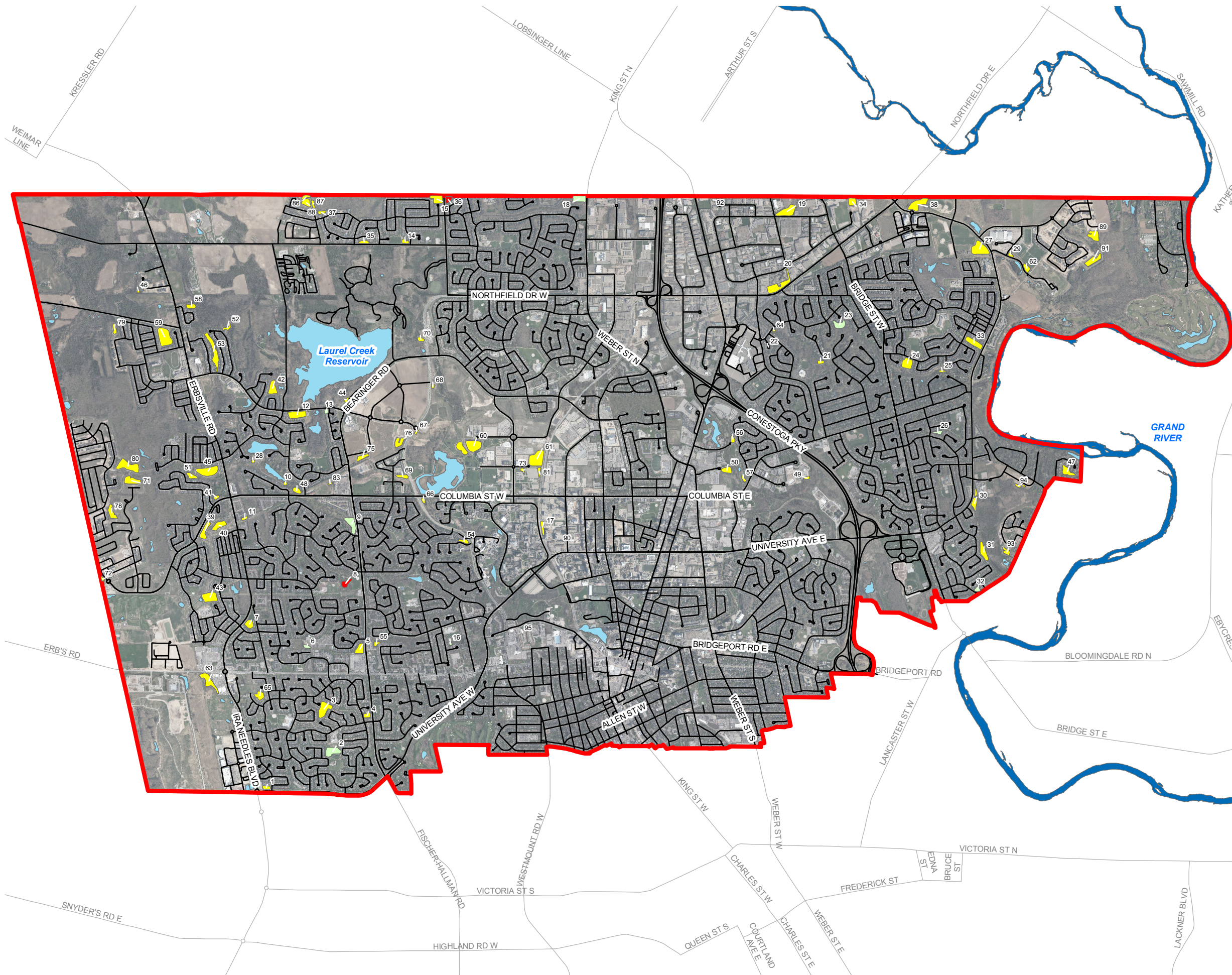
2 - Estimated values based on MOE Design Guidelines

3 – Ecosystem Recovery Surveyed Values (2016)

*Maintenance priority designation discussed in the following section

**FIGURE 4.2:
DRY SWM POND MAINTENANCE PRIORITY**

-  Roads
-  Stormwater Management Ponds
-  Water Bodies
-  Rivers
- SWM Facility Maintenance Priority**
-  High Priority
-  Moderate Priority
-  Low Priority



0 0.5 1 Kilometers



Although dry facilities provide mainly quantity control, some of these facilities were also designed to provide quality control per the included extended detention. Accumulation of high loads of sediment not only affects the peak runoff control, but may also invalidate the contribution of the extended detention volume. As shown in **Table 4.6**, facility 23 is currently operating with full capacity, and the remaining facilities operate at small to moderate loss.



Figure 4.3 High vegetation in Pond 36

Using the sediment loading rate obtained from the Stormwater Management Planning and Design Manual, Facility 22 would have a decrease in storage capacity of 12% indicating it was operating at a large loss. However, in 2016 Ecosystem Recovery observations indicate that facility 22 has not accumulated sediment, and remains in the state it was installed in in 1997. Therefore, this facility has been prioritized as a low priority for maintenance.

The previous surveys completed by Ecosystem Recovery (2016) noted high vegetation within Facilities 36 and 8, therefore these facilities have been prioritized for maintenance based on these observations.

4.6.2 Wet Facilities

Wet facilities are designed to provide quality control via the incorporation of a permanent pool. Volumetric water quality criteria differ according to the type of facility and the adopted level of protection, as discussed in the **Appendix 2** of this report. Similar to the analysis developed for the dry facilities, GIS data was used in order to fill data gaps from the original design brief reports. Also, sediment load estimates were necessary whenever there was no data on the study developed by Ecosystem Recovery in 2015 and 2016. **Table 4.7** includes the overview of the wet SWM facilities, including the ranking criteria utilized in this report. Facility 21 and Facility 64 control a tiered drainage system, and as such were removed from the analysis.

Table 4.7 – Wet SWM Facilities Summary

Number of Wet SWM facilities Analyzed	24
Number of Wet Facilities with No Decrease in TSS Removal Performance	0
Number of Wet Facilities with Decrease in TSS Removal Performance	24
1% - 5% loss of performance (small loss)	10
6% - 10% loss of performance (moderate loss)	9
11% - 20% loss of performance (large loss)	5
>20% loss of performance (extreme loss)	0

The decrease in performance considered in **Table 4.7** represents the loss when compared to the initial efficiency (estimated based on the original features of each facility according to the design brief reports), so only the influence of sediment accumulation is considered.








Table 4.8 includes the results of the sediment analysis performed for the wet SWM facilities, including performance estimates, maintenance requirements, cost estimates and maintenance forecasts. **Figure 4.4** displays the wet facilities prioritized for maintenance.

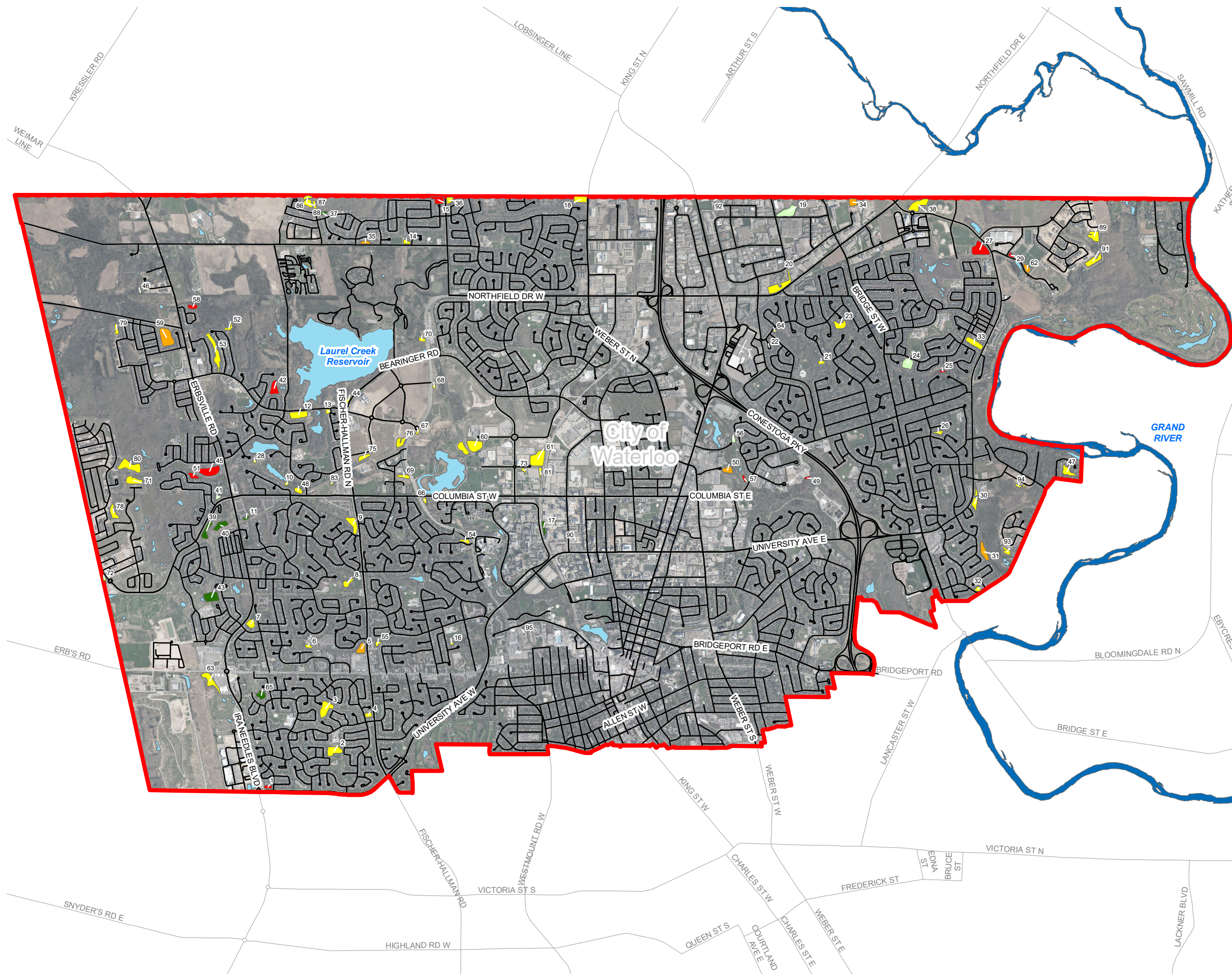
Table 4.8 – Wet Facilities Sediment Analysis Results

SWM Facility #	Type of Facility	Year of Construction	Control Type	Drainage Area (ha)	Imperviousness	Permanent Pool Volume (m ³)	Sediment Load Rate (m ³ /yr)	Volume of Sediment in 2019 (m ³)	Maximum Allowable Sediment Accumulation (m ³ /ha) in SWMFs	% of Maximum Allowable Sediment Accumulation	Maintenance Priority	Estimated Maintenance Cost
51	Wet	2000	Quantity/Quality	13.75	51%	689	3	587	183	321%	High Priority	105,660
42	Wet	1998	Quantity/Quality	34.9	38%	1350	3.2	1924	607	317%	High Priority	346,320
1	Wet	2000	Quantity/Quality	9.707	55%	300	2.8	516	194	266%	High Priority	92,880
27	Wet	2000	Quantity/Quality	45.72	40%	1377	2.4	2064	812	254%	High Priority	371,520
45	Wet	1999	Quantity/Quality	29.66	50%	6925	2.2	1327	571	232%	High Priority	238,860
49	Wet	2002	Quantity/Quality	6.3	80%	751	6.4	724.28	380	191%	Moderate Priority	130,370
35	Constructed Wetland	2002	Quantity/Quality	8	55%	432	15.2	258.4	160	162%	Moderate Priority	46,512
59	Constructed Wetland	2002	Quantity/Quality	8.13	55%	8825	15.447	262.599	163	162%	Moderate Priority	47,268
25	Wet	1986	Quantity/Quality	3.24	55%	104	0.8	89	65	138%	Moderate Priority	16,020
15	Wet	1995	Quantity/Quality	41.3	56%		1.2	1203	892	135%	Moderate Priority	216,540
29	Wet	2000	Quantity/Quality	8.21	70%	804	2.5	386	296	131%	Moderate Priority	69,480
57	Wet	2001	Quantity/Quality	5.18	53%	400	1.3	122	102	120%	Moderate Priority	21,960
58	Wet	2003	Quantity/Quality	5.83	60%	380	4.1	383	321	119%	Moderate Priority	68,940
62	Wet	2000	Quantity	7.4	10%	468	26	499	N/A	107%	Moderate Priority	89,820
34	Wet	1997	Quantity/Quality	24.9	81%	2740	1.6	855	903	95%	Low Priority	153,900
31	Wet	1995	Quantity/Quality	50.66	53%		1.8	826	1000	83%	Low Priority	148,680
5	Wet	2006	Quantity/Quality	80.2	55%	4679	1.1	1185	1622	73%	Low Priority	213,300
50	Wet		Quality	12.3	74%			306	452	68%	Low Priority	55,080
54	Constructed Wetland	2001	Quantity	8.13	45%	334	19	225	N/A	67%	Low Priority	40,500
19	Wet	2000	Quantity/Quality	36.6	82%	1500	0.9	652	1326	49%	Low Priority	117,360
41	Wet	1999	Quantity/Quality	18.1	59%	460	0.6	213	440	48%	Low Priority	38,340
56	Wet	1999	Quantity/Quality	25.55	58%	2245	0.4	201	511	39%	Low Priority	36,180
46	Wet	2013	Quantity	50.66	42%	1266	54	321	N/A	25%	Low Priority	57,722
24	Wet	1995	Quantity/Quality	80	58%	1600	0.6	422	6080	7%	Low Priority	75,960
											Total Cost	2,799,172

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**FIGURE 4:
WET SWM POND MAINTENANCE PRIORITY**

- Roads
-  Stormwater Management Ponds
-  Water Bodies
-  Rivers
- SWM Facility Maintenance Priority**
-  High Priority
-  Moderate Priority
-  Low Priority
-  No Maintenance Required



0 0.5 1 Kilometers



As shown in **Table 4.8**, sediment accumulation in facilities 51, 42, 1, 27, 45, 49, 35, 59, 25, 15, 29, 57, 58, and 62 have exceeded a 5% reduction in sediment removal efficiency. Due to this reduction these facilities cannot achieve the designed TSS removal.



Figure 4.5 Facility 51

Facilities 62, 46, and 54 provide quantity control for drainage areas that have additional water quality controls including ponds designed for water quality and OGS units. These units were analyzed based on loss in storage capacity using the same methodology as the dry facilities in the previous section.

Facility 62 was originally designed to function as a dry pond. However, as confirmed with City of Waterloo staff by Ecosystem Recovery (2015), this pond functions as a wet pond with a permanent pool volume. As concluded in the previous study, further analysis is required to determine if a retrofit is possible/necessary in addition to sediment clean-out.



Figure 4.6 Wet Pond 62

MECP design guidelines state a 5% loss of performance as the indication point of maintenance needs (STEP, 2016). Through the application of this criteria, only ten (10) of the twenty-four (24)

facilities currently do not require maintenance; however facility 34 should require maintenance within the next year.

5 OGS Units – Analysis & Results

5.1 Data Gaps

The provided Oil/Grit Separator Data lacks information regarding any previous inspection data for the OGS structures summarized in the following table:

Table 5.1 – OGS Units Lacking Inspection Data

OGS Units Requiring Inspection	
Asset #	Model
10184315	STC-2000
10080532	STC-750
10080533	STC-1500
10080653	STC-750
10080719	STC-4000
10184316	STC-750
10147141	STC-9000-OUT
10080507	STC-750
10080650	STC-6000
10080697	STC-1500
10080580	STC-750
10080601	STC-3000
10080605	STC-750
10080508	STC-3000

Analysis could not be performed for these units due to the lack of inspection data.

5.2 Sediment Accumulation

Similar to the Dry SWM Facilities' analysis, OGS units were analyzed based solely on their loss in sediment storage capacity, based on the manufacturers' specifications.

5.3 Maintenance Records

As discussed previously, twelve (12) of the most critical OGS units were tendered for clean out in 2016. **Table 5.2** displays the complete list of cleaned out units. As the drainage area and/or sediment loading rate is unknown for these units, a maximum 3 year maintenance period is recommended.

Table 5.2 – List of OGS units Cleaned Out in 2016

Asset ID	Make and Model	Install Year
10080661	STC-750	2005
10080637	STC-4000	2000
10080570	STC-750	2000
10080645	STC-4000	*
10080639	STC-4000	1998
10080535	STC-3000	1998
10080501	STC-1500	2000
10080698	STC-4000	2012
10080550	STC-1500	2003
10080608	STC-1500	1998
10080536	STC-3000	1998
10080654	STC-4000	2012

5.4 Cost Estimate

The cost analysis was based on the Flow Kleen Technology Ltd. Invoice provided by the City of Waterloo, containing the cost of maintenance for the thirteen (13) units cleaned out in 2016. The unit rates for each item remained the same regardless of model type. The cleanout was broken into three (3) items with the following costs:

- Labour and equipment required to clean OGS units (\$240/hr)
- Confined Space Entry (\$450/person)
- Disposal of waste material (\$63/m³)

Therefore, a disposal value of \$63/m³ is the basis of developing cost estimates within this report. Therefore, the cleanout cost was calculated to include the sum of sediment removal and 2 people with confined space entry for 2 hours.

In addition, 25% provisional cost was added to the final price in order to consider other services such as traffic control, implementation of the health a safety plan, removal of contaminated water, removal and replacement of existing damaged structures, supply of materials and other potential construction needs.

5.5 Maintenance Forecast

Due to the lack of specific information regarding the drainage areas and levels of imperviousness, the maintenance forecast was not performed for the OGS units. It should be assumed that maintenance should be performed on all OGS units on a regular schedule, per the manufacturer's specifications and best management practices.

5.6 OGS Results

Within the City of Waterloo there are sixty-one (61) city-maintained OGS units. The Stormceptor model was available for all of these units. Fourteen (14) of these units had no inspection data, therefore the sediment depth was unknown. The Imbrium Stormceptor OGS maintenance guidelines provide recommended maintenance sediment depths for each unit, which are approximately 15% of the unit's total storage capacity. Based on these criteria, eight (8) structures require maintenance. However, the reported sediment depths are based on 2016; it is assumed that two (2) additional units, 10080651 and 10080515, have reached the maintenance threshold and are included in the high priority cleanouts. **Table 5.3** includes the overview of the OGS structures facilities, including the ranking criteria utilized in this report.

Table 5.3 – OGS Units Summary

Number of OGS units Analyzed	61
Number of OGS Units without Inspection Data	14
Number of OGS Units Cleaned Out in 2016 Requiring Maintenance	12
Number of OGS Units with Accumulated Sediment	35
<15% Loss of storage (Maintenance Not Required)	25
Assumed >15% Requires Maintenance	2
>15% Requires Maintenance	8

Table 5.4 shows the results of the OGS sediment analysis, including maintenance prioritization and cost estimates. **Figure 5.1** displays the OGS units prioritized for maintenance purposes.













Table 5.4 – OGS Units Sediment Analysis and Maintenance Requirements

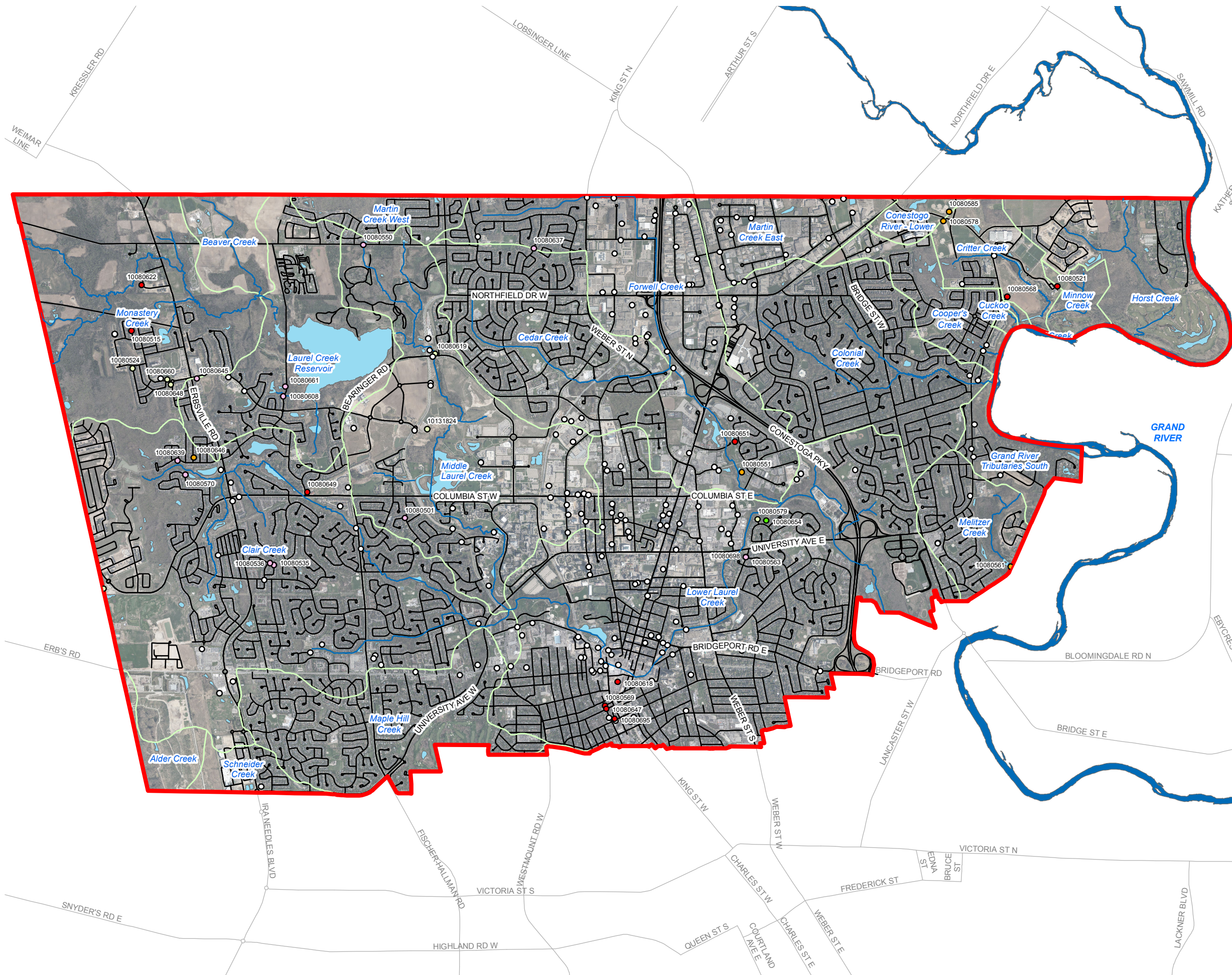
Asset ID	Make and Model	Install Date	Maintenance Threshold Sediment Depth (mm)	Loss in Maintenance Threshold Sediment Storage Capacity (2016)	Maintenance Priority	Total Clean-out cost - Includes Additional Costs for Complementary Services (i.e. Traffic control, Health and safety requirements, removal and replacement of existing structures, etc.) - Estimated as 25% of the total Cost
10080695	STC-1500	01-Jan-99	400	292%	High Priority	1,967
10080622	STC6000	31-Mar-15	425	239%	High Priority	2,566
10080647	STC-1500	01-Jan-99	400	222%	High Priority	1,909
10080563	STC-3000	21-Mar-12	475	160%	High Priority	2,005
10080569	STC-1500	01-Jan-99	400	152%	High Priority	1,851
10080521	STC-2000	24-Apr-01	350	116%	High Priority	1,874
10080649	STC-1000	10-Dec-02	275	111%	High Priority	1,788
10080618	STC-1500	09-Sep-05	400	108%	High Priority	1,814
10080651	STC-6000	29-Sep-99	425	90%	High Priority	2,040
10080515	STC-2000	13-Jun-05	350	87%	High Priority	1,837
10080661	STC-750	02-May-05	230	0%	Maintenance Required	1,773
10080637	STC-4000	12-Oct-00	400	0%	Maintenance Required	1,955
10080535	STC-3000	19-Oct-98	475	0%	Maintenance Required	1,900
10080501	STC-1500	20-Jun-00	400	0%	Maintenance Required	1,808
10080570	STC-750	21-Jul-00	230	0%	Maintenance Required	1,773
10080645	STC-4000	29-Jul-04	400	0%	Maintenance Required	1,955
10080698	STC-4000	21-Mar-12	400	0%	Maintenance Required	1,955
10080550	STC-1500	25-Sep-03	400	0%	Maintenance Required	1,808
10080639	STC-4000	03-Sep-98	400	0%	Maintenance Required	1,955
10080608	STC-1500	01-Jan-98	400	0%	Maintenance Required	1,808
10080536	STC-3000	19-Oct-98	475	0%	Maintenance Required	1,900
10080654	STC-4000	12-Mar-12	400	0%	Maintenance Required	1,955
10080568	STC-1500	21-Sep-09	400	76%	Low Priority	1,788
10080561	STC-2000	06-Sep-00	350	73%	Low Priority	1,818
10080585	STC-2000	15-Sep-00	350	73%	Low Priority	1,818
10080578	STC-4000	15-Sep-00	400	64%	Low Priority	1,871
10080646	STC-1500	03-Sep-98	400	57%	Low Priority	1,772
10080551	STC-6000	29-Sep-99	425	54%	Low Priority	1,914
10080524	STC-2000	13-Jul-04	350	29%	Low Priority	1,762
10080514	STC-1000	13-Jun-05	275	28%	Low Priority	1,741
10080579	STC-4000	21-Mar-12	400	25%	Low Priority	1,783
10080619	STC-4000	27-May-04	400	19%	Low Priority	1,769
10131824	STC-2000	08-Dec-14	350	15%	Low Priority	1,744
10080648	STC-6000	20-Nov-02	425	12%	Low Priority	1,767
10080660	STC-6000	20-Nov-02	425	12%	Low Priority	1,767
10080566	STC-750	15-Jul-10	230	11%	Low Priority	1,730
						\$67,728

Asset ID	Make and Model	Install Date	Maintenance Threshold Sediment Depth (mm)	Loss in Maintenance Threshold Sediment Storage Capacity (2016)	Maintenance Priority	Total Clean-out cost - Includes Additional Costs for Complementary Services (i.e. Traffic control, Health and safety requirements, removal and replacement of existing structures, etc.) - Estimated as 25% of the total Cost
10080572	STC-1000	01-Sep-98	275	0%	No Maintenance Required	
10080607	STC-1000	01-Jan-94	275	0%	No Maintenance Required	
10080644	STC-1000	01-Jun-99	275	0%	No Maintenance Required	
10080668	STC-1000	02-Aug-01	275	0%	No Maintenance Required	
10080635	STC-1500	28-Jul-03	400	0%	No Maintenance Required	
10080699	STC-2000	27-Oct-00	350	0%	No Maintenance Required	
10080522	STC-3000	26-May-99	475	0%	No Maintenance Required	
10080573	STC-3000	12-Jul-00	475	0%	No Maintenance Required	
10080575	STC-3000	12-Jul-00	475	0%	No Maintenance Required	
10080567	STC-9000-IN	15-Jun-11	375	0%	No Maintenance Required	
10147141	STC-9000-OUT	15-Jun-11	375		No Maintenance Required	
10080700	STC 1500	01-Jan-00	400		Inspection Required	
10184315	STC 2000	01-Jan-16	350		Inspection Required	
10080532	STC-750	26-Sep-02	230		Inspection Required	
10080533	STC-1500	26-Apr-04	400		Inspection Required	
10080653	STC-750	26-Apr-04	230		Inspection Required	
10080719	STC-4000	23-Oct-09	400		Inspection Required	
10184316	STC-750	01-Jan-16	230		Inspection Required	
10080507	STC-750	26-Apr-04	230		Inspection Required	
10080650	STC-6000	20-Jul-11	425		Inspection Required	
10080697	STC-1500	14-May-03	400		Inspection Required	
10080580	STC-750	26-Apr-04	230		Inspection Required	
10080601	STC-3000	08-Sep-99	475		Inspection Required	
10080605	STC-750	08-Sep-99	230		Inspection Required	
10080508	STC-3000	19-Sep-00	475		Inspection Required	

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**FIGURE 5.1:
OGS UNITS WITH MAINTENANCE PRIORITY**

-  Watercourse
 -  Roads
 -  Water Bodies
 -  Rivers
 -  Subwatershed Boundary
 -  Study Area
- Maintenance Priority**
-  High Priority
 -  Moderate Priority
 -  Low Priority
 -  Maintenance Required
 -  No Maintenance Required
 -  Null



0 0.5 1 Kilometers



6 CONCLUSIONS

This section contains the overall conclusions resulted from the sediment analysis described in this report.

6.1 General Aspects

Many of the SWM facilities (i.e. SWM facilities and OGS units) are currently operating under inefficient conditions and do not provide the required performance. It is important that maintenance actions be undertaken in order to reestablish the desired efficiency within these structures. Sediment accumulation within facilities and structures, and data gaps including design and maintenance data were some of the problems identified in this study. The following section summarizes the findings of this study and recommends actions to address the current status of the facilities.

6.2 Recommended Future Studies

Data gaps encountered within the background data compromised the analysis in some cases. In order to obtain a better profile of the function and maintenance requirements of the facilities it is important to conduct reliable and representative studies. Filling in data gaps should be a priority for future analysis.

In order to cover the data gaps encountered in the provided datasets, Aquafor Beech Ltd. recommends a subsequent study be completed intended to gather information regarding the structures in the following sections.

The methodology utilized as part of this study could then be applied to complete the analysis for all facilities.

6.2.1 *SWM Facilities*

Bathymetric surveys are recommended for facilities 35, 46, 47, and 59 to determine the volume of sediment currently in the facility.

6.2.2 *OGS Units*

The OGS Inspection report provided by the City of Waterloo did not contain multiple OGS units. These units, recorded in **Table 5.1**, should be inspected to determine the current depth of sediment and whether a cleanout is required.

6.3 SWM Facilities Conclusions

The following sections summarize the maintenance priorities for dry and wet stormwater management facilities and oil grit separator units.

6.3.1 Dry Facilities

Dry facilities 36 and 8 should be prioritized for maintenance due to the high vegetation within the facilities, as noted in the Ecosystem Recovery surveys (2016).

Dry facilities provide an opportunity to retrofit the existing facility to provide water quality control in addition to water quantity control. This can be achieved by extending the flow path and incorporating a forebay and permanent pool while maintaining the same facility footprint. The incorporation of water quality control will have the largest impact on facilities with larger drainage areas.

Estimated dry pond retrofit costs are based on previous surface facility construction within the local area within the previous ten (10) years. The unit cost ranged from \$150 to 215/m³ (avg. of \$190/m³) of permanent pool volume created. Previous studies in the GTHA have utilized a rate of \$100/m³ for excavation required to excavate down to the proposed facility inlet (i.e. pipe depth) and a rate of \$140.00/m³ of permanent pool volume created thereafter. Analysis of this approach revealed an average total unit cost of \$175/m³ of permanent pool volume created. As such a range of \$175/m³ to \$190/m³ has been applied to account for unit cost variability and project uncertainty. A minimum construction cost of \$250,000 per facility can be assumed for smaller facilities to account for costs associated with mobilization, demobilization, bonding, erosion and sediment control and dewatering etc.

The Subwatershed Health Analysis completed for the City of Waterloo prioritized subwatersheds based on the current health of the subwatershed. Using the results from this report, quantity control facilities with large drainage areas located in priority subwatershed are ideal retrofit locations. **Table 6.1** summarized the facilities providing the best retrofit opportunities.

Table 6.1 – Dry Pond Retrofit Opportunities

SWM Facility #	Control Type	Drainage Area (ha)	TIMP%	Water Quality Volume Requirement (cu.m/ha) per MOE 2003	Permanent Pool Volume Requirement (Cu.m)	Subwatershed Name and Priority	Estimated Retrofit Cost
18	Quantity	84	51	180	15,120	Forwell Creek-1	\$ 2,646,000
9	Quantity	81.5	51	180	14,670	Clair Creek – 2	\$ 2,567,250
8	Quantity	78.4	45	165	12,936	Clair Creek – 2	\$ 2,263,800
2	Quantity	37.9	52	182.5	6,917	Maple Hill Creek – 2	\$ 1,210,450

6.3.2 Wet Facilities

Sediment accumulation has resulted in a decrease in performance for multiple facilities, including reductions greater than a 5% reduction in TSS removal efficiency. Fourteen (14) wet facilities currently require maintenance due to sediment accumulation. Wet facilities 51, 42, 1, 27, 45, 49, 35, 59, 25, 15, 29, 57, 58, and 62 should be prioritized for maintenance.

Table 6.2 shows the list of wet facilities with high priority maintenance needs along with estimated costs.

Table 6.2 – Wet Ponds Maintenance Priority

Priority Ranking	SWM Facility #	Estimated Maintenance Cost (\$)
1	51	105,660
2	42	346,320
3	1	92,880
4	27	371,520
5	45	238,860
6	49	130,370
7	35	46,512
8	59	47,268
9	25	16,020
10	15	216,540
11	29	69,480
12	57	21,960
13	58	68,940
14	62	89,820

6.3.3 OGS Units

The list of OGS units with high priority for maintenance is shown in **Table 6.3**, along with the associated cleanout costs.

Table 6.3 – OGS Maintenance Priority

Priority Ranking	Asset ID	Estimated Maintenance Cost (\$)
1	10080695	1,990
2	10080622	2,646
3	10080647	1,926
4	10080563	2,032
5	10080569	1,863
6	10080521	1,889
7	10080649	1,794
8	10080618	1,823
9	10080651	2,070
10	10080515	1,848
TOTAL		19,881

Appendix 1 –Sediment loadings calculations per the MOE 2003 Stormwater Management Planning and Design Manual.

APPENDIX 1

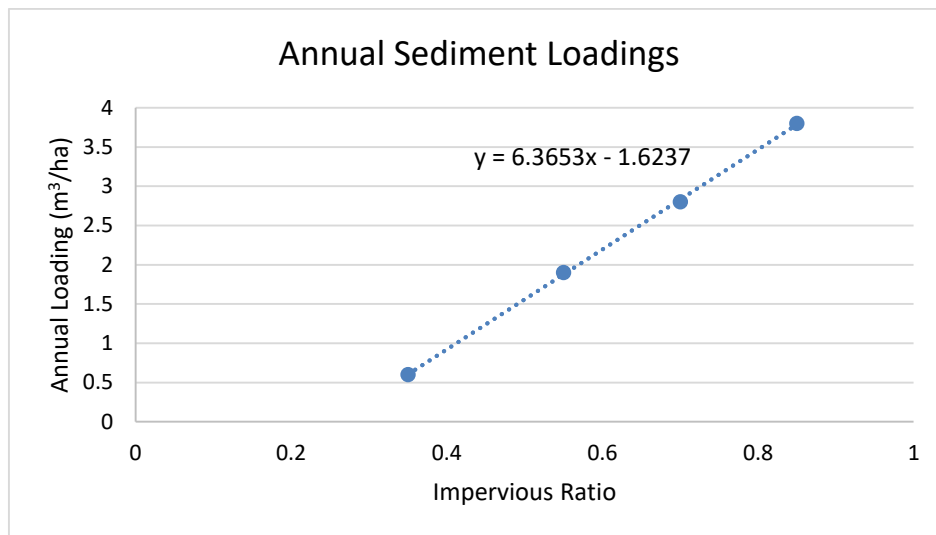
Table 1.A includes the values of the estimated annual sediment loadings for drainage areas based on the level of imperviousness.

Table 1.A - Annual Sediment Loadings

Catchment Imperviousness	Annual Loading (kg/ha)	Wet Density (kg/m3)	Annual Loading (m3/ha)
35%	770	1,230	0.6
55%	2,300	1,230	1.9
70%	3,495	1,230	2.8
85%	4,680	1,230	3.8

Figure 1.A shows the regression equation created from the data in **Table 1.A**. The annual loading rate, in cubic metres per year, is obtained by introducing the impervious area ratio in decimal format to value of x in the equation and multiplying by the total drainage area in hectares contributing to each facility. The actual sediment volume in 2015 is obtained from the annual loading rate and the age of each facility.

Figure 1.A - Annual Sediment Loading Regression Equation



Appendix 2 –Water Quality Storage Volume Calculations per the MOE 2003 Stormwater Management Planning and Design Manual

APPENDIX 2

Table 2.A displays the water quality storage requirements, as recommended by the MOE 2003 Stormwater Management Planning and Design Manual. Of the specified storage volume for wet facilities, 40 m³/ha is extended detention, while the remainder represents the permanent pool.

Table 2.A - Water Quality Storage Requirements Based on Receiving Waters

Protection Level	SWMP Type	Storage Volume (m ³ /ha) for Impervious Level			
		35%	55%	70%	85%
<i>Enhanced</i> 80% long-term S.S. removal	Infiltration	25	30	35	40
	Wetlands	80	105	120	140
	Hybrid Wet Pond/Wetland	110	150	175	195
	Wet Pond	140	190	225	250
<i>Normal</i> 70% long-term S.S. removal	Infiltration	20	20	25	30
	Wetlands	60	70	80	90
	Hybrid Wet Pond/Wetland	75	90	105	120
	Wet Pond	90	110	130	150
<i>Basic</i> 60% long-term S.S. removal	Infiltration	20	20	20	20
	Wetlands	60	60	60	60
	Hybrid Wet Pond/Wetland	60	70	75	80
	Wet Pond	60	75	85	95
	Dry Pond (Continuous Flow)	90	150	200	240

Regression equations for each SWM facility type were created from the values in **Table 2.A**. These equations are shown **Figure 2.A**, **Figure 2.B**, and **Figure 2.C** below. Again, the value “x” represents the contributing impervious area (in decimal form), and the result is a required storage volume in m³/ha. Then the entire equation is multiplied times the contributing drainage area to get the required treatment volume in cubic metres.

Figure 2.A - Water Quality Regression Equations Graph for Enhanced Protection

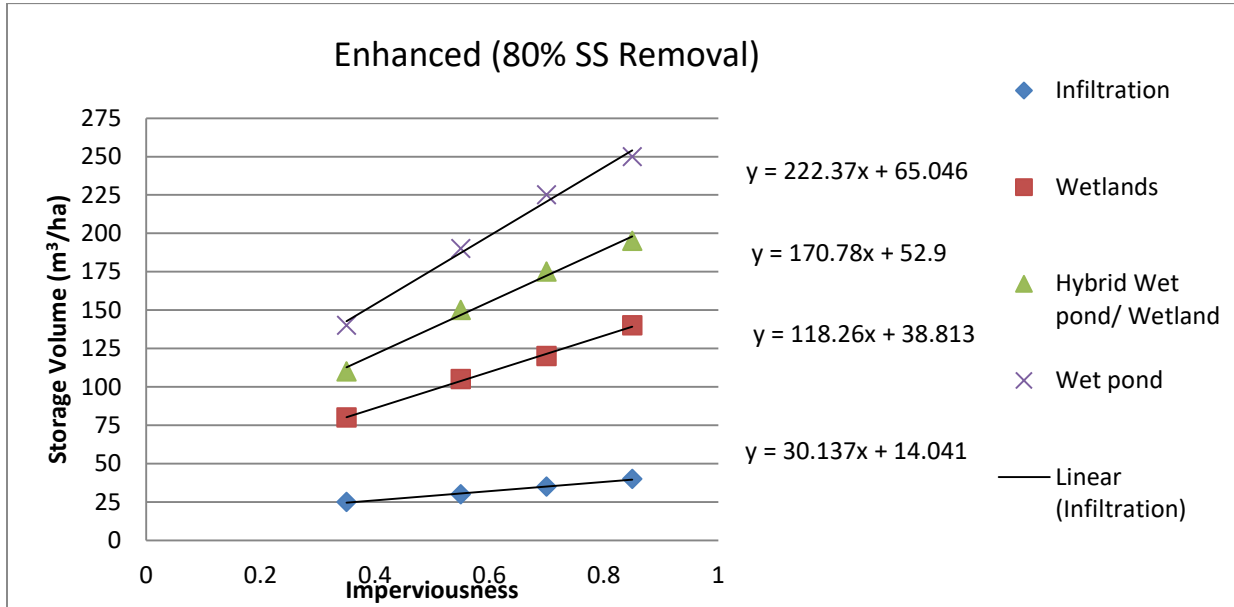


Figure 2.B - Water Quality Regression Equations Graph for Normal Protection

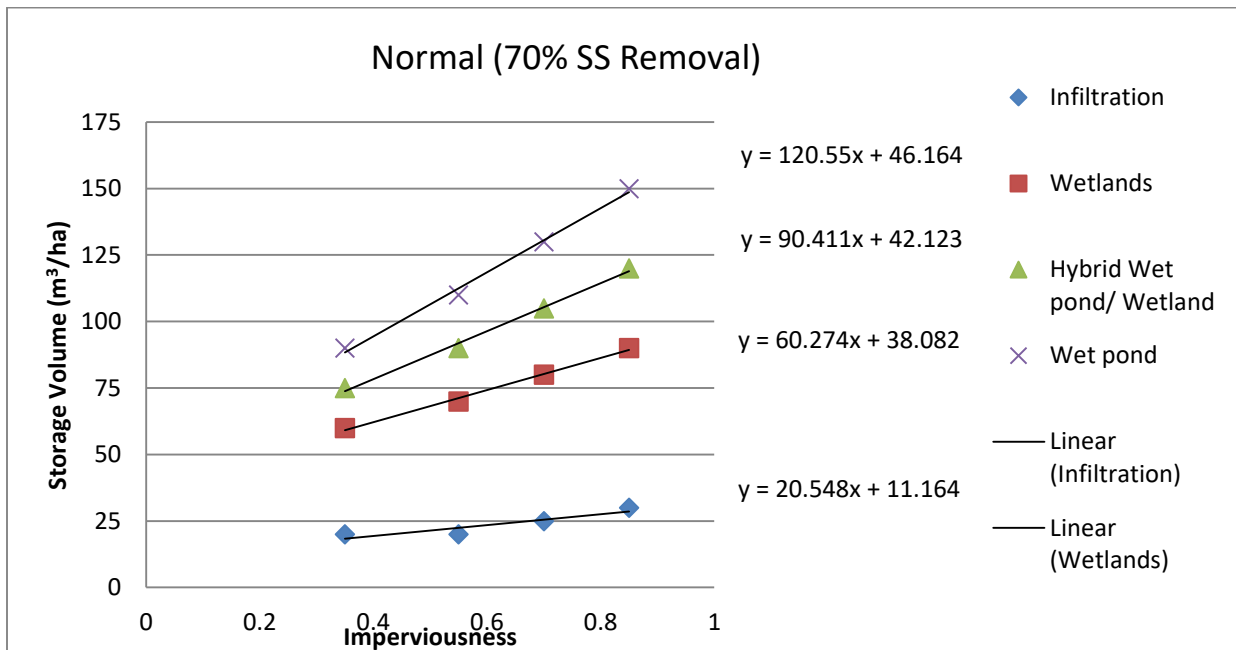
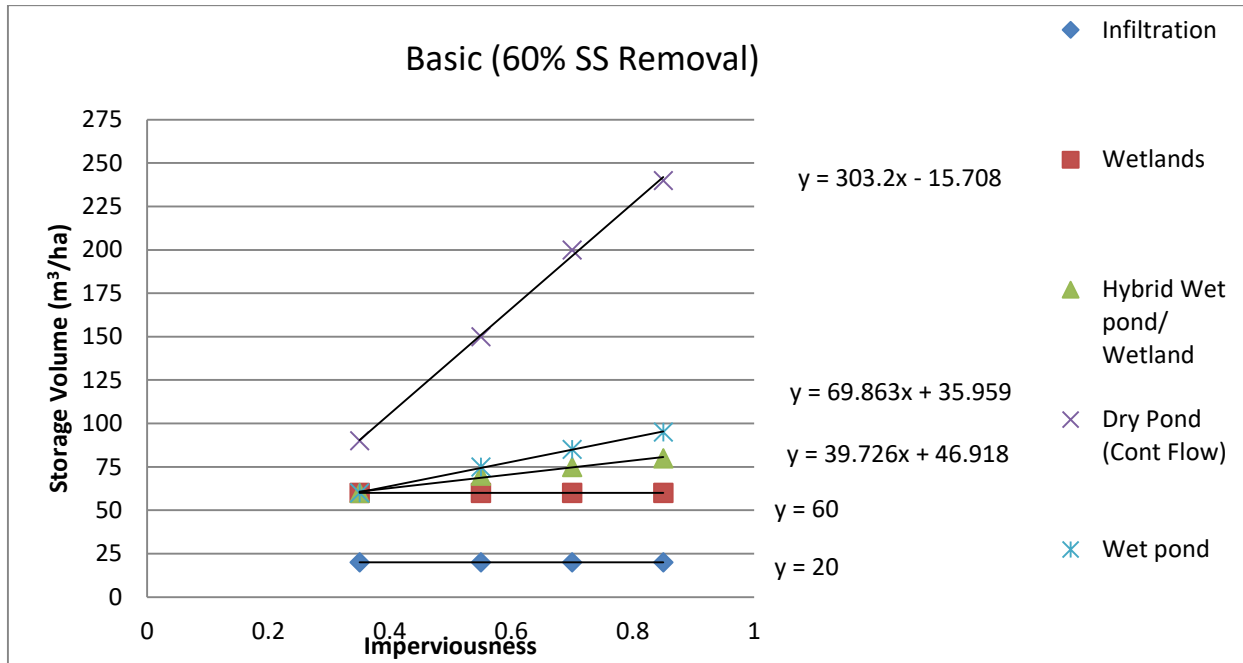


Figure 2.C - Water Quality Regression Equations Graph for Basic Protection



Appendix 3 –Maximum Allowable Sediment Accumulation (m³/ha) in SWMFs per the STEP Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands (2018)

APPENDIX 3**Table 4.1:** Maximum Allowable Sediment Accumulation (m³/ha) in SWMFs.

Protection Level	SWMF Type	Tributary Area Imperviousness			
		35%	55%	70%	85%
Enhanced	Constructed Wetland	12	20	26	33
	Wet Pond	37	52	61	60
Normal	Constructed Wetland	5*	10	16	18
	Wet Pond	17	20	37	36
Basic	Constructed Wetland	5*	5*	5*	5*
	Wet Pond	5*	15	14	19
	Dry Pond	40	69	111	133

Note: These values are based on the MOE SWMPD Manual Figures 4.2 to 4.5, which recommended an allowable 5% reduction in original design storage due to sediment accumulation. * Values cannot be interpolated from volume vs. treatment relations; approximate and/or extrapolated values used.

Appendix 4 – Waterloo Stormwater Management Facility 2017 Photo Inventory

Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 1



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 2



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 3



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 4



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 5



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 6



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 7



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 8



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 9



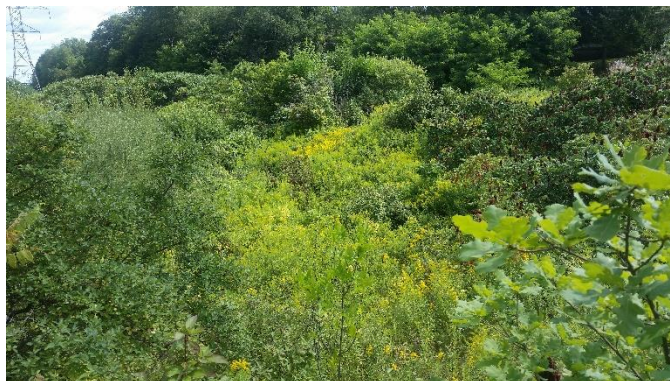
Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 10



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 11



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 12



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 13



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 14



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 15

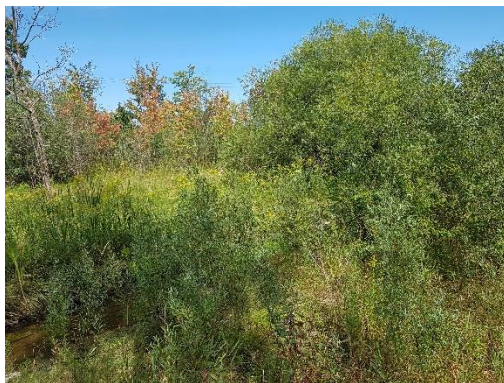


Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 17



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 18



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 19



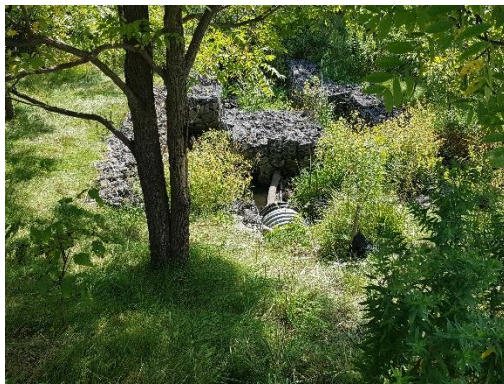
Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 20



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 21



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 23



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 24



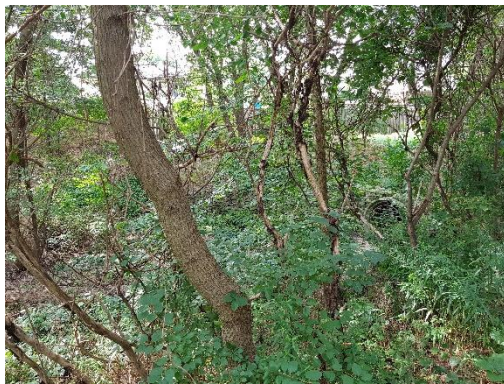
Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 25



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 26



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 27



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 29



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 30



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 31



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 32



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 33



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 34



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 35



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 36



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 37



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 38



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 39



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 40



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 41



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 42



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 43

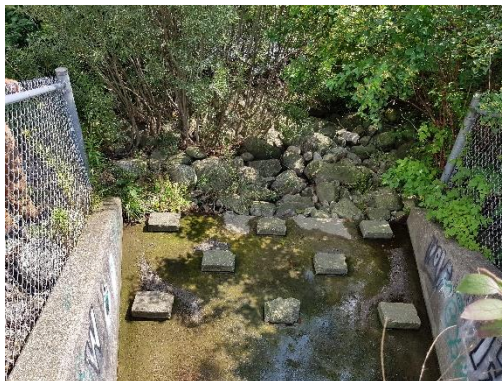


Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 44



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 45



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 46



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 48



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 49



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 50



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 51



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 52



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 53



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 54



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 55



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 56



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 57



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 58



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 59



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 60



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 61



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 62



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 63



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 64



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 65



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 66



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 67



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 68



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 69



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 70



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 71



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 73



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 75



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 76



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 77



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 78



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 79



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 80



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 81



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 83



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 84



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 86



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 87



Waterloo Stormwater Management (August 2017)
Photo Inventory: Pond 88



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 89



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 91



Waterloo Stormwater Management (August 2017)

Photo Inventory: Pond 93

