

INSPECTION AND MAINTENANCE GUIDE FOR STORMWATER MANAGEMENT PONDS AND CONSTRUCTED WETLANDS



Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands

2016 (revised April 2018)

Prepared by:

Toronto and Region Conservation and CH2M Hill Canada Ltd.

PUBLICATION INFORMATION

This guide represents a major update and elaboration of the *Stormwater Management Facility Sediment Maintenance Guide* completed in 1999 by Greenland International Consultants for TRCA and the Stormwater Assessment Monitoring and Performance (SWAMP) Program. This guideline was prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program. Consulting support was provided by Dr. Francine Kelly-Hooper, Soils Scientist, CH2M Canada Limited. Legal support was provided by Janet. L. Bobechko LLP, Certified Specialist (Environmental Law).

Citation: Toronto and Region Conservation Authority (TRCA) and CH2M Canada. 2016. *Inspection and Maintenance Guide for Stormwater Management Ponds and Constructed Wetlands*. Toronto and Region Conservation Authority, Vaughan, Ontario.

Documents prepared by the Sustainable Technologies Evaluation Program (STEP) are available at <u>www.sustainabletechnologies.ca</u>. For more information about this or other STEP publications, please contact:

Tim Van Seters Manager, Sustainable Technologies Toronto and Region Conservation Authority 9550 Pine Valley Drive, Vaughan, Ontario L4L 1A6 Tel: 289-268-3902 E-mail: tvanseters@trca.on.ca

Lisa Rocha

Project Manager, Sustainable Technologies Toronto and Region Conservation Authority 9550 Pine Valley Drive, Vaughan, Ontario L4L 1A6 Tel: 289-268-3914 E-mail: Irocha@trca.on.ca

Kristina Delidjakova

Technical Analyst, Sustainable Technologies Toronto and Region Conservation Authority 9550 Pine Valley Drive, Vaughan, Ontario L4L 1A6 Tel: 289-268-3906 E-mail: kdelidjakova@trca.on.ca

THE SUSTAINABLE TECHNOLOGIES EVALUATION PROGRAM

The Sustainable Technologies Evaluation Program (STEP) is a multi-agency program, led by the Toronto and Region Conservation Authority (TRCA). The program helps to provide the data and decision support tools necessary to support broader implementation of sustainable technologies and practices within a Canadian context. The main program objectives are to:

- monitor and evaluate clean water, air and energy technologies;
- assess barriers and opportunities for implementing technologies;
- develop supporting tools, guidelines and policies; and
- promote broader use of effective technologies through research, education and advocacy.

Technologies evaluated under STEP are not limited to physical products or devices; they may also include preventative measures, alternative urban site designs, and other innovative practices that help create more sustainable and liveable communities.

ACKNOWLEDGEMENTS

Funding support for this document was generously provided by:

- Government of Canada's Great Lakes Sustainability Fund
- City of Toronto
- Region of Peel
- York Region

We would also like to thank the many individuals who contributed to this guide by providing data, technical review and expert advice on behalf of the following organizations:

Aquatech Dewatering	Dynex Construction	
Bishop Water Technologies	Greenland Consulting Inc	
Building Industry and Land Development	Lake Simcoe and Region Conservation Authority	
Association	Layfield Group	
City of Brampton	Liquid Waste Technologies (LWT)	
City of Markham	Normrock Industries Inc	
City of Mississauga	Ontario Ministry of Natural Resources and Forestry	
City of Ottawa	Ontario Ministry of the Environment and Climate Change	
City of Toronto	Region of Waterloo	
City of Waterloo	Ryerson University	
Civica Infrastructure Inc	SCS Consulting	
Credit Valley Conservation Authority	Town of Ajax	
Crusafulli Sludge Removal Systems	Town of Richmond Hill	
DG Group		

NOTICE

While support was received from the above noted individuals and agencies to prepare this document, such support does not indicate their endorsement of its contents. Although every reasonable effort has been made to ensure the integrity of the contents of this document, the supporting individuals and 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. The purpose of this communication is to provide general information of a legal nature. It does not contain a full analysis of the law nor does it constitute an opinion on the points of law discussed.

TABLE OF CONTENTS

LIST OF	FIGURES
LIST OF	TABLESix
LIST OF	EXHIBITSix
1.0 II	NTRODUCTION
1.1	Purpose1
1.2	Use of this guide2
1.3	Why SWMF Maintenance is Necessary2
2.0 R	REVIEW OF CURRENT LEGISLATION AND REGULATIONS
2.1	Federal Fisheries Act (R.S.C. 1985)
2.2	Ontario Fish and Wildlife Conservation Act (S.O. 1997)
2.3	Ontario Water Resources Act (R.S.O. 1990)6
2.4	Ontario Environmental Protection Act (R.S.O. 1990)8
2.5	Ontario Conservation Authorities Act (R.S.O. 1990)8
2.6	Ontario Lakes and Rivers Improvement Act (R.S.O. 1990)
2.7	Ontario Municipal Act (R.S.O. 1990)9
2.8	Ontario Planning Act (R.S.O. 1990) & Building Code Act (S.O. 1992)10
2.9	Ontario Nutrient Management Act (R.S.O. 2002)
2.10	Ontario Endangered Species Act (S.O. 2007)10
3.0 F	UNCTION AND DESIGN OF STORMWATER PONDS AND CONSTRUCTED WETLANDS 11
3.1	How Stormwater Ponds and Wetlands Function11
3.2	Typical Design12
3.2.	1 Ponds
3.2.	2 Constructed wetlands
3.3	Volume and Treatment Efficiency16
3.4	Performance Monitoring17
3.5	Designing SWMFs for Reduced Maintenance
3.5.	1 Outlet Structure and Embankments19
3.5.	2 Reverse Sloped Pipe

3.5.3	Maintenance Drawdown Pipe19
3.5.4	Maintenance By-pass Pipe20
3.5.5	Sediment Forebay21
3.5.6	Sediment Management (Drying) Area23
3.5.7	Maintenance Access Roads23
3.5.8	Length to width ratios24
3.5.9	Outlet Channels24
3.5.10	Vegetation25
3.5.11	Facility Warning and Educational Signage27
3.5.12	Algae Control27
4.0 ASS	SUMPTION AND MAINTAINANCE OF STORMWATER MANAGEMENT FACILITIES
4.1 S	WMF Assumption
4.1.1	Operations and Maintenance Manual31
4.2 Ir	nplementing an Inspection and Maintenance Program
4.2.1	Record Keeping
4.2.2	Establishing maintenance priorities
4.2.3	Planning and budgeting for SWMF maintenance
4.3 Ir	nspection and Preventive Maintenance
4.3.1	Drainage Area Preventive Measures
4.3.2	Vegetation management
4.3.3	Aesthetics – debris and litter removal and repair of vandalized areas
4.3.4	Addressing nuisance issues
4.3.5	Sediment accumulation or spills
4.3.6	Mechanical equipment check37
4.3.7	Structural component check
4.3.8	Community involvement
4.4 C	orrective Maintenance Activities
4.4.1	Sediment removal
4.4.2	Unclogging of inlets and outlets40
4.4.3	Bank erosion/stabilization40

4.5	F	orecasting Sediment Accumulation	40
4	4.5.1 Forecasting Based on Sediment Depth Measurements		41
4	4.5.2	Desktop Modelling Approach	45
5.0	INI	TIATING A SEDIMENT REMOVAL PROCESS	47
5.1	P	Permits and Approvals	47
5	5.1.1	Ontario Ministry of Natural Resources and Forestry	48
<u> </u>	5.1.2	Ontario Ministry of the Environment and Climate Change	48
<u> </u>	5.1.3	Local Conservation Authority	49
<u> </u>	5.1.4	Local Municipality	49
<u> </u>	5.1.5	Ontario Ministry of Agriculture, Food and Rural Affairs	49
5.2	2 P	Procurement	54
<u> </u>	5.2.1	Creating and awarding a bid	54
<u> </u>	5.2.2	Establishing and verifying sediment volumes	55
5.3	E	nvironmental Protection and Restoration During SWMF Maintenance Activities	57
<u> </u>	5.3.1	Sediment Re-suspension Controls	57
5	5.3.2	Minimizing Habitat Disturbance	57
6.0	SEC	DIMENT FIELD ASSESSMENT METHODS	59
6.1	۵	Depth Measurement Methods	59
6	5.1.1	Core Sampler	60
6	5.1.2	Disc and Rod	60
6	5.1.3	Depth Sounding Method (SONAR)	61
6	5.1.4	Guided Radar Level	62
6	5.1.5	Non-traditional Techniques	62
6.2	s S	Sediment Sampling Methods	62
6	5.2.1	Planning Process and Field Methods for Sediment Collection and Analysis	62
6	5.2.2	Equipment List	63
6	5.2.3	Selecting Sediment Sampling Locations	65
6	5.2.4	Post-Dredging Re-Sampling and Analysis Strategy	66
7.0	SEC	DIMENT REMOVAL METHODS	69
7.1	Ν	Mechanical Dredging/Excavating	69
7	7.1.1	Mechanical sediment removal equipment	72

	7.1.2	Winter Sediment Removal	.72
7.	2 ł	Hydraulic (Suction) Dredging	.74
	7.2.1	Types of Dredges	.75
8.0	SEI	DIMENT DEWATERING AND CONSOLIDATION	81
8.	1 (Conventional Methods	.82
8.	2 F	Polymer-Assisted Methods	.82
	8.2.1	Polymer use with Mechanical Excavation	.83
	8.2.2	Polymer-Assisted Hydraulic Dredging	.85
	8.2.3	Reporting Dredged Sediment Volumes	.86
	8.2.4	Sediment Reuse Considerations	.86
9.0	AS	SESSING DISPOSAL AND BENEFICIAL REUSE OPTIONS BASED ON SEDIMENT QUALITY	187
9.	1 F	Regulatory Considerations	.87
	9.1.1	Ontario Regulation 347/90 – General Waste Management	.88
	9.1.2	Ontario Regulation 153/04 - Records of Site Condition	.88
	9.1.3	Management of Excess Soil – A Guide for Best Management Practices	.89
	9.1.4	Handbook for Dredging and Dredged Materials in Ontario	.92
	9.1.5	Proposed Excess Soil Management Policy Framework	.92
	9.1.6	Regulations and guidelines related to biosolids and non-agricultural source material	.96
9.	2 9	Sediment Quality Analysis Considerations 1	.00
	9.2.1	Contaminants in SWMF sediment1	.00
	9.2.2	Characterizing SWMF Sediment Quality1	.02
	9.2.3	Sediment Sampling Considerations1	.04
	9.2.4	Statistical Evaluation of Analyte Distributions in SWMFs1	.05
10.0	INS	SPECTION AND MAINTENANCE COSTS 1	.07
	10.1	Preventive Costs 1	.07
	10.2	Corrective Maintenance Costs 1	.07
11.0	CO	NCLUSIONS AND RECOMMENDATIONS 1	.13
12.0	REFE	E RENCES	.17

APPENDIX A: Pond/Wetland Construction Checklist

APPENDIX B: Pond/Wetland Maintenance Inspection Checklist

APPENDIX C: Rationale for SWMF Sediment Disposal and Beneficial Use Assessment Recommendatations: 2005-2014 Residential SWMF Sediment Quality Field Study

APPENDIX D: Box Plots of Stromwater Pollutants

APPENDIX E: Permission for Routine Infrastructgure Works Qualification Criteria, TRCA

APPENDIX F: Case Study - Polymer Assisted Hydraulic Dredging

APPENDIX G: Case Study - Polymer Assisted Hydraulic Dredging with On-site Disposal

<u>APPENDIX H</u>: Case Study - Water-Absorbing Polymer Assissted Mechanical Dredging

<u>APPENDIX I</u>: Case Study – Winter Mechanical Dredging of a Stormwater Pond

<u>APPENDIX J</u>: Case Study – Winter Mechanical Dredging of a Stormwater Pond Forebay

LIST OF FIGURES

Figure 3.1: Residential stormwater pond in Vaughan, ON	11
Figure 3.2: Profile view of a typical SWM pond (From CWP, 2009)	12
Figure 3.3: Plan view of a typical SWM pond (From CWP, 2009)	13
Figure 3.4: Constructed wetland schematic (From CWP, 2009)	13
Figure 3.5: Using low flow channels to maximize flow path in constructed wetlands (From MOE,	
2003)	15
<i>Figure 3.6.</i> Schematic of a reverse flow pipe for a typical stormwater pond design (from MOE, 2003)	20
<i>Figure 3.7:</i> Drained sediment forebay in the foreground and a partially drained permanent pool in	
the background. A berm separates the two areas	22
<i>Figure 3.8:</i> Sediment drying bags laid out on a sediment management area adjacent to the pond	22
Figure 3.9: Maintenance access road that is well-maintained. Sign provides information on the	
stormwater management function of the SWMF and outlines safety concerns	24
<i>Figure 3.10:</i> Schematic of a seepage outlet. (From City of Hamilton, 2009)	26
Figure 4.1: Hypothetical sediment forecasting example	43
<i>Figure 4.2:</i> Hypothetical examples of maintenance forecasting using measurements for a) constant sediment accumulation rate; b) increase in sediment accumulation rate; and c) decrease in sediment	
accumulation rate	44
<i>Figure 5.1:</i> SWMF clean out project flow chart - project initiation	50
Figure 5.2. Restoration plantings after a SWMF cleanout	58
<i>Figure 6.1:</i> Disc and rod sediment depth measurement with the help of a total survey station	61
Figure 6.2: Planning process and field methods for sediment sample collection	64
<i>Figure 6.3:</i> Top left: obtaining a sediment sample using a sediment core sampler; Top right: consistency of a sediment sample; Bottom: extracting the sediment core sampler from the water prior	
to removing the trapped sediment	65

<i>Figure 6.4:</i> Examples of sediment sample zones identified by inlet/outlet locations and flow patterns.	
A: Three sample zones for a SWMF with one inlet, one outlet and a linear flow path. B: Four sample	
zones for a SWMF with two inlets, one outlet and a forked flow path. *Grey dashed line indicate flow	
path direction	6
Figure 7.1: Mechanical excavation. Left: dredging of side slopes that have sufficiently dewatered	
due to gravity. Right: Pond bottom after dewatering but still visibly requiring significant	
consolidation	1
<i>Figure 7.2:</i> A sediment filter bag in use on a level, stable surface during pond draining	
<i>Figure 7.3:</i> Left: piling up of ice chunks on the side to facilitate berm repairs; Right: ice is thick and	
free of trapped sediment	,
<i>Figure 7.4:</i> A hydraulic dredge in a stormwater management pond	
<i>Figure 7.5:</i> Schematic of standard cutterhead hydraulic dredge (Crisafulli ® FLUMP)	,
Figure 7.6: Vertical auger cutterhead with submersible pump (Dragflow [®] MiniDredge)	/
Figure 7.7: Horizontal auger cutterhead dredge(LWT [®] Pit-Hog)	5
Figure 7.8: Horizontal auger cutterhead dredge schematic (Crisafulli [®] FLUMP)	5
Figure 7.9: Function of a pneumatic pump. From: Abbott and Price (eds.), 1993	,
Figure 8.1: Top - Sediment with a high water content being removed by an excavator. Bottom -	
Examples of slump tests on sediment that has been consolidated	
Figure 8.2: Wet sediment being mixed with mulch to expedite drying83	,
Figure 8.3: The application of an SAP product to wet sediment and the resulting sediment	
consolidation	Ļ
<i>Figure 8.4:</i> Left to right – trailer housing polymer injection system, geotextile bag capturing polymer	
dosed sediment, consistency of sediment in geotextile bag several weeks after hydraulic dredging	
with a polymer	,
Figure 9.1: Recommended process for determining SWMF sediment reuse and disposal options (See	
Figure 5.1 for the full SWMF clean out project flow chart)91	
Figure 9.2: Graphic depiction of the proposed provincial framework for excess soil management	
(MOECC, 2016)	,
Figure 9.3: Average PAH concentrations in SWMF sediments collected from 20 SWMFs and sludge	
collected from 19 municipal sewage treatment plants (STP)	j
<i>Figure 9.4.</i> Alternate SWM sediment disposal approach – treatment as biosolid, other waste, or non-	
agricultural source material (NASM)	1
Figure 10.1: Range of sediment removal project costs per removed volume of sediment (\$/m ³) with	_
associated volume of removed sediment	9
Figure 10.2: Kange of sediment removal project costs and volumes for select pond in the City of	_
Gueiph (Source: City of Gueiph, 2008)	2

LIST OF TABLES

Table 3.1: Components and Design Criteria for a SWM pond (MOE, 2003)	14
Table 3.2: Components and Design Criteria for a Constructed Wetland (From MOE, 2003)	16
Table 3.3: Water quality storage requirements based on receiving waters (MOE, 2003).	17
Table 4.1: Minimum SWMF Permanent Pool (Extended Detention for Dry Ponds) Volumes Prior to Maintenance (m³/ha)	42
Table 4.2: Maximum Allowable Sediment Accumulation (m³/ha) in SWMFs	42
Table 4.3: Annual sediment accumulation in enhanced level (80% removal efficiency) SWMFscalculated based on average loads (adapted from MOEE, 1994, Table 5.3)Table 7.1: The advantages and limitations of using hydraulic dredging in SWMF facilities	46 76
Table 9.1: Potential actions to be undertaken to implement the MOECC's proposed excess soilmanagement policy framework. (MOECC, 2016)	94 101
Table 10.1: Cost estimates for activities associated with SWMF sediment removal. (Source: City of Guelph, 2008)	112

LIST OF EXHIBITS

Exhibit 4.1: Summary list of inspection items to be addressed prior to SWMF assumption	30
Exhibit 4.2: Sample Table of Contents from a Stormwater Pond Operations and Maintenance	31
Manual	
Exhibit 4.3: Homeowner Checklist (CWP, 2009)	39

1.0 INTRODUCTION

1.1 Purpose

Stormwater management facilities (SWMF) are designed to protect downstream infrastructure from flooding by temporarily storing runoff, and to improve water quality by trapping pollutant laden sediment in runoff from urban drainage areas. Centralized collection of polluted sediments in these facilities helps to prevent their release into rivers, streams and lakes where they can degrade water quality, harm aquatic life and adversely impact downstream recreational areas.

Like other urban infrastructure such as roads, water supply, sanitary sewers and wastewater treatment plants, SWMFs require regular inspection and maintenance to ensure that they continue to meet their water quality and quantity design objectives. These maintenance tasks may include stabilization of banks, repair of outlet structures, landscaping and periodic removal of accumulated sediment.

Currently there are over 1000 SWMFs in the Greater Toronto Area alone, a growing number of which are in need of major maintenance interventions. The high cost of undertaking this task has brought SWMF maintenance into the public spotlight, and raised concerns among facility owners and operators about how cleanout projects can be carried out cost effectively.

The first guidance document on sediment maintenance of SWMFs in Ontario was published over 16 years ago (GIC *et al.*, 1999) when the practice of cleaning sediment from ponds was becoming more established. Since that time the science has advanced considerably, and maintenance practices have evolved with the development of new techniques and changes to government regulations and best practice guidance.

The purpose of this document is to provide guidance on the design, inspection and maintenance of two types of SWMFs – ponds and constructed wetlands - in order to help reduce the cost and effort required to operate these facilities over the long term. While the guidance herein is specific to the maintenance of stormwater management ponds and constructed wetlands, much of the information could also be applied to other SWMFs like underground detention and flow balancing systems. Throughout the document, the abbreviation SWMF is used to refer only to ponds and constructed wetlands. It should also be noted that the inspection and maintenance of Low Impact Development stormwater management *Practice Inspection and Maintenance Guide (TRCA, 2016)*.

This guideline builds on the earlier sediment maintenance guide completed by Greenland International Consultants (1999) and introduces new information based on international literature and interviews with leading experts in the field. Key topics addressed in this Guide include:

- A re-examination of current legislation, regulations, guidelines, and approval processes, including consideration of beneficial re-use options
- Key SWMF design considerations aimed at reducing long term maintenance

- Standard methods for measuring sediment accumulation depths and forecasting sediment removal
- Implementation of Inspection & Monitoring Programs through Asset Management Systems
- New approaches to dredging and treating sediment to facilitate off-site hauling
- Updated cleanout costs across a range of scenarios, and
- Case study examples of successes, challenges and costs associated with SWMF dredging operations in different contexts

The guidance provided herein will help SWMF owners/operators to make informed decisions when developing stormwater management and maintenance plans, thereby helping to ensure that SWMFs are maintained to the standards required by current legislation, regulations, guidelines and approval processes in Ontario.

1.2 Use of this guide

This document serves as a guideline to address fundamental elements that should be considered in routine SWMF inspection and maintenance and sediment removal and disposal decision making processes. It is not a regulation and does not change legislative powers. It supersedes the *Storm Water Management Facility Sediment Maintenance Guide (GIC et al., 1999)*.

Recommendations provided in this Guideline are supported by extensive interviews with industrial and municipal stakeholders, in addition to an updated SWMF sediment quality database. Lessons learned over the past sixteen years provide important information regarding current best management practices (BMPs) and legal requirements in Ontario. Case studies highlighting SWMF cleanout activities utilizing various methods and BMPs provide contextual information on different SWMF cleanout activities and processes. Sediment quality analysis of 194 samples collected from 61 residential SWMFs provide a better understanding of sediment disposal and beneficial reuse options. Statistical analysis of the sediment quality data provides the basis for suggested sampling zone locations and number of sample stations according to the unique features of each SWMF.

1.3 Why SWMF Maintenance is Necessary

Stormwater runoff is a leading source of pollution in watercourses and lakes, and the primary cause of flooding and stream erosion in urban areas. For decades, stormwater best management practices (BMPs) have been used to mitigate these impacts, with varying degrees of success. In Ontario, implementing different BMPs in series as part of a 'treatment train' is advocated as the preferred approach to managing stormwater. This may involve the use of several practices designed to achieve different levels of treatment, but in many cases stormwater wet ponds or constructed wetlands are included to mitigate flood risk and improve the quality of stormwater prior to discharge to the downstream water body.

These SWMFs are designed to temporarily detain and release water slowly over a period of 24 to 120 hours after a rain event, depending on the sensitivity of the receiving watercourse. This slow release helps to mitigate storm induced flooding of downstream infrastructure, while also promoting quiescent settling of contaminated sediment between rain events. In addition to their stormwater management functions, some SWMFs have been designed to provide other beneficial uses, such as aesthetic and recreational amenities and non-potable water supply for irrigation. It should be noted that while SWMFs may sometimes be inhabited or temporarily used by fauna and fish, they are classified as 'sewage works' under the Ontario Water Resources Act (OWRA) and as such do not constitute habitat. Compared to natural ponds and wetlands, they are subjected to several urban stresses. Tixier *et al.*, 2011 characterize these stresses as:

- <u>Physical</u> high discharge variability, alteration to the thermal regime, constructed habitat deviating from natural ecosystems
- <u>Chemical</u> suspended solids, nutrients, heavy metals, polycyclic aromatic hydrocarbons (PAHs)
- Biological constant human presence, introduction of exotic species, bacterial contamination

A SWMF acts as a buffer against the three stressors in order to protect downstream aquatic habitats that are not part of municipal infrastructure, but nevertheless receive stormwater runoff. To counteract and prevent transfer of environmental stressors to downstream ecosystems, facilities need to be regularly managed and maintained, as their capacity to mitigate the adverse effects of stormwater relies on the continued function of their various components.

Stormwater ponds and constructed wetlands may be compromised for several reasons, such as improper design and siting, poor vegetation management, clogged inlets and outlets, reduced storage capacity due to sediment accumulation, failed side slopes, and inadequate access for maintenance. Lack of maintenance could also lead to the development of mosquito breeding habitat, which may pose a health concern associated with West Nile Virus (Jackson *et al.*, 2009). Once compromised, these SWMFs no longer serve their intended function, potentially resulting in more frequent flooding or inadequate treatment of stormwater runoff. Owners of stormwater management facilities are responsible for ensuring that they are operating according to their original design and that all components are fully functional. The regulatory consequences of inadequately maintained SWMFs may include legal charges, restitution payments and/or substantial fines (see Section 2.0). Proactive SWMF maintenance is the key to ensuring that performance requirements are met to protect downstream communities, municipal infrastructure and the natural environment.

2.0 REVIEW OF CURRENT LEGISLATION AND REGULATIONS

The regulatory framework for designing, constructing, monitoring and maintaining SWMFs encompasses federal, provincial and municipal levels of government. This section of the guide describes how each framework component is relevant to SWMFs, from the time they are designed to the time that they require maintenance and repairs. It also highlights ambiguities in the current regulatory framework and how these can be addressed when planning SWMF related projects. Ontario standards, guidelines and criteria specific to the removal and disposal of sediments are addressed in Section 9.1 of this guide.

2.1 Federal Fisheries Act (R.S.C. 1985)

The Federal Fisheries Act is administered by the Department of Fisheries and Oceans (DFO). In Ontario however, the Act is enforced by the Ministry of Natural Resources and Forestry (MNRF). The Act has broad applicability to various land use activities including sediment removal and disposal operations that can potentially affect fish and fish habitats. In the Act, fish habitat is defined as areas that support spawning, rearing, food supply and migration. While online and offline SWMFs themselves are not fish habitat (since they are classified under the Ontario Water Resources Act as "sewage works") the activities surrounding their cleanout are still subject to the fisheries act.

The Act applies in two primary ways: (i) it prohibits any potential contaminant discharges to receiving water bodies and (ii) it requires approval for the construction and operation of any watercourse diversions. Section 36(3) of the Fisheries Act prohibits the deposition of any deleterious substance in water frequented by fish, which applies to any discharges to natural water bodies occurring during a cleanout and also to any bypass/diversion of a natural watercourse in place during the cleaning of an online SWMF. Section 35(2) of the Fisheries Act prohibits any activity that results in serious harm to fish that are part of a commercial, recreational or Aboriginal fishery. Under this section of the Act, an authorization (known as Paragraph 35(2)(b) Fisheries Act Authorization) would be required for the construction of a watercourse diversion in place during online SWMF cleaning.

2.2 Ontario Fish and Wildlife Conservation Act (S.O. 1997)

The provincial Fish and Wildlife Conservation Act, administered by the MNRF, governs the lawful hunting and trapping of fish and wildlife. Ontario Regulation (hereafter O.Reg.) 664/98, created under the Act, specifically requires that a license be obtained for fish collection. During the dredging of a SWMF, any collection, handling and deposition of fish would require a "License to Collect Fish for Scientific Purposes", which is issued by the MNRF.

Under the Act the MNRF also regulates the collection and handling of any wildlife species listed as protected in Schedules 6 through 11 of the Act. The lists of protected species include several amphibians

(e.g. Jefferson Salamander) and reptiles (e.g. Midland Painted Turtle) that could be found in and around SWMFs. Any collection, handling and deposition of protected wildlife species that may be necessary during a SWMF clean out project requires that a "Wildlife Scientific Collector's Authorization" be obtained from MNRF.

2.3 Ontario Water Resources Act (R.S.O. 1990)

The Ontario Water Resource Act (OWRA), administered by the Ontario Ministry of the Environment and Climate Change (MOECC, formerly the Ministry of Environment), has special relevance to the construction and maintenance of SWMFs. It is an offense under the OWRA to discharge any substance into the environment that may impair the quality of receiving waters. The OWRA definition of "sewage" includes: drainage, stormwater, commercial wastes and industrial wastes. Under the Act, SWMFs are designated as "sewage works", which are defined as any works for the collection, transmission, treatment and disposal of sewage or any part of such works. As such, the MOECC has jurisdiction over the design and operation of SWMFs.

The MOECC issues approval requirements for sewage works under Section 53 of the OWRA. Prior to 2011, the MOECC had issued these approvals as "Certificates of Approval" (CofA), but has since changed the name to "Environmental Compliance Approval" (ECA) for all SWMFs constructed during or after 2011. ECAs are a single type of approval that applies not only to sewage but also to emissions and discharges related to air, noise and waste. An ECA must be issued prior to construction, modification and/or alteration of a sewage works. Sewage works ECAs set approval requirements (e.g. monitoring, maintenance) for the purpose of protecting the natural environment (including receiving waterbodies, groundwater, plants and animals) from SWMF discharge impacts. In order to receive approval, the applicant must demonstrate that their proposal meets ministry requirements, based primarily on the Ontario Ministry of Environment 2003 Stormwater Management Planning and Design Manual (hereafter SWMPD Manual or MOE, 2003). It should be noted that while the ECA for SWMF construction or alteration is required by OWRA Section 53, it is actually issued under the Environmental Protection Act (R.S.O. 1990), which is discussed in Section 2.4.

The MOECC considers the owner of a stormwater sewage works as responsible for all aspects of designing, constructing, operating and maintaining the facility. While the owners are often municipalities, they can also be private sector or other public sector agencies. Although the MOECC has not introduced specific criteria for compliance with performance, it is the owner's obligation to maintain SWMFs in a state that ensures they function and perform according to their original design requirements. As indicated in Section 61 of the OWRA, "works shall at all times be maintained, kept in repair and operated in such manner and with such facilities". MOECC's Access Environment website provides examples of SWMF ECA requirements, which may include one or more of the following:

- Annual inspections with maintenance and repairs as needed;
- Operations and performance criteria;

- Required water quality monitoring and recording;
- Reporting incidents to the MOECC;
- Penalties for non-compliance under OWRA- s. 107(3) and 108.

The following examples of operations and maintenance requirements were compiled from several ECAs.

- "The Owner shall ensure that the designed minimum liquid retention volume(s) is maintained at all times."
- "The Owner shall inspect the Works at least once a year and, if necessary, clean and maintain the Works to prevent the excessive buildup of sediments and/or vegetation."
- "The Owner shall ensure that sediment is removed from the above noted stormwater management works at such a frequency as to prevent the excessive buildup and potential overflow of sediment into the receiving watercourse."
- "The Owner shall maintain a log book to record the results of these inspections and any cleaning and maintenance operations undertaken, and shall keep the log book at a readily accessible location for inspection by the Ministry. The log book shall include the following:
 - The name of the works.
 - The date and results of each inspection, maintenance and cleaning, including an estimate of the quantity of materials to be removed."

It should be noted that these are only examples and that these specific requirements may not be listed in all ECAs. It is important to refer to the ECA for the specific SWMF to determine what exactly is permitted and/or expected with respect to facility maintenance.

Legal Obligations and Liabilities Associated with the OWRA ECAs

Pursuant to the OWRA, the following legal obligation and liabilities may arise:

- i. Owners that fail to comply with the ECA requirements may face fines of up to \$500,000.
- ii. A MOECC Director and Provincial Officer can order an owner to maintain, repair and/or operate a SWMF in a specific manner. If the owner fails to comply with the order, MOECC may authorize an external body to complete necessary work, with the associated costs to be recovered directly from the owner.

Owners may also face liability under the common law tort of negligence, where they fail to adequately maintain a SWMF, and subsequent property damage occurs. To date, it is not certain whether a tort action based on negligence could be brought in this context, as there have been no court decisions on these issues. However, the case law suggests that this is possible, as successful negligence actions have

been brought against municipalities for property damage relating to insufficient maintenance of stormwater and sanitary sewage systems.

2.4 Ontario Environmental Protection Act (R.S.O. 1990)

The Ontario Environmental Protection Act (EPA), administered by the MOECC, is one of the primary pieces of pollution control legislation in the province. It prohibits discharges of any pollutants into the environment that are likely to cause adverse effects. Exceedances of these discharge limits can result in substantial fines, restitution payments and/or legal charges.

The EPA is directly relevant to SWMF clean out projects in two key ways:

- (i) Environmental Compliance Approvals: ECAs for both sewage works and waste management are issued under this Act, which sets out the MOECC Director's authority in this regard. Waste management ECAs can sometimes, but not always, be required as part of SWMF clean out, depending on the sediment characteristics and what is being done with the material (see Section 5.1.2 and Chapter 9.0).
- (ii) Classification of SWMF sediment for determining disposal options: the Waste Management regulation (O.Reg. 347/90) under the EPA provides contaminant thresholds for classification of wastes.

Ontario Regulation 347/90, made under the EPA, governs waste management for the protection of human and environmental health. It defines waste and hazardous waste and sets out requirements for their handling, storage, management and disposal. SWMF sediment that is determined to be hazardous waste, based on leachate quality criteria provided in the regulation, must be handled and disposed of as such.

Another regulation under the EPA, 'Records of Site Condition: O.Reg. 153/04', applies to the redevelopment of brownfield sites, but is also unofficially applied for characterizing SWMF sediment when reuse is being considered. The *Soil, Ground Water and Sediment Standards* (MOE, 2011a) that are part of O.Reg. 153/04 provide a series of tables that list prescribed contaminants and the applicable site condition standards.

The relevance of EPA Regulations 347 and 153 to the evaluation of SWMF reuse options is discussed in more detail in Section 9.0 of this guide.

2.5 Ontario Conservation Authorities Act (R.S.O. 1990)

The Conservation Authorities Act, administered by the MNRF, was first passed in 1946 at which time it authorized the creation of Conservation Authorities (CAs) throughout Ontario. Under the Act, individual

regulations have been passed for each CA entitled "Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses" (Ontario Regulations 42/06 and 146/06 to 182/06). The regulations are meant to control flooding and to prevent property damage, erosion, pollution and loss of life. They allow CAs to regulate development and other activities taking place within valley and stream corridors, wetlands and associated areas of interference and the Lake Ontario waterfront.

The regulation requires that a permit be obtained from the local Conservation Authority for cleanout of any SWMF that is located within a regulated area (e.g. valley and stream corridors). The diversion of a watercourse for the purpose of cleaning out an online SWMF would also require a permit. Where the SWMF is offline, and not located in a regulated area, a permit is also required if water from the facility is being pumped out and into a regulated area (natural water body). In most cases the permitting process for such works (cleanout of an offline facility that is not located within a regulated area) would be relatively straightforward.

2.6 Ontario Lakes and Rivers Improvement Act (R.S.O. 1990)

The Ontario Lakes and Rivers Improvement Act (LRIA) is administered by the Ontario MNRF. The LRIA regulates the management, protection, preservation and use of Ontario waters and the lands under them. Section 14 of the LRIA states that "no person shall construct a dam in any lake or river in circumstances set out in the regulations without the written approval of the Minister for the location of the dam and its plans and specifications". An approval would be required under this section of the Act for the construction of a watercourse diversion/bypass required during the cleanout of an online SWMF. Because this overlaps with the requirements for a Conservation Authority permit (see Section 2.1.5 above), the MNRF has determined that areas of the province that are within the jurisdiction of a CA do not have to apply for an LRIA section 14 approval. In areas of the province that are not CA jurisdiction, these kinds of projects would require Section 14 approval obtained directly form the MNRF.

2.7 Ontario Municipal Act (R.S.O. 1990)

The Ontario Municipal Act is administered by the Ontario Ministry of Municipal Affairs and Housing. The Act assists communities in the regulation of various activities, which may affect the local environment (e.g. stormwater management, solid waste disposal, sewer use, land use, etc.). A key aspect of the Act is that it provides individual municipalities with the freedom to adopt by-laws, policies and guidelines to suit the unique goals and needs of each local community. For example, municipalities can choose to develop stormwater utility programs that would fund SWMF monitoring and maintenance activities for the purpose of maintaining ECA requirements. Municipalities may also choose to delegate SWMF construction, monitoring and maintenance duties to a person or company through contract agreements. It is important to note however that municipalities may retain legal responsibility for the outcome of such delegated activities.

2.8 Ontario Planning Act (R.S.O. 1990) & Building Code Act (S.O. 1992)

The Ontario Planning Act and the Building Code Act are administered by the Ontario Ministry of Municipal Affairs and Housing. Section 41(7) of the Ontario Planning Act allows municipalities to require land owners to provide easements set aside for the maintenance or improvement of public utilities that belong to the municipality. In the case of SWMFs, this would allow municipalities to require land to be set aside adjacent to the facility as a sediment management/drying area. The Ontario Building Code Act requires appropriate operations, monitoring and maintenance of SWMFs for public health and safety considerations.

2.9 Ontario Nutrient Management Act (R.S.O. 2002)

The Ontario Nutrient Management Act (NMA) is administered by the MOECC and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). The NMA was designed to reduce the potential for water and environmental contamination from some agricultural practices. The NMA establishes the framework for nutrient management best practices, especially for the spreading of manure, biosolids and "other wastes" on agricultural land. This Act is highly relevant to the beneficial use of SWMF sediments as agricultural topsoil amendment materials. This topic is discussed further in Section 9.0 of this guide.

2.10 Ontario Endangered Species Act (S.O. 2007)

The Ontario Endangered Species Act (ESA) is administered by the Ontario MNRF. The ESA Regulation 242/08 protects endangered, threatened and in some cases extirpated, species that are listed on the Species at Risk in Ontario (SARO) List or their habitat from human activities that would cause adverse effects. Violations of the ESA can result in fines of up to \$1,000,000 for corporations, in addition to imprisonment. Although SWMFs are designed and classified as sewage Works, they do inevitably attract species that require aquatic and/or semi-aquatic habitats to sustain their life cycles. Prior to initiating a SWMF cleanout, the MNRF should be contacted to determine whether there are any at risk species on the site. If at risk species are believed to be on the site and/or have been observed on the site, then the MNRF will advise as to the procedures and protection measures that should be taken to safeguard the species from harm.

3.0 FUNCTION AND DESIGN OF STORMWATER PONDS AND CONSTRUCTED WETLANDS

3.1 How Stormwater Ponds and Wetlands Function

Retention ponds and constructed wetlands are stormwater flow control structures that retain and treat polluted stormwater runoff (Figure 3.1). They typically consist of a permanent pool and an active storage layer that allows slow release of stormwater during and after storm events to prevent erosion and reduce flood risk. Runoff is retained and treated in the permanent pool through settling and biological uptake until it is displaced by runoff from the next event. During rain events larger than the maximum design capacity of the facility, a portion of the stormwater bypasses the quality and quantity control functions via a spillway. The spillway also acts as the emergency conveyance structure in the event that the primary outlet becomes clogged.

The sediment that eventually finds its way to the bottom of the facility contains urban stormwater pollutants that bind to sediment particles. The more efficient the facility, the more the settled sediment will accumulate along the bed. This accumulated sediment adversely affects the water quality control functionality and reduces the available storage volume. Effective maintenance of structures and removal of accumulated sediment is imperative to ensuring continued performance of stormwater ponds and constructed wetlands.



Figure 3.1: Residential stormwater pond in Vaughan, ON.

3.2 Typical Design

3.2.1 Ponds

Figures 3.2 and 3.3 show profile and plan views of a typical pond. The forebay is a common feature that helps to improve the pollutant removal efficiency of the pond by increasing the surface area available for settling and allowing heavier particles to settle out. Lighter sediment particles pass into the main cell where they drop out of suspension during the retention period. Shallow aquatic or safety benches can also be added at the edges of the permanent pool to filter flow and promote biological uptake of nutrients. These features can help improve access for maintenance and act as a safety precaution to prevent accidental drowning.

There are several different outlet structure designs. Reverse slope pipes are often used to prevent floatables from clogging the outlet and help protect downstream aquatic life by drawing cooler water from below the surface of the permanent pool. Newer technologies like cooling trenches, seepage outlets and spreader swales can also be applied at SWMF outfalls to help protect receiving waters by cooling effluent, enhancing infiltration, and slowing discharge.

Pond maintenance drawdown pipes are installed to facilitate draining of the pond during maintenance. Anti-seepage collars help stabilize the embankment by preventing seepage through the structure. Clay liners may also be added on more permeable soils or in areas with high groundwater tables. Additional pond design criteria, taken from the OMOE's Stormwater Management Planning and Design Guide (2003), are listed in Table 3.1.



Figure 3.2: Profile view of a typical SWM pond (From CWP, 2009).



Figure 3.3: Plan view of a typical SWM pond (From CWP, 2009).

3.2.2 Constructed wetlands

Constructed wetlands (Figure 3.4) are similar to stormwater management ponds in function and design, with the most significant difference being that they are designed to incorporate shallow zones for wetland plants. A facility is normally characterized as a wet pond if shallow zones (<0.5 m deep) comprise less than 20% of its surface area, and is a wetland if shallow zones make up more than 70% of its volume.



Figure 3.4: Constructed wetland schematic (From CWP, 2009).

Design Element	Design Objective	n Objective Minimum Criteria Preferred Crite	
Drainage Area	Volumetric turnover	5 ha	≥ 10 ha
Treatment Volume	Provision of appropriate Level of Protection (See Table 3.2)	See Table 3.2	 i) Permanent Pool volume increased by expected maximum ice volume; ii) Active Storage increased from 40 m³/ha to 25% of total volume
Active Storage Detention	Suspended solids settling	24 hrs (12 hrs if in conflict with I	minimum orifice size)
Forebay	Pre-treatment	i) Minimum depth: 1 m; ii) Sized to ensure non-erosive velocities leaving forebay; iii) Maximum area: 33% of total Permanent Pool	i) Minimum depth: 1.5 m; ii) Maximum Volume: 20% of permanent pool
Length-to-Width Ratio	Minimize flow path and minimise short- circuiting potential	 i) Overall: minimum 3:1 (may be accomplished by berms, etc); ii) Forebay: minimum 2:1 	From 4:1 to 5:1
Permanent Pool Depth	Minimize re- suspension, avoid anoxic conditions	i) Maximum Depth: 3 m; ii) Mean Depth 1-2 m	i) Maximum Depth: 2.5 m; ii) Mean Depth 1-2 m
Active Storage Depth	Storage/flow control	i) Water quality and erosion control: maximum 1.5 m; ii) Total (including quantity control): 2 m	i) Water quality and erosion control: maximum 1 m; ii) Total (including quantity control): 2 m
Side Slopes	Safety and to maximize the functionality of the pond	 i) 5:1 For 3 m on either side of the permanent pool; ii) Maximum 3:1 elsewhere 	 i) 7:1 near normal water level plus use of 0.3 m steps; ii)4:1 elsewhere
Inlet	Avoid clogging/freezing	i) Minimum 450 mm; ii) Preferred pipe slope: >1%; iii) If submerged, obvert 150 mm below expected maximum ice depth	
Outlet	Avoid clogging/freezing	 i) Minimum: 450mm outlet pipe; ii) Reverse sloped pipe should have a minimum diameter of 150 mm; iii) Preferred pipe slope: >1%; iv) If orifice control used, 75 mm diameter minimum 	
Maintenance Access	Access for backhoes or dredging equipment	Provided to approval of Municipality	Provision of maintenance drawdown pipe
Sediment Drying Area	Sediment removal	While preferable, should only be incorporated into the design when it imposes no additional land requirement*	 i) To be provided above the maximum water quality water level; ii) Drainage returned to the pond
Buffer	Safety	i) Minimum 7.5 m above maxim level; ii) Minimum 3 m above h	num water quality/erosion control water igh water level for quantity control

Table 3.1: Components and Design Criteria for a SWI	A pond (MOE, 2003).
---	---------------------

* See section 3.5.6 for drying area recommendations

They are normally more land-intensive than wet ponds, as the wetland is made larger to compensate for their shallower depth. While this type of facility can provide the requisite storage for erosion control purposes, active storage for quantity (i.e. flood) control will not usually be incorporated because of the limits on active storage depth that are in place to protect wetland vegetation. Relative to a wet pond, a constructed wetland may offer added pollutant removal benefits due to enhanced biological uptake and the filtration effects of the vegetation.

While the minimum length-to-width ratio of 3:1 is recommended for both wet ponds and constructed wetlands, in the latter it is measured based on the flow path of low flows through the facility rather than on its dimensions. Constructed wetlands can be designed with low flow paths that will mitigate short-circuiting and maximize the flow path through the facility (Figure 3.5). The shallow depths of constructed wetlands also influence the types of inlets and outlets that can be used in these facilities. Submerged inlets are avoided due to the greater likelihood of freezing. While outlet configurations are generally the same as for wet ponds, reverse sloped pipe configurations can only be used if the constructed wetland has a deep pool at the outlet. Additional constructed wetland design criteria, taken from the OMOE's Stormwater Management Planning and Design Guide (2003), are listed in Table 3.2.



Figure 3.5: Using low flow channels to maximize flow path in constructed wetlands (From MOE, 2003).

Design Element	Design Objective	Minimum Criteria
Drainage Area	Sustaining vegetation, volumetric turnover	5 ha (≥10 ha preferred)
Treatment Volume	Provision of appropriate level of protection (Table 3.2)	See Table 3.2
Active Storage Detention	Suspended solids settling	24 hrs (12 hrs if in conflict with min. orifice size)
Forebay	Pre-treatment	Minimum depth: 1 m; ii) Sized to ensure non-erosive velocities leaving forebay; iii) Maximum area: 20% of total permanent pool
Length-to-Width Ratio	Minimize flow path and minimise short-circuiting potential	i) Overall: minimum 3:1; ii) Forebay: minimum 2:1
Permanent Pool Depth	Vegetation requirements, rapid settling	The average permanent pool depth should range from 150mm to 300mm
Active Storage Depth	Storage/flow control, sustaining vegetation	Maximum 1.0m for storms < 10 year event
Side Slopes	Safety	 i) 5:1 For 3 m above and below permanent pool (ii) Maximum 3:1 elsewhere
Inlet	Avoid clogging/freezing	 i) Minimum 450 mm; ii) Preferred pipe slope: >1%; iii) If submerged, obvert 150 mm below expected maximum ice depth
Outlet	Avoid clogging/freezing	 i) Minimum: 450mm outlet pipe; ii) Preferred pipe slope: >1%; iii) If orifice control used, 75mm diameter minimum; (iv) Minimum 100mm orifice preferable
Maintenance Access	Access for backhoes or dredging equipment	(i) Provided to approval of Municipality; (ii) Provision of maintenance drawdown pipe preferred
Buffer	Safety	Minimum 7.5 m above maximum water quality/erosion control water level

Table 3.2: Components and Design Criteria for a Constructed Wetland (From MOE, 2003).

3.3 Volume and Treatment Efficiency

Stormwater ponds and constructed wetlands are sized to meet a given water quality objective for different levels of impervious drainage area (MOE, 2003). As mentioned above, water quality control for the first 25 mm of rainfall is achieved through pollutant removal in the permanent pool. The capacity of the facility to remove sediments is determined by the amount of time that stormwater runoff resides in the facility, known as the hydraulic residence time. Both sedimentation and biological uptake are enhanced by longer hydraulic residence times. Most stormwater management facilities in Ontario are required to achieve an enhanced level of protection, or 80% removal of total suspended solids (TSS), except under special circumstances.

The storage requirements in Ontario presented in Table 3.3 are based on a 24 hour drawdown time (MOE, 2003). All wet facilities, including ponds, are designed with an extended detention storage volume of 40

m³ per hectare of drainage area, to provide temporary storage during large events. The values in this table only address water quality in the form of TSS removal efficiency; they do not address erosion, baseflow or flooding concerns. Based on the required treatment efficiency, a facility is due to be cleaned out once the target removal efficiency has decreased by 5% due to sediment accumulation (see Section 4.5 for guidance on how to forecast when sediment removal needs to be undertaken).

Protection Level	SWMF Type	Storage Volume (m³/ha) for Impervious Level			
		35%	55%	70%	85%
Enhanced 80% long-term S.S. removal	Constructed Wetlands	80	105	120	140
	Hybrid Wet Pond/Wetland	110	150	175	195
	Wet Pond	140	190	225	250
Normal 70% long-term S.S. removal	Constructed Wetlands	60	70	80	90
	Hybrid Wet Pond/Wetland	75	90	105	120
	Wet Pond	90	110	130	150
Basic 60% long-term S.S. removal	Constructed 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

Table 3.3: Water quality sto	rage requirements based on	receiving waters ^{1, 2,3} ((MOE, 2003).
------------------------------	----------------------------	--------------------------------------	--------------

¹Table 3.2 does not include every available SWMF type. Any SWMF type that can be demonstrated to the approval agencies to meet the required long-term suspended solids removal for the selected protection levels under the conditions of the site is acceptable for water quality objectives. The sizing for these SWMF types is to be determined based on performance results that have been peer-reviewed. The designer and those who review the design should be fully aware of the assumptions and sampling methodologies used in formulating performance predictions and their implications for the design.

² Hybrid Wet Pond/Wetland systems have 50-60% of their permanent pool volume in deeper portions of the facility (e.g., forebay, wet pond).

³For Wetlands, wetponds and hybrid wet ponds/wetlands, 40 m³ represents extended detention

3.4 Performance Monitoring

A large number of detailed studies have been conducted on the performance of stormwater ponds and constructed wetlands. In the Greater Toronto Area, the water quantity and quality performance of four stormwater ponds, a constructed wetland and a flow balancing system were each monitored for two or more years under the Stormwater Assessment Monitoring and Performance (SWAMP) program. In these cases, load based total suspended solids (TSS) removal efficiencies met or exceeded the 80% target, including one pond designed to MOECC's 'normal' protection level (SWAMP, 2005). Median effluent

event mean concentrations for TSS across all six facilities (n = 167) was 23 mg/L (Van Seters and David, 2015).

A similar finding was reported for a stormwater pond monitoring program in Ottawa (Graham et al, 2003). In that case, four centralized wet ponds serving catchment areas ranging from 210 to 991 hectares were constructed and designed to MOECC standards with multiple cells to improve retention times. A four year monitoring program of one of these facilities showed average seasonal effluent concentrations for suspended solids to be consistently below 10 mg/L and removal efficiencies ranging between 80 and 95%.

In the United States, performance monitoring data for stormwater ponds and other practices are provided through the national pollutant removal performance database (CWP, 2007) and the International Stormwater Management Best Practices database (Wright Water Engineers and Geosyntec Consultants, 2012). As of 2007, there were performance monitoring results in the CWP database for 46 stormwater ponds and 40 constructed wetlands. In the CWP database, the median TSS removal efficiency for ponds and wetlands was 80% and 72%, respectively. Although design standards for ponds and wetlands in many states are similar to those of Ontario, some of these facilities may not have been designed to Ontario 'enhanced protection level' standards, and would therefore not be expected to meet the 80% TSS removal efficiency target.

The US EPA International Stormwater Management Best Practices database (Wright Water Engineers and Geosyntec Consultants, 2012) summarizes performance results from a large number of stormwater ponds and constructed wetlands, including many of the same facilities included in the CWP database. The database does not publish removal efficiencies.¹ However, median TSS influent and effluent event mean concentrations (n > 150) provide the basis for approximating removal efficiencies if it is conservatively assumed that there was no water loss to infiltration or evapotranspiration. Accepting this assumption, and selecting northern states with a similar climate to Ontario, removal efficiencies for ponds and wetlands was 88% and 61%, respectively. On the surface, these data would suggest that constructed wetlands performed less effectively than ponds. However, the median TSS effluent concentration from wetlands (12 mg/L) was lower than ponds (16 mg/L), suggesting that lower wetland removal efficiencies were a result of lower influent concentrations, rather than poor removal performance.

Overall, these data from Canadian and northern US studies show that newly constructed stormwater ponds and constructed wetlands generally meet MOECC performance targets for TSS removal, and that median effluent concentrations are normally below 25 mg/L, particularly for stormwater ponds designed for "enhanced TSS removal". Further research is needed to document the change in performance that occurs as sediment accumulates in stormwater facilities, and relationships between land use and sediment loading. This research is needed to address concerns that sediment bound pollutants, such as

¹ Authors of the International Stormwater Best Management Practices (BMP) database do not regard percent removal as a valid measure of stormwater BMP performance because 'percent removal is primarily a function of influent quality' and is therefore 'more reflective of how 'dirty' the influent water is than how well the BMP is actually performing' (Wright Water Engineers and Geosyntec Consultants, 2007).

phosphorus and metals, are being remobilized as sediment accumulates and the pond biology and chemistry evolves over time.

3.5 Designing SWMFs for Reduced Maintenance

Practical experience with SWMF maintenance over the years has revealed several opportunities for the incorporation of specific design features during construction to facilitate anticipated maintenance activities. The following sections list some of the features that can help reduce the maintenance burden of these facilities and make the process of sediment removal less onerous for owners and local residents.

3.5.1 Outlet Structure and Embankments

The outlet structure or chamber should be accessible from the shore to facilitate regular inspections and minor repairs. The chamber and barrel outlet pipe should be constructed of reinforced concrete, or a material of similar strength, rather than corrugated metal which could be susceptible to corrosion. Anti-seepage collars should be installed to prevent leakage and seepage through the embankment, which can cause destabilization and failure. Emergency spillways must be designed to ensure flood flows are conveyed safely without the potential for dam failure. Standards and criteria for spillways and flood control structures are provided in a Technical Bulletin prepared by the Ontario Ministry of Natural Resources (MNR, 2011a).

3.5.2 Reverse Sloped Pipe

A reverse sloped pipe has gained popularity in recent years over the traditional perforated riser pipe and is recommended in stormwater ponds and wetlands in which a deep pool (>1 m) is provided at the outlet (MOE, 2003). Reverse sloped pipes help prevent clogging by floating trash or debris and avoid the discharge of warm surface water to downstream water bodies, thereby providing improved protection to aquatic life. Figure 3.6 illustrates a typical design, which is accessible for maintenance through the embankment and hidden from view. Gate valves are recommended to facilitate modification of extended detention drawdown times for improved pollutant removal and downstream erosion protection if design criteria change or the facility is found to be operating outside of existing design criteria. A deeper micro pool should be excavated at the outlet to provide additional depth for sediment settling and prevent localized sediment accumulation near the pipe opening.

3.5.3 Maintenance Drawdown Pipe

The maintenance drawdown pipe is among the best SWMF design elements for the facilitation of mechanical dredging. The inclusion of a gravity maintenance pipe at or near the facility bottom greatly reduces the time and cost normally required to pump the water out. This pipe can be incorporated as

part of the reverse sloped pipe structure within the same outlet chamber (Figure 3.6). Consideration should be given to whether the forebay will be the most frequently cleaned out feature, as it may require a separate gravity maintenance drawdown pipe to ensure that only the forebay is drained, as opposed to the entire facility. Maintenance drawdown pipes are prone to clogging and therefore should be regularly flushed to ensure they remain free of sediment. A corrosion-resistant gate valve should be provided to allow for controlled release of the permanent pool volume. This controlled release must be treated prior to release to downstream vegetated areas.



Figure 3.6. Schematic of a reverse flow pipe for a typical stormwater pond design (from MOE, 2003).

3.5.4 Maintenance By-pass Pipe

Although a gravity maintenance drawdown pipe drains the facility, it does not protect it from continuous dry weather flow conveyed during the interevent period when the pond is being cleaned out. A maintenance by-pass pipe ensures that new flow below the conveyance threshold of the pipe or control valve will by-pass the facility and be diverted to a different outlet or an overland flow path, depending on the design. Flows from wet weather events would enter the SWMF to avoid flooding and prevent discharge of untreated water to receiving waters. For on-line facilities, a bypass channel would normally be constructed to convey streamflows around the facility while it is being cleaned. The bypass channel would be constructed using natural channel design principles to prevent bed and bank erosion, and provide safe passage for fish and other aquatic organisms.

3.5.5 Sediment Forebay

Sediment forebays, a common feature in SWMFs, help improve pollutant removal in the main cell by trapping heavier sediments and allowing flow to disperse and become quiescent (Figure 3.7). They typically represent at least 10% of the permanent pool volume. Forebays and access roads should be designed to allow for effective removal of sediment accumulated in the forebay without disturbing the remainder of the facility. This is particularly important as a means of protecting the vegetation in constructed wetlands.

Forebay hardening should be considered to facilitate access by heavy machinery. Hardening of a forebay is not recommended in the current Ontario guidance manual (MOE, 2003) due to potential deterioration and damage during excavation. However, practitioner experience has shown that it may be favourable in some cases, and thus, should be considered as a design element on a case by case basis with an understanding of the type of maintenance equipment to be used for sediment removal. The presence of a hard bottom would facilitate the use of smaller machinery such as backhoes as opposed to long-reach backhoes, which cost more and require a larger working area.

For small drainage areas, oil grit separators (OGS) installed upstream of one or more of the facility inlets can be applied to reduce cleanout frequency of the forebay and/or main cell of the SWMF by removing coarse sediment. These devices may be undersized for the drainage area resulting in the bypass of high flows that would otherwise be treated in a more typical installation. OGS are designed to be cleaned out regularly with a standard vacuum truck. Where the OGS is sized appropriately for the drainage area, the device could potentially be applied to replace the sediment forebay. This was done in Richmond Hill as part of the rehabilitation of two SWMFs - Rumble Pond and Pioneer Park.

Some municipal stormwater operations staff have suggested that routine cleanouts of OGS, in accordance with manufacturer specifications on cleanout frequency, are easier to build into municipal operations budgets than infrequent and less predictable maintenance of forebays. However, the high frequency of maintenance that would be required can add up quickly, with OGS clean outs costing \$1000 to \$2000 and being required at least once per year if they are replacing a forebay. As such, this approach may not result in a significant cost savings compared to the alternative of designing the pond with a forebay and cleaning just the forebay and/or the entire pond as needed. A more detailed evaluation of the costs and benefits of this application of an OGS would be required in order to determine whether maintenance costs would in fact be reduced over the lifespan of the facility.



Figure 3.7: Drained sediment forebay in the foreground and a partially drained permanent pool in the background. A berm separates the two areas.



Figure 3.8: Sediment drying bags laid out on a sediment management area adjacent to the pond.
3.5.6 Sediment Management (Drying) Area

To facilitate a faster and smoother sediment removal operation, a sediment management area should be included as part of the design (Figure 3.8). Generally, the area should be sized for at least 10 years' worth of sediment accumulation. To avoid disturbance of nearby residents, the distance between the sediment drying area and the closest property line should be at least 3 m. Where available, local municipal guidance that specifies the distance between the property line and the drying area should be adhered to. It should also be located above the maximum water quality storage level (MOE, 2003) and, ideally, located close to the forebay as it requires more frequent dredging. Water drained from the sediment in the drying area should be conveyed back to the forebay of the SWMF so as to provide more opportunity for sediment settling as the water passes through to the outlet.

The Ontario SWMPD Manual (MOE, 2003) specifies this area as a preferred design element, rather than a requirement. In some cases, it may not be practical to utilize significant areas for infrequent maintenance activities. If this is the case, the additional cost and effort required to clean the SWMF should be fully disclosed and anticipated by future owners at the time of construction. In cases where a facility is constructed without a sediment management area, an adjacent parking lot or field can be utilized as such, given proper allowances by their owners, with the understanding that the water should drain back into the SWMF (see Appendix F for case study example). Additionally, a sediment management area is not necessarily limited to the drying of sediment meets the appropriate quality standards, it could be buried on site (Appendix G for case study example and see Section 9.0 for guidance on sediment disposal and reuse).

3.5.7 Maintenance Access Roads

Maintenance access roads are important design features that greatly assist and expedite the sediment removal process (Figure 3.9). They allow for access of essential equipment, whether it is for the purposes of mechanical or hydraulic dredging. They also allow access by trucks which need sufficient space to load the removed sediment. The presence of access roads as incorporated into the original design also reduces soil erosion and disturbance of vegetation that would otherwise occur.

It is recommended that two access points are integrated into the design to allow for looping to and from all essential SWMF features, such as inlets, outlets, spillways, sediment forebays, sediment drying areas and outfall channels. Since access roads are infrequently used and break the natural look of a SWMF, it is recommended that stone reinforced roads are built instead of asphalt. They require less maintenance than traditional pavement, and are more aesthetically pleasing, while providing a hard and stable ground for heavy machinery.



Figure 3.9: Maintenance access road that is well-maintained. Sign provides information on the stormwater management function of the SWMF and outlines safety concerns.

3.5.8 Length to width ratios

Long narrow SWMFs are preferable to short wide ones because they provide a longer flow path and less potential for short circuiting and 'dead zones'. This results in improved pollutant removal efficiency and less stagnant water and buildup of algae. Geese and other waterfowl are also not as attracted to narrow facilities because they require large stretches of open water to land and launch (CWP, 2009). During cleanouts, sediment can be more easily accessed from the shores.

3.5.9 Outlet Channels

The length of the outlet channel will vary among SWMFs, and is limited by the availability of land between the outlet and the receiving water body. Rip rap or plunge pool energy dissipators are recommended to prevent scour and erosion at the point of discharge. The use of natural channel design principles for longer outlet channels can help cool flows and maintain bank and channel stability. Modifications to conventional outlet channels are becoming more common, particularly upstream of sensitive watercourses, where thermal and hydrological impacts of SWMF flows are of greater concern. Some of these alternative outlet channels include cooling trenches, seepage outlets (Figure 3.10) and spreader swales.

Cooling trenches are typically located downstream of the pond or constructed wetland between the outlet and the receiving water system. However, they can also be installed to receive water from a secondary outlet that draws water continuously from just below the permanent pool water level (Van

Seters and Graham, 2013). The trenches usually consist of a filter sock wrapped perforated pipe embedded in a clear stone filled trench that is buried underground. Contact with the stone media allows transfer of heat from the water to the stone and surrounding soils, thereby reducing the temperature of water discharged to the stream. Seepage outlets are also designed to achieve temperature reductions through shading and heat transfer with surrounding media. They consist of a pipe buried in a gravel jacket that discharges through coarse open graded aggregate. Regular cleaning of the outlet is recommended to prevent blockage.

Cooling trenches and seepage outlets should be designed with a flow bypass to facilitate maintenance. The bypass can also be used to divert flows away from the structures during cold months when they are not serving their primary function (e.g. cooling). This would help to minimize sediment accumulation in the practices and lengthen their cleanout interval. Clean out ports should be located at both ends (inlet and outlet) of the practice to facilitate maintenance when it is ultimately required. If there are multiple outlet pipes for the practice, as in seepage outlets, each should have its own clean out port. Both types of systems should be designed with a degree of redundancy to compensate for potential blockage or reduced rates of discharge from the outlet pipe(s). Monitoring wells should be installed to allow for determination of when the practices require maintenance.

Spreader swales are design to evenly distribute concentrated flow from SWMFs over a large area, effectively converting concentrated flow to sheet flow, providing some moderation of discharge rates. They can also help to reduce effluent temperature and improve water quality through filtering of sediment bound pollutants. Spreader swales should have gentle slopes and be planted continuously along their entire length to provide stability and avoid rilling and erosion. As with cooling trenches and seepage outlets, these structures should also have overflow outlets or bypasses that divert high flows directly to downstream receiving systems (City of Hamilton, 2009).

As-Built Surveys

An as-built topographic survey should be completed prior to any silt depositing and after final grading of the facility has been completed and the impermeable clay liner has been installed (if applicable). The asbuilt survey sets the original condition for the SWMF and provides a baseline against which future surveys can be compared to assess the rate and depth of sediment accumulation. When sediment removal is required, the SWMF owner would use the difference between the two surveys to create a tender for project bidding. Over-excavation is not recommended, as SWMFs are designed with specific hydraulic functions, and the additional storage may alter these functions and potentially create anoxic conditions that increase the potential for release of phosphorus and heavy metals from sediments.

3.5.10 Vegetation

Vegetation is an essential part of the design of wet ponds and constructed wetlands and is beneficial to their overall health and functionality in the following ways:

- Trees around the SWMF provide shade to keep the water cooler, which is critical for cold water fish in the receiving water.
- Bushes planted on the bank slope can help to discourage animals and people from entering the facility, which is important for public safety and water quality.
- Aquatic plants in the SWMF reduce flow velocities and contribute to nutrient uptake and soluble pollutant removal.
- Appropriately selected vegetation will inhibit the spread of invasive species.
- Vegetation stabilizes soils and helps to prevent erosion
- Plants are important for aesthetics and overall community acceptance





Figure 3.10: Schematic of a seepage outlet. (From City of Hamilton, 2009)

Just like any other facility component, vegetation requires proper design and regular maintenance to support SWMF functions. It is advised that trees be grouped together in order to ease mowing activities. This design will also create diverse micro-habitats in these thickly-shaded clusters of trees. The trees should not be planted in areas where maintenance activities are anticipated to take place, such as the sediment management area, access route and outlet structures. For detailed planting guidance, refer to the TRCA's *Stormwater Management Pond Planting Guidelines* (TRCA, 2007) and the City of Toronto's Landscape Design Guidelines for Stormwater Management Ponds (City of Toronto, 2015).

3.5.11 Facility Warning and Educational Signage

Residents living near a SWMF need to be informed about their function and warned about the hazards of using SWMFs for recreational uses such as swimming or skating (Figure 3.9). It is also important to let residents know that the SWMF is a naturalized area, not a highly manicured landscape that will be subject to frequent grass cutting. Educational campaigns and warning signs are beneficial for the long-term operation of the facility as they are believed to reduce vandalism, while increasing community awareness and stewardship for this important infrastructure. This approach also offers the SWMF owner an increased number of unofficial 'inspectors' who are more likely to report a problem with the facility if they have an understanding of how it is designed to function.

3.5.12 Algae Control

Algae can become a problem in stormwater ponds, particularly when pond turnover rates are low and runoff into the facility contains abnormally high levels of nitrogen and phosphorus. Excess algae is unsightly and can create odours leading to complaints from surrounding residents. Algae can also compromise the treatment performance of the pond and clog outlets resulting in more frequent and costly maintenance. Some measures that can help avoid algae problems include:

- Ensure the pond is sized and configured correctly. Oversized ponds can reduce turnover rates that create stagnant water conditions favoured by algae. Ponds with short length-to-width ratios can also create 'dead zones' that are hot beds for algae growth. Upstream treatment practices that reduce volumes through infiltration or evapotranspiration should be considered in the sizing of pond permanent pools.
- Encourage the use of alternative organic fertilizers in public parks, gardens, private lawns/gardens, or agricultural areas draining to the stormwater pond.
- Install barley straw bags around the pond prior to assumption. When barley straw decomposes, it releases a chemical that produces hydrogen peroxide in the presence of sunlight. Low levels of hydrogen peroxide inhibit the growth of algae without harming plants and aquatic life. Hydrogen peroxide does not kill algae but it does inhibit its growth. Barley straw should be applied on dry land around the pond edge at a rate of 1 kg/1000 m² of pond surface area (City of Toronto, 2015).
- Discourage geese that introduce nutrients through their excrement by planting woody vegetation around the pond perimeter and reducing the area covered by mowed grass.

4.0 ASSUMPTION AND MAINTAINANCE OF STORMWATER MANAGEMENT FACILITIES

4.1 SWMF Assumption

The transfer of SWMF ownership from the developer to the future owner (usually a local municipality) shifts full responsibility for long term operation and maintenance of the facility to the new owner. This process of ownership transfer typically occurs several years after construction of the SWMF, when all building activities within the drainage area have been completed.

It is common practice for land developers to provide a Letter of Credit (LOC) to the municipality before they begin construction. In this context, an LOC is a document issued by a third party (e.g. financial institution) that guarantees that the developer has made a fixed amount of money available which the municipality could draw upon if needed. It essentially acts as an insurance policy in the event that the developer fails to meet certain agreed upon financial and/or performance obligations to the municipality. In the case of residential construction projects, the developer will provide the municipality with an LOC as part of a subdivision agreement – a fairly complex legal document that details the developer's responsibilities with respect to construction of services (e.g. SWMFs, sewers, parks, watermains) in the subdivision. The total amount of the LOC will vary by municipality, but there may be a specific amount set aside specifically for the SWMF, which will only be refunded to the developer when the facility is assumed by the municipality.

As part of the assumption process, there are a number of steps that the future owner needs to take to avoid potentially higher long term maintenance and repair costs over the life of the SWMF. The following steps should be taken prior to assumption and refunding of the LOC:

- (i) Complete an as-built survey that verifies that the SWM pond or constructed wetland has been returned to its original design capacity, as per approved drawings. This survey would also provide a baseline against which future sediment accumulation surveys can be compared. In cases where only a small amount of accumulation has occurred, owners may require that the developer provide an appropriate contribution to future maintenance work.
- (ii) Conduct an inspection and monitoring program to ensure that all structural components are functioning as designed and that the stage discharge relationship meets the requirements specified in the stormwater management report for the site.
- (iii) Verify that the facility is landscaped in accordance with approved plans and that there are no environmental concerns.
- (iv) Verify that the catchment is fully stabilized to ensure sediment loads to the SWMF are representative of long term loading rates.

Unless water quality sampling is required as part of the ECA for the SWMF, it is not usually necessary because previous monitoring studies in cold climates have shown that facilities sized and configured according to existing MOECC guidelines provide the required level of suspended solids removal (see Section 3.4). Unfortunately, detailed scientific water quality monitoring studies of ponds and constructed wetlands are difficult and expensive to conduct, and often require that inlets and outlets be custom designed and configured for flow and water quality monitoring. While these studies can provide a wealth of useful research data on the performance and function of the facilities, the level of effort required to conduct these studies typically exceeds what future owners require to confidently assume ownership of the facilities.²

Additional items that should be inspected by the future owner, prior to assumption, are provided in Exhibit 4.1. This list should be regarded as a general overview of common items that are indicative of proper SWMF function. A more detailed inspection checklist is provided in Appendix A.

Exhibit 4.1: Summary list of inspection items to be addressed prior to SWMF assumption.

- a) Check inlet and outlet structures for accumulation of mixed construction debris and other trash that may affect performance
- b) Confirm that water level is at the correct permanent pool level to determine if the SWMF is interacting with the ground water table
- c) Check for unusually extended detention drawdown time that could indicate a blockage in the outlet structure
- d) Check for sediment accumulation in the forebay and downstream of the facility
- e) Look for evidence of seepage along the berms
- f) Check for vandalism including illegal access (e.g. gates) or encroachment about the perimeter of the facility
- g) Confirm that safety and security measures are in good working order (e.g. inlet gate)
- h) Confirm that warning and educational signs are placed
- i) Check for the presence of any unusual erosion around berms and inlet or outlet structures
- j) Complete visual inspection to confirm that vegetation is healthy
- k) Complete visual inspection to confirm no oil sheen is present on water surface or presence of visible contaminants or odours
- I) Check drawdown valve and spill containment valve (if applicable) for proper operation

² Moreover, the stormwater management facility is designed according to standards agreed to by all parties prior to construction. If these standards are met, the future owner has little recourse to alter the size and configuration of the facility if water quality monitoring shows that performance expectations fall below expectations.

4.1.1 Operations and Maintenance Manual

At the time of assumption, an Operations and Maintenance Manual should be provided by the developer to the future owner assuming responsibility for the SWMF. This Manual would include site-specific operational instructions and a general description of individual facility components. The manual should describe how the facility performs under various storm events and the maintenance needed to ensure optimal performance over the life of the facility, including costs and recommended scheduling. A sample Table of Contents for a Stormwater Pond Operations and Maintenance Manual is provided in Exhibit 4.2. Agencies should modify as needed to provide the level of detail they expect.

Exhibit 4.2: Sample Table of Contents from a Stormwater Pond Operations and Maintenance Manual.

- a) Introduction
 - i. Overview of manual
 - ii. Location and drainage area
- b) Stormwater management plan
 - i. Refer to design brief stormwater management report, which includes a detailed description of the drainage area and type of facility designed
 - ii. The summary information should include the objectives of the facility such as water quality, erosion and flood control and level of protection as per MOE (2003).
- c) Characteristics and operation of stormwater management facility
 - i. Description of individual facility features and how they should be inspected and maintained
 - ii. Facility attributes, such as drainage area (contributing area, percent impervious), permanent pool (volume, bottom elevation, permanent pool elevation, depth of pool), extended detention (volume, surface level), quantity control (volume, surface elevation), total active storage (volume, depth), quality control release rate, erosion control, top of embankment, maintenance access (width and road type, maximum grade), orifice size and function, function of weir, method to drain facility, bypass method.
- d) Monitoring requirements
 - i. List of routine inspection checklists and their frequency (an example list is provided in Appendix B)
 - ii. Sediment loading calculations to determine removal frequency
- e) Maintenance activities
 - i. Description of how and when facility features should be changed, including the necessary equipment and responsible parties
 - ii. Procedure required to dewater the pond if it has a bottom draw outlet, this has to be described – what should the discharge rate be, are there sensitive seasonal times when it should not be dewatered with respect to downstream fisheries?
 - iii. Type of equipment to be used during sediment removal

- iv. Anticipated restoration post dredging activities
- v. Sediment testing procedure
- vi. Specialized equipment or services required
- vii. Time of year preference
- viii. Procedure on how to divert inflows from rain events during cleanout operations
- ix. What would winter maintenance involve?
- x. Provide a sediment handling, removal and disposal plan which would include:
 - i. Notice to residents
 - ii. Erosion and sediment control measures
 - iii. Sediment controls to prevent releases to receiving water
 - iv. Necessary chemical analysis
- xi. Sediment dewatering and drying techniques
- xii. Truck maintenance access route
- f) Sediment dewatering and drying techniques
- g) Truck maintenance access route
- h) Cost estimates
 - i. An estimate of annual operations and maintenance costs of the facility based on the schedule provided, including for:
 - Debris and litter removal
 - Grass cutting and weed control
 - Maintenance of aquatic/shoreline fringe and upland/flood fringe vegetation
 - Sediment testing
 - Sediment removal and disposal
 - Inlet/outlet structure repairs
 - Side slope and access road repairs
 - Retaining wall repairs

4.2 Implementing an Inspection and Maintenance Program

Implementation of an Inspection and Maintenance (I&M) Program for SWMFs is strongly recommended for facility owners. An I&M program describes the parameters to be inspected and monitored, and provides a record of management that can be used to verify due diligence in the event that the infrastructure fails or malfunctions (see Section 2.0). I&M programs also provide a platform upon which public agencies can respond more effectively to public concerns and help raise awareness of the importance of the stormwater facilities being monitored.

For the purpose of obtaining technical information and maintaining records, the goals of an I&M Program are to:

a) Establish a maintenance schedule based on the facility's past performance

- b) Evaluate the SWMF's hydraulic response to rainfall events with respect to peak flows and design drawdown times
- c) Assess the effectiveness of measures used to reduce bank erosion
- d) Monitor the condition of vegetation and wildlife using the facility
- e) Determine the budget for future long term inspection and maintenance works
- f) Maintain a record of site conditions and interventions

Additional water quality or temperature monitoring may be warranted in some cases, such as when the SWMF discharges to a sensitive watercourse, or when innovative features have been added to the facility to improve overall performance.

4.2.1 Record Keeping

Inspection and maintenance documents for a given SWMF should be compiled and recorded following a standard procedure for all SWMFs. These records would include details about the design and servicing of each stormwater facility as part of a SWMF asset management database. Programs like Microsoft Access or Excel may offer all the functionality needed to run the database for a smaller municipality (or owner with few SWMFs), while more specific database software such as SWMSoft[®] may be required for municipalities or owners of many SWMFs who wish to track all stormwater infrastructure using a single database. In addition to design details and dates of construction and assumption, the database may also include information on the following:

- General facility appearance
- Inlet and outlet structures
- Outlet channel
- Low flow channels
- Emergency overflow spillways
- Vegetation
- Banks
- Access roads and walkways
- Perimeter fencing
- Sediment accumulation
- Public safety
- Other notable features

Each feature could be nominally rated and ranked. For example:

- 1. Excellent (the component has no deterioration)
- 2. Satisfactory (some wear is noticed, but it does not affect the functionality)
- 3. Attention required (component is still functioning but has minor problems that may prevent the component from functioning properly during extreme events some simple upkeep is required)
- 4. Non-functional (the component is no longer functioning as designed or is missing)

5. Safety hazard (the component presents a safety hazard)

Some municipalities may also wish to use the database to keep a record of observed illegal activities that could impact the appearance or function of the SWMF, such as illegal encroachment or illegally installed private drains.

4.2.2 Establishing maintenance priorities

In order for SWMF owners to determine how maintenance activities should be prioritized, criteria must be established as part of the asset management database. These criteria should be based on historical maintenance requirements, drainage area and downstream sensitivity, and may include the following:

- a) Downstream sensitive areas
 - a. High priority natural wetlands
 - b. Impaired water bodies
- b) Pollutant removal capability
 - a. Based on SWMF size/permanent pool storage provided
 - b. Percent reduction in permanent pool due to sediment accumulation
- c) Safety
 - a. Historical flooding
 - b. Side slope stability
 - c. Sediment analysis results
- d) Ability to perform work
 - a. Construction access
 - b. Easements/ownership
 - c. Permitting
- e) Citizen involvement
 - a. Resident complaints
 - b. Resident participation in process

By assigning values to each of these factors based on their relative importance for the given facility, each SWMF can be given a score when they are assessed/inspected. The scores can be used to rank the SWMFs with respect to maintenance needs and thereby establish the priority projects for each year.

4.2.3 Planning and budgeting for SWMF maintenance

Detailed maintenance procedures should be developed based on the Operations and Maintenance Manual provided to owners/operators by the developer, which should include an inspection checklist for each significant component of the facility, an explanation of the equipment, and a schedule for maintenance activities. Based on the maintenance schedule and the cost estimates provided by the developer in the manual, SWMF owners can establish budgets for maintaining all their facilities. Keeping a record of these costs also allows the owner to forecast future expenditures associated with newly assumed SWMFs.

4.3 Inspection and Preventive Maintenance

Prior to each scheduled inspection, SWMF information available in the asset management database should be reviewed, including the age and function of the facility and details about past maintenance. A copy of the as-built drawing should be available during the inspection to identify the location and design of components being inspected. Photographs and descriptions of components inspected should be taken and stored within the database.

During the first inspection and maintenance visit to a SWMF, the inspector should document whether there were any problems accessing the areas inspected, so as to facilitate subsequent inspections. Major components of the facility should be inspected after every large precipitation event (≥25 mm), or a minimum of four times per year. Sediment depth should be measured (as detailed in Section 6.1) at least every 3 to 5 years, either by conducting a full bathymetric survey or by using a more basic method, such as measuring sediment depth at a minimum of three points in the SWMF along a longitudinal transect.

An overview of common inspection and maintenance activities is provided in the paragraphs below. See Appendix B for a detailed field checklist.

4.3.1 Drainage Area Preventive Measures

In addition to inspection of the SWMF and the immediately surrounding area, the contributing drainage area should also be inspected. The condition of the drainage area can have a significant impact on the maintenance cycle of a stormwater pond or other SWMF. Soil erosion, construction activities and upstream sources of contamination should be identified and addressed in a timely manner.

When it comes to maintenance of SWMFs, an ounce of prevention is definitely worth a pound of cure. Addressing sediment and other contaminants at their source, in the contributing drainage area, is often much more manageable and cost effective than to remove sediment that has already accumulated in the facility. Sources of solid and semi-solid materials that find their way into SWMFs originate from various sources within the contributing drainage areas, including:

- Litter and yard waste
- Sand and salt from winter operations
- Natural leaf litter and downed branches
- Soil loss from lawns and open areas
- Construction sediments
- Grit from roofing shingles
- Fluids, oils, grease and solvents from industrial areas
- Atmospheric deposition washoff
- Upstream erosion

Measures that can be taken to manage pollutant sources before they reach stormwater ponds and constructed wetlands include:

- Reducing pesticide and fertilizer use
- Good household practices
- Erosion and sediment control measures during construction
- Regular regenerative air street sweeping (or equivalent)
- Regular catchbasin cleaning
- Enforcing animal by-laws of proper pet waste disposal practices
- Promoting natural aquatic vegetation
- Industrial pollution prevention programs
- Optimizing practices for winter snow and ice management
- Reducing or eliminating the use of driveway coal tar sealants known to contain high levels of PAHs, which are washed off into SWMFs where they contribute to poor sediment quality.

Aside from its aesthetic benefits, street sweeping functions as an important drainage area preventive measure for keeping sediment out of catchbasins and SWMFs. A Toronto-based study (Rochfort *et al.,* 2009) concluded that the most significant environmental benefit of street sweeping is the removal of sediment that would otherwise end up accumulating in SWMFs. A Wisconsin study (Bannerman, 2007) found that street sweeping could in fact reduce annual TSS loads by up to 30%, depending on sweeping frequency and the type of equipment used. Street sweeping works especially well in combination with regular catchbasin cleaning, as the former reduces the frequency of catchbasin cleaning while the latter helps prevent scour and washout of accumulated sediment in catchbasins.

4.3.2 Vegetation management

Grass should not be mowed to less than 4-6 inches, as the presence of mature grass is beneficial for stormwater filtration and erosion prevention. Tall vegetation, particularly on side slopes, helps to prevent geese from entering the pond, thus reducing potential for eutrophication. Grass cuttings should be collected and removed, as they will otherwise enter the SWMF or decay on site, creating mosquito breeding habitat and increasing potential for algal blooms. The application of fertilizers, herbicides and pesticides in and around SWMFs should be avoided.

The presence of aggressive invasive species such as Common Reed has been identified as a maintenance issue for SWMFs. Common Reed (*Phragmites australis*, subsp. *australis*) is an invasive perennial grass that is easily transported by wind and water and is known to degrade biodiversity by destroying the habitat of other species (MNR, 2011b). A document published by the Ontario MNRF, *Invasive Phragmites – Best Management Practices*, (MNR, 2011b) outlines a number of control methods to reduce and possibly eliminate the presence of invasive *Phragmites*, such as herbicide application, mowing/cutting, compression/rolling, prescribed burning, hand-pulling/mechanical excavation, flooding, taping and biological controls. While they specify that the most effective approach in most circumstances is a combination of herbicide application, cutting/rolling and prescribed burning, the document specifically states that herbicides cannot be applied to *Phragmites* located in standing water. The suggested best management practices for controlling Phragmites in standing water include cutting/mowing the stalks or

tarping the area, however neither practice is described as an effective standalone method for eradicating invasive *Phragmites* from the body of water.

If invasive *Phragmites* control/removal is planned for a SWMF, it may be appropriate to schedule the work to coincide with sediment removal, since *Phragmites* removal methods would often require the dewatering of the facility. It's also important to consider that if invasive *Phragmites* are known to be present in the facility, and sediment removal is planned, the dredged sediment would potentially contain parts of *Phragmites*. If the sediment is to be reused at another site, rather than disposed of in a landfill, the *Phragmites* could be spread to the receiving site. In order to dispose of invasive *Phragmites* so as to prevent spreading, they must be dried and burned or deposited in a landfill.

4.3.3 Aesthetics – debris and litter removal and repair of vandalized areas

Stormwater ponds and constructed wetlands need to meet community aesthetic standards. Typically this means that vegetation is well maintained (see above), graffiti is eliminated, signs are maintained, and trash is regularly removed from the facility.

4.3.4 Addressing nuisance issues

This may include standing water, animal burrows, beaver activity, invasive species (e.g. phragmites) or algal blooms. Nuisance issues should be addressed proactively so that they don't turn into more significant and costly problems. Where a nuisance issue can be attributed to facility design, it may be advisable to consider facility retrofits that would mitigate the problem. For example, algal blooms may be mitigated by modifying the flow path and facility dimensions so as to eliminate any dead zones where water is stagnant.

4.3.5 *Sediment accumulation or spills*

During frequent inspections when sediment depth is not being measured, localized areas of excess sediment accumulation can be observed without measurement. Any localized areas of excess accumulation should be further investigated. Sediment accumulation in outlet channel structures like cooling trenches should also be checked and the pipe should be flushed routinely to maintain the capacity and functionality of the structure and prevent sediment from accumulating in the stone and/or sand surrounding the pipe. Visible contaminant spills in the SWMF should also be documented and investigated. Oils/grease or hydrocarbon spills may lead to unnatural odours and/or visible sheen on the water surface.

4.3.6 Mechanical equipment check

Inspection of any valves, pumps, fence gates, locks or other mechanical components should be performed during each visit. All mechanical equipment serves an important function and/or safety purpose for the facility. All movable parts should be free to operate.

4.3.7 Structural component check

Structural components should be regularly inspected in order to proactively identify when corrective actions will be needed. Inspection of structural components can reveal reasons for hydraulic malfunctioning (too high or too low water levels) which need to be addressed immediately. Inlets or outlets can become clogged with sediment and debris. Pipes are prone to corrosion and should therefore be checked during every inspection.

4.3.8 Community involvement

Residents living near the facility can be helpful in identifying potential problems, particularly if they are aware of the purpose of the SWMF. Educational programs and signage are the best means of making residents more aware of how the facility functions and the potential dangers of the facility during different seasons. A sample checklist for local residents to observe and report on potential problems is provided in Exhibit 4.3.

4.4 **Corrective Maintenance Activities**

Most of the major maintenance works associated with SWMF fall into one of the following categories: (i) major structural repair, (ii) bank stabilization, (iii) sediment removal from SWMF bottom and (iv) unplugging of inlets and outlets. These maintenance activities are inherently different from the preventive measures described in Section 4.3, as they address problems that significantly impair the functionality and/or safety of the facility. They are usually required much less frequently but are more costly. Among these, sediment removal is also fundamentally different because it is a normal aspect of how SWMFs work – since sediment is meant to accumulate in these facilities – while structural repairs and bank stabilization are not necessarily expected to occur. Like preventive maintenance, the need for corrective maintenance is identified during regular inspections. When inspections are carried out at the recommended frequency – after every major precipitation event or at least 4 times a year – the need for major corrective maintenance can often be identified early and budgets can be adjusted accordingly.

4.4.1 Sediment removal

When sediment accumulation in the SWMF has reached a point where removal efficiency has been reduced by 5% or more (detailed in Section 4.5), sediment removal is required. Once sediment dredging is complete, the SWMF is returned to its original design capacity and is again capable of providing effective hydraulic and water quality control. In-situ measurement of sediment depth should be carried out regularly (at least every 3 to 5 years) to determine when cleanout will be required. Sediment removal from cooling trenches and seepage outlets will also be required at some point during the lifespan of the practice. The clean out interval will vary according to various factors, and in particular the way it is operated (e.g. used only during summer months vs. year-round operation)

Exhibit 4.3: Homeowner Checklist (CWP, 2009).

We e to an	Homeowner Checklist We encourage you to copy this checklist and maintain a record of your inspections. Answering YES to any of these questions indicates a need for corrective action or consultation with a professional				
Na	imeDate Inspected				
Wh	at to look for	YES	NO		
1.	Does the facility show signs of settling, cracking, bulging, misalignment or other structural deterioration?				
2.	Do the embankments, emergency spillways, side slopes or inlet/outlet structures show signs of erosion?				
3.	Are the pipes going into and/or out of the facility clogged or obstructed?				
4.	Do the impoundment and inlet areas show erosion, low spots or lack of stabilization?				
5.	Are there trees present on the banks?				
6.	Is there evidence of animal burrows?				
7.	Are contributing areas destabilized with evidence or erosion?				
8.	Do vegetated areas need mowing or is there a buildup of clippings that could clog the facility?				
9.	Does sedimentation greatly decrease the BMPs capacity to hold water within the structure?				
10.	Is there standing water in inappropriate areas?				
11.	Is there accumulation of trash or debris?				
12.	Is there evidence of encroachment or improper use of the impounded areas?				
13.	Are there signs of vandalism?				
14.	Do any safety devices such as fences, gates or locks need repair?				
15.	Is there excessive algae or dominance of one type of vegetation?				
16.	Is there evidence of automotive fluids entering or clogging the facility?				
17.	Is there evidence of a fish kill?				
18.	Do you see a lot of mosquito larvae (small "wigglers" or "tumblers") in the water?				
19.	Is there evidence of excessive amounts of mosquitoes?				
Additio	onal Observations				

4.4.2 Unclogging of inlets and outlets

If an inspection reveals that the SWMF permanent pool level is higher than expected after several days of dry weather this may be an indication that the outlet is clogged with sediment, garbage and/or debris. Minor clogs that are accessible can be cleaned out by hand, but more significant clogs are removed by flushing or a combination of jet washing and suctioning with a vacuum truck. For outlets containing crushed stone, such as a hickenbottom, unclogging requires that the stone is washed and/or screened or replaced altogether.

4.4.3 Bank erosion/stabilization

Maintaining the structural integrity of banks keeps SWMFs safe and functioning as intended. Unstable banks and/or high erosion rates can lead to excessive sediment deposition and eventual bank failure. It is critical to keep effective ground cover on all vegetated areas to maintain stability and to promote infiltration and the effective filtering of runoff. The land area surrounding the SWM pond or constructed wetland should be fully stabilized and landscaped as part of its construction. During the life of the facility, any areas where vegetation has been removed and soils left exposed for any reason should be stabilized immediately and revegetated as soon as possible.

4.4.4 Structural repair/replacement

Sustained flow of sediment-laden stormwater through a SWMF contributes to slow degradation of concrete structures through scour and freeze/thaw cycles. Although it is expected that most facilities will require structural repairs at some point during their operating life, the type of repair and when it will be needed cannot usually be forecasted years in advance. The need for structural repairs must be identified through routine preventive maintenance visits. Eventually, the outlet or other structures such as the trash rack will need repair or replacement.

4.5 Forecasting Sediment Accumulation

Accurate forecasting of sediment accumulation in stormwater facilities helps managers schedule and budget for eventual cleanout and restoration of their infrastructure. The Ontario SWMPD Manual (MOE, 2003) recommends SWMFs be cleaned when the TSS removal efficiency declines below 5% of its original design criterion. For example, if ponds are designed to remove 80% of TSS - as they are at the "enhanced protection" level - an efficiency reduction to 75% triggers the need for sediment removal.

Estimates of accumulated sediment volumes corresponding to a 5% efficiency reduction for stormwater ponds and wetlands is based on modelling reported in the 1994 version of the Ontario SWMPD manual (MOEE, 1994). While these sediment accumulation estimates have not been field validated, they provide useful and justifiable targets that allow facility managers to schedule cleanouts in a manner that ensures the facilities continue to serve their intended function.

The rate of sediment accumulation is unique to each facility, and depends on factors such as:

- Type of facility (e.g. constructed wetland, pond)
- Permanent pool storage volume
- Characteristics of drainage area (e.g., land use; level of imperviousness; upstream construction activities and effectiveness of sediment and erosion control practices)
- Municipal practices (e.g. frequency of road/catchbasin cleaning, sanding/salting practices)
- Facility removal efficiency.

When considering sediment accumulation volumes, it is important to distinguish between the loading, or mass of dry sediment in runoff entering the facility, and the in situ sediment accumulation, which is the volume of sediment in a saturated condition. The latter represents only the volume of sediment that was retained in the facility, while the former includes the retained sediment as well as sediment that was discharged in the facility effluent during normal operation. Based on data compiled as part of this guide (see case studies in Appendices), annual in-situ sediment accumulation ranges from 0.2 to 5.9 m³ per hectare drainage area (n = 11). MOE (2003) suggests a smaller range of 0.5 to 3.0 m³/ha/year for catchment impervious covers of 35 to 85%. During the first few years after construction, sediment accumulation rates have been reported to exceed 20 m³/ha/year (TRH, 2003), highlighting the importance of assuming the SWMF only after the contributing drainage area has been fully stabilized.

In order to determine whether a given SWMF requires sediment removal, three key pieces of information must be obtained:

- 1. Current storage available in the SWMF: This can be derived from directly measuring sediment depth or from modelling of the TSS loading rate and facility removal efficiency.
- 2. The minimum SWMF efficiency permitted: Based on the MOE 2003 SWMPD Manual, the minimum efficiency is defined as a 5% reduction in efficiency.
- 3. The SWMF's treatment efficiency vs. storage relationship: This relationship shows the storage volume decline associated with a 5% decline in efficiency, which can then be directly compared the current storage available in the facility.

The following subsections describe two common methods for forecasting the need for sediment removal from SWMFs.

4.5.1 Forecasting Based on Sediment Depth Measurements

Physical measurement of sediment depths within a SWMF is the most common and accurate method of determining when a SWMF should be cleaned out, as it is based on a direct assessment of accumulation rates over time. Sediment depth should be measured (as detailed in Section 6.1) at least every 3 to 5 years, depending on how close the SWMF is to requiring a cleanout. This could be achieved by conducting a full bathymetric survey or by using a more basic method, such as measuring sediment depth at a minimum of three points in the SWMF along a longitudinal transect (see example locations in Figure 6.4). These three points should be staked so that measurements are taken at the same locations at every visit.

Sediment depth measurements are used to calculate the approximate total volume of sediment in the facility, which is then compared to the maximum allowable sediment accumulation based on a 5% reduction in treatment performance. The maximum allowable sediment accumulation - or minimum permanent pool volume - in SWMFs can be interpolated from curves relating TSS removal efficiency to available storage, which are provided in Chapter 4 of the MOEE (1994). The Manual provides a series of curves for different levels of catchment imperviousness and different kinds of facilities (e.g. wet pond, constructed wetland, etc). Interpolated values from these curves are provided in Tables 4.1 and 4.2 for ease of reference. The Tables provide minimum permanent pool volumes (Table 4.1) and maximum sediment accumulation volumes (Table 4.2) for constructed wetlands, wet ponds and dry ponds.

Protection		Tri	Tributary Area Imperviousness			
Level	SWMF Type	35%	55%	70%	85%	
Enhanced	Constructed wetland	28	45	54	67	
Limaneca	Wet Pond	63	98	124	150	
Normal	Constructed wetland	15*	20	24	32	
	Wet Pond	33	50	63	74	
	Constructed wetland	15*	15*	15*	15*	
Basic	Wet Pond	15*	20	31	36	
	Dry Pond	50	81	89	107	

Table 4.1: Minimum SWMF Permanent Pool (Extended Detention for Dry Ponds) Volumes Prior to Maintenance (m³/ha).

Note: These values have been interpolated from the 1994 MOEE SWMP Manual Figures 4.2 to 4.5, based on the recommended allowable 5% reduction in original design storage due to sediment accumulation. Wet pond/wetland values listed are permanent pool volumes (i.e., 40 m³/ha extended detention storage has been omitted) * Values cannot be interpolated from volume vs. treatment relations; approximate and/or extrapolated values used.

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

Table 4.2: Maximum Allowable Sediment Accumulation (m³/ha) in SWMFs.

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.

Sample forecasting exercise

Figure 4.1 illustrates conceptually how sediment volumes (calculated from measured sediment depths) can be used to forecast when sediment maintenance would be required. The example corresponds to a wet pond sized for 'enhanced' level protection, draining a catchment with 55% impervious cover. Using Table 3.3 in Section 3.3, the total design storage volume is 190 m³/ha, of which 40 m³/ha represents active storage above the permanent pool. Thus the design permanent pool for the facility is 150 m³/ha. From Table 4.1 the minimum allowable permanent pool volume for this facility is 98 m³/ha, which occurs when an average volume of 52 m³/ha of sediment has accumulated in the wet pond (Table 4.2).



Figure 4.1: Hypothetical sediment forecasting example.

Sediment measurement frequency

Regular (i.e., every 3 years) or sporadic (i.e., irregular cycle) field measurement of available storage along transects through and across the SWMF is useful when sediment accumulation occurs at a relatively constant rate (Figure 4.2a). More frequent measurements are required if sediment accumulation rates are affected by unanticipated changes in catchment loading rates or facility efficiency. As an example, Figure 4.2 depicts three different sediment accumulation scenarios and how the cleanout interval is affected. The scenarios are: (a) a constant and steady accumulation rate, (b) a period of accelerated accumulation, and (c) a deceleration in accumulation. Figure 4.2b illustrates a hypothetical situation in which one year of construction activities with poor erosion and sediment control practices have impacted the sediment

accumulation rate. The impact on the maintenance forecasting is drastic, misleading planners that the SWMF is not yet due for cleaning, while it has in fact reached its capacity.





The reverse situation is shown in Figure 4.2c. In this case, the reduced sediment accumulation rate could be caused by a reduction in removal efficiency, a reduction in street sanding, or the implementation of source control practices in the contributing catchment (e.g. street sweeping or infiltration practices). If less sediment is entering the facility (e.g. due to effective upstream controls), the maintenance time interval would be extended. These examples underscore the importance of being aware of the contributing drainage area during preventive maintenance visits, and understanding the extent to which these activities can impact sediment forecasting. They also demonstrate why using a desktop approach, which is described in the Section 4.5.2, will often result in an inaccurate assessment of how much sediment is in the SWMF.

As an alternative trigger, several agencies recommend that accumulation in the SWMF forebay alone should be used as a basis for determining the need for a cleanout. These agencies (e.g. Town of Oakville, 2012; Tennessee, 2015; MPCA, 2013) have determined that the SWMF should be dredged when forebay storage volume is reduced by 50%. On average, based on an enhanced level wet pond and 55% catchment imperviousness, the 5% efficiency reduction trigger is equivalent to a 35% reduction in total pond storage volume. Although this alternative forebay trigger would appear to be more forgiving, it would likely result in similar time intervals between cleanouts, since the forebay is designed to remove coarse sediment and fill more quickly than the rest of the facility. A more conservative trigger would be a 35% reduction in just the forebay storage volume, given the higher rate of sediment accumulation in the forebay and the fact that a 35% reduction in total pond storage volume would trigger maintenance based on the 5% efficiency reduction criterion.

4.5.2 Desktop Modelling Approach

An alternative approach to direct sediment measurement, involving continuous computer model simulations, is described in MOE (2003). It is recommended as a tool that may be used for screening and/or prioritizing SWMF cleanout projects, but not for specific forecasting of maintenance or as a substitute for direct sediment measurement.

This desktop modelling approach involves referencing curves provided in Section 5.5 of MOEE (1994), which relate sediment removal frequency to SWMF storage volume. The curves, developed based on the use of continuous simulation and a sedimentation model, are provided for four different catchment imperviousness levels – 35, 55, 70 and 85 percent – and for different types of SWMFs – wet ponds, constructed wetlands and dry ponds. Model simulations were carried out using typical TSS loading rates, which were subsequently converted to the sediment accumulation volume based on the expected density of the wet sediment. Table 4.3, adapted from the Manual, provides the annual TSS loading rates used in the modelling, average wet sediment density, and the annual sediment accumulation volume provided in the Table is calculated by dividing the annual loading by the wet density and then multiplying by the removal efficiency.

Catchment Imperviousness	Annual Loading (kg/ha)	Wet Density (kg/m ³)	Annual Sediment Accumulation (m³/ha)
35%	770	1,230	0.48
55%	2,300	1,230	1.52
70%	3,495	1,230	2.24
85%	4,680	1,230	3.04

Table 4.3: Annual sediment accumulation in enhanced level (80% removal efficiency) SWMFs calculated based on average loads (adapted from MOEE, 1994, Table 5.3).

To calculate cleanout intervals based on Table 4.3 data, the maximum allowable sediment volume for the pond (from Table 4.2) should be divided by the annual sediment accumulation volume provided in Table 4.3. For enhanced level wet ponds draining catchments with 35, 55, 70 and 85% imperviousness, maximum sediment accumulation volumes are 37, 52, 61 and 60 m³/ha, respectively. Based on these values the respective cleanout intervals are 77, 34, 27 and 20 years, which are longer than typical requirements, as most municipalities consulted in the development of this guide have indicated that SWMFs servicing stabilized catchments typically need to be cleaned after only 15 to 20 years of operation.

Ultimately, this type of load-based approach is not recommended for determining cleanout intervals, mainly because loading rates vary significantly from one catchment to another based on a number of factors. Further, it would be difficult to improve on these estimates through direct measurements of sediment loads for a given SWMF because accurate measurements of sediment loads are difficult to obtain, and sediment loads can vary substantially from year to year. The annual loading values listed in Table 4.3 can nevertheless provide a useful basis for comparison to measured sediment volumes, allowing SWMF managers to gauge whether sediment accumulation rates in their facility seem to be close to expected values.

5.0 INITIATING A SEDIMENT REMOVAL PROCESS

Early planning is critical to conducting a cost effective and timely sediment removal project. When it has been determined that a SWMF must be cleaned out, it is first important to determine the volume of accumulated sediment by conducting a bathymetric survey (as described in Section 6.1). Aside from sediment quantity, sediment quality must also be determined early in the process because it can have a substantial impact on the project budget. Sediment samples should be collected and submitted for laboratory analysis, as detailed in Sections 6.2 and 9.2.3. Sediment quality will determine what can be done with the sediment, such as landfill disposal or reuse on- or off-site. Another important early consideration is whether there is space for sediment dewatering on-site, or whether wet sediment will be hauled away for off-site dewatering (see Section 8.0). A flowchart depicting the major steps in a SWMF sediment clean out project, from project planning through to sediment disposal, is provided in Figure 5.1. The following subsections provide more detailed guidance on project initiation, with the exception of sediment disposal/reuse decisions, which are discussed in Section 9.0.

5.1 Permits and Approvals

The permits and approvals required for a given SWMF clean out will vary to some extent depending on project details such as:

- SWMF geographic location
- Whether the SWMF is in a conservation authority regulated area
- SWMF type
- Whether the SWMF is online or offline
- Proximity to protected natural features (e.g. Environmentally Significant Areas, Areas of Natural and Scientific Interest, Provincially Significant Wetlands)
- Presence of species that are at risk in Ontario
- Proposed clean out method
- Proposed sediment reuse/disposal method
- Time of year

The following subsections describe the permits and approvals issued by the various regulatory bodies commonly involved in this type of work, and the circumstances under which they would likely be required. It is recommended that these regulatory bodies be contacted and consulted with early in the project to allow time for any necessary permits and approvals to be issued, and thereby avoiding costly delays. The legislative basis for each of these permits is detailed in Section 2.0 which summarizes legislation and guidelines relevant to SWMFs.

5.1.1 Ontario Ministry of Natural Resources and Forestry

For more detailed guidance, refer to the MNRF Aurora District Stormwater Management Pond Clean-out Best Management Practices (May, 2016).

<u>Paragraph 35(2)(b) Fisheries Act Authorization:</u> Required for the construction of a watercourse diversion in place during the clean out of an online SWMF.

<u>License to Collect Fish for Scientific Purposes</u>: Issued under O.Reg. 664/98 for the collection, handling and deposition of fish, which may be required as a result of the dewatering of a SWMF.

<u>Wildlife Scientific Collector's Authorization</u>: Issued under the Fish and Wildlife Conservation Act for any collection, handling and deposition of protected wildlife species that may be necessary during a SWMF clean out.

<u>Lakes and Rivers Improvement Act section 14 approval</u>: In areas of the province that are not within conservation authority (CA) jurisdiction, an approval would be required for the construction of a watercourse diversion/bypass required during the cleanout of an online SWMF. In areas that are within CA jurisdiction, it is sufficient to obtain the CA permit that covers work occurring in the regulated area.

<u>Authorization under the Ontario Endangered Species Act</u>: This type of authorization is required if species at risk are on the site and there are works planned that would impact these species. Prior to initiating a SWMF cleanout, the MNRF should be contacted to determine whether there are any at risk species on the site. The need for this authorization can be avoided where it is possible to work around protected species and habitats so that they are not subject to any adverse effects. The MNRF will provide direction on the options available to best protect these species.

5.1.2 Ontario Ministry of the Environment and Climate Change

<u>Sewage works Environmental Compliance Approval (ECA)</u>: Issued under the Ontario EPA, ECAs must be issued prior to construction, modification and/or alteration of a sewage works. ECAs will often, but not always include requirements that the SWMF be maintained. As such, the facility ECA should be referenced in order to determine what activities are permitted. If the clean out work is being carried out as part of a larger project to modify the facility, an ECA would likely be required.

<u>Waste management Environmental Compliance Approval (ECA)</u>: ECAs are also issued for waste management activities, which the handling and disposal of SWMF sediment could be classified as, depending on the sediment quality. If the sediment is classified as waste based on its contaminant levels, any soil conditioning activities could be considered waste management and require an ECA. The site that receives the contaminated sediment and the hauler that transports it are both also required to have separate ECAs for their operations. Where sediment reuse is being considered, but contaminant levels exceed Table 1 of the *Soil, Ground Water and Sediment Standards* (MOE, 2011a), SWMF owners/operators should refer to the MOECC document entitled *Management of Excess Soil – A Guide for Best Management Practices* (MOECC, 2014) and consult directly with the local MOECC officer to determine what reuse

options are available. More information on sediment disposal and reuse is provided in Section 9.0 and the flowchart in Figure 5.1.

5.1.3 Local Conservation Authority

Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Permit: Under the CA Act, individual regulations have been passed for each Ontario CA entitled "Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses". The regulation requires that a permit be obtained from the local CA for a SWMF clean out if: (i) the facility is located within the regulated area; (ii) a watercourse diversion is required because the facility is online; or (iii) water from the facility is being pumped out and into a regulated area. Within the TRCA jurisdiction, if the facility is offline and located outside the regulated area, the requirement to obtain a permit could be replaced by permission for routine infrastructure works (RIW), provided that the project meets the qualification criteria. The application for permission for RIW is simpler, with a faster turnaround time and generally lower fees. The Interim Protocol that includes the qualification criteria for RIW is provided in Appendix E.

5.1.4 Local Municipality

By-laws specific the local municipalities must be considered to determine if the works planned will require any municipal permits. By-law regulated activities such as tree removal, disturbance to ravines and natural features, generation of excessive noise or dust, and discharge to storm sewers often occur during SWMF clean outs.

5.1.5 Ontario Ministry of Agriculture, Food and Rural Affairs

<u>Non-Agricultural Source Material (NASM) Plan Approval</u>: NASM is defined by OMAFRA as "treated and recycled material from non-agricultural sources like leaf and yard waste, fruit and vegetable peels, food processing waste, pulp and paper biosolids and sewage biosolids" (OMAFRA 2016). The General Regulation 267/03 under the Nutrient Management Act states that the application of certain types of NASM to agricultural land requires an approved NASM plan. Municipal sewage biosolids are classified as a category 3 NASM, which would be one of the types that would require this type of approval. If dredged SWMF sediment is to be applied to agricultural lands as an NASM, then it is necessary to receive an OMAFRA approval on the plan, which must be prepared by a professional certified by OMAFRA.



Figure 5.1: SWMF clean out project flow chart - project initiation.



Figure 5.1 cont'd: SWMF clean out project flow chart – sediment disposal and reuse options.







Figure 5.1 cont'd: SWMF clean out project flow chart – preparation of plans and budgets (left side) and project implementation (right side).

5.2 Procurement

5.2.1 Creating and awarding a bid

Prior to creating a tender document, the SWMF owner should understand the current state of the facility and the state to which it needs to be returned. This information should be available if the owner has a thorough inspection and maintenance program in place. Some SWMF owners (e.g. municipalities, developers) will choose to manage the entire project in house, while others will retain a consultant, usually through a request for proposals (RFP) process.

The following is a list of site-specific items that should be taken into consideration when creating a tender document for the purpose of cleaning out a SWMF. If a consultant is retained, they may be responsible for collecting some or all of this information on behalf of the SWMF owner.

- Location plan, including as-built drawing if available
- Site access route
- Potential site hazards
- Construction area restriction plans showing staging and storage areas
- Erosion and silt protection
- Existing and proposed typical cross-sections
- Bathymetric surveys
- Estimated excavation volumes
- Sediment quality and disposal options
- I Dredging options
- Dewatering techniques
- Material specifications and sundry construction
- Retrofit/repairs to the existing components of the SWMF structure
- Rehabilitation of eroded banks

The tender document may be prescriptive, specifying plans for sediment handling, removal and disposal, or it may allow for contractors to propose their own plans. The following are the key elements of a handling, removal and disposal plan. While the division of responsibilities among the contract administrator (consultant), the SWMF owner and the contractor will vary from one project to another, responsibilities are often divided as follows:

- a) Written notice to local residents within a minimum 120 m radius usually directly from the SWMF owner
- b) Temporary public notice to identify maintenance works and duration usually directly from the SWMF owner
- c) Summary of how issues like missing documentation and/or lack of as-built survey will be addressed SWMF owner or consultant
- d) Permits and approvals required for the process SWMF owner or consultant
- e) Site access points consultant or contractor

- f) Information on potential environmental impacts including tree removal, depth to ground water, and displacement of fauna consultant
- g) Erosion and sediment control plans contractor and/or consultant
- h) Sediment measurement techniques consultant
- i) Sediment testing techniques and disposal options consultant
- j) Dewatering techniques, estimated draw-down time, and erosion mitigation measures during SWMF drawdown consultant or contractor
- k) Sediment removal methods contractor and/or consultant
- I) Sediment drying techniques contractor and/or consultant
- m) Process for tracking volume of sediment removed contractor
- n) Plans for odour, dust and noise management contractor and/or consultant

While municipal owners of SWMFs often have procurement policies in place that require that they award the contract to the lowest bid, they may avoid the selection of a contractor lacking the requisite knowledge or experience by requiring pre-qualification (e.g. having completed a certain number of pond clean outs in the past). As mentioned above, the owner may also choose to specify the sediment removal and drying methods, giving them added control of the clean out process.

5.2.2 Establishing and verifying sediment volumes

The scope of work description should clearly state that the contractor must restore the SWMF to its original storage capacity. In cases where the facility was over-excavated (beyond its design storage volume) during its construction, the tender document can specify that sediment be removed to solid ground. The volume of accumulated sediment, based on in situ sediment depth measurements, must be stated in the tender document. It should be explicitly stated in the tender document that this value is based on estimates derived from survey results. If the time delay between the survey and the clean out is more than one year, a certain percentage should be added to the total sediment quantity based on the average sediment loading rate for the facility (see Section 4.5.2 and Table 4.3). Contractors typically charge according to the total volume of sediment removed from the SWMF, excluding any material added for dewatering or bulking of the sediment.

In the case of mechanical dredging, which requires dewatering of the SWMF, the sediment volume measured in-situ during the bathymetric survey will be less than the sediment volume that needs to be removed once the SWMF has been dewatered. This difference is a result of added water pressure when the pond or constructed wetland is full, which acts to partially consolidate the material. As water is pumped out, the pressure exerted on the sediment is reduced, and the fine sediment allows more water to penetrate into the pores. To compensate for this, SWMF owners/operators may choose to increase the measured in-situ sediment volume by 10 to 20% to better approximate the volume that will be removed. At the time of dredging, the contractor will determine how much bulking/dewatering is needed to minimize hauling costs. As a general rule, the addition of bulking material increases the sediment volume by about 10 to 15%.

The tender document should clearly outline the cost implications associated with removing more or less sediment than what is stated therein. This is especially important when sediment removal is provided as a lump sum. It may be useful to include an acceptable percentage variance from the sediment volume stated in the tender. For example, if 15% variance is allowed, and the sediment volume stated in the tender is 4000 m³, then the contractor would be required to justify any charges for removing more than 4600 m³ or less than 3400 m³. In the case that less sediment was removed, it is necessary to confirm that there isn't a significant amount left in the SWMF, usually with a follow up bathymetric survey. If the contractor claims to have removed significantly higher amounts of sediment, it may be wise to ask that they provide evidence that this quantity was removed.

One way to ensure that sediment removal volumes are in line with the expected budget is to request that the contractor notify the owner when the agreed upon volume has been removed, and then both parties can discuss the status of the project to determine how much sediment is remaining, possibly based on resurveying. Alternatively, a quick re-surveying could instead be done earlier, at 50 or 75% completion, to get a clear picture of where things stand and potentially re-assess which areas of the SWMF require the most cleaning.

Some of the reasons why sediment volume calculations based on surveys can differ from actual volumes of dredged sediment include:

- The SWMF design elevations are being used as a baseline (if no as-built survey was done) but the facility was not constructed according to the design (e.g. over-excavation).
- The percent added to compensate for the water pressure effect (discussed above) is an under- or over-estimate.
- The survey method selected to determine sediment accumulation has a low accuracy.
- The bathymetric survey used to assess sediment accumulation was done using a very different method than the survey done on the as-built SWMF (e.g. core sampler vs. depth sounding method).
- There was a long delay (>1 year) between the time of surveying and the time of clean out, and this wasn't compensated for in the volume calculation.

It is recommended, to ensure that the surveyed sediment volume is as accurate as possible, that sediment accumulation surveys are carried out using a method that measures not only the elevation of the top of the sediment but also the depth of sediment. For example, the disk and rod method (Section 6.1.2) and dual-frequency depth sounding method (Section 6.1.3) both involve measuring the top of the sediment and the bottom of the pond or wetland, which allows for sediment depth to be determined. The core sampling method (Section 6.1.1) also achieves this by directly measuring the height of sediment. This eliminates any source of error associated with relying on the SWMF design drawing or as-built survey for comparison. Instead, the only inaccuracies would be attributable to either the survey method itself or the 10 to 20% added to compensate for water pressure changes.

5.3 Environmental Protection and Restoration During SWMF Maintenance Activities

5.3.1 Sediment Re-suspension Controls

The process of removing sediment from stormwater ponds and constructed wetlands involves, by necessity, disturbing and re-suspending sediments that have accumulated over time. Once re-suspended, these sediments can be easily entrained and transported during storm events into downstream waterbodies. Sediment re-suspension controls are recommended as a best practice to prevent this occurrence. In mechanically dredged SWMFs, these may include the use of polymer assisted treatment systems and filter bags to treat water that is continuously pumped from the facility. It may also be necessary to cordon off the area where sediment is being removed. This may be done using silt curtains, which allow water to pass through freely while holding back suspended sediment, or a cofferdam type product that blocks out all water, creating a dry work area. Slopes should be appropriately stabilized to prevent erosion during storm events.

Timing of cleanout operations is an important consideration since large storms occurring during dredging can significantly delay dredging operations and have the potential to transport substantial quantities of suspended and eroded sediments directly into receiving waters. For these reasons, scheduling work during longer dry periods in July and August, or during the winter when cold temperatures prevent drainage of precipitation to the SWMF are generally preferred both from cost and environmental perspectives. Winter cleanouts are also preferred as a means of reducing re-suspension and erosion of sediments from work areas.

Hydraulic dredging operations present unique challenges because SWMFs are not emptied prior to cleaning. In these cases, even small storms can scour and re-suspend fine particles disturbed during dredging operations, making the timing of work relative to potential rain events an especially important consideration. Various operational controls can help to minimize resuspension, including reducing cutterhead rotation speed, slowing dredge head movement, increasing suction rate, and slowing the moving and placing of spud piles and swing anchors. Silt curtains that isolate dredging activities, or outlet controls designed to filter and slowly release water, can also be implemented to reduce release of suspended sediments. Contracting agencies should ensure that the bid clearly defines the proposed methods to prevent release of re-suspended sediments and that they are adhered to during the cleanout process.

5.3.2 Minimizing Habitat Disturbance

Special care should be taken during dredging operations to disturb as little vegetation as possible. This is especially true for vegetation on the flood and shoreline fringes of the SWMF, which function with the stormwater infrastructure to reduce erosion and improve infiltration and filtration. The fringe vegetation also provides vegetative cover that may be used by fauna, particularly in SWMFs that are in close proximity to natural areas. For this reason, such SWMFs should be more closely monitored for the

protection of threatened or endangered species. Some of these species include: American Toad, Northern Leopard Frog, Green Frog and Midland Painted Turtle. Although SWMF are not considered fish habitat, if these species are found, the time of year when dredging can occur will likely be limited, and the local municipality or Conservation Authority should be consulted.

It is expected that the SWMF will be disturbed, requiring site restoration when the dredging activities have been completed (Figure 5.2). Carrying out site restoration in the spring to allows for improved plant survival and more opportunity for vegetation establishment. The most effective means of limiting habitat disturbance is to use a facility access road, which may not be present in older facilities, but is recommended as an important design feature that should be considered in new SWMFs or retrofit situations (see Section 3.5).



Figure 5.2. Restoration plantings after a SWMF cleanout.
6.0 SEDIMENT FIELD ASSESSMENT METHODS

6.1 Depth Measurement Methods

As addressed in Section 4.5, measurement of sediment depth is recommended as the only accurate means of determining when and if SWMF cleanout is required. It is recommended that depth measurement should be carried out at least once every 3 to 5 years, and more frequently as needed, for example:

- During periods of construction or other activity in the catchment that are known to be generating higher than normal sediment loads
- If a routine depth measurement reveals that the SWMF is nearly reaching the threshold where a cleanout will be required

A routine sediment depth measurement can be carried out by a relatively basic or more comprehensive method, depending on the preference of the SWMF manager. A basic method may be sufficient for a relatively new SWMF, while a more thorough and accurate assessment may be warranted when the SWMF is at the age when a cleanout would be expected (i.e. 15 - 20 years). A basic method would entail measuring sediment depth at a minimum of two points in each zone in the SWMF for a minimum total of six or eight points (see zone delineation depicted in Figure 6.4). The three zones correspond to the recommended zones for extraction of sediment samples for the purpose of chemistry analysis. It may be advisable to reference the facility's as-built drawing to select depth measurement locations so that they best represent the average facility depth. This ensures that measurements are not taken in deep micropools or shallow areas, which would result in an over- or under-estimate of the quantity of accumulated sediment.

These six points should be staked so that measurements are taken at these same locations at each visit, making them directly comparable from year to year. Measured sediment accumulation can be compared to the annual loading values provided in the MOE SWMPD Manual (Table 4.3) to gauge whether the rate of accumulation is in the average range.

Once it has been determined that a SWMF requires cleanout, a detailed bathymetric survey should be carried out to accurately determine the volume of sediment accumulated in the SWMF before the cleanout process is initiated. It is important to have this reliable volume measurement as a basis for developing an accurate budget and appropriate cleanout and disposal method. The bathymetric survey should be conducted by a qualified surveyor, and should be based on in-situ sediment accumulations (i.e., not corrected for saturated water content). The survey must also be done at a sufficient resolution to allow for an accurate determination of the volume of sediment in the SWMF. If an as-built survey has been completed and is available, the new bathymetric survey should be done at a similar resolution. It may also be advisable for the survey to be georeferenced with city control. If the survey data collected is georeferenced, it allows for direct comparison to past and future georeferenced surveys. The following sections describe commonly used methods for measuring sediment accumulation.

6.1.1 Core Sampler

Core samplers are commonly used to measure sediment depths. The equipment consists of a clear tube corer attached to a support rod that is pushed down through the sediment layer. The bottom end of the tube is open to allow sediment to enter, while the top end is equipped with a cap or internal plunger which maintains the suction necessary to hold the sediment in place. The sample is collected by pushing the open end of the tube through the accumulated sediment layer into the native soil layer or clay liner of the basin. The tube is then withdrawn and the accumulated sediment layer and native soil interface is visually identified by the apparent differences in colour, consistency and texture. The accumulated sediment layer is typically dark black or brown in colour with a very soft consistency and fibrous texture. Depending on the grain size composition (e.g. gravel, sand, clay, etc.) the parent material is lighter in colour with a firm consistency and a granular texture. Based upon these visual differences, the accumulated sediment layer is identified and measured directly through the clear core sampler tube. A drawback of this measurement method is that it is prone to underestimation, as sediment could be consolidated during the pressing action.

6.1.2 Disc and Rod

Another common sediment monitoring technique employs a disc and standard survey rod (Figure 6.1). The disc is a circular steel plate generally used for obtaining water turbidity measurements.³ In this method, the disc and rod are lowered to the bed to settle on top of the sediment layer, and the water depth is recorded with the survey rod and onshore GPS total station. Subsequently, the rod (without the disc) is lowered into the loose sediment until it meets the native soil. The difference between the disc and rod depth readings is then used to determine the depth of accumulated sediment. Contours of the SWMF are created which are compared to a previous survey or as-built drawing. It may be difficult to access all parts of the SWMF using this method and the operator may need to use both a boat and chest waders. In addition, successful measurements require an initial permanent pool depth and care needs to be taken not to compact the sediment layer once the disc is initially lowered, or puncture the clay liner or parent material when the rod is lowered.

A variation of this method is to only measure the disc depth and compare that depth to the original or asbuilt design drawing. Caution should be exercised when comparing a disc depth reading to an original design drawing, as SWMF excavations commonly deviate from design requirements.

³ The steel plate should be heavy enough to sink through the water column, but not so heavy as to compact the sediment layer on the bottom of the pond. Secchi disks, for instance, have been shown by experience to be too heavy.



Figure 6.1: Disc and rod sediment depth measurement with the help of a total survey station.

6.1.3 Depth Sounding Method (SONAR)

The combined technologies of GPS and Sonar have the potential to provide highly accurate data. Sonar uses an echosounding technology to measure water depths by transmitting acoustic pulses. With a known speed of the travelling soundwaves, the sonar determines the distance by measuring the time interval between the transmission and return of the soundwave. The process is called echosounding, as the instrument listens for the echo of the sound. The utilization of a GPS unit is necessary in order to ensure that the instrument is following a predetermined route in the form of transects. Additionally, the GPS coordinates that the instrument follows can be saved and replicated during the next survey to ensure repeatability. The echosounder is launched on the water surface and is operated remotely, which does not require operators to enter the water. These instruments obtain thousands of points in very short periods of time, and QA/QC algorithms reduce these to a few hundred reliable readings, which are used to produce a bathymetric map. This map is then compared to the as-built map or a previous sediment survey to calculate the amount of sediment accumulation.

In using this method, contracting agencies should require calibration data documenting the relationship between sonar measurements and traditional disc and rod results. The volume of sediment to be removed is an important determinant of cost, and most contractors bid on projects based on measurements determined from the more traditional disc and rod method. Discrepancies between the two methods can, therefore, have significant cost implications. Although single-frequency echosounders, which measure only the top of sediment, are more widely available on the market, dual-frequency devices that also measure the top of the clay layer are now available as well.

6.1.4 Guided Radar Level

Recently, additional methods have been developed to assess sediment accumulation within SWMFs. The company Endress & Hauser in Christchurch, New Zealand has created two devices to measure depths for solids and liquids (NTA, 2010). First, there is a guided radar level, which continuously measures water levels or granular bulk solids. This device can be used within natural and synthetic environments and has not been reported to be clogged by dust, which allows for deployment within ponds on active construction sites (NTA, 2010).

6.1.5 Non-traditional Techniques

Some other available techniques have yet to be used in mainstream sedimentation monitoring. A device called a Manual Blanket Level Detector (MBLD) can detect sediment levels using a probe sensor at the end of a cable (NTA, 2010). The cable is lowered until it reaches the sludge or sediment bed, where it sets a datum and allows the user to read the depths on the cable as it is continuously lowered. The Liquid Sediment Detection Pole can be used the same way as the MBLD, however its accuracy is limited to depths between 0.02 m and 2.4 m. Nonetheless, the method is quite useful as it does not require the operator to collect core samples.

6.2 Sediment Sampling Methods

The descriptions of in-situ sediment sampling methods provided in this section are intended to assist with the planning and execution of field sampling activities. However, practitioners may choose to adapt methods to suit different site conditions and/or preferences. Although in-situ sediment sampling procedures are most commonly employed, in some cases it may be advisable to resample the sediment just prior to hauling (see rationale in Section 9.2.3). In those cases, the dredged sediment would be stored in the form of stockpiles within a sediment management area. The recommended sampling strategy for dredged sediment is described below in Section 6.2.4.

6.2.1 Planning Process and Field Methods for Sediment Collection and Analysis

As shown in Figure 6.2, the first step is to identify the land use type(s) for the catchment area that drains to the SWMF and determine if any spill incidents have been reported. This information provides the basis for selecting the most appropriate sediment chemistry list for each SWMF (see Section 9.2.1 for further guidance). The next step is to determine how many sample stations would be required according to the numbers of inlets and outlets. This information is necessary when ordering appropriate types and numbers of sample jars from the laboratory. Aerial photographs and bathymetry drawings should be reviewed to determine if the SWMF is shallow enough to access on foot or if it would require boat access.

Overall SWMF field conditions and sample locations should be photographed and site observations should be recorded in the field book (e.g. algae growth, unusual odours/colours of water, wildlife sightings, etc.). Whenever conditions allow, collect full depth sediment samples by pushing the core sampler through the soft sediment layer until it reaches the hard bottom (Figure 6.3). Variable sediment depths and grain size compositions may influence the volume of sediment that can be retrieved with each core sample. It may be necessary to use the core sampler multiple times at each sampling zone in order to obtain the sediment volume that would be required for laboratory analysis. For example, approximately 1L of sediment would be required for the complete list of analytes that are included in Section 9.2.1 of this manual. Sediment samples should be homogenized before they are transferred to sample jars. Store all samples in chilled coolers until they are submitted for laboratory analysis.

6.2.2 Equipment List

<u>Boat</u> – A boat would be required for sampling SWMFs with a permanent pool. Stable boats such as inflatable pontoon boats or light row boats work well and do not tip easily. They can also be easily transported from site to site. A boat safety kit (e.g. bailer, whistle, rope, etc.) should be kept in the boat at all times.

Life jackets - Life jackets should be worn when collecting samples from a boat.

<u>Chest/hip waders and/or rubber boots</u> – Waders and/or rubber boots will keep field staff dry when pushing the boat out from the shoreline to open water and working with wet samples in the boat. Waders are necessary when collecting samples from heavily vegetated SWMFs, which cannot be accessed by boat.

<u>Sediment core sampler</u> – A sediment core sampler should be used to ensure that the full depth of sediment can be collected. Choices can be made from a number of different models, depending on preference.

<u>Stainless steel bowl and mixing spoon</u> – These items are used to homogenize the sediment core samples in the field, before they are placed into sample jars.

<u>Protective gloves</u> – It is recommended that protective gloves be worn when collecting and processing sediment samples.

Miscellaneous items – Waterproof field book, camera, hand sanitizer and dry cloths.



Figure 6.2: Planning process and field methods for sediment sample collection.



Figure 6.3: Top left: obtaining a sediment sample using a sediment core sampler; Top right: consistency of a sediment sample; Bottom: extracting the sediment core sampler from the water prior to removing the trapped sediment.

6.2.3 Selecting Sediment Sampling Locations

The sediment sampling locations should be selected based on sediment sampling "zones", as depicted in Figure 6.4. The zones represent distinct areas of sediment deposition, with forebays defined as inlet zones and aftbay areas divided into two zones based on the flow path direction and location of the outlet structure. Sampling zones must be delineated prior to selecting the specific locations for sediment sampling for the following reasons:

• Sediment core sampler sizes are not large enough to capture – in one retrieval – the sediment volume that would be required to test for all the analytes recommended in this guidance

document. As such, it is necessary to collect a composite from multiple points within the sampling zone.

- Sediment depths can vary widely from one point to another within the same sampling zone. It may not be possible to collect samples from shallow sediment depths in one area, while ample sediment may be collected from a deeper area within the same sampling zone.
- A composite sample from multiple points within the sampling zone is more representative of the chemistry in the zone than a sample that is comprised of sediment from a single point.

This Guide does not recommend a specific number of sub-samples to be collected in each sampling zone. As a general rule, however, composite samples collected from larger areas, such as zone 2 in Figure 6.4A, should be made up of more sub-samples than composite samples collected from the smaller zone 1 and 3 areas. While this method would result in samples that are more representative of each zone, it is usually unnecessary to ensure that the number of sub-samples is exactly proportionate to the area represented because sediment data analysis does not show strong statistical differences sediment quality between zones (Kelly-Hooper (2015) study, as summarized in Section 9.2.2 and Appendix C).

As depicted in Figure 6.4, it is recommended that the numbers and locations of sediment sampling zones be selected according to the number of inlets and outlets and flow paths for each SWMF. For example, the facility in 6.4A has one inlet, one outlet and a linear flow path. Three composite samples collected from the inlet, centre and outlet zones would adequately represent the flow path and, therefore, the path of sediment deposition as well. Alternatively, a facility with two inlets and one outlet (Figure 6.4B) would require four samples to be collected – inlet 1, inlet 2, centre and outlet locations – in order to represent the full flow path.

6.2.4 Post-Dredging Re-Sampling and Analysis Strategy

When determining the appropriate number of samples to collect and analyse from the stockpile of dredged sediment, it is important to balance the need to get a representative number of samples with the desire for cost efficiency. As described above and in Section 9.2.3, research on in situ SWMF sediment quality has demonstrated that for most facilities, there is no statistically significant difference between the quality of the sediment collected from the inlet and the centre, and also no difference between the centre and the outlet. The only significant difference was between the inlet and the outlet (Kelly-Hooper, 2015, as summarized in Section 9.2.3). This demonstrates that contaminant distributions are relatively homogenous throughout a SWMF, based on in situ sampling, and would be expected to be similarly homogenous in a dredged sediment stockpile. Compared to contaminated soil, the presence of hotspots should be less of a concern in most SWMFs. Further, the process of drying, bulking and/or consolidating dredged sediment is not expected to increase contaminant levels, provided that the bulking/consolidating material does not contain elevated contaminant levels.

Given the demonstrated homogeneity of SWMF sediment, the following sampling strategy would be appropriate on most sites:

- Mixing of sediment in the stockpile, where possible, to make contaminant distributions as uniform as possible
- Collection of 15 discrete samples throughout the sediment stockpile
- Compositing of every 5 samples to create 3 homogenized samples to be submitted for laboratory analysis

Ultimately, dredged sediment sampling frequency should be a site-specific determination, based on consideration of factors like in situ sediment chemistry and the plan for reuse/disposal of the material. Where there are other complicating factors involved, it is advisable to consult with the local MOECC office to confirm whether the planned sediment sampling strategy is appropriate.





Figure 6.4: Examples of sediment sample zones identified by inlet/outlet locations and flow patterns. A: Three sample zones for a SWMF with one inlet, one outlet and a linear flow path. B: Four sample zones for a SWMF with two inlets, one outlet and a forked flow path. *Grey dashed line indicate flow path direction.

7.0 SEDIMENT REMOVAL METHODS

The selection of a sediment removal method is largely based on the scope of the project and the specific constraints and opportunities at the site. Some of the key things to consider when selecting an appropriate sediment removal method are:

- Season cleanout work is undertaken
- Amount of sediment to be removed
- Anticipated duration of cleanout
- Site characteristics (e.g. slope, area, vegetation, sensitivity of receiving waters, presence of wildlife)
- SWMF characteristics (e.g. size, length to width ratio, pattern of sediment accumulation, presence of maintenance drawdown and bypass pipes)
- Availability of access roads and how much they extend around the SWMF perimeter
- Proximity to residential developments and potential issues related to noise, dust or odours
- Extent to which area surrounding the SWMF is used for recreation (e.g. walking or biking trails)
- Sediment texture
- Project budget

The two most common sediment removal methods are mechanical and hydraulic dredging. Mechanical removal is the most common for SWMF maintenance projects, largely because it is an older more well-established method. As such, contractors are more familiar with mechanical dredging equipment, and it is often readily available. Although less popular, hydraulic dredging is also a well-established method for dredging large and small water bodies. For some projects, hydraulic dredging will the best available option due to site or project specific constraints (e.g. desire to avoid SWMF dewatering and clearing of vegetation, SWMF dimensions that restrict excavator access). See Figure 5.1 C, Project Planning: Sediment Removal Methods, for a simplified decision making flow chart.

7.1 Mechanical Dredging/Excavating

A distinction is made between mechanical dredging, which involves the removal of sediment from undrained water basins and mechanical excavating (Figure 7.1), in which sediment is removed from drained basins. Both mechanical dredging and excavation projects involve the use of traditional earthmoving equipment such as excavators, clamshell diggers, backhoes, etc., which are most effective in the removal of sediment with firm consistencies. Typically, SWMFs that have a permanent pool are drained, and thus mechanical excavating is the preferred method (See Appendices G, H and I for case study examples).

SWMFs constructed with a maintenance drawdown pipe can be dewatered by gravity prior to mechanical excavation, but a water bypassing pump is still needed at the inlet(s) to keep water from entering the pond during dredging activities. Municipal by-laws should be consulted to determine the maximum allowed discharge rates for downstream habitat protection. For SWMFs without a maintenance

drawdown pipe, a pump is used for dewatering. Water discharged from the outlet of the pump hose should be subject to treatment to prevent discharge of sediment to receiving waters, and water dispersal to prevent erosion along the flow path. Where a filter bag is used for treatment, it should be placed at least 30 m from the receiving water, on a level and stable surface so that it doesn't roll or shift (Figure 7.2). Ideally the bag should be surrounded by a permeable barrier like a compost biofilter, which can provide additional settling of suspended solids. The filter bag promotes overland drainage which is preferable to concentrated flows that cause erosion. The flow path to the storm sewer or receiving watercourse should always be stabilized, such as with grass or rip rap, which also promote additional settling and filtration of solids. Where the water drains to a storm sewer grate, covering the grate with filter fabric can be helpful as a means of enhancing TSS removal.



Figure 7.1: Mechanical excavation. Left: dredging of side slopes that have sufficiently dewatered due to gravity. Right: Pond bottom after dewatering but still visibly requiring significant consolidation.

SWMFs constructed with a maintenance drawdown pipe can be dewatered by gravity prior to mechanical excavation, but a water bypassing pump is still needed at the inlet(s) to keep water from entering the pond during dredging activities. Municipal by-laws should be consulted to determine the maximum allowed discharge rates for downstream habitat protection. For SWMFs without a maintenance drawdown pipe, a pump is used for dewatering. Water discharged from the outlet of the pump hose should be subject to treatment to prevent discharge of sediment to receiving waters, and water dispersal to prevent erosion along the flow path. Where a filter bag is used for treatment, it should be placed at least 30 m from the receiving water, on a level and stable surface so that it doesn't roll or shift (Figure 7.2). Ideally the bag should be surrounded by a permeable barrier like a compost biofilter, which can provide additional settling of suspended solids. The filter bag promotes overland drainage which is preferable to concentrated flows that cause erosion. The flow path to the storm sewer or receiving watercourse should always be stabilized, such as with grass or rip rap, which also promote additional settling and filtration of solids. Where the water drains to a storm sewer grate, covering the grate with filter fabric can be helpful as a means of enhancing TSS removal.

A primary advantage of mechanical excavating is that the equipment is readily available and contractors are more familiar with this method. Further, the wide variety of excavators on the market allows contractors to select a size best suited to the area being excavated. For well-drained SWMFs, the initial state of the material is denser than material removed by hydraulic dredging. In both cases, however, a sediment consolidating material is often required to render the sediment solid enough that it can be safely transported.



Figure 7.2: A sediment filter bag in use on a level, stable surface during pond draining.

There are a number of potential challenges to be considered when applying mechanical excavation for the removal of SWMF sediments. One of the most significant is machine accessibility. During extended wet weather periods, it may become difficult to move the excavator around the site, particularly if the working areas have not been adequately stabilized. Typically, equipment such as long reach excavators operate off-shore and are able to reach the centre of the pond or wetland without moving into the bed. Sometimes facility dimensions or site layout make the basin inaccessible from the shore. In these cases, an excavator would have to operate within the pond or wetland, which would mean the installation of weight-supporting materials (e.g. swamp mats) to keep the excavator from sinking. Although uncommon in carefully executed cleanout projects, mechanical dredging of poorly drained SWMFs can result in resuspension of sediments, which could delay the work and increase the risk of sediment release to receiving waters.

When compared to hydraulic dredging, mechanical excavation is less precise and more likely to result in over-excavation and damage to clay liners. Since conventional excavator accuracy is typically 15 cm, several passes may be necessary at successively greater depths to remove sediment in layers. The bottom pass can result in over-dredging, as can extending the dredge head laterally beyond the target area. In some cases, avoiding disturbance of neighbouring residents caused by noise, odour and dust can place limitations on how and when mechanical dredging/excavation is done.

Ideally, mechanical excavation should be carried out either during the winter when roads and soils are hard and equipment is easy to mobilize, or during summer when there are fewer rain events and evapotranspiration rates are highest, allowing for timely sediment drying.

7.1.1 Mechanical sediment removal equipment

Excavator

Front excavators scoop 'back' and 'up' into the digging face with a semi-open bucket on an articulating boom (Figure 7.1). The distance of on-shore excavation activities is limited by the reach of the boom, therefore it is important to confirm machine specifications prior to selecting this method. Excavators have more control and less sediment spillage than occurs with draglines (see below). They combine the agility of the clamshell and digging forces of the power shovel.

Clamshell Bucket

The clamshell bucket consists of two pieces joined on a hinge, allowing it to open and close like a clamshell. It is opened when lowered to scoop the sediment and then closed (two separate bucket pieces joined back together) to contain and lift the sediment out of the SWMF. Clamshell bucket attachments can be used on a conventional fixed arm or on a cable. Using the attachment on a cable arm is considered preferable as it is more lightweight and also because it results in a more horizontal bite that will not pit the bottom of the pond. For a 3.8 m³ bucket digging a 50% volume of solids over a two minute cycle, a production rate of 57 m³/h would be expected (Cushing, 1998).

<u>Dragline</u>

Dragline dredging uses wire ropes from the top and base of the boom to the bucket, to cast the bucket forward and then pull the bucket back through the material to be excavated. Digging force is a function of the bucket weight, the winching force and the relative slope of the excavation face to the bucket. The bucket does not have any moving parts and cannot close around the load. When working with non-cohesive materials, this becomes a disadvantage due to washout. It is frequently used to remove coarse sands and gravels.

7.1.2 Winter Sediment Removal

Sediment removal projects that take place during the winter could, weather permitting, significantly reduce project costs (See Appendices H and I for case study examples). It should be noted that mechanical dredging is the only option during winter operation as the permanent pool surface is covered in ice (Figure 7.3). The Minnesota Pollution Control Agency (2015) suggests that winter clean outs offer the following advantages:

• Precipitation events are in the form of snow, which reduces side slope erosion and flooding back into the basin.

- A portion of the SWMF is frozen, allowing for a large portion of the water to be removed as ice chunks and deposited on land or in a second SWMF cell.
- During the freezing process, suspended sediment settles out of the water column and onto the pond bottom. As such, the ice is virtually free of sediment, reducing the need for filtration once it melts back into place.
- Dormant vegetation is not as easily disturbed. Additionally, cattails do not pose a problem in the winter, eliminating the need to cut them down in order to get equipment closer to the pond or wetland edge.
- During winter cleanout there is often less dust, odour and noise to disturb residents, particularly because pumps are running for a shorter time.
- Carrying out a cleanout during construction low season opens up opportunities to rent machinery at lower costs, reducing the overall project cost.

Some of the potential drawbacks of winter cleanout operations include:

- The risk that weather could warm up and cause melting of ice and snow on side slopes, resulting in extremely muddy conditions.
- Winter road salt application resulting in higher sodium levels in dredged sediment, which would limit potential reuse options.
- Shorter working days would mean the project would take longer to complete.
- Working in sub-zero temperatures presents the potential risk of slips and falls.
- Working in sub-zero temperatures presents risks to the health of on-site workers. Work may proceed more slowly, because staff must follow guidelines to avoid hypothermia. Extreme cold may necessitate site shut-down to protect the health of workers.
- If temperatures fall too low, equipment may not operate properly and work may be delayed.
- Challenges associated with salvage of amphibians and reptiles that overwinter in the sediment layer (e.g. frogs, turtles, salamanders).

Once sediment has been removed, all ice removed from the SWMF should be left on sloped areas or within the SWMF, to ensure that the same water drains back into it during the spring melt.



Figure 7.3: Left: piling up of ice chunks on the side to facilitate berm repairs; Right: ice is thick and free of trapped sediment.

7.2 Hydraulic (Suction) Dredging

Hydraulic dredging, as implied by its name, requires the presence of water (or another liquid) to function. Since large volumes of water are removed along with sediment during hydraulic dredging, a stable volume of water beneath the dredge is necessary to allow it to operate properly (Figure 7.4). Hydraulic dredging would be more effective in a wet pond than a constructed wetland, as the technology requires a significant amount of open water. The technology would also be less viable in constructed wetlands due to the abundance of vegetation and shallow pools. Most dredges on the market have the disadvantage of having limited ability to access and clean areas near the shoreline due to presence of aquatic vegetation. For some SWMFs, hydraulic dredging may be the only clean out method available, particularly where the facility cannot be drained or the site characteristics do not allow for access by heavy machinery.

A hydraulic dredge functions by utilizing a centrifugal pump to create a powerful suction force to capture the settled sediment. In many cases, a steel cutterhead accompanies the pump and loosens the sediment before mixing it with water to create a slurry that can be more effectively suctioned. As the cutterhead is lowered towards the pond bottom, it dislodges and fluidizes sediment by mechanical agitation. At the same time, the centrifugal pump sucks up the slurry and pumps it onto a shore-based holding area via a floating pipe.



Figure 7.4: A hydraulic dredge in a stormwater management pond.

There are several varieties of dredges available on the market, offering different features and configurations. Some dredges, particularly smaller ones, are designed to be operated from the shore by remote control rather than by an operator on the dredge itself. Unmanned dredges are commonly maneuvered by a traverse cable system (see Figures 7.5 & 7.6) at speeds ranging from 0 m/min to 10 m/min. This slow speed is expected to reduce potential harm to bottom-dwelling creatures and fish, although no studies that would support this theory have been identified.

Steel cables are anchored on opposite ends of the pond to help guide the dredge in a forward and backward motion at a speed determined by the operator. This configuration allows dredge operators to re-anchor the cable along the pond length when the suction of each transect is completed. This grid-like maneuvering ensures that all desired segments of the pond bottom are suctioned. A less common dredge maneuvering technique for pond-scale projects involves the use of propellers and mechanical legs. The drawback of this method is that it has the potential to re-suspend sediment within the water column and reduce the dredge's efficiency.

Parts making up the pump and pipe conveyance system are selected based on project-specific requirements. Large ponds would require a long pipe conveyance system to transport the slurry to the designated sediment management area. To make this possible, the centrifugal pump – reaching as deep as 6.3 metres in some configurations – needs to be powerful enough to transport the slurry to the sediment management area. The most powerful pumps used can transport the sediment as far as 1 km away. The sediment removal efficiency of a hydraulic dredge is defined by the percent solids it can pump, which ranges from 10% to 30%.

Once the slurry is pumped to the sediment management area, it is usually dewatered in order to yield a sediment dry enough that it can be hauled offsite as a solid rather than a liquid. Often, the slurry is pumped through a geotextile sediment bag (Figures 7.2 and 7.4) to filter out the bulk of the sediment and then the water is pumped back into the SWMF. To enhance the separation of sediment from the water, a polymer may be mixed in with the slurry before it enters the bag (see dewatering guidance in Section 8.0).

The advantages and limitations of using hydraulic dredging for SWMF clean outs are summarized in Table 7.1. Examples of case studies highlighting hydraulic dredging operations are presented in Appendices E and F. Both case studies describe pond dredging operations which utilize polymers and sediment dewatering bags.

7.2.1 Types of Dredges

Cutterhead (Auger Option) Hydraulic Dredge

A common hydraulic dredge is the cutterhead dredge (Figure 7.5), which uses a rotating cutter device equipped with revolving blades to loosen sediment. A variation of the cutterhead includes an auger-style borer which works on the same basis as an Archimedean screw. It has the advantage of more precisely directing the agitated sediment into the inlet of the suction pump. In all variations, the agitated sediment mixture (i.e. slurry) is sucked in by a pump inlet located close to the cutterhead. The pump outlet is connected to a floating pipe (Figure 7.6) that conveys the slurry to an offshore holding location for subsequent dewatering (this often involves a sediment dewatering bag). The cutterhead digs into the sediment in an arc-shaped sweeping motion initiated by the pulling motion of anchored swing winches, or laterally without the need to alter the height of the pump to move forward. The depth of the cutterhead can be altered during operations upon the discretion of the operator depending on the desired/expected colour of the pumped slurry. Optional add-ons to cutterhead dredges include a cutter

serving the purpose of 'pre-treating' the mixture in cases where cattails or other aquatic vegetation may interfere with the standard cutterhead.

Advantages	Limitations			
 Minimal disturbance of bank vegetation Less disturbance of receiving water due to lack of dewatering 	 Limited ability to operate in SWMFs containing a large amount aquatic vegetation Limited ability to operate in shallow pools 			
 Facility continues to function throughout the clean out, without needing a bypass 	 Limited ability to remove sediment from shoreline areas 			
Where sediment bags are used, sediment may be better contained and the site will require	 Higher average cost compared to mechanical excavation* 			
less clean up	Less availability of qualified local professionals			
 Risk of damage to clay pond liner may be lower since slurry colour can be monitored 	 Less local availability of equipment 			
• Can be carried out during wet weather	 Cannot be carried out during the winter when SWMF is frozen over 			
 Can remove sediment from ponds that are too large to be accessed from the bank by long reach excavators 	Debris/garbage from pond bottom may compromise the cutterhead and/or pump, requiring them to be serviced and resulting in			
 Avoided costs associated with dewatering (pumps, labour, risk of project delays) 	project delays.			
 Less disruption to local residents (e.g. less noise and dust) 				
 Recreational functions of the SWMF area could potentially remain available (e.g. trails) 				
 Allows continued use by waterfowl 				

*This is largely project dependent. On some projects, hydraulic dredging may be the more cost effective option, but in general, hydraulic dredging will cost more, particularly if a polymer injection system is also being used.



Figure 7.5: Schematic of standard cutterhead hydraulic dredge (Crisafulli ® FLUMP).



Figure 7.6: Vertical auger cutterhead with submersible pump (Dragflow[®] MiniDredge).

Horizontal Auger Hydraulic Dredge

A horizontal auger dredge uses a rotating auger to loosen the sediments as described in the previous section, except that the horizontal auger cutterhead resembles an Archimedean screw that is at a right angle to the suction pipe (Fig. 7.7). The sediment is augered from both sides of the cutterhead towards the centre and into the suction pipe (Fig. 7.8), resulting in high efficiency sediment suctioning and reduced turbidity. For additional reduction in sediment resuspension, a mud cap can be added, which covers the top part of the auger. When dredging in light materials, a spiral auger can replace the more aggressive cutter auger, thus creating less turbidity and reducing the dredge's fuel consumption.



Figure 7.7: Horizontal auger cutterhead dredge(LWT® Pit-Hog).



Figure 7.8: Horizontal auger cutterhead dredge schematic (Crisafulli [®] FLUMP).

Plain Suction Vacuum-Type Dredge

The plain suction dredge functions similarly as the cutterhead dredges described above, except that it is not equipped with a cutterhead to disturb the material before it is suctioned. As such, it functions like a vacuum for the bottom of a water body, and the suctioned sediment is transported via a floating pipeline to an offshore sediment management area.

Pneumatic Hydraulic Dredge

Unlike hydraulic suction pumps that apply centrifugal force to draw sediments in, pneumatic hydraulic dredges are equipped with a pneuma pump operating through compressed air/hydrostatic pressure to displace sediment (Figure 7.9). They function on the 'evacuator' principle, whereby a differential pressure is created inside a chamber with the outlets closed, creating an influx of sediments through the inlets and into the chamber. When the chamber is filled, the inlets are closed and the outlets opened. The compressed air is pumped out, forcing the sediment out through an outlet. When enough negative pressure has built up, the inlets are opened and the material is sucked into the chamber. The mixture is pumped out of the chamber and the cycle is repeated. The pump has no rotating parts or mechanisms in contact with the sediment, minimizing resuspension problems. In loose sediment, the pump inlets are lowered directly into the deposit. In more cohesive materials, a scoop or cutterhead is mounted to the pump body to feed loosened material to the suction inlet and the unit is winched through the deposit.



Figure 7.9: Function of a pneumatic pump. From: Abbott and Price (eds.), 1993.

8.0 SEDIMENT DEWATERING AND CONSOLIDATION

A limiting factor with respect to sediment transport and disposal is its water content. Once sediment has been removed from the SWMF, either hydraulically or mechanically, its water content will typically need to be reduced before it can be transported as a solid material. The material must pass a 'slump test' to determine whether it is a liquid or a solid (Figure 8.1). The test is described in EPA O. Reg 347 Schedule 9 - Test for the Determination of Liquid Waste for Solid Waste Landfilling.



Figure 8.1: Top - Sediment with a high water content being removed by an excavator. Bottom - Examples of slump tests on sediment that has been consolidated.

Dewatering or consolidating the material to the point that it can pass the slump test is desirable because it facilitates both transport and disposal/reuse. Reducing water content before transport means that the total volume transported will be lower and the material will not swish around in the back of the vehicle and spill out onto the road. Where liquid sediment is transported, it is necessary to fill trucks only part way full so as to avoid this spillage. This requires more trips back and forth between the source site and the receiving site, resulting in greater expenditures on labour, vehicle rental and fuel. With respect to disposal/reuse, it may be more challenging to find a suitable landfill or receiving site for liquid sediment material. Landfills that accept liquid waste are scarcer and tipping fees are higher at these facilities. Where the plan is to reuse the material, liquid material also poses the greater challenge, as the number of potential receiving sites would be fewer than there would be if the material was solid. Despite these challenges, some SWMF owners do choose to transport sediment as a liquid. This may be the most viable option if there is no space for onsite drying or if there is a time constraint requiring the site to be quickly restored to its original condition.

There are two distinct methods used to render wet sediment solid enough to pass a slump test: dewatering and bulking. While dewatering refers to the removal of water though gravity, compression or air drying, bulking involves the addition of water absorbing materials that reduce the percentage of water in the slurry.

8.1 Conventional Methods

During mechanical dredging, sediment removed from the SWMF is typically stockpiled in a designated sediment management area and left to dewater by gravity and air drying before it is hauled offsite (Figure 8.2). This method is most effective during hot, dry summer months when evaporation levels are at their highest and precipitation levels are at their lowest. In the case of small SWMFs, and where there is limited space for sediment management, the sediment can be left to dry within the basin once it has been pumped down. This would reduce the amount of vegetation clearing to create a sediment management area, but could only be carried out on a pond where there are no issues with groundwater upwelling, and only over a long dry period.

One important factor that impacts the amount of time and space required to dry sediment in this way is its grain size distribution. Fine grained sediments (e.g. silt, clay) have a high water holding capacity, and are therefore more difficult to dry than coarse grained sediment (e.g sand, gravel). As a result, fine grained sediment will need to be spread thinner, over a larger land area. The addition of bulking materials is a common and established method used to expedite the sediment drying process. Materials typically used include sawdust, mulch, and straw. These materials are added and mixed through to help absorb excess water to yield a more solid sediment. This method is widely used, particularly when gravity or air drying alone would take too long, since the goal is to complete the process before the next rainfall event. Bulking with a superabsorbent polymer product is a newer approach which is described in the next section.

8.2 Polymer-Assisted Methods

A newer approach to sediment dewatering is the application of polymers to the wet material. There are two main types of polymers that are typically used to help with sediment consolidation: (i) flocculants and (ii) superabsorbent polymers.

Polymer flocculants have been used for decades to facilitate solid-liquid separations in various industries, including waste and drinking water treatment. During flocculation, the polymer adsorbs onto suspended

particles and forms bridges between them, creating larger aggregate masses, or flocs. These larger, heavier aggregate particles are more susceptible to being removed from



Figure 8.2: Wet sediment being mixed with mulch to expedite drying.

suspension by gravitational settling or other removal methods, such as filtration. One of the more common polymer flocculants used for consolidation of wet sediment is polyacrylamide (PAM). The PAMs used for this application are negatively charged (anionic), high molecular weight, water soluble molecules formed by polymerization of the monomer acrylamide. Compared to cationic PAM and other commonly used flocculants, anionic PAM has exhibited low toxicity and promising performance in multiple studies (Rocha and Van Seters, 2013), and as such is most suitable for environmental applications such as SWMF sediment dewatering. Guidance on the use of anionic PAM for sediment management applications is provided in the *Anionic Polyacrylamide Application Guide for Urban Construction in Ontario* released by TRCA in 2013 (TRCA, 2013).

Superabsorbent polymers (SAPs) differ substantially from polymer flocculants with respect to their chemical nature and behaviour. Instead of causing sediment particles to bind to one another, the SAPs simply absorb water from the slurry, causing them to swell and become gel-like in their consistency. Because they are meant to absorb water, they function like conventional bulking materials, except that their absorption capacity is much greater. Their capacity to absorb a large amount of water relative to their own mass makes them useful in a variety of liquid absorbing products, such as baby diapers and packaged meat liners. One of the most common SAPs is sodium polyacrylate, which is used to consolidate slurries in a variety of industries.

8.2.1 Polymer use with Mechanical Excavation

The role of polymers in mechanical excavation is to consolidate wet sediment after the SWMF has been dewatered. Polymers may be added in situ, before the sediment is excavated from the SWMF, or after excavation, when the wet material is stockpiled in the sediment management area. Both types of polymers described above – flocculants and SAPs – can be applied to wet sediment in this way. They are normally applied as a powder and mixed through with the excavator. While they are similarly applied, the

two types of polymers function differently, and as a result are subject to somewhat different usage guidelines.

Where a granular anionic PAM based product is to be applied directly to the sediment, the following guidelines apply:

- Site specific sediment and water samples should be taken at each site and sent to the polymer manufacturer for lab testing. Sediment samples should also be tested using a manufacturer supplied test kit to compare with the lab results and confirm that the product will be effective.
- Proponents should follow the manufacturer's recommended application rate.
- Standing water should be removed to the extent feasible prior to PAM application for consolidation of wet sediment, as moisture content will affect performance. Proponents should discuss treatment options with the manufacturer where it is not possible to dewater the SWMF prior to clean out.
- The product should be mixed into the sediment as per the manufacturer's recommendations as this will provide more opportunity for the polymer to react with the sediment, and result in better performance. Extending the contact time will also help to improve performance.
- Anionic PAM based products are more effective in warmer temperatures (i.e. above 11°C). If the product is being applied during cold weather, a manufacturer supplied test kit should be used to confirm its effectiveness at the expected air and sediment temperatures.

Where an SAP based product is being used, some of these same guidelines apply. The manufacturer's recommended application rate should be used when the product is applied on top of the slurry, which should be dewatered as much as possible in order to maximize the product's effectiveness. An excavator can be used to help apply, disperse and mix the product through the slurry, after which the slurry will be left to sit for a period of time as the SAP absorbs water (Figure 8.3). To avoid inhalation, the use of a dust mask is recommended during the application of both anionic PAM and SAP powder.



Figure 8.3: The application of an SAP product to wet sediment and the resulting sediment consolidation.

While the use of these products can significantly expedite sediment dewatering and consolidation, their addition does have the disadvantage of increasing the total volume of sediment to be hauled. With anionic PAM the increase is slight, since the amount of polymer added is small relative to the quantity of sediment, and the polymer acts to separate water and sediment so that when the sediment is removed the water stays behind on site. Conversely, SAPs absorb the water and swell, trapping that water within the sediment pile. As a result, the final volume to be hauled and disposed of is greater than it would be after conventional air drying. It may however be similar to the increased volume resulting from conventional bulking methods (e.g. sawdust, mulch).

8.2.2 Polymer-Assisted Hydraulic Dredging

Material removed by hydraulic dredging has a high water content (commonly 10:1 to 5:1 ratio of water content to sediment) and a great deal of dewatering is required before it can pass a slump test. Filtration of this material through geotextile bags without the addition of a flocculant is an inefficient means of removing suspended sediment since the majority of particles are too small to be filtered out. As such, polymer flocculants are typically applied inline during hydraulic dredging to help bind sediment together so that it is susceptible to settling and/or filtration (see Appendices E and F for case study examples).

Among the existing flocculants used for solid-liquid separations, anionic PAM is the most suitable for this type of application due to its effectiveness and low toxicity to aquatic organisms. There are two liquid forms of anionic PAM that are effective for use in hydraulic dredging – solutions and emulsions. While emulsions are often cited as easier to use because they are less viscous, they also contain emulsifiers and surfactants that often make them more toxic than anionic PAM solutions.

In polymer-assisted hydraulic dredging, the dredge suctions the slurry which is then pumped to the polymer injection system (Figure 8.4). While these systems may vary in complexity depending on the service provider, their key function is the inline injection of the polymer into the slurry, followed by mixing of the dosed slurry. In order to ensure the optimal performance of the polymer as a flocculant, bench tests are carried out before the start of dredging to determine (i) the appropriate product formulation, (ii) the ideal dosing rate and (ii) the minimum amount of mixing time that should be provided. One of the challenges of polymer-assisted hydraulic dredging is maintaining the correct dosing with fluctuating solids levels in the slurry. The systems featured in case studies in Appendices E and F deal with fluctuating solids levels by applying an algorithm (developed based on bench testing) to continuously calculate the necessary amount of polymer to be injected based on flow rates and real time measurement of solids levels.

Once the slurry has been dosed and mixed, it can be pumped to a geotextile sediment bag where the sediment particles that have bound together under the influence of the polymer are either filtered or settled out of suspension. Water draining from the bag should be directed back into the SWMF, ideally close to the forebay. The amount of time required for drying of the sediment in the bags will vary based on its grain size distribution and the weather conditions, but based on the case studies the material was dry enough to haul within 2 to 4 weeks.



Figure 8.4: Left to right – trailer housing polymer injection system, geotextile bag capturing polymer dosed sediment, consistency of sediment in geotextile bag several weeks after hydraulic dredging with a polymer.

8.2.3 Reporting Dredged Sediment Volumes

Once dredging is complete, documenting the quantities of sediment removed can be a useful way to assess project success and help estimate costs of future projects. Since volumes can vary based on moisture content and other factors, such as the addition of bulking material, it is recommended that two volumes be reported - the total volume of hauled sediment and the total volume of restored SWMF capacity. The former measure is valuable for assessing the necessary volume to be hauled and associated cost, while the latter measure is an indicator of the success of the cleanout project in protecting the downstream environment. The total volume of restored SWMF capacity, which should be determined based on a post-cleanout survey, is also a more consistent measure that would allow for direct comparisons of costs from project to project. It is also important to note that if the dredged material will be disposed of, it is also necessary to provide the total weight of the material to the landfill rather than just the volume.

8.2.4 Sediment Reuse Considerations

Sediment disposal and reuse options should be considered when selecting dewatering methods and materials. For example, landfill disposal options would be compatible with all of the methods and materials discussed in this manual, provided that slump test requirements can be met. However, some reuse options may not be viable for sediment that has been mixed with certain types of dewatering materials. For example, sediment may not be suitable as a tree nursery soil amendment if it was mixed with sawdust from unknown sources, due to the potential for introduction of tree diseases/parasites to the tree nursery population. As another example, plant growth requirements would need to be considered if polymer treated sediment was to be used as a soil amendment. While anionic PAM would not present restrictions in this regard (TRCA 2013), the use of other polymers could be problematic if they have not been tested and proven to be viable soil amendments.

9.0 ASSESSING DISPOSAL AND BENEFICIAL REUSE OPTIONS BASED ON SEDIMENT QUALITY

The chemistry of the sediment removed from SWMFs during clean outs can have a significant impact on the total project cost, as it will determine the fate of dredged sediment – reuse or landfill disposal. Fees for landfilling contaminated sediment in Ontario constitute a substantial proportion of the total clean out cost. Landfill facilities in the Greater Toronto Area have tipping fees ranging from approximately \$76-112 per m³, but in some areas of the province, these rates can be even higher. The fee for disposing of contaminated SWMF sediment at the Waterloo Landfill is roughly \$150 per tonne (Ritchie, 2015), which is roughly equivalent to \$300 per m³ based on a standard sediment conversion factor of 2 tonnes per 1 m³. For some clean out projects, these fees would represent more than 100% of the total project cost (see costing data in Chapter 10.0)

Given the significant expense of landfilling, it is important to understand the regulatory framework and the most efficient and cost-effective methods of characterizing sediment quality. This chapter provides guidance on these two aspects of SWMF sediment management – the regulatory considerations and the sediment analysis considerations. It should be noted that the guidance herein represents TRCA's interpretation of the current regulatory framework as it relates to SWMF sediment disposal and beneficial reuse. Where the interpretation is not the official written policy of the MOECC, this is explicitly stated.

9.1 Regulatory Considerations

Within Ontario, stormwater sewage works (e.g., ponds, constructed wetlands) are governed under the OWRA, as described in Section 2.1.3 of this Guide. Section 53 of the ORWA states that "no person shall use, operate, establish, alter, extend or replace new or existing sewage works except under and in accordance with an Environmental Compliance Approval (ECA)". As described in Section 5.1.2, ECAs for an existing SWMF should be referred to in order to determine what activities are permitted. However, even when the facility ECA specifically states that regular clean out and maintenance are required, it does not serve as an approval for the sediment management and disposal aspect of the clean out. Depending on the extent to which the material is contaminated, activities such as the processing, transport, reuse and disposal of sediment dredged from a SWMF will typically require separate consultation with, and in some cases, approvals from, regulatory agencies.

In Ontario, various provincial regulations and guidance documents allow for the consideration of SWMF sediment as material that can be disposed of on land for beneficial reuse. SWMF sediment can align with the definitions of 'other waste' under the Biosolids Guideline, non-agricultural source material (NASM) under the Nutrient Management Act, or excess soil under the Excess Soil BMP. Consequently, beneficial reuse options for SWMF sediment may be evaluated under each of these definitions with the support of appropriate professional expertise on a case-specific basis.

The following subsections describe the relevant Ontario regulations and policies that can help to define SWMF sediment, and how these regulations can be applied in the assessment of its disposal and reuse options.

9.1.1 Ontario Regulation 347/90 – General Waste Management

O.Reg. 347/90 defines different categories of waste, including hazardous waste, and sets out requirements for handling, storage, management and disposal. SWMF sediment that is classified as waste based on its contaminant levels is governed by this regulation and the Environmental Protection Act, Waste Management Part V. Generally, Part V of the EPA and O.Reg. 347 require that waste be transported by a licenced carrier with delivery to a licensed receiver, both of which must have ECAs.

Schedule 4 of O.Reg. 347 provides a table of leachate quality criteria, which forms the basis for the definition of hazardous waste. The toxicity characteristic leaching procedure (TCLP) is an extraction method that would typically be used to create a leachate sample from soil or sediment. The test simulates the leaching that occurs in a landfill. Once a liquid leachate sample is created it can be analysed for the hazardous chemicals listed in Schedule 4. If the contaminants levels in the leachate exceed any of the values listed in Schedule 4, the soil or sediment is classified as hazardous waste and must be handled and disposed of as such.

A key first step in characterizing SWMF sediment is to analyze the leachate from the sediment to determine whether it should be categorized as hazardous waste in accordance with O.Reg. 347 Schedule 4 (Figure 9.1). While SWMF sediment from residential, institutional and commercial sites is unlikely to contain contaminant levels that would exceed Schedule 4 (see field study results in Appendix C), the MOECC typically requires that this leachate testing is carried out to provide certainty that the material is non-hazardous.

While various sources of guidance and information may be used, the responsibility for waste characterization under O.Reg. 347 lies with the owner of the waste. For SWMF sediment this would be the owner of the facility. While O.Reg. 347 verbally defines "inert fill", it does not include chemical quality criteria to support the definition. In its absence, the MOECC has, on a case-by-case basis, accepted the contaminant thresholds in Table 1 of the *Soil, Ground Water and Sediment Standards* (part of O.Reg. 153/04) as a basis for classifying sediment as inert.

9.1.2 Ontario Regulation 153/04 - Records of Site Condition

In Ontario, environmental exceedance standards for soil and sediment are based on the *Soil, Ground Water and Sediment Standards for Use under Part XV.1 of the Environmental Protection Act* (MOE, 2011a, Section 9.1). The O.Reg. 153/04 standards were developed for the protection of human and ecosystem health. Table 1 in the Standards lists the "Full Depth Background Site Condition Standards" which are considered upper limits of typical province-wide background concentrations in uncontaminated soils (MOE, 2011a). Roughly 98% of uncontaminated Ontario soils will be below the Table 1 Standards for a specific substance (MOECC, 2014). Tables 2 lists generic site condition standards for soil and

groundwater in a potable water condition, and the same is provided in Table 3 for a non-potable water condition. Within the Standards the values are listed according to land use category (agricultural, residential/parkland/institutional, commercial/industrial).

The purpose of O. Reg. 153/04 is to set out directives for conducting site assessments and defining who is a Qualified Person (QP) for the purposes of conducting environmental site assessments (ESA) or risk assessments (RA), and making Record of Site Condition (RSC) certifications. The regulation is typically applied to support the assessment and clean-up of contaminated sites, however, the standards set out under O. Reg. 153/04 are frequently more broadly applied for screening purposes at non-ESA and non-RSC sites. For example, the standards set out by O. Reg. 153/04 are widely used in the construction industry to evaluate the quality of soil being imported to or exported from active construction sites.

The Standards can also be useful for characterizing SWMF sediment quality and evaluating risk in projects where reuse of sediment is being considered. It is important to note that this broader application of the standards for other screening activities does not constitute official MOECC policy. Where the Standards are being used to characterize the quality of SWMF sediment for making reuse decisions, the local MOECC office should be consulted to determine whether their application is appropriate. The flowchart shown in Figure 9.1 provides guidance on how the Standards may be applied in the SWMF reuse/disposal decision making process. It is important to note that Figure 9.1 does not depict MOECC operational practices, through which the applicability of the Standards are assessed on a case by case basis.

9.1.3 Management of Excess Soil – A Guide for Best Management Practices

In January 2014, the MOECC published and circulated a document entitled "*Management of Excess Soil – A Guide for Best Management Practices*" (hereafter "Excess Soil BMP Guide"). The intent of the guide is to encourage the beneficial reuse of excess soil in a manner that promotes sustainability while also protecting the environment from contamination. It defines "excess soil" as soil that has been excavated, mainly during construction activities, and that cannot or will not be reused at the source site. The Excess Soil BMP Guide relies on the following definition for "soil" which from O.Reg. 153/04:

"unconsolidated naturally occurring mineral particles and other naturally occurring material resulting from the natural breakdown of rock or organic matter by physical, chemical or biological processes that are smaller than 2 millimetres in size or that pass the US #10 sieve".

SWM pond sediment that has been removed from a pond could meet this definition once the excess water has been extracted via either standard dewatering or bulking techniques.

According to the Excess Soil BMP Guide, reuse of excess soil requires assessment and confirmation that the planned soil placement at the receiving site will not degrade its existing conditions. As an example, the source soil should not introduce a new contaminant or increase existing contaminant concentrations at the receiving site. Professional expertise and judgment is required to support this assessment. The Excess Soil BMP Guide specifically refers to the use of QPs, as defined under O. Reg. 153/04. If reuse is

being considered a QP should be enlisted to evaluate reuse options, prepare a soil management plan, and determine the extent of soil testing to be undertaken, including both the frequency of sampling and the types of parameters for which the soil should be analysed.

The Excess Soil BMP Guide aligns in some ways with the Biosolids Guideline (see Section 9.1.6) and Nutrient Management Act in that it promotes the reuse of excess materials for beneficial purposes, albeit not only for plant nutrition or soil amendment purposes; beneficial off-site uses of excess soil could include filling, site alteration, re-grading, and so on.

The Guide suggests potential excess soil management options that may be considered depending on soil quality and other site-specific considerations. These include:

- Reuse on the same site (source site)
- Processing and reusing soil on the source site, which could require an ECA if the soil is classified as a waste based on contaminant levels
- Reuse at an offsite construction or development project for use as fill, or for site alteration or re-grading
- Processing and treating soil at an MOECC approved treatment facility (that holds an ECA)
- Reuse at a commercial fill site
- Transport to an MOECC approved landfill (which holds an ECA), where it may be suitable for use as daily cover (at a lower tipping fee) or disposed of as waste

Despite the apparent reliance of the Excess Soil BMP Guide on the standards put in place by O.Reg. 153/04, the document notes that these standards are not intended to address overall soil management activities; QPs must consider the assumptions behind the standards when they are applied to manage excess soil. The Guide specifies that soils with contaminant concentrations that exceed the O.R. 153/04 Standards should not necessarily be considered a waste or assumed to be a risk to human or environmental health. It states that if concentrations exceed the Standards, additional site-specific studies and/or assessments could be carried out to determine what reuse options remain available, provided that they are done in accordance with the guidance set out in the Excess Soil BMP Guide.



Figure 9.1: Recommended process for determining SWMF sediment reuse and disposal options (See Figure 5.1 for the full SWMF clean out project flow chart).

Note: This flowchart does not depict MOECC policy but rather a recommended approach based on TRCA's understanding of current MOECC operational practices.

9.1.4 Handbook for Dredging and Dredged Materials in Ontario

An overview of management options for the handling of dredged material is provided in an MOECC document entitled "Evaluating Construction Activities Impacting on Water Resources Part III A: Handbook for Dredging and Dredged Materials in Ontario – Legislation, Policies, Sediment Classification and Disposal Options" (MOE, 2011b). The Handbook defines dredging as "the planned, mechanical movement of material located below the surface of a waterbody, or at the land/water interface". The guidelines provided are to apply to all forms of dredging and would thus include removal of sediment from a SWMF.

The Dredging Handbook promotes the assessment of the physical, chemical and biological quality of dredged material to confirm potential disposal options, and outlines the requirements of dredging/disposal applications. It outlines the classification of sediments as contaminated or uncontaminated, and describes disposal options available for sediment depending on the degree of contamination, including: 1) open water disposal; 2) disposal on land; 3) disposal at a certified confined disposal facility (dewatering permitted); and 4) specialized disposal at a certified confined disposal facility (with no dewatering). Although the Dredging Handbook is largely focused on evaluating the suitability of material for open water disposal facilities, it does acknowledge disposal on land as a management option for dredged material. Like the Excess Soil BMP Guide, the Handbook notes the importance of considering management options on a site by site basis and includes consideration of O. Reg 153/04 and its standards.

9.1.5 Proposed Excess Soil Management Policy Framework

In January 2016 the MOECC announced that it had completed an Environmental Bill of Rights (EBR) review of the need for excess soil related policy. They concluded that an improved policy framework is necessary to support the guidance provided in the Excess Soil BMP Guide (described in Section 9.1.3). Based on the results of the EBR review, the MOECC has developed a proposed Excess Soil Management Policy Framework which was posted for on the EBR Registry for a public review and comment period ending March 26, 2016.

As part of the EBR review, the province conducted listening sessions with various stakeholder groups and the public. One of the key messages that came out of these sessions was that "the current system for oversight and management of excess soil requires stronger direction and clear and enforceable rules which clearly identify the roles and responsibilities as excess soil is generated and then moved from a source site to a final receiving site." The proposed framework places somewhat greater emphasis on the responsibilities of owners of source sites with respect to chain of custody. They will be responsible for characterizing excess soil and tracking it after it leaves the site, including confirming that it reaches the intended final destination (i.e. a receiving site or disposal site).

The various elements of the proposed framework are depicted in Figure 9.2 (MOECC, 2016). One key element of the framework is a new regulation on excess soil management to be developed under the Environmental Protection Act. The proposed regulation would require larger and/or riskier source sites to

develop and implement excess soil management plans certified by a Qualified Person (which would be defined in the regulation) and made available to MOECC and local authorities. Based on the current information provided, it is unclear whether the definitions of "large" and "risky" would encompass SWMF sites, but it would appear that the regulation itself, once developed, will provide some clarity on the issue. Table 9.1, taken from section 6.0 of the proposed framework document, lists several potential actions associated with the implementation of the framework, including anticipated timelines. In the Table, the development of the regulation is planned for 2016.



Figure 9.2: Graphic depiction of the proposed provincial framework for excess soil management (MOECC, 2016).

Table 9.1: Potential actions to be undertaken to implement the MOECC's proposed excess soil management policy framework. (MOECC, 2016).

Action Item	Proposed Action	Currently Underway	Short-term (2016)	Longer- term
1	MOECC to work with partner ministries to develop a new regulation under the EPA requiring larger and/or riskier <i>source sites</i> to develop and implement excess soil management plans certified by a Qualified Person and made available to MOECC and local authorities.		X	
2	MMAH and MOECC, could require proof of an Excess Soil Management Plan for issuance of certain building permits.			Х
3	MMAH and MOECC, to promote linking requirements for <i>excess soil management</i> to applicable Planning Act approvals through guidance.			Х
4	MOECC to work with Qualified Persons on <i>excess soil management</i> guidance.	Х		
5	MOECC to clarify when waste approvals apply to excess <i>soil processing sites</i> and prescribe requirements for temporary storage sites.		x	
6	MMAH with MOECC to consider approaches that would encourage municipalities to identify appropriate areas (e.g. industrial) for <i>excess soil</i> storage and processing to encourage local re-use, to be achieved through ongoing updates to the provincial land use planning framework, including the coordinated review of provincial plans.	Х		
7	MMAH and MNRF to consider amendments to legislation to remove restrictions on site alteration by-laws in conservation authority regulated areas.	X		
8	MMAH and MOECC to develop educational materials respecting receiving sites, including larger (commercial) sites, to inform municipalities in the development or updating of by-laws.		x	
9	MMAH and MNRF to explore, with partners, legislative and non-legislative ways to improve compliance and enforcement with Municipal Act and Conservation Authorities Act requirements.	х		
10	MNRF to consider requiring record keeping for fill being brought to licensed and permitted aggregate sites, through the current review of the Aggregate Resources Act.	x		
Table 9.1 cont'd: Potential actions to be undertaken to implement the MOECC's proposed excess soil				
--				
management policy framework. (MOECC, 2016).				

11	OMAFRA and MOECC to develop best practice guidance for farmers to limit impacts of the importation of soil onto farmland		Х	
12	MOECC to develop approaches and standards for reuse of excess soil that provide for environmental protection and sustainable reuse of <i>excess soil</i> .		Х	х
13	MOECC to develop clear guidance to inform requirements on testing of <i>excess soil</i> .			Х
14	MOECC to develop guidance for smaller, lower risk source or receiving projects or sites.			Х
15	MMAH with MOECC to identify opportunities to encourage municipalities to develop soil re-use strategies as part of planning for growth and development (e.g. official plans, master planning) through ongoing updates to the provincial land use planning framework, including the coordinated review of provincial plans.	х		
16	MOECC to develop guidance for the consideration of <i>excess soil</i> in the environmental assessment processes that govern large infrastructure and other development projects.			Х
17	Province to support pilot projects identifying opportunities and procedures for <i>excess soil</i> re-use.		Х	
18	MOECC to integrate and align various aspects of provincial policy including Regulation 347 (Waste) and O. Reg. 153/04.		Х	
19	Province, including MOECC, MTO and MEDEI, to review and update existing guidance for provincial projects (e.g. transportation and infrastructure) to ensure alignment.			x
20	MOECC to develop a stakeholder group (and potential sub- working groups) to provide input on proposed policies, technical matters, guidance and implementation, including coordination with external programs.		x	
21	Industry and MOECC will jointly investigate approaches to program delivery, e.g. like the UK CL:AIRE model, that promote market-based mechanisms to encourage the reuse of excess soil.		Х	

9.1.6 Regulations and guidelines related to biosolids and non-agricultural source material

While the Excess Soil BMP Guide does not emphasize the beneficial reuse of SWMF sediment on agricultural land, it also does not preclude this option. In order to be able to assess the potential for reuse of SWMF sediment on agricultural land, it is first necessary to understand the definition of non-agricultural source material (NASM) and how it relates to biosolids. According to OMAFRA (website), NASM are "materials from non-agricultural sources that can be applied to agricultural land." They contain levels of nutrients and organic matter that can be beneficial to soils and crops. NASM is an umbrella term for many different kinds of materials; biosolids are just one category of NASM. Other materials considered NASM are leaf and yard waste, fruit and vegetable peels, and food processing waste.

One guidance document that may be a relevant reference where reuse of SWMF sediment on agricultural land is being considered is the *Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land* (MOE and OMAFRA, 1996). The Guidelines were produced to facilitate the beneficial use of biosolids and other waste materials on agricultural land. The Biosolids Guidelines note these materials must benefit crop production or soil health (e.g. provide essential plant nutrients and/or organic matter) without degrading the environment.

The document provides supporting guidance for the beneficial use of "other wastes" which includes materials not defined as sewage biosolids, septage, or agricultural waste in O. Reg. 347. Given this broad definition, SWMF sediment may be interpreted as belonging to this waste category. Consequently, the evaluation process and criteria presented within the Biosolids Guideline would be applicable to SWMF sediment and could be applied to support the beneficial use of these materials on suitable agricultural land (beneficial reuse flowchart).

The Water Environment Association of Ontario's (WEAO) May 2010 literature review entitled Assessing the Fate and Significance of Microconstituents and Pathogens in Sewage Biosolids provides definitions of "municipal sewage sludge" and "biosolids" that may also shed light on the characterization of SWMF sediment. The document defines municipal sewage sludge as:

"a mixture of solids and water that is generated from the treatment of municipal wastewater"

and biosolids as:

"municipal sewage sludge that has been treated by physical, chemical and/or biological processes to reduce pathogen and vector attraction potential, and that meet quality criteria such as metals and pathogens concentration".

Given that SWMF sediment is a mixture of solids and water generated from the treatment of municipal wastewater, and that it has been treated by physical processes, it may be appropriate to interpret SWMF sediment both as municipal sewage sludge and also as a biosolid. Thus either by considering the WEAO definition for biosolids, or the Biosolids Guideline definition for "other wastes", it would be appropriate to consider the beneficial use of SWMF sediment on suitable agricultural land.

In order to determine whether SWMF sediment will be beneficial at an agricultural receiving site, it is necessary to consider the suitability of the material with respect to: (i) beneficial qualities that support plant growth (e.g. organic matter and nutrient concentrations) and (ii) contaminant levels relative to the appropriate guidelines.

Beneficial use requirements for NASM

As discussed above, OMAFRA lists sewage biosolids as a type of NASM. Based on Section 98.0.6 of O.Reg. 267/03 (under the Nutrient Management Act), NASM is required to meet conditions that ensure the material will be beneficial to the land to which it is applied. For solid NASM, at least one of the following conditions must be met:

- The material has total organic matter that constitutes at least 15% of its total weight
- Material is to be used to increase soil pH
- The material has a total concentration of more than 13,000 mg/kg of plant available nitrogen, phosphate and potassium, calculated on a dry weight basis.

These regulatory requirements are in place to ensure that NASM applied to agricultural lands provide a significant benefit to the soil. While SWMF sediment chemistry varies from site to site, typical levels of total organic matter and nutrients would be below those listed in the conditions above. While certain agricultural land uses (e.g. crop production) do require soils that contain these levels of organic matter and nutrients, other agricultural land uses, such as tree nurseries, can sometimes operate with soils having an organic matter content below 1% (Kelly-Hooper study (2015) summarized in Appendix C). SWMF sediment from some sites may contain organic matter levels that are higher than this, and therefore be of some benefit in tree nurseries and other non-food producing agricultural land uses. The grain size distribution of SWMF sediment may also be beneficial to these types of operations as a means of adding silt and clay to the existing soils that may be predominantly sand. As described in section 5.1.5, the application of SWMF sediment to agricultural lands as an NASM would require the preparation of an NASM plan, approved by OMAFRA, and prepared by a professional holding an OMAFRA issued NASM Plan Development Certificate.

Contaminant thresholds for biosolids and NASM

The evaluation process and criteria presented within the Biosolids Guideline is strongly focused on metals and excludes criteria for many organic parameters, such as polycyclic aromatic hydrocarbons (PAHs). O.Reg. 267/03 under the Nutrient Management Act also excludes PAHs, only providing criteria for metals and pathogens (Schedules 5 and 6 of the regulation). The exclusion of criteria for PAHs from the Biosolids Guideline and O.Reg. 267/03 is supported by the WEAO Document, which states that *"PAHs, and particularly benzo(a)pyrene in land applied sewage sludges do not present significant human or environmental health risks"*. The WEAO goes on to affirm that, based on the literature reviewed, PAHs should be categorized as Group I contaminants, meaning that there is enough credible scientific information to ensure that following current agricultural land application guidelines will protect the health of humans, other organisms, and the environment, including crops and soils (WEAO, 2001).

Figure 9.3 presents average PAH concentrations in SWMF sediment from 20 ponds and sewage sludge from 19 municipal sewage treatment plants (STPs). Average concentrations for 7 out of 12 PAHs are higher in sewage sludge than in SWMF sediment. For the 5 PAHs for which the SWMF sediment has a higher average concentration, only 2 PAHs – benzo(a)pyrene (BaP) and flouranthene – have an average concentration higher than the O.Reg. 153/04 Table 2 soil standards. For both parameters, the average concentration in SWMF sediment is comparable to that observed in STP sewage sludge. Considering this data, an argument could be made that since PAH levels are not factored in when evaluating the quality of biosolids, and SWMF sediment will often contain PAH levels similar to those in a conventional biosolid material (sewage sludge from STPs), it may be appropriate to use the criteria in the Biosolids Guideline to evaluate SWMF sediment quality in cases where reuse as a NASM is being considered. This alternative reuse approach, in which SWMF sediment is treated as potential NASM, is depicted in Figure 9.4



Figure 9.3: Average PAH concentrations in SWMF sediments collected from 20 SWMFs and sludge collected from 19 municipal sewage treatment plants (STP).



Figure 9.4. Alternate SWM sediment disposal approach – treatment as biosolid, other waste, or non-agricultural source material (NASM).

9.2 Sediment Quality Analysis Considerations

9.2.1 Contaminants in SWMF sediment

A variety of contaminants can enter SWMFs depending on the catchment size and the type of land-use (e.g. residential vs. industrial). Generally, pollutants sorbed to sediments in SWMFs are present at low concentrations and in the order of ppm (parts per million), ppb (parts per billion) and ppt (parts per trillion) by mass. Table 9.2 lists several parameter groups for which SWMF sediment should be analyzed. The parameters are typical contaminants present in urban stormwater runoff that are retained in SWMF sediments. In addition to the parameters, Table 9.1 also provides the contaminant sources and their relevance to the O.Reg. 153/04 Standards (described in Section 9.1.2). The parameters listed in Table 9.2 are defined below in greater detail.

Total Petroleum Hydrocarbons (PHCs)

PHC is a term used to describe a family of several hundred organic chemical compounds originating from crude oil and coal, which are primarily composed of hydrogen and carbon atoms. They are also present in coal tar, which is a product of coal and refined crude oil products such as gasoline, diesel, motor oil and asphalt. Since there are so many different chemicals in crude oil and in other petroleum products, it is impractical to analyze samples for each one. As a result, PHCs are divided into fractions based on carbon chain length. The O.Reg. 153/04 Standards list four PHC fractions: F1 (C6-C10), F2 (C10-C16), F3 (C16-C34), and F4 (>C34).

Total Polycyclic Aromatic Hydrocarbons (PAHs)

Like PHC, the term PAH also describes a family of several hundred organic chemical compounds, which are primarily composed of hydrogen and carbon atoms. However, the chemical structure of PAHs is unique as they have two or more aromatic (benzene) rings, which are fused together when a pair of carbon atoms is shared between them. PAHs originate from coal, coal tar, crude oil and refined crude oil products. Other PAH sources include the incomplete combustion of organic materials such as fossil fuels, wood and barbequed food.

Sodium Adsorption Ratio

SAR is a widely accepted agricultural index for characterizing soil sodicity. It is the ratio of the amount of cationic charge contributed by sodium, to that contributed by calcium and magnesium in a soil solution. Elevated SAR levels indicate the presence of poorly drained, tight soil structures, which restrict plant seedling emergence and root growth. Road salt applied for winter road maintenance is the most common source of elevated SAR levels in urban environments.

Urban SWMF sediment quality parameters	Contaminant sources	¹ Relevance to O.Reg. 153/04 Soil Standard Exceedences
²Petroleum Hydrocarbons (PHCs)	Transportation sources: gasoline, diesel, motor oils, engine emissions, asphalt pavement, coal tar pavement sealants, tires. Non-transportation sources: roofing tar.	Elevated F3 PHCs (C16-C34) are the most important cause of O.Reg. 153/04 Table 1 Soil Standard exceedances.
³ Polyaromatic Hydrocarbons (PAHs)	Transportation sources: gasoline, diesel, motor oils, engine emissions, asphalt pavement, coal tar pavement sealants, tires. Non-transportation sources: roofing tar, barbecue smoke, wood smoke, coal power plant emissions.	Elevated PAHs are the most important cause of O.Reg. 153/04 Table 2 and 3 Soil Standard exceedances.
⁴ Sodium Adsorption Ratio	Winter road salt de-icing applications	Important cause of O.Reg. 153/04 Table 1, 2 and 3 Soil Standard exceedances.
⁴Cyanide	Decomposition of ferrocyanide which is added to road salt as an anti-caking compound.	Potential cause of O.Reg. 153/04 Table 1, 2 and 3 Soil Standard exceedances.
^{5,6} Metals	Automobiles (zinc from tire wear, brake pads, leaks and spills of oil), bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes.	Important cause of O.Reg. 153/04 Table 1 Soil Standard exceedances, but not an important cause of Table 2 or Table 3 exceedances
⁵ Pesticides and Herbicides	Lawns and gardens, utility right of ways.	Ontario banned cosmetic pesticides and some herbicides in 2008, but certain industries are exempted (e.g. golf courses, tree nurseries). Site specific features should be considered when deciding if sediment should be analyzed for pesticides and herbicides.
^{5,6} Sediment grain size	Winter sanding of pavements, construction activities, gardens/lawns, atmospheric deposition, drainage channel erosion.	Many O.Reg. 153/04 soil standards are set for fine (silt, clay) versus coarse (sand, gravel) particles sizes. Particle size analysis will determine if each sample should be compared to the fine or coarse soil standards.

Table 9.2. Urban SWMF sediment quality parameters and their relevance to O.Reg. 153/04 Soil Standards.

<u>Notes</u>: ¹See Table 9.2 for a detailed list of SWMF sediment analytes that exceeded O.Reg. 153/04 soil standards <u>Information Sources</u>: ²Wang et al 2009; ⁴Health Canada 2013; ⁵MOE 2003; ⁶Marsalek J, et al 1997

<u>Cyanide</u>

Ferrocyanide is a compound that may be added to road salt for anti-caking purposes. Ferrocyanide can decompose to cyanide with exposure to sunlight and certain types of bacteria.

Trace Metals

Trace metals are elements that normally occur at very low levels in natural environments. While living organisms do require small amounts of trace metals, elevated levels of certain metals can be highly toxic. Cars and trucks are the primary sources of trace metals in residential catchments.

Particle Size Analysis

SWMFs are designed to collect and retain soil and sediment particles in urban runoff. Common sources include construction activities, lawns and gardens, atmospheric deposition, drainage channel erosion, and sand application to improve traction on icy roads. SWMF sediment particle size categories include: clay (0.98-3.9 μ m); silt (3.9-62.5 μ m), sand (62.5 μ m – 2 mm) and gravel (2-64 mm). O.Reg. 153/04 includes different soil standards for fine soils (clay and silt) and coarse soils (sand and gravel). Particle size distribution is also important for evaluating suitability for different reuse options.

9.2.2 Characterizing SWMF Sediment Quality

The selection of sediment quality analysis parameters should reflect the catchment area's land use characteristics and reported spill histories. This guide provides a suggested minimum list of analytes that would be suitable for residential SWMFs with no histories of point source contamination. However, it is recommended that the MOECC be contacted to determine if any spill events or other site specific circumstances would require additional analytes as well. The following step-by-step process would provide data that is necessary to conducting landfill disposal versus beneficial use evaluations. The analyte lists included below have been determined based on a comprehensive study and statistical analysis of sediment quality and grain size analysis data for 61 Canadian residential SWMFs (summarized in Appendix C).

Step 1A: O.Reg. 347 Leachate Test

The O.Reg. 347 leachate test establishes whether or not the SWMF sediment is hazardous waste, which would require disposal at a hazardous waste facility. This information is typically required by the MOECC as a key first step in characterizing SWMF sediment. It may be advisable to conduct this analysis concurrently with Step 1B (O.Reg. 153/04 Bulk Soil Analysis) so that samples for both tests can be collected during the same visit.

A list of 29 recommended analytes for the leachate test is provided in below. The general groups of analytes are identified as Volatile Organic Compounds (VOCs) and nonconventionals. This list is a subset of the analytes in O.Reg. 347 Schedule 4. Contaminants from Schedule 4 that are omitted from the list are those that not found in SWMF sediment from residential, commercial and institutional catchments.

- Arsenic, leachable
- Barium, leachable
- Boron, leachable
- Cadmium, leachable
- Chromium, leachable
- Fluoride, leachable
- Lead, leachable
- Mercury TCLP
- Selenium, leachable
- Silver, leachable

- Uranium, leachable
- 1,1-Dichloroethylene
- 1,2-Dichlorobenzene
- 1,2-Dichloroethane
- 1,4-Dichlorobenzene
- Benzene
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Dichloromethane

- Methyl Ethyl Ketone
- Tetrachloroethylene
- Trichloroethylene
- Vinyl chloride
- Cyanide, weak acid dissociable
- Nitrate and Nitrite as N
- Total PCBs

Although the leachate test is required, data collected as part of the study referenced above (Kelly-Hooper (2015) summarized in Appendix C) shows that sediment from residential, institutional and commercial sites is unlikely to contain contaminant levels that would exceed Schedule 4 (see leachate results for six SWMFs in Appendix C, Table C.2). Sediment from all six of the SWMFs sampled met the O.Reg. 347 non-hazardous waste disposal criteria. Most of the analytes were not detected, and the concentrations of the detectable analytes were one to three orders of magnitude below the criteria.

Step 1B: O.Reg. 153/04 Bulk Soil Analysis

Bulk soil analysis based on the O.Reg. 153/04 Standards is carried out to evaluate whether SWMF sediment is suitable for beneficial reuse or requires landfill disposal. As described in Section 9.1.2, the MOECC has, on a case-by-case basis, accepted the contaminant thresholds in O.Reg. 153/04 Table 1 as a basis for classifying sediment as inert. Inert sediment can be used off-site without regulatory approval. Sediments that exceed Table 1 soil standards would require a risk evaluation to identify potential beneficial reuse options according to land use type (see Figure 9.1). Table C.3 in Appendix C provides a summary of O.Reg. 153/04 bulk soil analysis results showing percentage exceedances of the standards for 61 residential SWMFs. These results provide valuable information about the typical chemistry of residential SWMF sediment in Canada.

The following is a base list of bulk soil analytes. It may be necessary to include additional analytes if land use activities in the catchment or past spills are believed to have introduced contaminants that are listed in the Standards but not included in this list.

- Trace metal scan including hot water extractable boron
- Cyanide
- Polycyclic Aromatic Hydrocarbons (PAHs)

- Petroleum Hydrocarbons (PHCs)
- Sodium Adsorption Ratio (SAR)
- Conductivity
- Particle size distributions

Step 2: Topsoil Analysis and Certified Crop Advisor Report for Beneficial Use Evaluations

The topsoil analysis would only be conducted if the O.Reg. 153/04 bulk soil tests determine that the sediment does not require landfill disposal due to high contamination levels (see Figure 9.1). Topsoil analysis would be necessary to demonstrate that amending the receiving site soils with the sediment would provide a benefit to the soils, as required by the Nutrient Management Act, without inhibiting plant growth. The list of analytes to be considered includes:

- Trace metals
- Hot water extractable boron
- SAR
- Conductivity and pH
- Available nutrients
- Particle size distributions

9.2.3 Sediment Sampling Considerations

Sampling and analysis of in-situ sediment, before dredging has been carried out, is necessary for initial sediment characterization and project planning purposes. In some cases, it may also be advisable to sample and analyze dredged sediment after bulking/dewatering, just prior to hauling. Because bulking and dewatering materials can alter contaminant levels, resampling can help to provide certainty about the quality of the sediment leaving the site, and help to inform the final decision on the fate of the sediment (i.e. landfill disposal vs. reuse at a receiving site).

The processes of dredging, dewatering and bulking can increase or decrease sediment contaminant levels. If a bulking/dewatering material is added that has lower or higher contaminant levels than the sediment, and it is added in significant amounts, it can alter contaminant levels in the final dried material. While the MOECC prohibits the addition of materials for the purpose of dilution of contaminant levels, bulking/dewatering agents are normally permitted because their purpose is to expedite sediment drying. Contaminant levels may also be reduced by exposure of dredged sediment to air, which can provide an opportunity for some contaminants to volatilize (e.g. low molecular weight PAHs). The extent to which volatilization of low molecular weight PAHs would occur depends on various case-specific factors such as the length of drying time, air temperature, humidity, wind speed, and soil type and moisture content.

It may also be important to resample if in-situ sodium adsorption ratio levels (SAR) exceed the relevant standards because SAR levels in pond sediment reflect sodium concentrations in the water. Therefore,

SAR levels will generally be higher when dredging occurs in the winter or spring than when the facility is dredged during the summer of fall. If dredged sediment is exposed to rain for a period of time, SAR levels may fall below levels measured in-situ.

On projects where post-dredging sediment resampling is not needed and is being omitted as a cost and/or time saving measure, it may still be advisable to sample and analyse any bulking or dewatering agents to be used in order to ensure that contaminant levels are not higher than those in the sediment.

9.2.4 Statistical Evaluation of Analyte Distributions in SWMFs

For the 61 SWMFs sampled as part of the Kelly-Hooper (2015) study (Appendix C), sediment chemistry comparisons were conducted using statistical analysis to determine if significant differences occurred between the inlet, centre and outlet sample zones. Appendix D includes boxplot results for all detectable analytes included in this study, and a detailed description of the statistical analysis is provided in Appendix C.

The analysis carried out identified significant differences between samples that were collected from the inlet versus the outlet areas. However, significant differences were not identified between the inlet and centre samples or between the centre and outlet samples. This trend was especially pronounced for the particle size distributions. Sand concentrations were generally highest at the inlets, while silt and clay were highest at the centre and outlets. This is to be expected due to gravitational settling of heavier particles at the inlet. As stormwater flows into the facility it slows down and the heavier sand particles in suspension are deposited in the forebay, close to the inlet, while the lighter silt and clay particles are carried to the centre and outlet locations.

These statistical results support the strategy of selecting sediment sampling "zones" that was previously discussed in Section 6.2.3 and shown in Figure 6.4. The zones represent distinct areas of sediment deposition, with forebays defined as inlet zones and aftbay areas divided into two zones based on the flow path direction and location of the outlet structure.

10.0 INSPECTION AND MAINTENANCE COSTS

Accurate cost estimation is critical for budgeting and planning for the maintenance needs of stormwater management facilities. This section provides a high-level overview of expected costs for routine and non-routine maintenance of SWMFs derived from literature and survey data. Since costs are highly site-dependent, the assumptions used to generate them should be carefully examined.

It should be noted that all costs presented below have been adjusted for inflation based on total inflation incurred between the year of a costed item and 2015 as per Bank of Canada's consumer price index.

10.1 Preventive Costs

Once a SWMF is assumed, a program for routine preventive inspection and maintenance should be developed. A checklist of items for inspection is provided in Appendix B. It is recommended that inspections be conducted at the onset of each season and following major storm events, resulting in a minimum of 4 annual inspections. The cost of the inspection program will vary based on frequency and staff salaries, but on average, the cost could fall between \$713⁴ and \$1425⁵. Additional costs would be incurred if the need for repair or additional landscaping work is revealed through the inspections. Over time, the costs of the inspection and maintenance program would be adjusted based on the history of costs for a specific site.

10.2 Corrective Maintenance Costs

Costs for corrective maintenance are incurred infrequently but are associated with large lump sum expenditures that could put a dent in the owner's budget. The cost to remove sediment from SWMFs varies widely based on a number of site-specific factors. For 11 clean out projects surveyed during the development of this guide, total project costs ranged from \$53 to \$512 per m³ of sediment removed. In 5 separate clean out projects for which disposal data was available as a separate line item, it was determined that disposal costs alone ranged from \$76 to \$112 per m³. Some of the factors contributing to the wide range of final costs include:

- Site accessibility
- Extent of site clearing and preparation
- Level of in-situ sediment accumulation
- Dewatering method/time

Toronto and Region Conservation Authority and CH2M, 2016

⁴ Based on a technician cost of \$59.40/hr (RS Means 2010 data with 8.79% inflation and 10% for overhead), for 3 hour inspection done 4 times per year.

⁵ Based on a technician cost of \$59.40/hr (RS Means 2010 data with 8.79% inflation and 10% for overhead), for 3 hour inspection done 8 times per year.

- Bulking method/time
- Volume of removed sediment
- Disposal or re-use options based on sediment contamination level
- Distance of transportation to disposal site
- Amount of restoration required after completion
- Need for retrofit elements

The influence of these factors on costs can be determined prior to cleanout through detailed site assessment. Commonly, older SWMFs which were constructed without much consideration for future maintenance would generate higher costs associated with vegetation clearing to create a sediment management area, access road construction and dewatering constraints. Conversely, newly constructed SWMFs are often designed with maintenance-enabling elements in mind, which ease the sediment removal process to some extent. For more information on SWMF design elements that facilitate future maintenance, see Section 3.5. Older SWMFs are also a more likely target for retrofit works, given that design standards for both operation and maintenance aspects have evolved over the last few decades. Consequently, retrofit and sediment maintenance works for older SWMFs are often grouped and occur at the same time under an umbrella of shared costs in the form of mobilization, demobilization, equipment rental, and more. Costs for sediment removal from older SWMFs may therefore be measurably larger than for newer ones that do not yet require any retrofit works.

Commonly, SWMFs with larger volumes of accumulated sediment would generate lower costs per unit volume than those with small volumes of accumulated sediment. This is often the case for larger facilities that are designed with considerable available volume for sediment accumulation over their life cycle. Site assessment, sediment testing, mobilization and demobilization costs are fixed regardless of how large and how full a facility may be. The consumables (materials used to conduct the cleanout such as bulking materials, plantings, erosion and sediment control measures) increase with increasing SWMF size and sediment volume at an approximate rate of \$1,500 per 100 m³ of sediment. The number of days that rental equipment may need to be secured for also increase with increasing facility size and sediment volume, at an approximate rate of 0.5 days per 100 m³ of sediment; this in turn increases the rental and labour costs. Although not supported by a concrete set of data, it is possible that large SWMFs exhibit inflated costs associated with logistical hurdles. These hurdles could be tackled by utilizing hydraulic dredging techniques that do not necessitate SWMF dewatering.

If the aforementioned costs could be approximated based on historical costs in a municipality's books, the sediment removal, hauling and disposal costs would be the remaining major unknowns. Frequently reported disposal costs can vary from \$76 to \$112 per m³ for contaminated sediment requiring landfill. Prices will vary based on disposal facility tipping fees and changing contract bidding rates. Given that these costs likely comprise a significant portion of the entire cleanout budget, SWMF owners are advised to resample sediment for chemistry analysis post bulking/dewatering and prior to potentially landfilling sediment that was initially determined to be contaminated. For more information on sediment sampling considerations, see Section 9.2.3.

SWMF cleanout costs collected from various projects in the Greater Toronto Area are presented in Figure 10.1. It is difficult to identify a clear correlation between the volume of removed sediment and the total cost per unit volume, highlighting the need to evaluate each pond individually as a unique case. Each of the featured facilities is characterized by a unique set of circumstances that determine the final cost, which are described in the following paragraphs.



Figure 10.1: Range of sediment removal project costs per removed volume of sediment (\$/m³) with associated volume of removed sediment.

Pond 1 was cleaned out in 2010 after being in service for 14 years. The estimated volume of sediment requiring removal was 1160 m³, however, the volume was conservatively tendered as 2000 m³. This equated to \$53/m³ to complete the sediment removal project. The total cost of the project includes the pond survey and sediment testing as part of the preliminary site assessment; site preparation, dewatering and dredging, and site restoration. Part of the cost went into the construction of a berm from the dredged sediment, which was deemed safe for on-site disposal. Consequently, the low total cost can mostly be attributed to not needing to landfill the sediment, but also due to dry weather and an overall maintenance-friendly pond design. The dredging activity without hauling and disposal costs, cost nearly \$35,000, while the site restoration was nearly \$25,000. The site restoration included plantings, seeding, access road and storage area repair.

Pond 2 was cleaned out post 2011. It had accumulated 325 m³ of sediment from a mainly residential drainage area. The pond was cleaned out using mechanical dredging and the sediment was disposed of at a registered landfill as some of the parameters exceeded O.Reg. 153/04 Table 1 background standards. The cost to clean out the pond was \$103/m³, which sits at the low end of the

Toronto and Region Conservation Authority and CH2M, 2016

range presented in Figure 10.1. Items included in this cost estimate are pond dewatering, sediment removal and disposal, facility component maintenance, and site restoration. The project management costs are also included.

Sediment removal costs presented for Ponds 3, 6 and 7 are in the form of project tenders initiated by the developer for the purpose of assumption by the municipality. Despite the fact that these ponds were in receipt of sediment for a short period of time, the tender documents identify that 3500 m³, 2000m³ and 3500 m³ of sediment required removal, at a cost of \$124/m³, \$149/m³ and \$170/m³ from Ponds 3,6 and 7, respectively. Tasks included in the costs are inspecting, flushing and cleaning of storm sewer pipes, manholes, ditch inlets and sanitary sewers, removal and replacement of rip-rap stones, servicing of hickenbottom, and all tasks associated with the dewatering, dredging, drying, hauling and disposal of sediment.

Pond 4 was cleaned out during the winter of 2013-2014 after being in service for 8 years and receiving stormwater runoff from a residential drainage area. Since only the forebay was cleaned of sediment for the purpose of assumption by the municipality, the total volume of removed sediment amounted to just 120 m³. The total cost, normalized by volume of sediment removed, is \$130/m³. Given the fact the (de)mobilization, preliminary site assessment and site restoration are fixed costs that are not influenced by the volume of removed sediment, this per unit cost would be significantly lower if the entire facility was cleaned out. It is not expected that municipalities would have to remove such small amounts of sediment at the end of the life cycle of a SWMF, suggesting that lower costs per m³ should be anticipated. More details about this pond can be found in a case study in Appendix J.

Pond 5 was cleaned out during the winter of 2009/2010 after being in service for 15 years and without prior servicing for the purposes of assumption, as is more common practice now. Its drainage area is a mixed residential and commercial. The total volume of the mechanically removed sediment amounted to approximately 600 m³, which was disposed of at a registered landfill facility as it exceeded O.Reg. 153/04 Table 1 background contaminant levels. The total cost was estimated at \$149/m³, which includes preliminary site assessment in the form of sediment and bathymetric surveys, site preparation in the form of erosion and sediment control measures and vegetation clearing, dewatering, dredging, hauling and disposal of sediment, and site restoration. More details about this pond can be found in a case study in Appendix I.

Pond 8 was cleaned out in 2010. An estimated 2625 m³ of contaminated sediment were removed from the pond and disposed of at a registered landfill facility at a cost of \$273,000. The total project cost of \$186/m³ includes site (de)mobilization, restoration, installation of a bottom draw outlet, red sand filter, and an oil and grit separator and sediment removal and disposal. As part of the cleanout process but not reflected in the costs presented here, approximately \$145,000 worth of excess soil was removed to enlarge the pond and forebay, while new infrastructure was added at a cost of \$40,000. This highlights the potential variability in cleanout costs, as the sediment removal process is seen as an opportunity to retrofit other aspects of the pond.

Ponds 9 and 10 were constructed in 1997 and were receiving stormwater runoff for 16 years before they were cleaned out. Pond 9 receives runoff from a mixed residential and commercial drainage area, while Pond 10 receives runoff from a commercial land use drainage area. After each was mechanically dredged, sediment dewatering was achieved with the help of a superabsorbent polymer, which increased the final costs. Nevertheless, these costs were offset by not needing to dispose of the pond sediments at a registered landfill, as the sediment was clean enough to allow its re-use at an offsite residential/parkland site. The total costs were \$259 and \$260 per m³ for Pond 9 and Pond 10 respectively. The costs include equipment, materials and labour associated with all aspects of the sediment removal process. More details about these ponds can be found in a case study in Appendix H.

Pond 11 was built in 1987 and was in service for 26 years before it was cleaned of sediment. The 400 m³ of mechanically removed sediment was transported to be used as fill at an industrial site. The total cost was \$512/m³, which is at the high end of the range of costs collected. Tasks accounted for in the final cost are site assessment, preparation and restoration, and sediment dredging, dewatering, hauling and disposal. Worked within all costs are equipment, materials and labour costs. The high cost could be explained by a combination of the need for industrial land-use disposal and the relatively small amount of sediment that was removed, resulting in less savings based on economies of scale.

Clean out project cost estimates provided the City of Guelph's *Stormwater Management Facility Inventory Assessment and Maintenance Needs Plan* (2008) also provide some insight into the average range of costs corrective maintenance. A consulting firm was retained to assess the City's stormwater infrastructure and prioritize the need for sediment removal from their greenways, and wet and dry ponds. The estimated costs were derived using fixed line item costs as presented in Table 10.1. The only costs that were not the same from site to site were the ones affected by facility size – sediment dredging and landscape restoration costs. Other costs that would be expected to vary from one facility to another – namely restoration of slopes and access road restoration – were kept at a fixed number of units – 500 and 50 m², respectively – for all the facilities considered. This is likely because this figure is not expected to vary significantly from one site to the next.

The determination of the total cost per unit volume is based on two scenarios – landfill disposal of sediment or onsite reuse. The report identified five ponds as priority works, and their total estimated costs are presented in Figure 10.2 for both these scenarios. The estimated volumes of sediment that have to be removed from ponds 1 through 5 in Figure 10.2 are 1051 m³, 766 m³, 248 m³, 174 m³ and 112 m³. Figure 10.2 shows that the cost per unit volume decreases with as the volume of sediment removed gets larger and increases with the need for landfill disposal. Although these costs are simply estimates and it is expected that the fixed line items would vary to some extent for different projects, the volume of sediment and the manner in which it is disposed will ultimately have the largest impact on the final cost.



Figure 10.2: Range of sediment removal project costs and volumes for select pond in the City of Guelph (Source: City of Guelph, 2008).

Table 10.1: Cost estimates for activities associated with SWMF sediment removal. (Source: City of Guelph, 2008).

Activity	Amount	Unit	Cost Per Unit*	Landfill Disposal Total Cost	Onsite Disposal Total Cost
Sediment & Erosion Control		m		5,000	5,000
Mobilization	1		10,000	10,000	10,000
Bypass	1		15,000	15,000	15,000
Soil Sampling & Testing	1		2,000	2,000	2,000
Dredge Sediment (Landfill Disposal)	As Measured	m³	140		
Dredge Sediment (Onsite Disposal)	As Measured	m³	15		
Restoration of Slopes (Seed & Erosion Mat)	500	m²	30	15,000	15,000
Repair Existing Erosion	1		10,000	10,000	10,000
Remove Existing Silt Fence	1		1,500	1,500	1,500
Remove Existing Debris	1		1,500	1,500	1,500
Landscape Restoration (Aquatic Planting)	As Needed	ha	1,500		
Access Road Restoration	50	m²	20	1,000	1,000
Sediment Monitoring				1,800	1,800
			Subtotal		
			Contingency	10%	10%
			Total		

* Based on 2008 dollars

Toronto and Region Conservation Authority and CH2M, 2016

11.0 CONCLUSIONS AND RECOMMENDATIONS

Organizational Stage

- 1) Stormwater ponds and constructed wetlands provide important benefits that can be realized only through appropriate and timely inspection and maintenance. Maintenance requirements are required by law under the OWRA in the form of Environmental Compliance Approvals (formerly Certificate of Approval) issued for each facility. Owners/operators of stormwater facilities are legally bound to maintain their facilities through the ECAs, and may also face legal action under common law tort of negligence, whereby inadequate maintenance results in property damage.
- 2) SWMF features that reduce the maintenance burden of SWMFs should be incorporated into designs whenever possible. These features include a maintenance drawdown pipe for gravity dewatering of the permanent pool, a maintenance by-pass valve, sediment maintenance and drying areas, looping access roads and easily accessible outlet structures.
- 3) When the ownership of SWMFs is transferred from the developer, the future owner should verify through surveys and monitoring prior to acceptance that the SWMF has the storage capacity and hydraulic functions specified in the original approved design. The contributing drainage area should also be fully stabilized at the time of transfer to ensure sediment does not accumulate at higher rates during the first few years of ownership.
- 4) SWMF owners should conduct a comprehensive inventory of their infrastructure and maintain an asset management database that records relevant design data as well as routine and non-routine inspection and maintenance activities and costs. Sediment chemistry sampling should be conducted on SWMFs scheduled for maintenance within the near future. The database, in combination with regular inspections and servicing, will help improve the accuracy of future SWMF maintenance requirements and cost projections.
- 5) Regular inspection and preventive maintenance is critical to the proper functioning of SWMFs and timely identification of potential corrective maintenance needs. Preventive maintenance activities can significantly reduce long term costs and prevent potential long term hazards associated with improper SWMF function.
- 6) The state of the SWMF drainage area influences sediment loads to SWMFs as well as sediment reuse and disposal options. Consequently, good municipal management strategies play an important role in the maintenance of SWMFs. Street sweeping and catchbasin cleaning during the late fall and early spring are particularly important in reducing the quantity of sediment and associated pollutants flushed into the facility.

7) Local residents and landowners need to be well-informed of the purpose and function of SWMFs within their neighbourhood. Improved awareness will help decrease illegal dumping, vandalism, encroachment and illegal private drain installations. It will also improve household practices and empower residents to report issues or problems with the operation of the facility.

Planning and Removal Stage

- 1) SWMFs should be cleaned when the TSS removal efficiency declines below 5% of its original design criterion, as specified in the Ontario SWMPD Manual (MOE, 2003). Calculations of sediment accumulation should be based on in-situ sediment depth measurements, which are more accurate than computer models for sediment accumulation forecasting. A minimum depth measurement frequency of 5 years is suggested to capture medium and long-term variability in accumulation rates.
- 2) The permits and approvals required for a SWMF clean out will vary based on factors such as location, facility type, proximity to protected natural features, proposed clean out and disposal methods, time of year, and presence of species at risk. It is recommended that the relevant regulatory agencies are consulted early in the project to allow time for any necessary permits and approvals to be issued.
- 3) Standard disk and rod measurements of sediment depth provide reliable estimates that do not depend on the availability or accuracy of as-built surveys. Sonar methods provide for better resolution of sampling, but SWMF owners should confirm that estimates of sediment depth by this method are equivalent to the standard method, especially when an accurate as-built survey is not available.
- 4) The estimated volume of sediment accumulation as stated in tender documents represents insitu volume with no correction for water content of the saturated sediment. When the SWMF is drained, the volume to be removed is expected to increase by an estimated 10-20% resulting from decreased pressure and less sediment consolidation. Therefore, it is common practice to add 10-20% to the surveyed sediment volume to serve as a high end of the expected volume to be removed. Contractors may further air dry the sediment or add bulking agents, which may reduce or increase the volume, but charges are typically based on the volume of sediment dredged, rather than the volume hauled.
- 5) To ensure that the surveyed sediment volume is as accurate as possible, it is recommended that sediment accumulation surveys are carried out using a method that measures not only the elevation of the top of the sediment but also the depth of sediment. This eliminates any source of error associated with relying on the SWMF design drawing or as-built survey for comparison.

- 6) Bids for sediment cleanout can vary substantially. It is recommended that owners conduct their own cost assessment based on site-specific conditions and solicit bids from a large number of qualified contractors. If SWMF owners have procurement policies that require that they award the contract to the lowest bid, they may avoid the selection of a contractor lacking the requisite knowledge or experience by requiring pre-qualification. The owner may also specify the sediment removal and drying methods, giving them added control of the clean out process.
- 7) Both mechanical and hydraulic sediment removal should be considered during project planning. Each method offers distinct advantages and disadvantages that should be assessed on a case-bycase basis.
- 8) Winter sediment removal should be considered during the planning process. It offers numerous advantages over mechanical excavation conducted during the growing season, including cheaper machine rental rates, simpler dewatering processes, easier sediment handling, less habitat disturbance and reduced soil erosion potential.
- 9) On projects where a polymer flocculant is needed to help dewater and consolidate sediment (e.g. during hydraulic dredging), anionic PAM is recommended due to its low toxicity to aquatic organisms and proven effectiveness. In general, the use of cationic polymers in this type of application should be avoided due to their higher toxicity to aquatic organisms. Prior to selecting any polymer-based product for use during a SWMF clean out, bench-scale testing should be done to confirm its effectiveness on the site sediment, and product toxicity reports should confirm that it is not toxic at the anticipated dosing rate.
- 10) It is recommended that removed sediment volumes be reported in two ways: the total volume of hauled sediment and the total volume of restored SWMF capacity. The former measure is valuable for assessing the necessary volume to be hauled and associated cost, while the latter measure is an indicator of the success of the cleanout project in protecting the downstream environment.
- 11) Sediment bulking and dewatering materials, including polymer flocculants, water absorbing polymers, or conventional materials (e.g. mulch) should be compatible with any beneficial reuse being considered so that the addition of these materials does not limit the available options.
- 12) Sediment handling in Ontario allows for consideration of SWMF sediment as material that can be reused in a beneficial way at a suitable receiving site, even in cases where some contaminants exceed the values in Table 1 of the *Soil, Groundwater and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act.* If beneficial reuse options are being considered, suitable sediment handling options should be addressed on a case-specific basis with the aid of Qualified

Person and with reference to *Management of Excess Soil: A Guide to Best Management Practices* (OMOE, 2014).

13) Dredged sediment should be sampled and analyzed after bulking and/or dewatering, just prior to hauling, since the added materials and exposure to the air can alter contaminant levels. Resampling will provide certainty about the quality of the sediment leaving the site, and help inform the final decision on the fate of the sediment. It is also advisable to sample and analyse any bulking or dewatering agents before they are added in order to ensure that contaminant levels are not higher than those in the sediment.

12.0 REFERENCES

Bannerman R (2007) Reducing the uncertainty in the calculations of street cleaner performance for Wisconsin municipalities. Wisconsin Department of Natural Resources.

Centre for Watershed Protection (CWP) (2007) National Pollutant Removal Performance Database, Version 3. Elliot City, MD.

Centre for Watershed Protection (CWP) (2009) Stormwater Pond and Wetland Maintenance Guidebook. Elliot City, MD.

City of Guelph (2008) Stormwater Management Facility Inventory, Assessment and Maintenance Needs Plan. (as posted on: http://guelph.ca/wp-content/uploads/13-075_reports.pdf)

City of Hamilton, (2009) Landscape Design Guidelines for Stormwater Facilities, Hamilton, Ontario

City of Toronto (2015) Landscape Design Guidelines for Stormwater Ponds, Toronto, Ontario.

Cushing BS (1998) Falling Short of the Mark: The limits of dredging as a feasible technology for contaminated sediment removal. *Water Environment and Technology*, pp. 61-66.

Graham B, Brooke RG, Mathews R (2003) Stormwater Management in the Lower Ridau River Watershed. In *Water Stewardship: How Are We Managing?*. Ottawa, ON.

Greenland International Consulting Inc. (GIC) (1999). Storm Water Management Facility Sediment Maintenance Guide. Prepared for the Toronto and Region Conservation Authority and the Stormwater Assessment Monitoring and Performance Program, Toronto ON.

Health Canada (2013) Archived – Priority Substance List Assessment Report for Road Salts. ISBN: 0-662-31018-7. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/index-eng.php#a2138

Jackson MJ, Gow JL, Evelyn MJ, Mekleham NE, McMahon TJS, Koga E, Howay TJ, Wang L, Yan E (2009) Innovative Approaches to Stormwater Management in Canada. *Water Quality Research Journal of Canada*, 44, 103-110.

Kelly-Hooper F (2015) Sediment Quality Field Survey of 61 Residential Stormwater Management Ponds/Wetlands.

Marsalek, J, Marsalek PM (1997) Characteristics of Sediments from a Stormwater Management Pond. *Water Science and Technology*, 36, 117-122.

Minnesota Pollution Control Agency (MPCA) (2013) Typical inspection/maintenance frequencies for stormwater wetlands. Minnesota Stormwater Manual Online Manual. Accessed March, 2015.

Minnesota Pollution Control Agency (MPCA) (2015) Managing Stormwater Sediment Best Management Practice Guidance. Doc # WQ-STRM4-16.

New Zealand Transport Agency (NTA) (2010) Sediment Accumulation Monitoring Techniques. Auckland Motorways Transport Agency.

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Non-Agricultural Source Materials. Online document. Accessed: March 12, 2016. (as posted on: http://www.omafra.gov.on.ca/english/nm/nasm.html)

Ontario Ministry of Natural Resources (MNR) (2011a) Technical Bulletin for Spillways and Flood Control Structures. Available online at Ontario.ca/dams.

Ontario Ministry of Natural Resources (MNR) (2011b) Invasive Phragmites – Best Management Practices. Ontario Ministry of Natural Resources, Peterborough, Ontario.

Ontario Ministry of Natural Resources and Forestry (2016) - Stormwater Management Pond Clean-out Best Management Practices.

Ontario Ministry of the Environment (MOE) (2003) Stormwater Management Planning and Design Manual. Queen's Printer of Ontario.

Ontario Ministry of the Environment (MOE) (2011a) Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act. PIBS # 7382e01.

Ontario Ministry of the Environment (MOE) (2011b) Evaluating Construction Activities Impacting on Water Resources Part III A: Handbook for Dredging and Dredged Materials in Ontario – Legislation, Policies, Sediment Classification and Disposal Options. Standards Development Branch. Queen's Printer of Ontario.

Ontario Ministry of the Environment (MOE) and Ministry of Agriculture, Food and Rural Affairs (OMAFRA) (1996). Guidelines for the Utilization of Biosolids and Other Wastes on Agricultural Land.

Ontario Ministry of the Environment and Climate Change (MOECC) (2014) Management of Excess Soil – A Guide for Best Management Practices. Central Region, Operations Division. Queen's Printer of Ontario.

Ontario Ministry of the Environment and Climate Change (MOECC) (2016) Proposed Excess Soil Management Policy Framework. Ontario.

Ontario Ministry of the Environment and Energy (MOEE) (1994) Stormwater Management Practices Planning and Design Manual. Queen's Printer of Ontario.

Ritchie N (2015) Personal Communication.

Rocha L and Van Seters T (2013) Polymer Backgrounder: The Nature, Efficacy and Safety of Polymers for Erosion and Sediment Control. Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program, Toronto, Ontario.

Rochfort Q, Exall K, Png J, Shi V, Stevanovic-Briatico V, Kok S, Marsalek J (2009) Innovative approaches to stormwater management in Canada. *Water Quality Research Journal of Canada*, 48, 48-58.

Stormwater Assessment Monitoring and Performance Program (SWAMP) (2005) Synthesis of Monitoring Studies Conducted under the Stormwater Assessment and Monitoring Performance Program. Toronto and Region Conservation Authority, Toronto, Ontario.

Tennessee (2015) Tennessee Permanent Stormwater Management and Design Guidance Manual. Tennessee Department of Environment and Conservation Division of Water Resources and University of Tennessee.

Tixier G, Lafont M, Grapentine L, Rochfort W, Marsalek J (2011) Ecological risk assessment of urban stormwater ponds: Literature review and proposal of a new conceptual approach providing ecological quality goals and the associated bioassessment tools. *Ecological Indicators*, 11, 1497-1506.

Toronto and Region Conservation Authority (TRCA), (2007) *Stormwater Management Pond Planting Guidelines*, TRCA, Toronto, Ontario.

Toronto and Region Conservation Authority (TRCA) (2013) *Anionic Polyacrylamide Application Guide for Urban Construction in Ontario*, TRCA, Toronto, Ontario.

Town of Oakville (2012) Stormwater Monitoring Guidelines North of Dundas Street: Operation, Maintenance and Monitoring of Stormwater Management Ponds. Development Engineering Department.

Town of Richmond Hill (2003) Stormwater Management Facility Sediment Study. Parks, Recreation and Culture Department.

Van Seters, T and Graham, C (2013) Evaluation of Innovative Techniques for Augmenting Stream Baseflows and Mitigating the Thermal Impacts of Stormwater Ponds. Sustainable Technologies Evaluation Program, Toronto and Region Conservation Authority, Toronto, Ontario.

Van Seters, T. and David, Y. (2015) Water Quality Summary of Canadian Stormwater Best Management Practice Studies (as posted on www.sustainabletechnologies.ca).

Wang Z, Yang C, Kelly-Hooper F, Hollebone BP, Peng X, Brown CE, Landriault M, Sun J and Yang Z (2009) Forensic Differentiation of Biogenic Organic Compounds from Petroleum Hydrocarbons in Biogenic and Petrogenic Compounds Cross-contaminated Soils and Sediments. *Journal of Chromatography A*, 1216, 1174-1191.

Wright Water Engineers and Geosyntec Consultants (2007) Frequently Asked Questions Fact Sheet for the International Stormwater BMP Database: Why does the International Stormwater BMP Database Project omit percent removal as a measure of BMP performance? (as posted on www.bmpdatabase.org)

Wright Water Engineers Inc. and Geosyntec Consultants (2012) International Stormwater Best Management Practices (BMP) Database: Narrative Overview of BMP Database Study Characteristics (as posted on www.bmpdatabase.org).

1

APPENDIX A

POND/WETLAND CONSTRUCTION CHECKLIST (CWP, 2009)

Toronto and Region Conservation Authority and CH2M, 2016

Date:		Time:	
Project	:		
Locatio	n:		
Site Sta	atus (active, inactive, completed):		
Inspect	ror(s):		
Type o	f Practice:		
	Micropool ED Pond		Shallow Wetland
	Wet Pond		Shallow ED Wetland
	Multiple Pond System		Pond / Wetland System
	Pocket Pond		Pocket Wetland

Construction Sequence	Satisfactory	Unsatisfactory	Comments
I. Pre-Construction / Materials and Equipment			
Pre-construction meeting			
Pipe and appurtenances on-site prior to construction and dimensions checked			
1. Material (including protective coating, if specified)			
2. Diameter			
3. Dimensions of metal or pre-cast concrete riser			
 Required dimensions between water control structures (orifices, weirs, etc.) are in accordance with approved plans 			
 Barrel stub for prefabricated pipe structures at proper angle for design barrel slope 			
6. Number and dimensions of prefabricated anti-seep collars			
7. Watertight connectors and gaskets			
8. Outlet drain valve			
Project benchmark near pond site			
Equipment for temporary de-watering / sediment and erosion control			
II. Subgrade Preparation			
Area beneath embankment stripped of all vegetation, topsoil, and organic matter			
Core trench excavated and backfilled			
III. Pipe Spillway Installation			
Method of installation detailed on plans			
A. Bed preparation			
Installation trench excavated with specified side slopes			
Stable, uniform, dry subgrade of relatively impervious material (If subgrade is wet, contractor shall have defined steps before proceeding with installation)			
Invert at proper elevation and grade			

Adapted from WMI, 1997

Construction Sequence		Satisfactory	Unsatisfactory	Comments
B. Pipe placement				
Metal / plastic pipe				
 Watertight connectors and gas installed 	skets properly			
 Anti-seep collars properly space watertight connections to pipe 	ced and having			
 Backfill placed and tamped by "haunches" of pipe 	hand under			
 Remaining backfill placed in m using small power tamping equipation cover over pipe is reached 	nax. 8 inch lifts uipment until 2 feet			
Concrete pipe				
1. Pipe set on blocks or concrete low cradle	slab for pouring of			
2. Pipe installed with rubber gask spalling in gasket interface are	ket joints with no ea			
 Excavation for lower half of an with reinforcing steel set 	ti-seep collar(s)			
 Entire area where anti-seep co contact with pipe coated with r approved waterproof sealant 	ollar(s) will come in nastic or other			
 Low cradle and bottom half of installed as monolithic pour an mix 	anti-seep collar Id of an approved			
 Upper half of anti-seep collar(s reinforcing steel set 	s) formed with			
 Concrete for collar of an approvibrated into place (protected for curing, if necessary) 	oved mix and from freezing while			
 Forms stripped and collar insp honeycomb prior to backfilling. necessary. 	ected for . Parge if			
C. Backfilling				
Fill placed in maximum 8 inch lifts				
Backfill taken minimum 2 feet abo collar elevation before traversing v equipment	ve top of anti-seep with heavy			
IV. Riser / Outlet Structure Installa	tion			
Riser located within embankment				
A. Metal riser				
Riser base excavated or formed o to design dimensions	n stable subgrade			
Set on blocks to design elevations	and plumbed			
Reinforcing bars placed at right ar projecting into sides of riser	ngles and			
Concrete poured so as to fill inside of barrel	e of riser to invert			
B. Pre-cast concrete structure				

Constr	uction Sequence	Satisfactory	Unsatisfactory	Comments
Dry	and stable subgrade			
Ris	er base set to design elevation			
If m inte plac	nore than one section, no spalling in gasket erface area; gasket or approved caulking material ced securely			
Wa join	tertight and structurally sound collar or gasket t where structure connects to pipe spillway			
C. Pou	ured concrete structure			
Foc des	oting excavated or formed on stable subgrade, to sign dimensions with reinforcing steel set			
Stru rein	ucture formed to design dimensions, with iforcing steel set as per plan			
Cor (pro	ncrete of an approved mix and vibrated into place otected from freezing while curing, if necessary)			
For bac	ms stripped & inspected for honeycomb prior to kfilling; parge if necessary			
V. Em	bankment Construction			
Fill mat	terial			
Compa	iction			
Emban	kment			
1. Fill app	placed in specified lifts and compacted with propriate equipment			
2. Cor and	nstructed to design cross-section, side slopes I top width			
3. Cor sett	nstructed to design elevation plus allowance for tlement			
VI. Im	pounded Area Construction			
Excava	ated / graded to design contours and side slopes			
Inlet pi	pes have adequate outfall protection			
Foreba	y(s)			
Pond b	enches			
VII. Ea	arth Emergency Spillway Construction			
Spillwa riprap,	y located in cut or structurally stabilized with gabions, concrete, etc.			
Excava bottom	ated to proper cross-section, side slopes and width			
Entrano design	ce channel, crest, and exit channel constructed to grades and elevations			
VIII. O	utlet Protection			
A. End	d section			
Sec	curely in place and properly backfilled			
B. Enc	dwall			
Foo des spe	oting excavated or formed on stable subgrade, to sign dimensions and reinforcing steel set, if ecified			

Construction Sequence	Satisfactory	Unsatisfactory	Comments
Endwall formed to design dimensions with reinforcing steel set as per plan			
Concrete of an approved mix and vibrated into place (protected from freezing, if necessary)			
Forms stripped and structure inspected for honeycomb prior to backfilling; parge if necessary			
C. Riprap apron / channel			
Apron / channel excavated to design cross-section with proper transition to existing ground			
Filter fabric in place			
Stone sized as per plan and uniformly place at the thickness specified			
IX. Vegetative Stabilization			
Approved seed mixture or sod			
Proper surface preparation and required soil amendments			
Excelsior mat or other stabilization, as per plan			
X. Miscellaneous			
Drain for ponds having a permanent pool			
Trash rack / anti-vortex device secured to outlet structure			
Trash protection for low flow pipes, orifices, etc.			
Fencing (when required)			
Access road			
Set aside for clean-out maintenance			

Additional Comments:

Action to be Taken:

No action necessary. Continue routine inspections.

Correct noted site deficiencies by

1st notice

2nd notice

Submit plan modifications as noted in written comments by

Notice to Comply issued

Final inspection, project completed

APPENDIX B

POND/WETLAND MAINTENANCE INSPECTION CHECKLIST

(CWP, 2009)

Inspection and Maintenance Guide for SWM Ponds and Constructed Wetlands

POND / WETLAND MAINTENANCE INSPECTION FORM

Facility Number:		Date:				Time:	
Subdivision Name:		Waters	hed:				
Weather:		Inspect	or(s):				
Date of Last Rainfall: Amount: Inches	s	Streets					
Mapbook Location:		GPS C	oordina	tes:			
Property Classification: Residential 9 Govern	nment	9		Comm	ercial	9 0	ther:
Type of Practice: Wet Pond 9 Dry Pond 9	Mic	ropool El) 9	М	ultiple	Pond System 9	Pocket Pond 9
Shallow Wetland 9 Shallow ED 9	Pon	nd/ Wetla	nd 9	P	ocket \	Wetland 9	
Confined 9 Unconfined 9 Barrel Size		As-	built Pla	an Avail	able?	Yes 9	No 9
Is Facility Inspectable? Yes 9 No 9 Why?			Co	mments	Speci	ific Location(s):	
Scoring Breakdown:							
N/A = Not Applicable 1 = Monitor (potential for	future	problem	exists	5)	*	Use open space	in each section to
N/I = Not Investigated 2 = Routine Maintenance	Requir	red				further explain s	scoring as needed
0 = Not a Problem 3 = Immediate Repair Net	0 = Not a Problem 3 = Immediate Repair Necessary						
1. Outfall Channel(s) from Pond							
Woody growth within 5' of outfall barrel N/A	N/I	0	1	2	3		
Outfall channel functioning N/A	N/I	0	1	2	3		
Manholes, Frames and Covers N/A	N/I	0	1	2	3		
Released water undercutting outlet N/A	N/I	0	1	2	3		
Erosion N/A	N/I	0	1	2	3		
Displaced rip rap N/A	N/I	0	1	2	3		
Excessive sediment deposits N/A	N/I	0	1	2	3		
Other: N/A	N/I	0	1	2	3		
2. Downstream Dam Bank							
Cracking, bulging, or sloughing of dam N/A	N/I	0	1	2	3		
Erosion and/or loss of dam material N/A	N/I	0	1	2	3		
Animal burrows N/A	N/I	0	1	2	3		
Soft spots or boggy areas N/A	N/I	0	1	2	3		
Woody growth or unauthorized plantings on dam N/A	N/I	0	1	2	3		
Other: N/A	N/I	0	1	2	3		
3. Upstream Dam Bank							
Cracking, bulging, or sloughing of dam N/A	N/I	0	1	2	3		
Erosion and/or loss of dam material N/A	N/I	0	1	2	3		
Animal Burrows N/A	N/I	0	1	2	3		
Soft spots or boggy areas N/A	N/I	0	1	2	3		
Woody growth or unauthorized plantings on dam N/A	N/I	0	1	2	3		
Other: N/A	N/I	0	1	2	3		

POND / WETLAND MAINTENANCE INSPECTION FORM

4. Emergency Spillway								
Woody growth or unauthorized plantings	N/A	N/I	0	1	2	3		
Erosion or back cutting	N/A	N/I	0	1	2	3		
Soft or boggy areas	N/A	N/I	0	1	2	3		
Obstructions / debris	N/A	N/I	0	1	2	3		
5. Principal Spillway Built to Plans								
# of Barrels: Size:	RCP	CMP	P\	/C	STEEL	or	MASONRY	(Circle One)
Confined space entry permit required for entry into all	riser and barre	ls	Er	itry A	oproved 9)	Entry Denied 9	
Minor spalling or parging (<1")	N/A	N/I	0	1	2	3		
Major spalling (exposed rebar)	N/A	N/I	0	1	2	3		
Joint failure	N/A	N/I	0	1	2	3		
Loss of joint material	N/A	N/I	0	1	2	3		
Leaking	N/A	N/I	0	1	2	3		
Corrosion	N/A	N/I	0	1	2	3		
Protective material deficient	N/A	N/I	0	1	2	3		
Misalignment or split seams / joints	N/A	N/I	0	1	2	3		
Other:	N/A	N/I	0	1	2	3		
6. Riser Built to Plans								
Size:	CONC	CMP	or		MASON	IRY	(Circle One)	
Minor spalling or parging (<1")	N/A	N/I	0	1	2	3		
Major spalling (exposed rebar)	N/A	N/I	0	1	2	3		
Joint failure	N/A	N/I	0	1	2	3		
Loss of joint material	N/A	N/I	0	1	2	3		
Leaking	N/A	N/I	0	1	2	3		
Manhole access and steps acceptable	N/A	N/I	0	1	2	3		
Corrosion	N/A	N/I	0	1	2	3		
Protective material deficient	N/A	N/I	0	1	2	3		
Misalignment or split seams / joints	N/A	N/I	0	1	2	3		
Anti-vortex device secure / acceptable	N/A	N/I	0	1	2	3		
Sediment Accumulation within riser	N/A	N/I	0	1	2	3		
Woody or vegetative growth within 25' of riser	N/A	N/I	0	1	2	3		
Safety Rebar/pipes in place	N/A	N/I	0	1	2	3		
Safety Rebar/pipes corroded	N/A	N/I	0	1	2	3		
Other:	N/A	N/I	0	1	2	3		
7. Low Flow Built to Plans								
Orifice and/or trash rack obstructed	N/A	N/I	0	1	2	3		
Trash Rack Corrosion	N/A	N/I	0	1	2	3		
Other:	N/A	N/I	0	1	2	3		
8. Weir Trash Rack								
Structurally sound	N/A	N/I	0	1	2	3		
Debris removal necessary	N/A	N/I	0	1	2	3		
Corrosion	N/A	N/I	0	1	2	3		

POND / WETLAND MAINTENANCE INSPECTION FORM

9. Control Valve(s) Built to Plans								
Size: Type:			-					
Operation limited	N/A	N/I	0	1	2	3		
Exercised	N/A	N/I	0	1	2	3		
Leaks	N/A	N/I	0	1	2	3		
Chains & Locks	N/A	N/I	0	1	2	3		
Set to design opening	N/A	N/I	0	1	2	3		
Other:	N/A	N/I	0	1	2	3		
10. Pond Drain Valve								
Operation limited	N/A	N/I	0	1	2	3		
Exercised	N/A	N/I	0	1	2	3		
Leaks	N/A	N/I	0	1	2	3		
Chained & locked correctly	N/A	N/I	0	1	2	3		
Other:	N/A	N/I	0	1	2	3		
11. Toe & Chimney Drains Clear & Functioning	N/A	N/I	0	1	2	3		
12. Rip-Rap Pilot Channel (Micropool only)								
Sediment or debris build up	N/A	N/I	0	1	2	3		
Erosion/ Undermining	N/A	N/I	0	1	2	3		
13. Permanent Pool								
Visible pollution	N/A	N/I	0	1	2	3		
Shoreline and / or side slope erosion	N/A	N/I	0	1	2	3		
Aquatic bench inadequately vegetated	N/A	N/I	0	1	2	3		
Abnormally high or low water (pool) levels	N/A	N/I	0	1	2	3		
Sediment / debris accumulation	N/A	N/I	0	1	2	3		
Bathometric study recommended			No		Yes			
Other?	N/A	N/I	0	1	2	3		
14. Dry Storage			-					
Vegetation sparse	N/A	N/I	0	1	2	3		
Undesirable woody or vegetative growth	N/A	N/I	0	1	2	3		
Low flow channels obstructed	N/A	N/I	0	1	2	3		
Standing water or spots	N/A	N/I	0	1	2	3		
Sediment or debris accumulation	N/A	N/I	0	1	2	3		
Bathometric study recommended			No		Yes			
Other:	N/A	N/I	0	1	2	3		
15. Pretreatment								
Maintenance access	N/A	N/I	0	1	2	3		
Is pretreatment a practice other than a forebay			No		Yes		Of so,	(code)
Dredging required			No		Yes			
Hard pad condition (Wet pond only)	N/A	N/I	0	1	2	3		
Fixed vertical sediment depth marker present			No		Yes			
Marker Reading								
Sediment accumulation	N/A	N/I	0	1	2	3	Estimated % full	%

N/A = Not Applicable N/I = Not Investigated

- 1 = Monitor for Future Repairs 2 = Routine Repairs Needed
- 3 = Immediate Repair Needed

0 = Not a Problem Toronto and Region Conservation Authority and CH2M, 2016
POND / WETLAND MAINTENANCE INSPECTION FORM

16. Inflow Points								
Number of inflow pipes:	Direction	on: N	E		W	S		
Endwalls, headwalls, end sections	N/A	N/I	0	1	2	3		
Outfall pipes	N/A	N/I	0	1	2	3		
Discharge undercutting outlet or displacing rip-rap	N/A	N/I	0	1	2	3		
Discharge water is causing outfall to erode	N/A	N/I	0	1	2	3		
Sediment accumulation	N/A	N/I	0	1	2	3		
17. Wet Pond Vegetation								
Invasive plants	N/A	N/I	0	1	2	3		
% cover								
Vegetation matches landscape design plan	N/A	N/I	0	1	2	3		
Planting needed	N/A	N/I	0	1	2	3		
Shore erosion	N/A	N/I	0	1	2	3		
Coverage needs improvement	N/A	N/I	0	1	2	3		
18. Pond Buffer			•					
Encroachment by structures	N/A	N/I	0	1	2	3		
Clearing of vegetation	N/A	N/I	0	1	2	3		
Planting needed	N/A	N/I	0	1	2	3		
Predominant vegetation types:	Forest	ed 🗆	Shrubs	Shrubs 🗆 Me		w 🗆	Maintained Grass	Other:
19. Special Structures								
Manhole access (steps, ladders)	N/A	N/I	0	1	2	3		
Manhole access (steps, ladders) Vehicular access	N/A N/A	N/I N/I	0	1 1	2 2	3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition	N/A N/A N/A	N/I N/I N/I	0 0 0	1 1 1	2 2 2	3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks	N/A N/A N/A	N/I N/I N/I N/I	0 0 0	1 1 1	2 2 2 2	3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows	N/A N/A N/A N/A N/A	N/I N/I N/I N/I	0 0 0 0	1 1 1 1 1	2 2 2 2 2 2	3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal	N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I	0 0 0 0 0	1 1 1 1 1 1	2 2 2 2 2 2 2 2	3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts	N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0	1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous	N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0	1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area	N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0	1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition	N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition Safety signs	N/A N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition Safety signs Complaints from local residents	N/A N/A N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition Safety signs Complaints from local residents Graffiti	N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition Safety signs Complaints from local residents Graffiti Public hazards	N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3		
Manhole access (steps, ladders) Vehicular access Concrete/masonry condition Trash racks Elbows Sediment / trash removal Manhole lockable nuts 20. Miscellaneous Encroachment in pond area and/or easement area Fence condition Safety signs Complaints from local residents Graffiti Public hazards Excessive mosquitoes	N/A N/A N/A N/A N/A N/A N/A N/A N/A N/A	N/I N/I N/I N/I N/I N/I N/I N/I N/I N/I	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3		

Overall Condition of Facility	
Total number of concerns receiving a:	 (1) - Need Monitoring (2) - Routine Repair (3) - Immediate Repair Needed
Inspector's Summary	

Pictures	Clock/Degrees
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	

Prin. Spill. Barrel Joints	Clock/Degrees
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	

Sketches, If Necessary:

APPENDIX C

KELLY-HOOPER (2015) STUDY SEDIMENT QUALITY FIELD SURVEY OF 61 RESIDENTIAL STORMWATER MANAGEMENT PONDS/WETLANDS

Rationale for SWMF Sediment Disposal and Beneficial Use Assessment Recommendations: 2005-2014 Residential SWMF Sediment Quality Field Study

Study Background and Objectives

The 2005-2014 Residential SWMF Sediment Quality Field Survey began as a collaborative initiative between the Ontario Ministry of the Environment (MOE, now MOECC); the Ontario Ministry of Food, Agriculture and Rural Affairs (OMAFRA); Kelly Hooper Environmental (KHE); and 22 municipalities located in the provinces of Alberta, British Columbia, Manitoba, Ontario and Saskatchewan. From 2005 to 2013, 40 SWMFs were sampled by KHE and participating municipalities, and additional 21 SWMFs were sampled by CH2M Canada in 2014. The same protocols and equipment were used to identify sediment sampling zones and to collect samples from each SWMF. The primary objectives of this evolving SWMF sediment study are described as follows:

- To study concentrations and spatial distributions of pollutants, nutrients and particle sizes (clay, silt, sand, gravel) from the inlet(s) to outlet(s) of each SWMF;
- To quantify the number of SWMFs that would trigger landfill disposal requirements due to exceedances of the O.Reg. 153/04 Table 1 soil standards;
- To quantify the number of SWMFs that would meet Excess Soil Best Management Practices for offsite reuse; and
- To identify reuse options in accordance with MOECC and OMAFRA requirements.

General SWMF Descriptions

The 61 SWMFs included 53 wet ponds and 8 wetlands, which were located in the 19 municipalities shown below. All of the SWMFs were offline and were 8 to 22 years old. Most of the SWMF wet areas ranged from 0.5 to 1.0 hectares in size and had only one inlet and one outlet. Sediment had been removed from each SWMF prior to transfer of ownership from developers to municipalities. All of the catchment areas were primarily residential with several including some light commercial land uses.

- - Calgary 2 wet ponds
 - Medicine Hat 1 wet pond
 - Wood Buffalo 1 wet pond
- British Columbia
 - City of Surrey 2 wet SWM ponds
- Manitoba
 - Winnipeg 1 wet pond
- Ontario
 - Burlington 1 wet pond
 - Cambridge 1 wet pond
 - Guelph 5 wet ponds

- Kingston 1 wet pond
- Kitchener 13 wet ponds; 8 wetlands
- London 3 wet ponds
- Markham 1 wet pond
- Mississauga 2 wet ponds
- Oakville 8 wet ponds
- Ottawa 4 wet ponds
- Richmond Hill 1 wet pond
- Toronto 1 wet pond
- Waterloo 3 wet ponds
- Whitby 1 wet pond
- Saskatoon
 - Saskatchewan 1 wet pond

Sediment Sampling Methods

A total of 194 sediment samples were collected from the 61 SWMFs. Most of the SWMFs had only one inlet and one outlet. In these cases, three samples were collected from inlet, centre and outlet sample zones (see Figure C.1A). However, additional sample zones were added to SWMFs that had additional inlets and/or outlets (see Figure C.1B). Most samples were collected during the months of July to September. Wet ponds were accessed by boats and wetlands were accessed on foot. Stainless steel core samplers were used to collect full-depth sediment samples by pushing the sampler through the soft sediments until it reached the hard basin material (e.g. clay, concrete, etc.). In some cases however, it was necessary to use alternative sample collection methods. For example, sediment with unusually high sand content did not provide enough suction for the effective use of the core sampler. The core sampler was also ineffective at collecting samples from highly vegetated wetland sediments with dense root coverage. In these cases, it was necessary to collect the samples with shovels and/or large spoons. This was however not the preferred method for the reason that it was not possible to collect full depth samples. All sediment samples were homogenized in mixing bowls and subsampled into wide-mouthed glass jars. The filled jars were placed into chilled coolers for same-day delivery to ALS Environmental (ALS) laboratory, located in Waterloo, Ontario and SGS Agri-Food Laboratories Inc. (SGS), located in Guelph.





Figure C.1: Examples of sediment sample zones identified by inlet/outlet locations and flow patterns. A: Three sample zones for a SWMF with one inlet, one outlet and a linear flow path. B: Four sample zones for a SWMF with two inlets, one outlet and a forked flow path. *Grey dashed line indicate flow path direction.

Selection of Sediment Quality Analysis Lists

O.Reg. 347 Landfll Leachate Tests

Leachate analysis was beyond the study scope for most of the SWMFs. Sediment samples collected from 6 SWMFs were submitted for leachate analysis to determine if they would be classified as non-hazardous or hazardous waste. In each case, the local landfill facility managers were contacted to determine which analytes would need to be tested. These analyte groups included: metals, VOCs and conventionals (see Table C.2)

O.Reg. 153/04 Soil and Sediment Standard Evaluations

The O.Reg. 153/04 soil standards are primarily set for the protection of human and ecological health in terrestrial environments, while sediment standards are set for the protection of aquatic life. O.Reg. 153/04 soil quality analysis list was selected to evaluate sediment disposal and beneficial reuse options in terrestrial and aquatic environments. Initial considerations focused on bulk soil analysis to identify O.Reg. 153/04 Table 1 sediment and soil standard exceedances. Table 1 soil standard exceedances trigger requirements waste disposal regulatory approvals. Concentrations were also compared to O.Reg. 153/04 Table 2 (full depth potable groundwater condition) soil standards and Table 3 (full depth non-potable groundwater condition) soil standards to evaluate Excess Soil BMP reuse options. Table 1 sediment standard exceedances indicated consistently elevated aquatic ecology risks associated with open disposal of contaminated sediments. Table C.1 lists recognized urban SWMF sediment quality analytes, which are regulated by O.Reg. 153/04 soil standards. The parameters listed in Table C.1 are defined below in greater detail.

Total Petroleum Hydrocarbons (PHCs)

PHC is a term used to describe a family of several hundred organic chemical compounds originating from crude oil and coal, which are primarily composed of hydrogen and carbon atoms. They are also present in coal tar, which is a product of coal and refined crude oil products such as gasoline, diesel, motor oil and asphalt. Since there are so many different chemicals in crude oil and in other petroleum products, it is impractical to analyze samples for each one. As a result, PHCs are divided into fractions based on carbon chain length. The O.Reg. 153/04 Standards list four PHC fractions: F1 (C6-C10), F2 (C10-C16), F3 (C16-C34), and F4 (>C34).

Total Polycyclic Aromatic Hydrocarbons (PAHs)

Like PHC, the term PAH also describes a family of several hundred organic chemical compounds, which are primarily composed of hydrogen and carbon atoms. However, the chemical structure of PAHs is unique as they have two or more aromatic (benzene) rings, which are fused together when a pair of carbon atoms is shared between them. PAHs originate from coal, coal tar, crude oil and refined crude oil products. Other PAH sources include the incomplete combustion of organic materials such as fossil fuels, wood and barbequed food.

Sodium Adsorption Ratio

SAR is a widely accepted agricultural index for characterizing soil sodicity. It is the ratio of the amount of cationic charge contributed by sodium, to that contributed by calcium and magnesium in a soil solution. Elevated SAR levels indicate the presence of poorly drained, tight soil structures, which restrict plant seedling emergence and root growth. Road salt applied for winter road maintenance is the most common source of elevated SAR levels in urban environments.

<u>Cyanide</u>

Ferrocyanide is a compound that may be added to road salt for anti-caking purposes. Ferrocyanide can decompose to cyanide with exposure to sunlight and certain types of bacteria.

Trace Metals

Trace metals are elements that normally occur at very low levels in natural environments. While living organisms do require small amounts of trace metals, elevated levels of certain metals can be highly toxic. Cars and trucks are the primary sources of trace metals in residential catchments.

Particle Size Analysis

SWMFs are designed to collect and retain soil and sediment particles in urban runoff. Common sources include construction activities, lawns and gardens, atmospheric deposition, drainage channel erosion, and sand application to improve traction on icy roads. SWMF sediment particle size categories include: clay (0.98-3.9 μ m); silt (3.9-62.5 μ m), sand (62.5 μ m – 2 mm) and gravel (2-64 mm). O.Reg. 153/04 includes different soil standards for fine soils (clay and silt) and coarse soils (sand and gravel). Particle size distribution is also important for evaluating suitability for different reuse options.

Table C.1: Recognized urban runoff pollutants that may be present in residential SWMF sediments – relevance to O.Reg. 153/04 Soil Standards.

Urban SWMF Sediment Quality Analytes	Analyte Sources	¹ Relevance to O.Reg. 153/04 Soil Standard Exceedences
² Petroleum Hydrocarbons (PHCs)	Examples of transportation sources: gasoline, diesel, motor oils, engine emissions, asphalt pavement, coal tar pavement sealants, tires, etc. Examples of non-transportation sources: roofing tar, etc.	Elevated F3 PHCs (C16-C34) are the most important cause of O.Reg. 153/04 Table 1 Soil Standard exceedances.
³ Polyaromatic Hydrocarbons (PAHs)	Examples of transportation sources: gasoline, diesel, motor oils, engine emissions, asphalt pavement, coal tar pavement sealants, tires, etc. Examples of non-transportation sources: roofing tar, barbecue smoke, wood smoke, coal power plant emissions, etc.	Elevated PAHs are the most important cause of O.Reg. 153/04 Table 2 and 3 Soil Standard exceedances.
⁴ Sodium Adsorption Ratio – indicator of sodium chloride (salt) impacts	Winter road salt de-icing applications is the primary source of elevated SAR in Ontario.	Important cause of O.Reg. 153/04 Table 1, 2 and 3 Soil Standard exceedances.
⁴Cyanide	Ferrocyanide may be added to road salt as anti-caking compound. Can decomposes to cyanide with exposure to sunlight and certain bacteria.	Potential cause of O.Reg. 153/04 Table 1, 2 and 3 Soil Standard exceedances.
^{5,6} Metals	Examples: automobiles (zinc from tire wear, deteriorating brake pads, leaks and spills of oil), bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes, etc.	Important cause of O.Reg. 153/04 Table 1 Soil Standard exceedances, but not an important cause of Table 2 or Table 3 exceedances
⁵Pesticides and Herbicides	Examples: gardens/lawns, utility right of ways, etc.	The Government of Ontario banned the use of cosmetic pesticides and some herbicides in 2008. However, certain industries are exempted from the general ban (e.g. golf courses, tree nurseries, etc.). Site specific features should be considered when deciding if pesticides and/or herbicides should be included in SWMF sediment quality analysis lists.
^{5,6} Soil Particles	Examples: winter sanding of pavements, construction activities, gardens/lawns, atmospheric deposition, drainage channel erosion, etc.	Many O.Reg. 153/04 soil standards are set for fine (silt, clay) versus coarse (sand, gravel) particles sizes. Particle size analysis will determine if each sample should be compared to the fine or coarse soil standards.

<u>Notes</u>: ¹See Table 9.2 for a detailed list of SWMF sediment analytes that exceeded O.Reg. 153/04 soil standards <u>Information Sources</u>: ²Wang et al 2009; ⁴Health Canada 2013; ⁵MOE 2003; ⁶Marsalek J, et al 1997

Selection of SWMF Sediment Quality Analysis List for Topsoil Amendment Beneficial Reuse Evaluations

The sediment quality analysis list shown below was developed through collaborative discussions with OMAFRA and SGS AgTest Laboratories, both located in Guelph Ontario. This list addresses both plant toxicity concerns and plant growth requirements. Trace metals and SAR limits are addressed by the Ontario Biosolids Guidelines. Topsoil recommendations for remaining analytes and SAR were addressed SGS AgTest Laboratory topsoil recommendations. The SGS AgTest laboratory reports included topsoil amendment recommendations for each sediment sample.

- Trace metals (compared to Ontario Biosolids Guidelines)
- Hot water extractable boron (compared to Ontario Biosolids Guidelines)
- SAR (compared to Ontario Biosolids Guidelines and SGS AgTest topsoil recommendations)
- Chloride and total salts (compared to SGS AgTest topsoil recommendations)
- Conductivity and pH (compared to SGS AgTest topsoil recommendations)
- Available nutrients (compared to SGS AgTest topsoil recommendations)
- Particle size distributions (compared to SGS AgTest topsoil recommendations)
- Total Organic Carbon (compared to SGS AgTest topsoil recommendations)

Sediment Quality Results

O.Reg. 347 Leachate Analysis Results

All 6 SWMFs that were analyzed met the O.Reg. 347 non-hazardous waste disposal criteria (Table C.2). Most of the analytes were non-detectable. The concentrations of the detectable analytes were one to three orders of magnitude below the criteria.

O.Reg. 153/04 Bulk Soil Analysis Results - Comparisons to Tables 1, 2, 3 soil standards and Table 1 sediment standards

As shown in Table C.3, 92% of the SWMFs would require regulated wasted disposal approval due to exceedances of Table 1 soil standards for all land uses due to elevated F3 PHCs. 56% of the SWMFs exceeded the Table 2 and Table 3 soil standards for residential/parkland/institutional land uses due to elevated PAHs. 52% of the SWMFs exceeded the Table 2 and Table 3 soil standards for community/commercial/industrial land uses due to elevated PAHs. The results indicate that slightly less than half of the SWMFs could be reused for the land use types listed in the Table 2 and Table 3 soil standards. 98% of the SWMFs exceeded the O.Reg. 153 sediment standard for copper. These results indicate that open water disposal would not be a likely option for residential SWMFs.

	0.Reg 347	Pond 33		Pond 34		Pon	d 35	Pond 36	Pond 37	Pond 38
Analytes	Schedule 4 Criteria	Composit e	Inlet	Centre	Outlet	Inlet	Outlet	Composit e	Composit e	Composit e
Arsenic (As)	2.5	0.026		0.017						
Barium (Ba)	100	1.02	0.4	0.35	0.65	0.99	1.23	0.76	1.3	0.5
Boron (B) Leachable	500			0.63	0.53					
Cadmium (Cd)	0.5					0.0042	0.004		0.0056	
Chromium (Cr)	5									
Fluoride (F)	150									
Lead (Pb) Leachable	5	0.03		0.016		0.019	0.128			
Mercury (Hg) TCLP	0.1									
Selenium (Se)	1									
Silver (Ag) Leachable	5									
Uranium (U)	10									
1,1-Dichloroethylene	1.4									
1,2-Dichlorobenzene	20									
1,2-Dichloroethane	0.5									
1,4-Dichlorobenzene	0.5									
Benzene	0.5									
Carbon tetrachloride	0.5									
Chlorobenzene	8									
Chloroform	10									
Dichloromethane	5									
Methyl Ethyl Ketone	200									
Tetrachloroethylene	3									
Trichloroethylene	5									
Vinyl chloride	0.2									
Cyanide, Weak Acid	20									
Nitrate and Nitrite as	1000									
Total PCBs	0.3					NA	NA	NA	NA	NA

Table C.2: Leachate Analysis Results for 6 SWMFs – All sediment samples met non-hazardous waste disposal requirements.

Notes:

"--" Double dashes indicate non-detectable concentrations

NA – not analyzed

Table 7.2: Summary of SWM pond/wetland sediment field survey summary: percentage exceedances of O.Reg 153/04 Soil Standards.

	Number of	Р	Percentage of SWMFs that Exceeded 0.Reg. 153/04 Soil and Sediment Standards				
Analytes	Analyzed	¹ Sediment	² Table 1 Soil All	² Table 2 Soil R/P/I	³ Table 2 Soil C/C/I	⁴Table 3 Soil R/P/I	⁵Table 3 Soil C/C/I
SAR	61	NS	46%	26%	16%	26%	16%
Cyanide	21	NS					
			<u>Metals</u>	<u>r</u>			
Antimony (Sb)	60	NS	48%				
Arsenic (As)	60	28%	2%	2%	2%	2%	2%
Barium (Ba)	60	NS	7%	2%		2%	
Beryllium (Be)	60	NS					
Boron (B)	60	NS	2%	2%	2%	2%	2%
Boron (B), Hot Water Ext.	33	NS	NS	9%	3%	9%	3%
Cadmium (Cd)	60	18%	2%	2%		2%	
Chromium (Cr)	60	57%	2%				
Cobalt (Co)	60						
Copper (Cu)	60	98%	7%				
Lead (Pb)	60	35%	3%	3%	3%	3%	3%
Mercury (Hg)	35						
Molybdenum (Mo)	60	NS	7%				
Nickel (Ni)	60	58%					
Selenium (Se)	60	NS					
Silver (Ag)	60	10%	10%				
Thallium (TI)	60	NS					
Uranium (U)	60	NS					
Vanadium (V)	60	NS					
Zinc (Zn)	60	67%	12%	7%	7%	7%	7%
		<u>Poly</u>	<u>aromatic Hydro</u>	<u>carbons (PAHs)</u>			
Acenaphthene	61	NS	26%				
Acenaphthylene	61	NS	10%	7%	5%	7%	5%
Anthracene	61		30%	3%	3%	3%	3%
Benzo(a)anthracene	61	46%	44%	39%	30%	39%	31%
Benzo(a)pyrene	61	52%	54%	54%	52%	54%	52%
Benzo(b)fluoranthene	61	NS	5/%	44%	36%	44%	36%
Benzo(g,h,i)perylene	61	69%	38%				
Benzo(k)fluoranthene	61	48%	39%	36%	18%	36%	28%
Chrysene	61	62%	18%				
Dibenzo(an)anthracene	61	48%	39%	39%	38%	39%	38%
Fluoranthene	61	56%	00%	50%	5%	50%	5%
Fluorene	61	11%	21%				
Indeno(1,2,3-cd)pyrene	61	0Z%	57%	40%	30%	40%	30%
1-Methylnaphthalene	61	NS NC					
2-meurymaphunaiene Nanhthalono	61	NC	 E0/-				
Phononthrono	61	1304	3%0				
	61	670	120%	270		270	
ryielle	01	0270	+0%	rhons (PHCs)			
F2 (C10-C16)	61	NS	<u>4</u> 2%	3%		3%	
F3 (C16-C34)	61	NS	97%	44%	11%	44%	3%
F4 (C34-C50)	61	NS	92%	2%		2%	

Notes: ¹Sediment standards for the protection of aquatic life; ²Table 1: full depth background soil standards ³Table 2: Full depth generic site condition standards in a potable ground water condition ⁴Table 3: Full depth generic site condition standards in a non-potable ground water condition "NS" indicates no sediment standard "---" double dashes indicate 0% exceedences of standards

Beneficial Reuse as Topsoil Amendment Evaluation Results

All 61 SWMFs were analyzed for trace metals, SAR, TOC and particle size distributions. 33 SWMFs were analyzed for hot water extractable boron. SGS AgTest topsoil recommendation reports were completed for 30 SWMFs. The results are summarized as follows:

- None of 61 SWMFs exceeded the Biosolids Guidelines for trace metals or hot water extractable boron;
- Most of the sediment samples had <4% TOC. This would be identified as "mineral" soil according to the Biosolids Guidelines minimum 17% TOC for organic soils.
- Most of the sediment samples had low available nutrients;
- Most of the sediment samples did not exceed the topsoil recommendations for SAR, chlorides, total salts, conductivity or pH.
- Most of the sediment samples were primarily composed of silt particles. Sand was the least dominant and clay was present at intermediate amounts.

Statistical Evaluation of Analyte Distributions from SWMF Inlets to Outlets – Rationale for Sediment Sampling Strategy Shown in Section 6.2.3

SWMF analyte comparisons were conducted to determine if significant differences occurred between the inlet, centre and outlet sample zones. Appendix D includes boxplot results for all detectable analytes included in this study. All statistical analysis was carried out in R version 3.1.3 (2015-03-09) for windows (R Core Team, 2015). Distributions of data were assessed for normality through graphic methods (quantile-quantile plots), and using Shapiro-Wilk normality test. Data were assessed for each analyte as a whole (all ponds, any location in pond) and separately for locations within each pond (inlet, centre, outlet). Generally, data sets did not follow normal distributions (p < 0.05). Subsequent data analysis was carried out using non-parametric analyses, such as Kruskal-Wallis test for analysis of variance (testing whether samples originate from the same distribution). Data for each parameter were analyzed using the Kruskal-Wallis test to determine if there was evidence for differences in sediment samples concentration distributions from the different sampling locations in the stormwater ponds. Where a significant difference among the groups was detected (p<0.05), post hoc analysis was carried out using pairwise comparisons of the groups with the Wilcoxon-Mann-Whitney test.

The statistical analysis results identified significant differences between samples that were collected from the inlet versus the outlet areas. However, significant differences were not identified between the inlet data and the centre data or between the centre data and the outlet data. This trend was especially apparent for the particle size distributions. Sand concentrations were generally highest at the inlets, while silt and clay were lowest at the centre and outlets. This is to be expected due to gravitational settling of heavier particles at the inlet. As stormwater flows into the pond, the flow

velocity slows and the heavier sand particles are deposited into the basin while the lighter silt and clay particles are carried to the centre and outlet locations. Most analytes included in this study adhere more strongly to silt and clay particles as opposed to sand particles, which would affect their distributions from the inlets to the outlets as well.

These statistical results support the sampling strategy that was previously discussed, which identifies the number of sample locations according to the number of inlets and for each SWMF. As shown in example Figures C.1A and C.1B, one sample would be collected per inlet, outlet and centre area.

References

Health Canada (2013) Archived – Priority Substance List Assessment Report for Road Salts. ISBN: 0-662-31018-7. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/index-eng.php#a2138

Marsalek, J, Marsalek PM (1997) Characteristics of Sediments from a Stormwater Management Pond. *Water Science and Technology*, **36**, 117-122.

Wang Z, Yang C, Kelly-Hooper F, Hollebone BP, Peng X, Brown CE, Landriault M, Sun J and Yang Z (2009) Forensic Differentiation of Biogenic Organic Compounds from Petroleum Hydrocarbons in Biogenic and Petrogenic Compounds Cross-contaminated Soils and Sediments. *Journal of Chromatography A*, **1216**, 1174-1191.

APPENDIX D

BOXPLOTS OF STORMWATER POLLUTANTS



























APPENDIX E

TRCA ROUTINE INFRASTRUCTURE WORKS CRITERIA



Permission for Routine Infrastructure Works Qualification Criteria

INTERIM PROTOCOL

- 1. Fees for Permission for Routine Infrastructure Works (RIWs) are \$350 for service agreement partners, or \$750 for minor and \$1400 for major RIWs with site visit or technical review for non-service agreement partners. The Fee will be confirmed by the TRCA Project Manager based on the level of review required. This is determined by TRCA during the screening of the application.
- 2. The works outlined in Table 1 must classify as Schedule A or A+ under the Municipal Class Environmental Assessment, or equivalent, to qualify for Permission for Routine Infrastructure Works.
- 3. Any works that require Authorization from Fisheries and Oceans Canada (DFO) under the Fisheries Act do not qualify for Permission for Routine Infrastructure Works.
- 4. TRCA staff will confirm if the proposed works meet the evaluation criteria and basic design requirements.
- 5. Permission for works outlined in Table 1 is subject to TRCA staff review and approval. Permission for Routine Infrastructure Works constitutes an approval under Ontario Regulation 166/06.
- 6. Permission for works outlined in Table 1 is subject to the proposed works no implications to the control of flooding, erosion, dynamic beaches, pollution or the conservation of land.
- 7. Fee to be paid at the time of submitting an application to the TRCA. No Permission for Routine Infrastructure Works will be issued without payment.
- 8. TRCA staff reserves the right to request additional technical studies (e.g. geotechnical, ecological).
- 9. Erosion and sediment control plans and reports shall be prepared in accordance with "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.
- 10. TRCA staff reserves the right to require the proposed works be processed through a regular permit application under Ontario Regulation 166/06.
- 11. TRCA staff reserves the right to require that the proposed works be processed through a regular permit application after Permission for Routine Infrastructure Works is granted, should the proposal change during construction.
- 12. This protocol and fee structure is subject to change as a result of further review and assessment.
- 13. All works/access on TRCA property may require archaeological investigations, temporary/permanent easements, or permission to enter, subject to screening by TRCA staff.

Development Type		Evaluation Criteria and Basic Design Requirements
Road / Pathway Resurfacing or Reconstruction	1.	The works will not include any resurfacing or hardening beyond the existing road, pathway limits, shoulders or driveways. Resurfacing may also include the addition or replacement of traffic control devices (e.g. signing, signalization) or safety projects (e.g. lighting, grooving, glare
	2.	screens). If any works are proposed within 30 metres of a watercourse, PSW or ORM wetland, or 15 metres from any other wetland.
	3. 4.	No in-water works will be required. Appropriate debris controls will be implemented to isolate the works from
	5.	Construction / maintenance activities, including access, will not negatively impact any watercourses, wetlands or other natural features. Vegetation removals and restoration plans must be provided and approved by TRCA Ecologist.
	6.	Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.
	7.	Any fill, grading or alterations will have no adverse impacts to erosion, pollution, or the storage or conveyance of flood waters, as approved by
	8.	All disturbed areas will be stabilized and restored upon completion of the works.
Structure Maintenance	1.	No widening or other structural encroachment beyond the existing structure footprint will be required.
(e.g. bridges, retaining walls)	2. 3.	No in-water works will be required. Appropriate debris controls will be implemented to isolate the works from any watercourses or other natural features
	4. 5.	Works will be limited to concrete patching or other routine maintenance. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands or other natural features. Vegetation removals and restoration plans must be provided and approved by TRCA Ecologist.
	6.	Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment control Guideline for Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.
	7.	Any fill, grading or alterations will match existing conditions, and will have no adverse impacts to erosion, pollution, or the storage or conveyance of flood waters, as approved by TRCA Water Resources Analyst
	8.	All disturbed areas will be stabilized and restored upon completion of the works.
	9.	The works will comply with the Fisheries and Oceans Canada (DFO) Ontario Operational Statement for Bridge Maintenance, if applicable.

Sewer,	1.	Construction will be limited to existing Municipal Road Right of Ways or
Watermain or		existing Utility Right of Way or existing Utility Corridor, any approved
Utility		connections as long as they meet the criteria of the RIW.
Installation or	2.	If a watercourse crossing associated with an existing structure (e.g.
Maintenance		attached to an existing bridge) is required, see criteria Structure
Within an		Maintenance.
Existing	З.	Where required by TRCA, a geotechnical/hydrogeological investigation
Roadway		has confirmed that there will be no dewatering requirements and no
(ie relining etc)		significant risk of other groundwater conflicts or geotechnical difficulties,
		this information must be provided to TRCA for review and approval.
	4.	Any maintenance pumping of excavated areas (e.g. unwatering) will be
		directed a minimum of 30 metres away from any watercourses or other
		natural features, and will be discharged to a vegetated area or through
	_	other appropriate erosion and sediment controls.
	5.	Construction/maintenance activities, including access, will not negatively
		Impact any watercourses, wetlands or other natural features. Vegetation
		removals and restoration plans must be provided and approved by TRCA
	6	Ecologist.
	о.	Appropriate erosion and sediment controls will be implemented along the
		nifili of the work area to protect any aujacent watercourses of other
		site has been stabilized and restored. Please refer to "The Fresion and
		Sediment Control Guideline for Urban Construction" December 2006
		prepared by the Greater Golden Horsesboe Area Conservation
		Authorities
	7	Any fill grading or alterations will match existing conditions, and will have
	1.	no adverse impacts to erosion pollution or the storage or conveyance of
		flood waters as approved by TRCA Water Resources Analyst
	8	All disturbed areas will be stabilized and restored upon completion of the
	0.	works.

Sewer	1	The crossing will be constructed using horizontal directional drilling
Watermain or	••	nunch and hore, or another trenchless construction method
I Itility	2	Where required by TBCA, a geotechnical/bydrogeological investigation
Watercourse	۷.	has confirmed that there will be no dewatering requirements and no
		has commed that there will be no dewatering requirements and no
		significant risk of other groundwater conflicts of geotechnical difficultes,
		this information must be provided to TRCA for review and approval.
lechnology	3.	The obvert of the infrastructure, including grouting and casing, will be
		located a minimum of 2 metres below the invert of the watercourse.
	4.	Working pits will be located within existing roadways, shoulders,
		boulevards, or Right of Ways (ROW) a minimum of 10 metres from the
		watercourse.
	5.	Any maintenance pumping of excavated areas (e.g. unwatering) will be
		directed a minimum of 30 metres away from any watercourses or other
		natural features, and will be discharged to a vegetated area or through
		other appropriate erosion and sediment controls.
	6.	Construction/maintenance activities, including access, will not negatively
	••	impact any watercourses wetlands or other natural features. Vegetation
		removals and restoration plans must be provided and approved by TBCA
		Follogist
	7	Appropriate erosion and sediment controls will be implemented along the
	<i>'</i> .	limit of the work area to protect any adjacent watercourses or other
		nitilit of the work area to protect any aujacent watercourses of other
		natural leatures. All controls will be monitored and maintained until the
		site has been stabilized and restored. Please refer to The Erosion and
		Sediment Control Guideline for Urban Construction", December 2006,
		prepared by the Greater Golden Horseshoe Area Conservation
		Authorities.
	8.	Any fill, grading or alterations will match existing conditions, and will have
		no adverse impacts to erosion, pollution, or the storage or conveyance of
		flood waters.
	9.	All disturbed areas will be stabilized and restored upon completion of the
		works.
	10.	The works will comply with the Fisheries and Oceans Canada Ontario
		Operational Statements for Punch and Bore Crossing or High-Pressure
		Directional Drilling, if applicable.
	11	To be considered only where there is considered to be a low risk of frac-
		out as determined by TBCA staff. Contingency details/plans may be
		required
	NOTE	In the event of a frac-out or other complications during construction
	rovised	construction, revised construction plans may be required for sonarate
	approv	al under the regular permit application process, including restoration
	appiov	ai unuei me regulai permit application process, including restoration
	plans.	

Offline	1.	The pond will be restored to functioning order as per design
Stormwater		specifications.
Management	2.	A sediment and water management plan will be required to appropriately
Pond		address water removal and dredged spoils. Containment of wet, dredge
Maintenance		material requires special consideration, the proposed treatment of this
(e.g. sediment		material should be outlined for TRCA review. Pumped water will need to
removal from		be filtered and redirected prior to discharge.
an existing	3.	Any dredged material will be disposed of outside the Regulation Limit.
stormwater		Temporary storage, if required, will be located outside of the regulatory
management		flood plain, and isolated by appropriate sediment and erosion controls.
facility)	4.	Construction/maintenance activities, including access, will not negatively
		impact any watercourses, wetlands or other natural features. Vegetation
		removals and restoration plans must be provided and approved by TRCA
		Ecologist.
	5.	Appropriate erosion and sediment controls will be implemented along the
		limit of the work area and on any outlet structures to protect any adjacent
		watercourses or other natural features. All controls will be monitored and
		maintained until the site has been stabilized and restored. Please refer to
		"The Erosion and Sediment Control Guideline for Urban Construction",
		December 2006, prepared by the Greater Golden Horseshoe Area
		Conservation Authorities.
	6.	All disturbed areas will be stabilized and restored upon completion of the
		works.
Drainage	1.	If works consist of the removal of in-stream blockages due to debris from
Structure		urban debris/garbage, fallen or eroded trees/branches, or other natural
General		woody material, see the TRCA Debris Jam Clearance Protocol
Maintenance		(September 2007) in the Planning & Development Procedural Manual.
(e.g. ditch	2.	Works will take place in the dry (e.g. works will be timed to avoid periods
cleaning,		of flow, storm events)where possible.
culvert	3.	Any dredged material will be disposed of outside the Regulation Limit.
relining)		Temporary storage, if required, will be located outside of the regulatory
		flood plain, and isolated by appropriate sediment and erosion controls.
	4.	Construction/maintenance activities, including access, will not negatively
		impact any watercourses, wetlands or other natural features. Vegetation
		removals and restoration plans must be provided and approved by TRCA
		Ecologist.
	5.	Appropriate erosion and sediment controls will be implemented along the
		limit of the work area to protect any connecting or adjacent watercourses
		or other natural features. All controls will be monitored and maintained
		until the site has been stabilized and restored. Please refer to "The
		Erosion and Sediment Control Guideline for Urban Construction",
		December 2006, prepared by the Greater Golden Horseshoe Area
		Conservation Authorities.
	6.	Any fill, grading or alterations will match existing conditions, and will have
		no adverse impacts to erosion, pollution, or the storage or conveyance of
		flood waters, as approved by TRCA Water Resources Analyst.
	7.	All disturbed areas will be stabilized and restored upon completion of the
		works.
Borehole Investigations1.Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands or other natural features. Vegetation removals and restoration plans must be provided and approved by TRCA Ecologist2.Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.3.All disturbed areas will be stabilized and restored upon completion of the works.Utility Poles (Hydro,1.Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
--		
Investigationsimpact any watercourses, wetlands or other natural features. Vegetation removals and restoration plans must be provided and approved by TRCA Ecologist2.Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.3.All disturbed areas will be stabilized and restored upon completion of the works.Utility Poles (Hydro,1.Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
 removals and restoration plans must be provided and approved by TRCA Ecologist Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro, 		
 Ecologist Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro, 		
 Appropriate erosion and sediment controls will be implemented along the limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro, 		
 limit of the work area and on any catch basins or drainage features to protect any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro, 		
any adjacent watercourses or other natural features. All controls will be monitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.3. All disturbed areas will be stabilized and restored upon completion of the works.Utility Poles (Hydro,1. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
wonitored and maintained until the site has been stabilized and restored. Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities.3. All disturbed areas will be stabilized and restored upon completion of the works.Utility Poles (Hydro,1. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
Please refer to "The Erosion and Sediment Control Guideline for Urban Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. 3. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro, 1. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
Construction", December 2006, prepared by the Greater Golden Horseshoe Area Conservation Authorities. 3. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles (Hydro,		
Area Conservation Authorities. 3. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles 1. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
 3. All disturbed areas will be stabilized and restored upon completion of the works. Utility Poles Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features. 		
works. Utility Poles 1. Construction/maintenance activities, including access, will not negatively (Hydro, impact any watercourses, wetlands, valley slopes, or other natural features.		
Utility Poles 1. Construction/maintenance activities, including access, will not negatively impact any watercourses, wetlands, valley slopes, or other natural features.		
(Hydro, impact any watercourses, wetlands, valley slopes, or other natural features.		
lighting, etc) Vegetation removals and restoration plans must be provided and approved		
by TRCA Ecologist		
2. The proposal will not have any impacts to the storage or conveyance of flood		
waters, as approved by TRCA Water Resources Analyst.		
3. Appropriate erosion and sediment controls will be implemented along the		
limit of the work area to protect any connecting or adjacent watercourses or		
other natural features. All controls will be monitored and maintained until the		
site has been stabilized and restored. Please refer to "The Erosion and		
Sediment Control Guideline for Urban Construction", December 2006,		
prepared by the Greater Golden Horseshoe Area Conservation Authorities.		
Fences 1. Construction/maintenance activities, including access, will not negatively		
impact any watercourses, wetlands or other natural features. Vegetation		
removals and restoration plans must be provided and approved by TRCA		
Ecologist		
2 The proposal will not have any impacts to the storage or conveyance of flood		
waters, as approved by TRCA Water Resources Analyst.		
3. Appropriate erosion and sediment controls will be implemented along the		
limit of the work area to protect any connecting or adjacent watercourses or		
other natural features. All controls will be monitored and maintained until the		
site has been stabilized and restored. Please refer to "The Fresion and		
Sediment Control Guideline for Construction", December 2006, prepared by		

APPENDIX F

CASE STUDY

POLYMER ASSISTED HYDRAULIC DREDGING



Polymer Assisted Hydraulic Dredging of a Stormwater Pond CASE STUDY



INTRODUCTION

As stormwater ponds introduced in the 1990's continue to age, the number of ponds requiring cleanouts is increasing rapidly. Mechanical dredging of the settled sediment layer is the conventional method of choice; however, there is growing interest in alternative methods that may help reduce cost and overall disturbance of the landscape. Polymer assisted hydraulic dredging is one such method that helps reduce the impact of cleanout operations on the neighbouring community while also providing enhanced protection of the environment.

The use of polymer technology to facilitate water clarification and sediment consolidation during stormwater pond cleanouts is a relatively new approach within the Greater Toronto Area. While cost effectiveness is often a principal concern, other constraints such as space limitations and tight timelines are also key priorities. The current case study describes an application of the polymer anionic polyacrylamide (PAM) to aid in sediment removal from a stormwater management pond in the City of Vaughan, Ontario.

POND PROFILE

Municipality	City of Vaughan
Cleanout Party	Layfield Canada Ltd.
Drainage Area Land Use	Residential
Pond Age at Time of Cleanout	5 years
Drainage Area (ha)	35.02
Permanent Pool Depth (m)	1.00
Permanent Pool Volume (m ³ /ha)	110
Water Quality and Erosion Control Volume (m ³ /ha)	178
Sediment Removal Method	Hydraulic Dredging
Sediment Handling Method	Landfill Disposal



PROJECT OBJECTIVES

In Ontario, municipalities typically require landowners to remove sediment accumulated in stormwater management ponds before ownership is transferred to them from the developer. After the pond has been cleaned out, a bathymetric survey of the pond is completed and compared to as-built or original design drawings to confirm that the pond has been restored to its full capacity. The dredging of Pond 4 was undertaken by the Block 11 Landowners Group in 2013 in order to render the pond suitable for assumption by the City of Vaughan.

Based on the completion of a bathymetric survey, it was determined that a total of 1230 m³ of sediment had accumulated in the pond. Over and above the primary objective of removing this accumulated sediment, the method selected for the dredging of Pond 4 was also required to meet the following secondary objectives.

- Avoid the clearing of vegetation on pond embankments and surrounding areas so as to keep restoration and replanting costs to a minimum;
- Return the pond to its original design capacity for the purpose of assumption by the City of Vaughan;
- Minimize disturbance to local residents and individuals who use the walking trails around the pond;
- Minimize the ecological disturbance of dredging activities to wildlife that inhabit the pond area, particularly waterfowl;
- Prevent the release of sediment to the receiving stream; and
- Complete project on schedule and budget.

SITE DESCRIPTION

The pond is located on Block 11 in the City of Vaughan, Ontario, near the intersection of Rutherford Road and Bathurst Street (Figure 1). It receives stormwater runoff from 35 hectares of primarily residential land and drains to a tributary of the Upper East Don River. The parkland immediately surrounding the pond is a well vegetated area containing walking trails frequented by local residents. To the south, between the pond and Rutherford Road, is a synagogue and parking lot.

The pond was constructed during the earthworks phase of construction for the residential development in 2006 and functioned as a construction sediment control pond. To date, the pond has never been dredged as it was relatively recently constructed and had not been assumed by the municipality at the time of cleanout.



Figure 1. Location and drainage area for Pond 4, Block 11 in Vaughan.

METHODS

Based on these objectives and the specific constraints and opportunities available at the site, the proponent elected to use a relatively new and unconventional method to clean out Pond 4 — polymerassisted hydraulic dredging. This method involves the hydraulic dredging of wet sediment, the injection of an anionic polyacrylamide solution into the sediment slurry, and the conveyance of the material to large filter bags for dewatering. The entire cleanout process is detailed in the following subsections.

Pond Survey

The pre-cleaning bathymetric survey took place in April, 2011. The survey indicated that a total of 1330 m³ of sediment has accumulated in the pond - 770 m³ in the sediment forebay and 460 m³ in the main cell. A GPS total station was used together with a disk and rod to obtain coordinates for the top of the sediment layer. The bathymetry of the pond was compared to the pre-cleaning as-built survey to provide an accurate estimate of accumulated sediment volume.

2

Sediment Characterization

The sediment accumulated in the bottom of Pond 4 was sampled in May and April of 2011, and samples were submitted to Maxxam Analytics in Mississauga for laboratory analysis to assess whether the material was suitable for use as fill at a nearby school construction site.

One sample was collected from the forebay and three samples were collected from the main part of the pond (referred to as the wet cell), using an Ekman Dredge Sampler. All samples were analyzed for a series of petroleum hydrocarbons and metals, and concentrations were compared to the Ontario Ministry of Environment's *Soil, Ground Water and Sediment Standards for Use Under Part XV.I of the Environmental Protection Act* (2011). Within the standards, the contaminant thresholds listed under the category for Residential/Parkland use within Table 1, entitled "Full Depth Background Site Condition Standards" was used as the basis for comparison to the contaminant levels in the pond sediment.

A toxicity characteristic leaching procedure (TCLP) was also carried out on the pond sediment samples, in accordance with Ontario Regulation 347/4 which was created under the Environmental Protection Act and addresses the management of waste. TCLP is a method in which landfill-like conditions are applied to a solid waste material in order to yield a leachate — a liquid sample containing dissolved and particulate matter that have drained out of the original material. Schedule 4 lists the maximum acceptable contaminant concentrations for leachates. If contaminant concentrations in the leachate exceed values listed in Schedule 4, the solid material from which the leachate was derived is defined as hazardous waste and must be disposed of accordingly.

Site Preparation

Based on the dredging method selected, large excavators were not required in the pond and surrounding area. As a result, there was no significant vegetation removal and the need for erosion and sediment control measures was minimal. In order to mitigate the release of sediment from the pond during dredging activities, work was scheduled in the summer during a period over which dry weather was forecasted. Because more than 60% of accumulated sediment was located in the forebay part of the pond, the risk of sediment release to receiving waters was considered to be low. The primary activities associated with preparing the site for dredging were:

- The preparation of a lay down area for the sediment dewatering bags;
- The placement of the hydraulic dredge and steel cable system in the pond; and
- The installation of the pumps, pipes and hoses conveying material between the dredge, polymer supply trailer, and sediment dewatering bags.

The area designated for the placement of the Geotubes[®] (measuring 45 by 100 feet) was a vacant gravel parking lot immediately south of the pond (Figure 3). The first step in preparing the area was leveling the ground with a backhoe and creating earthen berms around the perimeter. These measures ensured that the Geotubes[®] would not shift or roll once they were filled. Following this grading, the area was covered with a plastic liner, plastic netting for drainage, and a nonwoven geotextile fabric (Figure 2).



3

Figure 2. Preparation of laydown area for sediment dewatering Geotubes® (left). The same area with the Geotubes® in place and filtering water (right).



Conservation

for The Living City



Figure 3. Schematic aerial view of the Pond 4 site during polymer-assisted hydraulic dredging.



Figure 4. :Pit Hog[™] dredge operating in Pond 4.

Figure 3 illustrates the overall site set up for the dredging of Pond 4. The remote controlled, floating, auger-type dredge used – a Pit Hog^M – was lifted into the pond and removed at the conclusion of dredging with the use of a crane (Figure 4). A diesel generator was put in place to provide power to the dredge. Hoses from the dredge were connected to a trailer housing the prepared polymer solution in large drums, as well as the metering and dosing equipment. Hoses also connected the trailer to the Geotubes[®] to which the polymer dosed material was conveyed to allow for settling and filtration.

Dewatering and Dredging

As depicted in Figure 3, the sediment slurry was suctioned by the dredge, pumped to the trailer for inline polymer injection and mixing, and then pumped to a Geotube[®] for dewatering (Figure 5). Water drained from the Geotubes[®] was conveyed back into the forebay part of the pond.

The operation of the dredge (Figure 4) was done by remote control, with the dredge's forward, reverse and lateral movements guided by a steel rail system installed at the ends of the pond. The movement of the dredge was determined based on real time measurement of solids levels in the material being suctioned. The concentration of solids in the slurry being pumped through the dredge was measured by a density meter in the polymer metering and dosing trailer. These real time measurements were observed by an individual in the trailer who remained in constant radio contact with the person remotely operating the dredge. The percent solids level indicated whether or not that part of the pond bottom had been cleared of sediment. When the percent solids decreased at a specific spot, it served as a cue to the operator

that the dredge had sufficiently suctioned the sediment in that area, and should be moved forward to suction the next area.

The role of the polymer used – a solution made from granular anionic PAM and water – is to promote the binding together of the



Figure 5. Sediment dewatering bag laydown area.

suspended sediment particles in the slurry so that they form larger aggregate particles. Once formed, these larger particles are more susceptible to being removed from suspension by gravitational settling or filtration in the Geotube[™]. In order to ensure the optimal performance of the polymer as a flocculant, the following factors should be considered:

POLYMER FORMULATION. Choosing the optimal polymer formulation to use for a given project is based primarily on the sediment characteristics. In preparation for the dredging, bench tests were carried out to determine which polymer formulation would work best with the material. Bench testing reveals not only the extent to which the polymer will cause flocculation, but also the extent to which it will cause a strong floc to form rather than a weak floc that will break apart and be susceptible to re-suspension. For this project, 80 separate 250 mL samples were collected from Pond 4 in order to accurately characterize the material to be treated, and select the best polymer formulation. The product selected, Solve 109AQ supplied by WaterSolve LLC, is an anionic PAM based powder. It was mixed with water in order to prepare the 0.5% solution used in this project.

POLYMER DOSING RATE. Once the polymer formulation is determined, additional bench testing and preliminary onsite testing determines the optimal dose of polymer based on the suspended solids level in the slurry. In this project, establishing the relationship between solids concentration and polymer dose allowed for the development of an algorithm. A computer housed in the trailer (Figure 5) applied the algorithm to provide continuous calculation of the amount of polymer to be injected into the slurry, based on real time measurements of flow rate and solids concentration.

MIXING TIME. Once the polymer is injected into the sediment slurry, mixing provides an opportunity for the polymer to react with the suspended sediment particles. Based on bench testing results, the optimal mixing time for the polymer dosed slurry was determined. Within the trailer, the slurry flows through an additional length of pipe and is subjected to turbulence in order to provide the necessary length and quality of mixing.

The final step in the dredging/dewatering process was the pumping of the dosed and mixed slurry into the Geotube[™]. Here, much of the sediment either settles or is filtered out of suspension (Figure 6). Water draining from the Geotube[™] pools slightly in the containment area, where there is some additional sediment settling. The effluent was discharged back into the pond forebay area via two 6" pipes, with a plastic liner installed on the ground at the discharge point to prevent erosion (Figure 6).



5

Figure 6. Filled sediment dewatering bag (left) and clarity of effluent water after it drains from the sediment dewatering area (right).



Conservation

for The Living City

The Geotubes[™] used to contain the sediment were left to drain for a period of two months. This drying period was longer than what would normally be required, reflecting delays in scheduling of hauling rather than the actual time needed for sediment to be dry enough. Typically, a few weeks of drying time would be sufficient, but this can vary significantly according to the type of material being dewatered and weather conditions. For this project, the solids concentration was 56% at two weeks and roughly 60% at two months post dredging, demonstrating that the additional drying time resulted in a relatively marginal benefit.

Sediment Hauling and Disposal

At the time of hauling, the Geotubes[™] were cut open and the dried sediment (roughly 60% solids) was scooped out with an excavator. Roni Excavating was retained to remove the sediment and transport it to the designated site.

The laboratory analysis of sediment samples revealed that two types of petroleum hydrocarbons exceeded the MOE Table 1 standards. In their analysis of sediment disposal and reuse options, Pinchin Environmental concluded that the sediment could only be reused as fill at a nearby school construction site if contaminant levels in the sediment were similar to, or better than, those at the school site. This option for sediment reuse is part of Ontario Regulation 153/04 (as amended by 0.Reg. 511/09), which allows sediment to be reused as fill at a Record of Site Condition (RSC) property, provided that the material does not contain higher contaminant levels than those present at the destination site. An RSC property is a property for which the environmental condition and an RSC has been filed with the Ontario Ministry of Environment's Brownfields Environmental Site Registry.

Based on the petroleum hydrocarbon levels in the pond dredgate, it was determined that the material would not in fact be suitable for reuse at the future school property, and would instead need to be disposed of at a landfill. The sediment – a total volume of 1033 m^3 – was hauled to a municipal landfill at a cost of \$40/tonne for hauling and disposal.

Site Restoration

A number of dead cattails were removed at the banks of the pond for ease of access. The presence of two access roads eliminated the need to cut down any trees, which ultimately minimized the site restoration activities. Some grading of the access roads was necessary to ensure the optimal function and safety of the pond perimeter and ease of future access.

RESULTS

The dredging of Pond 4 was carried out successfully and as planned. The following subsections describe and evaluate the success of the project relative to its specific objectives.

Removal of 1300 m³ of sediment

Based on a bathymetric survey of the pond completed in 2011, an estimated total of 1230 m³ of in-situ sediment had accumulated in the pond – 770 m³ in the forebay and 460 m³ in the wet cell. The total removed sediment was 800 m³ from the forebay and 500 m³ from the permanent pool for a total of 1300 m³, which indicates that the method used to estimate the volume of accumulated sediment was relatively accurate. The total volume of sediment-laden pond water removed by the hydraulic dredge was 4,336 m³. At a daily average percent solids of 4.9%, the bone-dry equivalent of the



Figure 7. Consistency of Pond 4 sediment at the time of hauling, after two months in the Geotubes[™].



Figure 8. The well-established plantings surrounding Pond 4 that remained undisturbed during dredging.

sediment retained in the geotubes amounted to approximately 215 m³ (Figure 7).

Estimating the total volume of removed sediment during hydraulic dredging is quite different than during mechanical dredging. Since the pumped slurry has a very high water content, very large amount of slurry needs to be pumped in order to obtain a fraction of that volume in the form of workable sediment. The amount of removed sediment is then estimated by applying a solids fraction at the time of removal based on the proportion of solids in the slurry sample. Note that a single sample may misrepresent the solids proportion, as hydraulic dredging removes differing proportions of solids depending on how deep within the sediment depth the pump is submerged. Therefore, a substantial number samples should be acquired to obtain a representative determination of the average sediment contents of the dredged slurry. during a large 39 mm rainfall event that occurred on June 10, during which the pond continued to provide its stormwater management function. Dredging was continued even while the pond was full because, based on effluent monitoring, the increase in turbidity caused by the operation of the dredge was minimal and did not result in any significant sediment release from the pond.

Completing the Project on Schedule and Within Budget

The preparation of the laydown area was carried out within three days at the end of May 2013, and dredging was subsequently carried out over the course of ten days, from June 3rd to 13th. The project was carried out as planned and on budget, with no significant delays reported by the project team.

Preserving Vegetation and Site Features

The dredging method used was largely non-invasive, with no excavators requiring access to the pond and only a crane used to lift the dredge into and out of the pond. As such, no significant vegetation removal was necessary to facilitate pond access, and the established vegetation stabilizing pond embankments was also preserved (Figure 8). As a result, the only site restoration activities necessary were the removal of the materials lining the containment area and the re-grading of the parking lot to its original condition. Because there were few construction vehicles required on site, walking trails around the pond area remained accessible to local residents throughout the dredging process.

Minimizing Ecological Disturbance and Sediment Release to Natural Features

Pond 4 remained functional throughout the dredging process, since the technology used did not require that it be pumped down. The presence of the permanent pool allowed birds and other wildlife to continue to use the pond, while also allowing the pond to continue to function for stormwater management. This was evidenced



7

CHALLENGES AND LESSONS LEARNED

Overall, the project was completed successfully while addressing all objectives. Since hydraulic dredging is still an emerging technology within the environmental consulting industry of pond cleanouts, there were lessons learned that would be beneficial for future implementations.

Discrepancies in volume estimations may occur due to the different type of sediment handling during hydraulic dredging. Because bathymetric surveys are in fact measuring in situ saturated sediment, these total volumes are comprised mostly of water. If a good estimation of the actual solids ratio is unknown, it can be difficult to assess whether the amount of sediment removed is adequate, since the dredgeate has a different solids content than the in situ sediment. This is not a major issue for mechanical dredging, where in-situ sediment estimations are commonly increased by 10-20% to better estimate the expected volume of removed sediment, in its state prior to dewatering.

Uncertainties in estimating sediment volumes made it difficult to determine the number of dewatering bags needed to accommo-

date the dredged sediment. To prepare for a high end of potentially removed sediment volume, technicians allotted more space than was necessary for dewatering. Extra sediment dewatering bags were prepared, but were only opened as required, which helped to reduce costs.

The polymer product used was very effective at dewatering the sediment directed to the sediment dewatering bags. Although it would have only required few weeks to sufficiently dewater, the bags were left on site for two months due to conflicting hauling schedules. In this case, the fact that the sediment was contained in the dewatering bags was highly beneficial, as it was not subject to erosion as it sat over the two month period. The sediment dewatering bags work exceptionally well as sediment containment areas, making the subsequent management of this sediment a smooth operation.

Lastly, there was a minimal amount of land disturbed to facilitate the cleanout, as there was no need to use heavy machinery. Additionally, the adjacent underused parking area served as an ideal sediment management area, further minimizing the need for vegetation clearing and subsequent restoration.



For information on STEP's other stormwater management initiatives, or to access the new guidance on stormwater pond cleanouts, visit us online at www.sustainabletechnologies.ca

This case study has been prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program. Layfield Canada Ltd. and Bishop Water Technologies carried out the pond clean out project described herein, and as such provided the information and site access required for the development of this document. Funding support for this study was provided by Region of Peel, Region of York, City of Toronto and Government of Canada's Great Lakes Sustainability Fund. The contents of this report do not necessarily represent the policies of the supporting agencies. For more information about this project, please contact STEP@trca.on.ca.



APPENDIX G

CASE STUDY

POLYMER ASSISTED HYDRAULIC DREDGING WITH ON-SITE DISPOSAL



Anionic Polyacrylamide Hydraulic Dredging with On-site Disposal CASE STUDY



INTRODUCTION

The use of polymer technology during both mechanical and hydraulic dredging operations is gaining popularity as non-conventional methods are explored by the stormwater management community. Hydraulic dredging offers a viable alternative to stormwater management facility clean out when site and project specific constraints make mechanical dredging difficult or impossible. Polymer flocculants are often used in conjunction with hydraulic dredging as a means of separating sediment from water in a slurry. The current case study describes the use of polymer-assisted hydraulic dredging to remove sediment from a stormwater management pond in the City of Vaughan. The sediment, which was captured in sediment dewatering bags used to dewater the slurry, was buried in the onsite sediment drying area, within the bags.

POND PROFILE

Municipality	City of Vaughan
Cleanout Party	Aquatech Dewatering
Drainage Area Land Use	Residential
Pond Age at Time of Cleanout	5 years
Drainage Area (ha)	42.95
Permanent Pool Depth (m)	1.40
Permanent Pool Volume (m ³ /ha)	70
Water Quality and Erosion Control Volume (m ³ /ha)	95
Sediment Removal Method	Hydraulic Dredging
Sediment Handling Method	Buried on Site





PROJECT OBJECTIVES

One of the primary conditions imposed by municipalities before they will assume a stormwater management pond is that the facility is restored to its original design capacity. The stormwater pond described in this case study was owned by the developer, Metrus Development, and had not been assumed by the City of Vaughan at the time of dredging in 2014. Based on a bathymetric survey completed in 2013, it was determined that 750 m³ of sediment had accumulated in the pond since it was constructed.

The primary objective of the project was to remove this accumulated sediment so that the pond would be restored to a condition in which it could be assumed by the City of Vaughan. Metrus Development retained the services of Aquatech Dewatering to complete this work. Other project objectives included:

- Prevent the release of sediment to the receiving stream;
- Minimize the ecological disturbance of dredging activities to wildlife that inhabit the pond area;
- Repair water control structures where needed;
- Re-plant pond banks and any restore any other areas where vegetation removal was required for maintenance access and sediment on-site disposal;
- Complete dredging and associated activities on schedule and within budget.

SITE DESCRIPTION

The new Vellore Village development has three stormwater ponds to treat stormwater runoff, all scheduled to be cleaned out at different times prior to assumption by the City of Vaughan. Pond 91, highlighted in this case study, is located west of Pine Valley Drive between Major Mackenzie Drive and Rutherford Road in Vaughan, Ontario (Figure 1). It receives stormwater runoff from a 46.2 ha drainage area in which the land use is primarily residential. The pond effluent is discharged to a Marigold Creek tributary, which makes its way to the East Humber River through the adjacent Kortright Centre for Conservation. The Vellore Village development construction was initiated in 2005, while the pond was built in 2009.

METHODS

Following a site assessment and considering the side slopes of the pond, it was determined that mechanical dredging was not a feasible option for this pond. The contracted company (Aquatech Dewatering) was also interested in using this pond as a pilot for



Figure 1. Location of Pond 91 in Vaughan, ON.

assessing a new series of equipment for hydraulic dredging. While there was some risk associated with the use of this new equipment, the parties involved reached an agreement on price and contingency that allowed the project to move forward.

Pond Survey

An as-built survey was conducted in 2010 to establish a baseline bathymetry of the pond. Once the pond cleanout planning was underway, a bathymetric survey was conducted in 2013 utilizing sonar technology. It was determined that the sonar survey overestimated the volume of sediment that had accumulated in the pond, and thus the pond was re-surveyed using the disk and rod method (Figure 2). In this method, a flat disk is attached to a long metal rod, which is submerged in the water until the bottom of the disk is positioned relatively flat on the pond bottom. A GPS total station survey was utilized to obtain high resolution vertical and horizontal measurements of the disk through a reflector attached at the top of the disk. Based on the survey, it was determined that the total volume of sediment accumulated in the pond was 750 m³, which is equivalent to 48% of the permanent pool volume.

Sediment Characterization

Four composite sediment samples were collected from the northeast, southeast, southwest and northwest quadrants of Pond 91



Figure 2. Field crew conducting a bathymetric survey of Pond 91 using a standard disk, rod and total station method.

using hand sampling methods. Samples were submitted to Maxxam Analytics for analysis of general inorganic parameters and select metals. Results were compared to both Tables 1 and 2 of the Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act. For all the parameters for which the sediment was tested, it was found to meet the thresholds in Table 2 as well as the more stringent criteria in Table 1. Based on these results, it was determined that the chemistry of the material would make it suitable for reuse on any land based sites. As such, it was considered appropriate to bury the material onsite as planned from the outset of the project.

Site Preparation

Site preparation was dictated by the sediment disposal and dredging methods selected for this project (Figure 3). The cleanout was initiated in the spring when water levels are relatively high, which is helpful as it allows the hydraulic dredge easier access to all areas, particularly those near the shoreline. The AquaBarrier shown in Figure 3 was initially going to be used to get water levels to be high enough to operate the dredge in one half of the pond at a time. This ultimately was not necessary because water levels were naturally high enough to operate the dredge effectively. This is an important factor that distinguishes hydraulic dredging from mechanical dredging, which is typically carried out during hot, dry weather when water levels are at their lowest. As no heavy machinery is required for hydraulic dredging, there was no significant vegetation



Figure 3. Schematic aerial view Pond 91 of site preparation.





removal and the necessary erosion and sediment control measures were minimal. However, cattail removal was necessary to maximize the dredge's accessibility to the shores (Figure 4). The site has two access roads, which were both utilized during the site mobilization and set-up. The primary activities associated with preparing the site for sediment removal were:

- Excavation of a large area for sediment dewatering in Geotubes, and also for permanent burial;
- Launching the hydraulic dredge and preparation of a steel cable system to facilitate its movement;
- Installation of pumps, pipes and hoses conveying pond water and polymer between the dredge, polymer supply trailer, polymer and effluent mixing trailer and sediment dewatering bags.

Within the existing sediment drying area, an excavator was used to create a dewatering and burial area that was 30 ft wide, 300 ft long and 3 ft deep. The area was sized to house five large dewatering bags but ultimately only four were needed to capture the dredged sediment. Excavated material was hauled to a construction site to use as fill material. The excavation was sized to house five sediment dewatering bags, but only four were necessary to accommodate the extracted volume of sediment. A layer of geosynthetic cloth was placed along the bottom of the excavation followed by a layer of gravel. The dewatering bags were laid out on top. The gravel stone maintained a porous volume though which water from the dewatering bags was able to drain. The water re-entered the pond through three fluming ditches (containing 12" DR17 HDPE pipes) in each bag.

The remote controlled Dragflow[®] Mini Dredge with an electric submersible pump (Model EL12.5 SS) was deployed in the pond during the dredging operation (Figure 5). This hydraulic dredge operates in a grid-like pattern with the help of a cable system connecting opposite sides of the pond. A diesel generator provided power to the dredge. Water pumped by the dredge is directed to trailers set up for dosing with polymer and mixing of the dosed sediment slurry. The slurry was then directed to the dewatering bags in the sediment management area, where water was drained and conveyed back to the pond.

Dewatering and Dredging

HYDRAULIC DREDGE FUNCTION. Hydraulic dredging operates through a substantial amount of pumping and water conveyance. The dredge is operated with a remote control to guide the speed of the dredge and depth of the submerged pump. The hydraulic dredge uses high and low pressure fields at the pond bottom created by the pump.



Figure 4. Shoreline cattail removal.



Figure 5. Hydraulic mini dredge.



Figure 6. Sediment dewatering bags.

The pump creates a high pressure at the top of the sediment, which results in a low pressure at the suction point of the pump. As such, the slurry moves from the high pressure to the low pressure and into the pump, which creates a circulation. The pump functions at a rate of 80 m³/hour.

The movement of the dredge was guided by steel cables attached at either end of the pond, while a remote control was used to move the dredge forward and backward, control its speed and determine the depth of the submersible electric pump. The colour of the slurry being pumped into the dosing and mixing trailer was monitored in real time as a means of determining when the pump should be moved. If the slurry appeared to be relatively clear with low solids content, the pump would be lowered in order to capture the dark sediment at the pond bottom. A lighter coloured slurry with high solids content was indicative that the pump had reached the clay pond liner and thus the pump could be advanced forward to clean the next section.

POLYMER FORMULATION AND DOSING RATE. As a flocculant, anionic PAM functions by causing sediment particles to bind to one another to create larger agglomerated masses. These heavier agglomerated particles are more prone to gravitational settling and easier to filter using a dewatering bag. For the polymer dosing and mixing aspect of the clean out, Aquatech Dewatering retained the services of of Bishop Water Technologies. Bishop Water procured the polymer product and provided the infrastructure necessary to dose and mix the slurry. The polymer product was injected in-line into the slurry as it was pumped out of the pond and into the dosing trailer. The solution injected was a mixture of granular anionic PAM and water, and was selected base on its proven effectiveness and low toxicity (Rocha and Van Seters, 2013). Prior to commencement of the dredging, bench tests were carried out to determine the appropriate polymer and required amount per unit volume of slurry. The dosing rate was determined through an algorithm developed on site following in-situ testing of the actual suspended solids in the slurry. The algorithm, dependent on measured solids concentrations, was applied to the polymer release tank to control the volume of polymer injections in real time.

DEWATERING. The chemical reaction between the injected polymer and suctioned slurry begins its reaction while in the polymer and effluent mixing tanks while being conveyed through hoses into the sediment dewatering bags for further consolidation and dewatering (Figure 6). The PAM dosed slurry was pumped though a mixing zone that created turbulent flow conditions allowing for the polymer to react more fully with the sediment. After this mixing occured, the slurry was pumped into the dewatering bags, which filtered out



Figure 7. Clear water exiting the sediment dewatering bags.



Figure 8.Level of sediment consolidation from within the dewatering bags.



Figure 9. Sediment dewatering bags at the end of dredging.

5



Conservation

for The Living City

any particles larger than 425 μ m. In addition to filtration, the bags also provide an opportunity for gravitational settling of suspended sediment particles. There were two entry points in each dewatering bag so that as one side became filled with sediment, the hose could be removed and re-attached at the adjacent entry point. The water that drained from the bags was conveyed from the dewatering area and back into the pond via three 4-inch pipes (Figure 7). The flow path from the pipe to the pond was stabilized with geotextile fabric to prevent erosion.

The four sediment bags were consecutively filled with polymer-laden effluent and therefore the dewatering process was ongoing throughout the duration of dredging and beyond. Since the sediment was to be left on site within the dewatering bag containment area, the duration of sediment drying did not pose a constraint on the project timeline. The expected time for sediment consolidation was one month; however, the back-filling of the containment area took place roughly two months following the end of the dredging operations as per the contractor's availability.

Sediment Disposal

The sediment contained in the dewatering bags was left within the excavated containment area, avoiding the need to haul and dispose of sediment off site (Figure 8-9). The top of the bags was cut open to allow the dredged consolidated sediment to integrate with the soil used to backfill the sediment containment area. The area was backfilled, leveled and hydroseeded. On sites where sediment contains higher contaminant levels than on this site, it is possible that this method of onsite reuse and integration with existing site soils could result in reduced contaminant levels over time. The churning of the soil by microbes could potentially help to mix the dredged sediment with the backfilled soil, and also help reduce contaminant levels through biological breakdown and uptake. While this has not been proven through a field study specifically looking at dredged stormwater facility sediment, the soil remediation power of microbes is a widely accepted phenomenon.

Site Restoration

The pond facility was designed with a sediment management area and two access roads, which nearly eliminated the need to remove or damage existing vegetation. Therefore, site restoration mainly involved the backfilling of the sediment dewatering bags containment area. Fill from a different construction site was used for this purpose.

RESULTS

The duration of the dredging of Pond 91 took longer than anticipated for various reasons (see below). Nevertheless, the sediment removal undertaking was successful in restoring the pond volume back to its design objective, enabling the transfer of ownership between the developer and City of Vaughan.

Removal of 1000 m³ from Pond 91

The total volume of sediment to be removed was 750 m³, however by the end of the operation 1000 m³ of sediment had been removed. The larger volume of removed sediment is attributed to the real time monitoring of the effluent colour and density. This strategy allowed technicians to ensure that all sediment was removed from an area before advancing the dredge to the next area. The fact that significantly more sediment was removed than initially surveyed indicates that an error was present either in the as-built bathymetric survey or the sediment accumulation survey. A total of 5000 m³ of water was pumped from the pond, which resulted in 1000 m³ of removed sediment, at 20% sediment removal density.

Need for minimal site alteration and restoration

The odours and dust generation often associated with mechanical dredging are not present during hydraulic dredging operations, and were therefore not an issue for the current project. Heavy machinery was not utilized and noise was significantly reduced.

Improved pond functioning

The removal of 1000 m³ restored the pond to its original design and facilitated the successful transfer of ownership from the developer to the City of Vaughan. The sediment removed was largely associated with erosion of soils from the construction site, which are generally much cleaner than sediment transported in runoff from paved surfaces. Therefore, land disposal of sediment was considered to be an acceptable approach in this instance.

Excessive cattail growth hindered the commencement of the dredging

Although cattails serve biological, erosion prevention and hydraulic functions within the facility, their excessive growth in the pond fringe areas hindered access to the open water area. Because hydraulic dredges operate from the surface of open water, while cattails reduce the area of open water, they need to be removed in order to allow the dredge to access the fringe areas of the pond.

Garbage from the bottom of the pond clogged the electric submersible pump

Garbage that has washed off into the pond during storm events or deliberately deposited there by local residents posed a problem during the suction process, as the equipment is designed to suction fine sediment only. A cutter is attached to the submersible pump to cut through some bottom thriving vegetation and cattail, but this cutter is not powerful enough to mince large pieces of garbage (e.g. sweaters and shoes) into pieces small enough that they could be suctioned. Throughout the first stages of dredging, articles would frequently get stuck in the cutter, which resulted in an electrical shutdown of the dredge. After multiple attempts were made to overcome this issue, technicians decided to remove the cutter and halt dredging only when garbage clogged the pump. This procedure reduced the frequency of electrical shutdowns of the pump.

CHALLENGES AND LESSONS LEARNED

The clean out of Pond 91 applied hydraulic dredging due to site constraints and also as an opportunity to pilot a new hydraulic dredging process for the contractor, Aquatech Dewatering. Although the project plan was laid out in detail and the hydraulic dredge functioned as expected, there were site specific challenges that hampered the contractor's ability to complete the work cost effectively and within the projected timeline. Obtaining a bathymetric survey using a new technology, such as sonar, proved to be problematic when comparing results to those obtained from standard methods. This is especially important for hydraulic dredging when the depth of the pump is pre-determined based on the bathymetry of the pond. Although the technical team was able to resolve this issue, it slowed the process during the initial project stages. The second major issue was the presence of large articles in the pond bottom, which can be mitigated by ensuring that trash racks and safety grates remain locked, and by educating local residents on the function of the facility.

Overall, the cleanout operation was concluded successfully with the pond restored to its original design capacity. The project is interesting as it serves as a demonstration several unconventional methods, including polymer-assisted hydraulic dredging and onsite sediment burial. It should be noted that on-site disposal of sediment is not typically feasible during the clean out of older ponds, which are usually under municipal ownership. These ponds that drain built out catchments tend to contain sediment that is more contaminated, which will often limit the reuse options for that material. Further, many older ponds that exist today have not been built to include a sediment management area, and there is usually limited space for sediment storage adjacent to the pond.

REFERENCES

Rocha L, Van Seters T (2013) Polymer Backgrounder: The Nature, Efficacy and Safety of Polymers for Erosion and Sediment Control. Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program, Toronto, Ontario.



For information on STEP's other stormwater management initiatives, or to access the new guidance on stormwater pond cleanouts, visit us online at www.sustainabletechnologies.ca

This case study has been prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program, with funding support from the City of Toronto, York Region, Region of Peel, and the Great Lakes Sustainability Fund. Aquatech Dewatering and Bishop Water Technologies carried out the pond clean out project described herein, and as such provided the information and site access required for the development of this document. For more information about this project, please contact STEP@trca.on.ca.



APPENDIX H

CASE STUDY

WATER-ABSORBING POLYMER ASSISTED MECHANICAL DREDGING



Water-Absorbing Polymer Assisted Mechanical Dredging

CASE STUDY



INTRODUCTION

Mechanical dredging is one of the most common methods used to remove sediment accumulated in stormwater management facilities. It involves the removal of sediment by dredging the material out of the water body being cleaned, typically with an excavator. Prior to implementation, excess water is pumped out of the pond as much as possible before mechanical dredging is initiated. The remaining sediment is very wet, making it difficult to remove and haul offsite. Where sediment drying areas are available, the material is typically stockpiled and allowed to dry out for days or weeks. This passive drying method requires dry weather conditions and thus works best during hot summer months when

POND PROFILE

	SOSI	Lansing
Municipality	City of Toronto	City of Toronto
Cleanout Party	TRCA	TRCA
Drainage Area Land Use	Mixed Residential and Commercial	Commercial
Pond Age at Time of Cleanout	16 years	16 years
Drainage Area (ha)	18.3	16.1
Permanent Pool Depth (m)	1.40	2.25
Permanent Pool Volume (m ^{3/} /ha)	85	149
Water Quality and Erosion Control Volume (m³/ha)	169	222
Sediment Removal Method	Mechanical Dredging	Mechanical Dredging
Sediment Handling Method	Residential/Parkland Fill	Residential/Parkland Fill

rainfall is less frequent and ambient temperatures can expedite the drying process. Winter conditions can also be favourable because the dredgeate requires less intensive dewatering because it is frozen, which makes it easier to handle and haul offsite.

In some cases, materials such as mulch, straw and sawdust are applied to help dry and/or consolidate the wet material at a faster rate. There are two types of polymers that can also be applied for this purpose: erosion control polymers (e.g. linear anionic polyacrylamide) and superabsorbent polymers. The superabsorbent polymer particles swell as they absorb water, and become gel-like in consistency. The current case study details the clean out of two stormwater management ponds in the City of Toronto, in which mechanical dredging was used for sediment removal and a mix of superabsorbent and bentonite clay polymer was applied to wet sediment to make it easier to transport offsite.



Toronto and Region

for The Living City-

PROJECT OBJECTIVES

As stormwater management ponds age, they become filled with sediment, which diminishes their capacity to effectively treat the stormwater runoff they receive. This results in higher contaminant levels discharged from the pond and deposited into receiving water bodies, ultimately degrading downstream aquatic habitat. When ponds are filled with sediment, they are also unable to provide the flood protection they were designed for, and as such can be a significant liability to the land owner.

Within the City of Toronto there are several ponds that have been identified as being at capacity and in need of maintenance, including the Sisters of St. Joseph (SOSJ) and Lansing ponds described in the current case study. Based on sediment surveys of both ponds carried out in the summer of 2013 by the Toronto and Region Conservation Authority (TRCA, retained by the City to complete the pond clean outs), the SOSJ Pond was 58% full and Lansing Pond was 42% full relative to their original designs. The corresponding volumes of sediment to be removed were estimated to be up to 1320 m³ for SOSJ and 1200 m³ for Lansing. Over and above the primary objective of removing this accumulated sediment, these pond clean out projects were also undertaken to meet the following secondary objectives.

- Prevent the release of sediment to the receiving stream;
- Minimize the ecological disturbance of dredging activities to wild life that inhabit the pond area, particularly waterfowl;
- · Repair water control structures where needed;
- Remove any dead vegetation that has impaired the functionality of the pond;

• Assess the potential for installation of sediment drying areas and construct the areas where possible;

• Re-plant pond banks and restore any other areas where vegetation removal was required for maintenance access;

- · Complete dredging and associated activities on schedule;
- Complete dredging and associated activities on budget.

SITE DESCRIPTION

The ponds, SOSJ and Lansing, are located in the east end of the City of Toronto, Ontario. The former is immediately northwest of the intersection of St. Clair Avenue East and Warden Avenue, and the latter is just off of William Kitchen Road, located southeast of Kennedy Road and Hwy 401 (Figure 1). Both ponds were constructed in 1997 and prior to 2013 neither had been dredged.

The SOSJ pond captures stormwater from an 18.3 ha subdivision and discharges to Taylor Massey Creek, a branch of the Don River. The land surrounding the pond is well-vegetated, with valley land immediately south of the pond extending to St. Clair Avenue. Providence Health Care Centre is located to the west of the pond, Warden Subway Station to the east, and a residential subdivision to the north.

Lansing Pond is an online stormwater management pond that receives runoff from 16.1 ha of commercial land, and discharges to the Bendale Branch of West Highland Creek. While the land immediately surrounding the pond is well-vegetated and there is valley land to the south, the surrounding land is largely commercial and light industrial, containing a large proportion of paved surfaces.



Figure 1. Locations of the Lansing (left) and SOSJ (right) ponds in the east end of Toronto.

2

METHODS

Considering these specific project objectives, it was determined that the most appropriate and cost-effective method would be mechanical dredging with onsite sediment drying. It was originally intended that mulch would be used to expedite sediment drying, however due to the prolonged periods of wet weather experienced in October 2013, when the project was being carried out, the mulch could not render the sediment dry enough to be piled on the embankments without sliding back into the pond. A super-absorbent and bentonite clay polymer mix was selected as an alternative to help absorb the water and consolidate the wet sediment.

Pond Survey

The pre-cleaning bathymetric surveys for both ponds took place in April, 2013. Topographic surveys were conducted using a GPS total station, and bathymetric surveys were conducted with a SONAR remote controlled floating device. The bathymetric surveys revealed that SOSJ and Lansing ponds had in-situ accumulated sediment volumes of 1320 m³ and 1200 m³, respectively.

Sediment Characterization

In June 2013, samples of in-situ sediment were collected at three different locations in each of the ponds – near the inlet, the middle, and near the outlet. Samples were submitted to AGAT Laboratories in Mississauga, Ontario and analysed for a variety of parameters, including grain size, general chemistry, nutrients, metals, pesticides and polycyclic aromatic hydrocarbons. The objective of this initial sediment testing was to compare contaminant levels to the Ontario Ministry of the Environment's *Soil, Ground Water and Sediment*

Standards for Use Under Part XV.I of the Environmental Protection Act (2011). Based on whether the sediment contaminant levels exceeded these standards, options for disposal or re-use of sediment could be considered and cost estimates for the alternative options could be compiled.

Results of this initial sediment quality analysis showed that contaminant levels exceeded the Soil, Ground Water and Sediment Standards, for re-use of the sediment on residential, parkland or institutional property. For both ponds, the parameters that exceeded the Standards included several hydrocarbons and the sodium adsorption ratio (SAR). Sediment from the Lansing Pond also had elevated levels of several heavy metals.

If the sediment, once dredged, was still found to contain these contaminant levels, re-use would not be permitted on residential, parkland or institutional property. If the contaminant levels were to exceed the previous guideline, but meet the guideline for industrial, commercial and community use, the sediment could be hauled to a licensed disposal facility. Ultimately, only the sediment quality at the time of hauling is relevant, and must comply with the Standards in order to be permitted for offsite re-use. At both ponds, sediment was resampled once it had been dredged, mixed with the polymer, and allowed to dry. Samples were again submitted to AGAT Laboratories for analysis, and during this second round, sediment contaminant levels were found to meet the Ministry of the Environment Standards, which meant that the material could be re-used offsite where the land use is parkland or residential/institutional land.

Site Preparation

The preparation of both sites began in October 2013 (Figure 2). In



3

Figure 2. Preparation of laydown areas for Lansing (left) ad SOSJ (right) ponds.



order to make the sites accessible for construction vehicles, it was necessary to create a clear path to the pond by removing several of the established trees and shrubs at both sites. The trees removed from the site were later chipped to make the mulch used to aid sediment drying.

Site preparation also involved the installation of erosion and sediment controls, including silt fencing and geotextile filter bags to be used during pond dewatering, and the installation or placement of equipment required for the project such as the pumps, hoses, super absorbent polymer bags, and heavy machinery.

Dewatering and Dredging

When applying mechanical dredging and onsite sediment drying in a pond cleanout project, it is beneficial to remove as much water from the pond as possible before dredging begins (Figure 3). At the start of dewatering for both ponds, water from the top of the water column was pumped out of the pond and discharged to the receiving watercourse. In both cases, gabion stones were in place at the discharge point, providing an erosion resistant path to the watercourse. During the dewatering process, geotex-tile sediment bags were installed at both sites to filter water being pumped out of the pond into the receiving watercourse.

Once dewatering was largely complete, the dredging process was initiated. A long reach excavator was used to scoop the wet sediment out of the pond, place it on the sediment drying/staging area on the pond banks, and mix the sediment with the super absorbent polymer. A skilled operator was retained to ensure that as much sediment as possible was removed from the pond without damaging the clay pond liner. Pond liners are installed during pond construction to minimize the exchange of water between the pond and the groundwater. This ensures that the appropriate permanent pool level is maintained and also that contaminants are not migrating out of the pond and into the groundwater.

POLYMER APPLICATION. The polymer product used at both sites to absorb water and improve the manageability of the wet sediment is LiquiSorb 2000[®]. The product contains both bentonite clay and polyacrylate superabsorbent polymer, and is specifically designed to absorb water from, and aid in solidification of, dredgeates or any industrial wastewater with high solids content. The polymer used in this product differs substantially from other polymers used for erosion control and water clarification (e.g. linear anionic polyacrylamide). While anionic polyacrylamide (PAM) binds sediment particles to one another so that the sediment becomes consolidated, the superabsorbent polymer simply absorbs water in the sediment mixture. Polyacrylate superabsorbent polymers are capable of absorbing a very large amount of water relative to their own mass, and as a result are very useful in personal hygiene products like baby diapers and as a soil additive to improve water retention for plants. They are also approved by the U.S. Food



Figure 3. Pumping of Lansing pond.



Figure 4. Sediment consistency after dewatering and prior to polymer application.



Figure 5. Polymer application using long reach excavators for spreading.

and Drug Administration for use in food packaging, such as the absorbent liners in packaged meats.

Prior to the addition of the polymer, wet sediment samples were collected and used to determine the quantity of polymer that should be applied to the excavated sediment. Due to the high moisture content of the sediment (Figure 4), a small depression was created within the sediment drying/staging area to contain the sediment dredgeate during the polymer application and mixing process. Once the appropriate dosage rate was determined, the LiquiSorb 2000[®] powder was sprinkled over the surface of the wet sediment. This was achieved by suspending a large bag of polymer from an excavator and cutting the bag open while suspended in the air above the sediment holding area (Figure 5). Dust masks were worn by onsite construction staff during this application and mixing process to avoid inhalation of wind-blown polymer dust. Once the polymer was applied, it was thoroughly mixed with the wet sediment using an excavator. It was then left to sit for up to 24 hours, giving the polymer the opportunity to absorb the water within the sediment dredgeate (Figure 6). The amount of time required for this process depends primarily on the water content in the dredgeate and the amount of polymer applied.

Sediment Hauling and Disposal

Once the polymer treated sediment was mixed and allowed to sit, slump tests were performed in order to determine whether the sediment had solidified enough to be hauled away (Figure 7). When the material was ready for hauling, it was transported to conservation lands in the City of Pickering, roughly 35 and 40 km away from the SOSJ and Lansing ponds, respectively. The sediment was used to fill an excavation from which contaminated soils had previously been removed. The lands are slated for development of recreational multi-use trails in the future.

Site Restoration

An effort was made to disturb as small an area as possible during dredging operations (Figure 8), and the intention was to leave the site in better condition than before the maintenance. Once all the sediment had been dredged, dried, and transported offsite, the sites were partially restored in preparation for the winter. Construction materials, including erosion and sediment controls and fencing, were removed and the sites were cleaned up and graded. The pond embankments were graded, seeded and covered in erosion control blankets. The blankets were put in place to prevent bank erosion and protect the seed so that it would germinate the following spring. Because the projects were completed in the fall of 2013, it was recognized that re-establishing vegetation would not be feasible due to cold weather conditions. As a result, the full restoration of the site, including planting of trees and shrubs, was planned for the following spring 2014. As part of the site restoration, an access path/road was left open to aid future maintenance activities.



Figure 6. Swelling of LiquiSorb particles following water absorption.



Figure 7. Consistency of sediment after polymer addition.



Figure 8. Preservation of natural features to the maximum extent feasible.





RESULTS

The dredging of the SOSJ and Lansing ponds were carried out successfully and as planned. The following summarizes the success of the projects relative to their objectives.

Removal of 790 m³ and 644 m³ of sediment from SOSJ and Lansing, respectively

There was a discrepancy between the initial sediment volume estimated and the actual volume of sediment removed. Part of this discrepancy may be explained by the difference between wet and dry sediment volumes. Sediment that are saturated contain more water which translates to larger volumes.

Diversion of sediment from landfill

The resampling of sediment prior to removal showed that sediment was not contaminated which enabled its re-use at parkland, residential or institutional land use types. The decision to resample the sediment prior to removal rather than rely on outdated information resulted in the diversion of the removed sediment from landfill facilities.

Completing the Project on Schedule and Within Budget

Both pond clean out projects were completed within approximately the amount of time projected during project planning. From the initiation of dewatering to the removal of dredged sediment from the site, the SOSJ project was completed in 4 weeks and the Lansing project in 3 weeks. The cost savings resulting from diverting dredged sediment from landfill was applied to cover the cost of the polymer.

Improved Pond Functioning

While suspended solids levels in pond effluents have not been measured since the dredging operations were complete, visual

observation suggests improved pond functioning. Water discharged from the ponds is visibly clearer (less turbid) than it was before the pond clean out projects were initiated.

CHALLENGES AND LESSONS LEARNED

One of the major challenges encountered during the cleanout projects was the occurrence of wet weather during the fall season. While the pond dewatering process was conducted during dry weather, maintaining the sediment in a dewatered state was found to be difficult due to rain events. For this reason, a polymer was introduced as a bulking agent.

The ideal season for mechanical dredging is late summer, when rainfall is at a minimum and evaporation is at a maximum. However, due to high demand for equipment and many ongoing seasonal projects, the driest parts of the summer do not always align with project timelines. Winter is also a viable season for mechanical dredging when resources are more readily available and subzero temperatures make removal of sediment and water easier.

It was found through this cleanout project that in situ sediments can have significantly different contaminant levels than dried sediment, suggesting that retesting dried sediment prior to selection of disposal is beneficial in some cases.

It should be anticipated that if a cleanout project occurs outside of the growing season, a full restoration of the site (i.e. planting) cannot be completed until the following spring. If the pond facility also provides a recreational function, a communication strategy would be required to reach out to local residents and groups, explaining the function of the facility and the necessity to perform maintenance. This communication can take the form of signs at the facility, pamphlets distributed within the neighbourhood, and a letter to inform the local municipal councilor.



For information on STEP's other stormwater management initiatives, or to access the new guidance on stormwater pond cleanouts, visit us online at www.sustainabletechnologies.ca

This case study has been prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program. Toronto and Region Conservation Authority's Restoration Services carried out the pond clean out project described herein, and provided the information and site access required for the development of this document. Funding support for this study was provided by Region of Peel, York Region, City of Toronto and Government of Canada's Great Lakes Sustainability Fund. The contents of this report do not necessarily represent the policies of the supporting agencies. For more information about this project, please contact STEP@trca.on.ca.



APPENDIX I

CASE STUDY

WINTER MECHANICAL DREDGING OF A STORMWATER POND



Winter Mechanical Dredging of a Stormwater Pond

CASE STUDY



INTRODUCTION

Stormwater ponds are commonly used in urban settings to control the quantity and quality of stormwater runoff. However, as ponds age, the level of accumulated sediment rises which ultimately displaces the potential volume available for water storage and treatment during storms.

Mechanical dredging is the method often used to clean out stormwater sediments from ponds. This is commonly achieved with an excavator or a clamshell (grab) bucket dredge. In order to conduct mechanical dredging, the pond water volume needs to be pumped out or drained. The remaining muck consists of an unconsolidated mixture that is difficult to dredge and often requires the addition of an absorbing material, such as a polymer, straw or wood chippings. Dredging during the winter can help to simplify the process because the water-based muck is nearly frozen or can rapidly freeze overnight, given favourable winter temperatures. Water in the pond can also be removed as chunks of ice, rather than waiting multiple days for water to be pumped out. These and other advantages can make the removal of sediment from ponds cheaper and quicker than if the same operation were carried out during warm weather. This case study showcases a winter pond dredging operation and provides insight into its benefits and drawbacks.

POND PROFILE

Municipality	City of Vaughan
Cleanout Party	Dynex Construction
Drainage Area Land Use	Mixed residential and com- mercial
Pond Age at Time of Cleanout	15 years
Drainage Area (ha)	13.4
Permanent Pool Volume (m ³ /ha)	99
Water Quality and Erosion Control Volume (m³/ha)	231
Sediment Removal Method	Mechanical Dredging
Sediment Handling Method	Landfill Disposal





SITE DESCRIPTION

The pond considered for this case study is known as Pond 51, located at the northeast corner of Major Mackenzie Drive and Jane Street in Vaughan, Ontario (Figure 1). A supermarket plaza is situated adjacent to the pond, and is part of the drainage area. Another pond on the other side of the plaza, Pond 50, receives the remaining development runoff. Pond 51 is a wetland facility with a sediment forebay that captures drainage from 13.4 ha of mixed residential and commercial areas with relatively high traffic parking lots (Figure 1). Outflow from the pond discharges into a tributary of the West Don River as part of the Don River Watershed. The surrounding area



Figure 1. Location of Pond 51 in Vaughan.

is mainly industrial, consisting of a Wonderland Amusement Park parking lot, and two large plazas at the northeast and southeast corners of the main intersection. To the west of the pond is a barren short grass field.

PROJECT OBJECTIVES

The primary objective of maintaining stormwater ponds is to restore their design flood and quality control capacity by removing sediment that has settled to the pond bottom over the course of its service. Pond 51 was constructed in 1994 when the development was built and has never been dredged. Based on a bathymetric survey carried out in 2003, it was estimated that 468 m³ of sediment needs to be removed from the detention wetland. This figure indicates that at the time of the survey, Pond 51 was 35% full relative to its original design. Thus, the objectives of this project were to:

- Remove the accumulated sediment;
- Provide improved access for machinery ;
- Minimize ecological disturbance to wildlife through wintertime dredging;
- Provide a larger sediment-drying area when vegetation is dormant.
- Complete the project on time and on budget.

METHODS

Pond Survey

The only known bathymetric survey of Pond 51 was conducted in 2003. A flat disk was attached to a long metal rod, which was submerged in the water until the bottom of the disk was positioned relatively flat on the pond bottom. A total station survey was used to obtain coordinates for the measurement locations so that the survey could be compared to the as-built drawing and future bathymetric surveys. The pond survey revealed that in 2003, there was 468 m³ of sediment volume that needed to be removed from the detention wetland. Additional sediment would have accumulated in the six years between the survey and the dredging operation.

Sediment Characterization

At the time when the bathymetric survey was conducted in 2003, sediment samples were extracted and submitted to a laboratory for testing. Testing included grain size analysis, general chemistry, nutrients, metals, pesticides and polycyclic hydrocarbons. The results were compared to the contaminant levels to Tables 1,2 and 3 of the *Ontario Ministry of Environment's Soil, Ground Water and Sediment Standards for Use Under Part XV.I of the Environmental Protection Act* (2011) to determine how the sediment should be disposed.

Results of this initial sediment quality analysis showed that contaminant levels exceeded the Soil, Ground Water and Sediment Standards for re-use of the sediment on residential, parkland or institutional property. It is presumed that even if the sediment met Table 1 standards, it would still be disposed at a landfill due to its high moisture content, presence of organics and overall visual appearance.

Site Preparation

The site preparation was initiated in December, 2009. The three day process included the installation of erosion and sediment controls, vegetation removal and access road preparation. The pond has two existing access roads - one at the north end of the pond and the other at the southeast end. A new access road was constructed at the south end of the pond to provide easy access to the sediment forebay and to avoid the clearing of vegetation that had grown over the two existing access roads.

Site preparation also involved the installation of erosion and sediment controls, including silt fencing and geotextile filter bags for use during pond dewatering, and the installation or placement of equipment required for the project such as pumps, hoses and heavy machinery. As the cleanout was scheduled for December, it was presumed that the ground would be frozen, providing a sturdy surface for the heavy machinery. Mean temperatures for the month of December, 2009 were -2.4 °C, although the daytime maximum temperature reached 10.5 °C on December 2. This wave of warm temperatures in the beginning of the month resulted in melting of ground frost, limiting site access.

Dewatering and Dredging

At the time of the pond cleanout, some of the water had frozen, which allowed the excavator to physically remove chunks of ice from the pond and place them on the pond banks. To ensure that mechanical dredging of pond sediment was efficient and successful, the pond was pumped out using a 3" pump nozzle and discharged into the receiving watercourse. The duration of the pumping was approximately 5 days, which coincided with dry weather and no antecedent rain events. Since the formation of an ice layer prevented the generation of turbulence in the pond, sediment had settled to the bottom, significantly reducing the turbidity of the water that was being pumped out. Geotextile sediment bags were laid out on a flat part of the ground and used to filter pumped water before it was discharged to the receiving stream. A challenge was presented due to melting snow originating from the pond banks and surrounding drainage area; this delayed the dewatering process.

The dewatering process was completed when it was determined that the remaining water could not be pumped out. It was integrated with the sediment at the bottom of the pond. Two excavators, each with a capacity of 3 tonnes, were used to scoop out the muck. (Figure 2). Due to continuously melting snow from the banks of the pond, the muck was very wet and introduced a challenge during the removal process. In general, to ensure that the clay liner is not damaged during the dredging process, a skilled and experienced worker



Figure 2. (Left) Excavator removing wet sediment at Pond 51; (Right) Close-up view of the wet sediment at the pond bottom. Sub-zero temperatures have contributed to some freezing of the water-based muck.

An Initiative of:



needs to be designated to operate the machinery. This is essential to the functioning of the pond, as a clay liner retains a minimum pond volume and prevents contaminants from entering the soil and groundwater reservoirs.

Sediment Hauling and Disposal

A designated drying area adjacent to the access road was used to spread the wet sediment out and allow it to dry and freeze. The drying/freezing took place over the span of 4-5 days. The frozen sed-iment passed the slump test, allowing it to be hauled to an off-site landfill. The total amount of removed sediment was approximately 600 m³ (80 truck loads), which was hauled to a landfill facility 60 km from the site.

Site Restoration

Vegetation clearing was required for the construction of one new access road. Nevertheless, as the other access roads were under-utilized, it was not necessary to remove any shrubs or trees, thereby greatly minimizing site restoration efforts. The only vegetation that required removal were cattails, which can regrow the following season without any additional restoration efforts. Construction materials that had been in place for an extended period of time were removed from the site, leaving behind noticeable alterations at the site. These materials included erosion and sediment control fencing, which were associated with settled sediment that required cleanup. These areas, as well as other heavily used spots, required topsoil amendment, decompaction and reseeding. Lastly, the heavily used access roads were repaired and cleaned from muck carried over by the machinery.

RESULTS

Removal of approximately 600 m³

Because the last bathymetric survey was in 2003, which provided an estimated sediment accumulation of 468 m³, the figure of 600 m³ is not surprising. Over the 6 years between the survey and cleanout, it is estimated that sediment accumulated at a rate of 22 m³/year or 1.64 m³/yr/ha. Over the 14 year life of the pond, sediment accumulated at an average rate of 63 m³/yr or 3.2 m³/yr/ha, which suggests that more rapid accumulation occurred during construction when the catchment was not full stabilized.

Completion of the project on schedule

The primary activities carried out as part of the clean out were site preparation which took 3 days, dewatering which took 5 days, dredging which took 10 days, and site restoration which occurred over the course of 4 days. Sediment was dried over the course of 4 or 5 days, during which some of these other activities listed above were also underway. In total, this pond cleanout was completed in 3 weeks. Although the project was completed within the expected timeframe, there were delays due to warm weather that increased the temperature of the ground, which made it difficult to mobilize the two 3 tonne hydraulic excavators close to the pond bed. Furthermore, melting snow on the pond banks increased the duration of the dewatering.

Completion of the project over budget

The project was completed over budget mainly as a result of the large time gap between the sediment survey in 2003 and the dredging operation in 2009. The budgeting did not take into account the volume of sediment accumulation that would have occurred within that time period.

Improved pond functioning

While suspended solids levels in pond effluents have not been measured since the dredging operations were complete, visual observation suggest improved pond functioning. Water discharged from the pond is visibly clearer (less turbid) than it was before the pond cleanout project was initiated.

Table 1. Actual project costs for dredging 600 m^3 of sediment from Pond 51. Costs are expressed as \$ per m^3 of removed sediment.

Category	Cost (per m ³ of removed sediment)	Details
Preliminary assessment	\$16.67	 Bathymetric survey of existing conditions. Review site information to determine the type & amount of work required. Calculate sediment volumes and test quality to assess contamination.
Site preparation	\$8.67	 Clearing of vegetation as needed. Install erosion and sediment controls, fencing and access roads. Installation of equipment (e.g. pumps, hoses).
Dredging and dewatering	\$27.50	- dewatering was done by a by-pass outlet
Hauling	\$64.17	- 600 m ³ of sediment hauled 60 km
Disposal	\$7.50	- Dump fee at \$7.50/m ³
Site restoration	\$10.83	 General site cleanup and removal of fencing. Re-grading, pond bank seeding and installation of erosion control blankets. Topsoil addition and decompaction and reseeding
Project Total	\$135.33	

CHALLENGES AND LESSONS LEARNED

The time when the pond was cleaned out was selected in order to minimize plant disturbance and take advantage of the cold December weather. However, an unexpected (although not atypical) warm stretch of weather in early December introduced complications. The ground had undergone melting, which made it difficult to mobilize the heavy machinery. This presented delays during the site dredging stage. The warm weather also caused the surrounding snow to melt back into the pond bed, which delayed dewatering and added new water during dredging that diluted the sediment. Additional challenges presented as a result of the timing were shorter day lengths that contributed to less efficient working conditions and the need for more resources (i.e. mobile construction lights).

During the implementation of future winter cleanout projects, it is important to anticipate changes in weather conditions, and if possible, avoid periods when warm conditions are likely to occur. To accomplish this, the initial project budget should include a designated window of time that is considerably longer than the anticipated time frame required for the operation to be completed. Under favourable weather conditions during the winter (i.e. prolonged sub-zero temperatures that result in frozen ground, frozen water, and rapid sediment freezing), the project will likely be completed on schedule and under budget, but flexibility needs to be built in to allow for contingencies. Additionally, conducting a bathymetric survey closer to the cleanout date would provide a better assessment of the amount of sediment that needs to be dredged, hauled and disposed. These factors make up large proportions of the budget and need to be estimated in greater detail.



For information on STEP's other stormwater management initiatives, or to access the new guidance on stormwater pond cleanouts, visit us online at www.sustainabletechnologies.ca

This case study has been prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program. Dynex Construction carried out the pond clean out project described herein, and as such provided the information and site access required for the development of this document. Funding support for this study was provided by Region of Peel, Region of York, City of Toronto and Government of Canada's Great Lakes Sustainability Fund. The contents of this report do not necessarily represent the policies of the supporting agencies. For more information about this project, please contact STEP@trca.on.ca.



APPENDIX J

CASE STUDY

WINTER MECHANICAL DREDGING OF A STORMWATER POND FOREBAY



Winter Mechanical Dredging of a Stormwater Pond Forebay

CASE STUDY



INTRODUCTION

Stormwater management ponds have been widely implemented since the 1990's to detain and remove pollutants from urban stormwater runoff. Their primary means of water quality improvement occurs through settling of pollutant-laden sediment under low turbulence conditions. Sediment removal efficiency decreases with pond age due to the accumulation of sediment that displaces pond volume available for treatment. As a result, stormwater ponds need to be dredged periodically in order to restore their storage capacity and their ability to retain sediment and associated contaminants coming in from the contributing drainage area.

Dredging of stormwater ponds is generally considered to be a seasonal activity, and often occurs towards the late summer months when the water level is at a minimum and evaporation is high. However, pond cleaning activities can take place year-round. Under the right conditions, winter operations have particular advantages that could result in less laborious and more cost-effective project outcomes. This case study highlights the process involved in winter operations that utilize mechanical dredging for cleaning a pond forebay.

POND PROFILE

Municipality	Town of Whitchurch-Stouffville
Cleanout Party	SCS Consulting
Drainage Area Land Use	Residential
Pond Age at Time of Cleanout	8 years
Drainage Area (ha)	14.55
Permanent Pool Depth (m)	1.85
Permanent Pool Volume (m ³ /ha)	179
Water Quality and Erosion Control Volume (m³/ha)	217
Sediment Removal Method	Mechanical Dredging
Sediment Handling Method	Landfill Disposal


The primary objective of any pond cleanout operation is to remove the sediment that has settled and accumulated at the bottom of the stormwater pond. Timely maintenance will significantly decrease the potential liability to the land owner (often the municipality) by ensuring the presence of the flood protection and water quality enhancement functions for which they were originally designed.

The developer, Geranium Corporation, contracted the cleanout of stormwater pond RC5 to Griffith Property Services, (administered by SCS Consulting Group Ltd.) to be completed during the winter of 2013-2014 for the purpose of assumption by the Town of Whitchurch-Stouffville. Based on a pre-cleaning bathymetric survey conducted by SCS Consulting in July 2013, it was estimated that 120 m³ of accumulated sediment needed to be removed from the sediment forebay in order to restore the pond to its original design storage capacity prior to assumption by the Town. In addition to the primary objective of removing this accumulated sediment for pond assumption, the pond cleanout project was also undertaken to meet the following objectives:

- Prevent the release of sediment to the receiving stream;
- Repair and re-instate the pond forebay berm back to design elevations;
- Remove any dead vegetation that has impaired the functionality of the pond;
- Re-plant pond banks and restore any other areas where vegetation removal was required for maintenance access;

- Complete dredging and associated activities on schedule;
- Complete dredging and associated activities on budget.

SITE DESCRIPTION

The RC5 pond in the Town of Whitchurch-Stouffville is located east of Highway 48, south of Bethesda Sideroad and north of Stouffville Road. The pond was constructed in 2006 as part the Northwest Stouffville Secondary Plan lands that incorporate approximately 385 ha of land. These lands are within the Rouge River watershed and drain to the Little Rouge Creek and the Stouffville Creek. The RC5 pond is servicing the Geranium Residential Development and outlets to the Little Rouge Creek. A 14.55 ha drainage area feeds residential stormwater runoff to the RC5 pond with a normal surface area of 2489 m² (Figure 1). The pond design includes two access roads at the northeast and southwest corners.

METHODS

The pond maintenance was scheduled during the winter months and ultimately took place in February, 2014 during subzero temperatures. The timing of the project ruled out the possibility of utilizing hydraulic dredging for this operation, and mechanical dredging was thus implemented. One of the sought-after advantages of cleaning the pond during the winter was to mechanically remove water in its solid state rather than pumping the full volume of water. The cold winter of 2013-2014 cooperated with the planned dredging operations. Long range weather reports were monitored in advance

of project commencement to select a time frame suitable for this work.

Pond Survey

The pre-cleaning bathymetric survey conducted by SCS Consulting took place in July, 2013. A Trimble R8 model GPS device was used to obtain high resolution pond bottom measurements with a 15 mm vertical accuracy (Figure 2). The device was attached to the top portion of a metal rod with a flat metal plate feeding into the bottom of the rod. A GPS reading was taken when the disk reached and rested on top of the sedi-



Figure 1. Location of Stouffville RC5 pond and associated drainage area. Aerial photo was captured prior to completion of the planned development.



Figure 2. Bathymetric survey of a pond using a rod, disk and a GPS unit.

ment. The original as-built survey was overlayed with the existing bathymetric survey, and the difference between the two measurements was used to determine the existing pond sediment volume. To increase the efficiency of the method, the as-built bathymetric survey was uploaded to the GPS device, which compared the live feed of GPS points to the uploaded as-built survey. This allowed the survey technicians to concentrate their measurements in areas that showed large depth deviations between the two surveys. This process increased the accuracy of the survey by isolating the sediment accumulation hot spots, capturing key pond contours and structures, and diverting efforts to those locations. Based on the survey, it was



Figure 3. Access road snow clearing and grading prior to pond dredging.

estimated that 120 m³ of sediment had to be removed from the RC5 pond. The entire volume was found to be concentrated in the pond sediment forebay area, eliminating the need to dewater and dredge the aftbay of the pond.

Sediment Characterization

Sediment samples were obtained on December 4, 2013. One grab sample was obtained from the north end of the pond adjacent to the headwall, and the other grab sample was obtained at the south end of the pond. Samples were submitted to AGAT Laboratories in Mississauga, Ontario and analyzed for metals, inorganics and petroleum hydrocarbons (F1-F4). The objective of this sediment testing was to compare contaminant levels to the *Ontario Ministry of Environment's Soil, Ground Water and Sediment Standards for Use Under Part XV.I of the Environmental Protection Act* (2011). Based on whether the sediment contaminant levels exceeded these standards, options for disposal or re-use of sediment could be considered and cost estimates for the alternative options could be compiled.

Results of this sediment quality analysis showed that contaminant levels met the thresholds in Table 1 of the Soil, Ground Water and Sediment Standards for residential, parkland or institutional property. As such, the material was considered inert and could be re-used on offsite if a receiving site was available.

Site Preparation

The stormwater pond had been designed with two access roads, which improved the site access and preparation process (Figure 3). As these roads had not been in use for an extended period of time, some regrading and snow clearing was required to ensure that the machinery had a safe and stable access route. The timing of the dredging operations nearly eliminated the need for vegetation clearing to ensure clear access for equipment.

A single geotextile filter bag was placed over a nearby drain that joins to the pond outlet. Site preparation also included the installation or placement of equipment required for the project such as pumps, hoses and heavy machinery.

Dewatering and Dredging

Unlike hydraulic dredging, mechanical dredging requires that the maximum possible amount of water is removed from the pond before dredging operations begin. Due to the timing of operations and relatively cold winter, the pond had frozen almost to the bottom, resulting in an ice layer that was 375 mm thick, leaving very little water that needed to be pumped (Figure 4). A hole was punctured in the ice through which a 3" pump nozzle was inserted. The pumped





Figure 4. Pumping of sediment forebay water through the ice layer (left) which was 375 mm thick (right).

water was directed to a 4 m² geotextile sediment bag, which retained less than 0.1 m³ of sediment. Filtered water from the bag was directed back into the aftbay of the pond. The frozen layer of ice restricted the generation of turbulence in the pond, thereby allowing the sediment to settle to the bottom. This resulted in relatively clean discharge from the outlet, as suspended sediment was minimal.

The ice removal and dredging activities were conducted simultaneously; the excavator moved further into the center of the forebay after removing the ice and dredging newly exposed sections (Figure 5). A CAT 330 excavator was used to break the forebay ice into chunks and move them into the aftbay area of the pond. The frozen state of the water made the work easier as it allowed the ice to be moved around as a solid material. The ice remained in the aftbay until warmer spring weather redistributed the meltwater throughout the entire pond.

The same excavator was used to dredge the nearly frozen pond bottom sediment from the pond sediment forebay area. The lack of vegetation and cattails at the perimeter of the pond allowed the excavator to freely move around the edges of the forebay and work its way towards the center without sinking into pond muck. When the excavator reached about 2/3 of the way to the center of the forebay, it was estimated that the required amount of sediment had



Figure 5. Ice break-up and removal by a mechanical excavator (left); exposed pond sediment forebay bottom after ice has been removed and some sediment had been dredged.

been removed from the pond.

Sediment Hauling and Disposal

The removed sediment was left in 20 m³ stockpiles near the north access road and left to drain and freeze overnight, eliminating the need for bulking material. The following day, the frozen material was hauled on dump trucks. A small amount of completely dry material was imported and used to seal the trucks tail gates to prevent spillage during transportation. The sediment was hauled away in approximately 12 truckloads and transported for re-use at another of the contractor's construction sites. The location was chosen by the contractor due to the site fill requirements and proximity to the pond (12 km).

Site Restoration

Given the time of year when the dredging was conducted, the presence of vegetation did not introduce a major obstacle to the process. A number of cattails were removed at the banks of the pond for ease of access. The presence of two access roads eliminated the need to cut down any trees, which ultimately minimized the site restoration activities. Some re-grading of the access roads was necessary to ensure the optimal function and safety of the pond perimeter and ease of future access.

RESULTS

The dredging of the Stouffville RC5 pond was carried out successfully and as planned. Assumption of the pond took place at the end of the first growing season to ensure that the facility functioned properly and had been adequately restored. The following summarizes the success of the project relative to its objectives.

Removal of 120 m³ of sediment.

The initial estimated volume of sediment to be removed based on the pre-dredging bathymetric survey was an accurate estimate of the actual amount of removed sediment. However, it is important to note that the dredging operations were discontinued once the intended volume of sediment had been dredged, which leaves little room for discrepancy between the estimated and actual volume of sediment. SCS Consulting conducted a post-dredging survey to ensure that the actual amount of sediment had been removed from the pond and its storage volume had been restored.

Completion of the project on schedule.

The project was completed earlier than scheduled, mainly due to favorable weather needed for winter pond dredging operations. The temperatures remained at subfreezing levels during the process,

ensuring that ice chunks could be easily mobilized to their intended locations. No seepage occurred, little water needed to be pumped, and minimal flora disturbance was necessary.

Completion of the project on budget.

The project was completed on budget (Table 1), due to favourable weather conditions and expected volume of dredged sediment. The lack of water seepage and rain during the period ensured that pumping was not prolonged more than necessary.

Improved pond functioning.

The berm separating the sediment forebay and aftbay was restored and elevated by 20 cm to improve the overall pond functioning. Additionally, the removed sediment restored the original pond design storage volume, ensuring that the pond provides satisfactory flood control and water quality functions.

Table 1. Actual project costs for dredging 120 m³ of sediment from the Stouffville RC5 pond. Costs are expressed as \$ per m³ of removed sediment.

Category	Cost (per m ³ of removed sediment)	Details
Preliminary assessment	\$50.00	- Topographic and bathymetric survey of pre- and post-dredging conditions
		 Review site information to determine the type & amount of work required.
		 Calculate sediment volumes and test quality to assess contamination.
Site preparation	\$10.00	- Clearing of vegetation as needed.
		 Install erosion and sediment controls, fencing and snow clearing and re-grading of access roads. Installation of equipment (e.g. pumps, hoses).
Dredging and dewatering	\$20.83	- Equipment, labor and supplies.
Hauling	\$20.83	- 120 m ³ of sediment hauled 12 km.
Disposal	\$20.00	- Sediment hauled to the contractor's re- use site.
Site restoration	\$6.67	- General site cleanup and removal of fencing.
		 Re-grading, pond bank seeding and installation of erosion control blankets.
Project Total	\$128	

CHALLENGES AND LESSONS LEARNED

Overall, the project was conducted as planned, mainly due to the suitable weather during the scheduled cleanout period. Since the cleanout of the RC5 stormwater pond was conducted during the winter, an anticipated challenge for the workers was the cold weather and shorter working days. Additionally, the pump did not operate adequately and the hose froze on multiple occasions due to persistently frigid weather. The winter conditions also presented a slip and fall hazard, which was minimized through a harness worn by each worker.

Despite the challenges outlined above, conducting pond cleanout operations during the winter comes with many advantages, mainly associated with the frozen state of the water. The frozen pond water volume was easily removed from the forebay and placed within the aftbay, eliminating the need to pump large volumes of water into the receiving creek. Since nearly all sediment had settled out during the freezing process, the decision to leave the chunks of ice in the pond to eventually melt did not pose a risk of reintroducing sediment into the pond after the dredging was finished. The ice formation and sediment settling resulted in minimal suspended sediment retention within the geotextile bag during the pumping of the remaining water. The cold temperatures also resulted in minimal mud tracking and required restoration due to the frozen ground surface and sediment, which allowed the machinery to move around and within the pond bed. The cold weather also contributed to a nearly frozen state of the dredged sediment after settling overnight, eliminating potential slump test issues during hauling. Removal and restoration of vegetation was not an issue since the cleanout was conducted during the winter. Finally, local residents are less likely to use their backyards and the location as a recreational facility during the winter months, which significantly reduces the chance of resident complaints about lack of access, noise, dust and smell.

This case study outlined numerous advantages of pond dredging operations during the winter. However, the success of such projects is highly dependent on the weather, which is beyond the control of the individuals undertaking those projects. Building in flexibility to allow operations to occur when long term forecasts indicate the presence of favourable weather conditions can help, but pond owners need to budget for contingencies, when despite best efforts, suitable weather conditions fail to materialize.



For information on STEP's other stormwater management initiatives, or to access the new guidance on stormwater pond cleanouts, visit us online at www.sustainabletechnologies.ca

This case study has been prepared by the Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program. SCS Consulting Ltd. carried out the pond clean out project described herein, and as such provided the information and site access required for the development of this document. Funding support for this study was provided by Region of Peel, Region of York, City of Toronto and Government of Canada's Great Lakes Sustainability Fund. The contents of this report do not necessarily represent the policies of the supporting agencies. For more information about this project, please contact STEP@trca.on.ca.



INSPECTION AND MAINTENANCE GUIDE FOR STORMWATER MANAGEMENT PONDS AND CONSTRUCTED WETLANDS

2016

Sustainable Technologies Evaluation Program www.sustainabletechnologies.ca

