August 2005
05/22/WQPC-WWF
EPA/600/R-05/138

Environmental Technology Verification Report

Stormwater Source Area Treatment Device

Stormwater Management, Inc. CatchBasin StormFilter™

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

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Stormwater Source Area Treatment Device

Stormwater Management, Inc.
CatchBasin StormFilter™

Prepared for:

NSF International
Ann Arbor, Michigan 48105

Prepared by:

Environmental Consulting & Technology, Inc.
Detroit, Michigan 48226

Under a cooperative agreement with the U.S. Environmental Protection Agency

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Edison, New Jersey 08837

August 2005

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**STORMWATER TREATMENT TECHNOLOGY**	
APPLICATION:	**SUSPENDED SOLIDS AND ROADWAY POLLUTANT TREATMENT**	
TECHNOLOGY NAME:	**THE STORMWATER MANAGEMENT CATCHBASIN STORMFILTER™**	
TEST LOCATION:	**ST. CLAIR SHORES, MICHIGAN**	
COMPANY:	**STORMWATER MANAGEMENT, INC.**	
ADDRESS:	**12021-B NE Airport Way** **Portland, Oregon 97220**	PHONE: **(800) 548-4667** FAX: **(503) 240-9553**
WEB SITE:	**http://www.stormwaterinc.com**	
EMAIL:	**mail@stormwaterinc.com**	

NSF International (NSF), in cooperation with the U.S. Environmental Protection Agency (EPA), operates the Water Quality Protection Center (WQPC), one of six centers under the Environmental Technology Verification (ETV) Program. The WQPC recently evaluated the performance of the CatchBasin StormFilter™ (CBSF) manufactured by Stormwater Management, Inc. (SMI), of Portland, Oregon. The CBSF was installed at the St. Clair Shores Department of Public Works (DPW) yard in St. Clair Shores, Michigan. Environmental Consulting & Technology, Inc. (ECT) of Detroit, Michigan performed the testing.

The ETV program was created to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups, which consist of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

TECHNOLOGY DESCRIPTION

The following description of the CBSF was provided by the vendor and does not represent verified information.

The four-cartridge CBSF consists of a storm grate and filter chamber inlet bay, flow spreader, cartridge bay, overflow baffle, and outlet bay, housed in a 10.25 ft by 2 ft steel vault. The inlet bay serves as a grit chamber and provides for flow transition into the cartridge bay. The flow spreader traps floatables, oil, and surface scum. This StormFilter was designed to treat stormwater with a maximum flow rate of 60 gpm. Flows greater than the maximum flow rate would pass the overflow baffle to the discharge pipe, bypassing the filter media.

The CBSF contains filter cartridges filled with SMI's CSF filter media (an organic granular media made from composted deciduous leaves), which is designed to remove sediments, metals, and other stormwater pollutants from wet weather runoff. Water in the cartridge bay infiltrates the filter media into a tube in the center of the filter cartridge. When the center tube fills, a float valve opens and a check valve on top of the filter cartridge closes, creating a siphon that draws water through the filter media. The filtered water drains into a manifold under the filter cartridges and to the outlet bay, where it exits the system through the discharge pipe. The system resets when the cartridge bay is drained and the siphon is broken. The CBSF is equipped with an overflow weir designed to bypass flows exceeding the peak hydraulic treatment capacity and prevent catch basin backup and surface flooding. The bypass flow is discharged through the outlet pipe along with the treated water.

The vendor claims that a single StormFilter cartridge configured to treat flows at 15 gpm using a coarse perlite media was shown to have a TSS removal efficiency of 79% (with 95% confidence limits of 78% and 80%) for a sandy loam material comprised of 55% sand, 45% silt, 5% clay (USDA) by mass, in laboratory studies using simulated stormwater, and can also remove metals and oil and grease from wet-weather flows. The vendor did not provide specific claims for the removal efficiency of the CSF media, used in this verification. Further detail about the specific vendor claims appears in the verification report.

VERIFICATION TESTING DESCRIPTION

Methods and Procedures

The test methods and procedures used during the study are described in the *Test Plan for Stormwater Management, Inc. Storm Filter*, November 5, 2002. The CBSF received runoff collected from an impervious 0.16-acre portion of the DPW yard, where uncovered stockpiles of sand, gravel, construction debris and excavated aggregate consisting of sand, silt, topsoil and clay, are maintained. Southeast Michigan receives an annual average of nearly 37 in. of precipitation, and experiences warm to hot summers and cold, snowy winters.

Verification testing consisted of collecting data during a minimum of 15 qualified events that met the following criteria:

- The total rainfall depth for the event, measured at the site, was 0.2 in. (5 mm) or greater (snow fall and snow melt events did not qualify);
- Flow through the treatment device was successfully measured and recorded over the duration of the runoff period;
- A flow-proportional composite sample was successfully collected for both the influent and effluent over the duration of the runoff event;
- Each composite sample was comprised of a minimum of five aliquots, including at least two aliquots on the rising limb of the runoff hydrograph, at least one aliquot near the peak, and at least two aliquots on the falling limb of the runoff hydrograph; and
- There was a minimum of six hours between qualified sampling events.

Automated monitoring and sample collection devices were installed to collect composite samples from the influent and effluent during qualified flow events. Additional influent and effluent sample ports were also installed so that discrete samples could be collected by manually actuating peristaltic pumps to collect samples for hydrocarbon analysis. In addition to the flow and analytical data, operation and maintenance (O&M) data were recorded. Samples were analyzed for the following parameters:

Sediments
- total suspended solids (TSS)
- suspended sediment concentration (SSC)

Metals
- total and dissolved cadmium, lead, copper and zinc

Hydrocarbons
- total petroleum hydrocarbons (TPH), gasoline-range organics (GRO) and diesel-range organics (DRO)
- polynuclear aromatic hydrocarbons (PAH)

VERIFICATION OF PERFORMANCE

Verification testing of the CBSF lasted approximately 13 months, with four months off during the winter of 2004. Sixteen storm events were successfully sampled. However, due to problems with the automated sampling equipment in 2003, ECT collected flow-weighted aliquots for all analyses by manually actuating the peristaltic pump for events 1 through 6 and event 8. During remobilization in the spring of 2004, ECT and SMI debugged the automated sampling equipment, and for all subsequent events, samples for sediment and metals analyses were collected with the automated sampling equipment.

Test Results

The ETV protocol and test plan do not specify maximum sediment concentration in stormwater, nor did SMI's literature specify a maximum sustained concentration for their stormwater treatment devices to function effectively. However, the vendor, TO, and VO recognized that the sediment loadings in this drainage basin were atypical, and exceeded a concentration and mass loading range in which a valid measure of the removal performance of the CBSF could be conducted. According to the vendor, the four-cartridge CBSF has a maximum sediment storage capacity of 27 ft^3 or 200 gal in the sump, plus a maximum of 100 lb in the cartridges (25 lb per cartridge). The influent calculated sum of loads (SOL) mass for TSS and SSC was approximately 2,000 lb for all events. Based on SOL calculations, the sediment loadings for qualified events likely exceeded the CBSF sediment capacity after only a few events.

The precipitation data for the rain events are summarized in Table 1. The peak runoff intensity exceeded the CBSF peak hydraulic treatment capacity of 60 gpm during 10 of the 16 events, which means that a portion of the flow bypassed the filtering process during these events. During high flow conditions, the effluent includes both filtered and unfiltered water, so these values do not represent the performance of the system under designed flow conditions. Recorded flow volumes were substantially higher than predicted using the rational method, especially during events with higher peak discharge rates.

The monitoring results were evaluated using event mean concentration (EMC) and SOL comparisons. The EMC or efficiency ratio comparison evaluates treatment efficiency on a percentage basis by dividing the effluent concentration by the influent concentration and multiplying the quotient by 100. The efficiency ratio was calculated for each analytical parameter and each individual storm event. The SOL comparison evaluates the treatment efficiency on a percentage basis by comparing the sum of the influent and effluent loads (the product of multiplying the parameter concentration by the precipitation volume) for all storm events. The calculation is made by subtracting the quotient of the total effluent load divided by the total influent load from one, and multiplying by 100. SOL results can be summarized on an overall basis since the loading calculation takes into account both the concentration and volume of runoff from each event. The analytical data ranges, EMC range, and SOL reduction values are shown in Table 2.

Table 1. Rainfall Data Summary

Event Number	Start Date	Start Time	Rainfall Amount (in.)	Rainfall Duration (hr:min)	Runoff Volume (gal)	Peak Discharge Rate (gpm)
1	9/22/03	7:40	0.31	1:45	2,990	196
2	9/26/03	23:50	0.26	2:00	1,510	44
3	10/14/03	11:14	0.68	6:30	2,950	41
4	11/18/03	7:50	0.44	17:45	4,940	13
5	11/24/03	4:09	0.33	10:45	17,900	99
6	12/10/03	14:05	0.75	7:45	19,800	85
7	12/23/03	3:34	0.42	10:30	11,200	85
8	12/29/03	8:25	0.31	7:45	2,270	9
9	1/1/04	21:51	0.20	2:30	868	10
10	5/10/04	22:26	0.29	3:30	4,450	273
11	5/23/04	18:45	1.39	3:45	22,500	335
12	6/10/04	13:09	0.28	2:30	5,030	171
13	7/7/04	15:12	0.30	1:45	3,700	274
14	7/14/04	16:25	0.18	0:45	3,330	175
15	8/28/04	7:21	0.52	2:45	10,100	223
16	10/23/04	19:25	0.21	4:30	3,970	39

Table 2. Analytical Data, EMC Range, and SOL Reduction Results

Parameter	Units	Influent Range	Effluent Range	EMC Range (%)	SOL Reduction (%)
TSS	mg/L	1,100 – 5,200	570 – 8,600	-120 – 63	11
SSC	mg/L	930 – 9,100	700 – 12,000	-44 – 53	9.2
Total cadmium	µg/L	0.6 – 44	<0.2 – 7.6	-41 – 87	52
Total copper	µg/L	6.0 – 390	6.6 – 250	-64 – 42	20
Total lead	µg/L	15 – 580	3.2 – 200	-47 – 79	20
Total zinc	µg/L	72 – 1,800	24 – 1,100	-82 – 70	29
Dissolved cadmium[1]	µg/L	<0.2 – 2.0	<0.2 – 1.8	-9 – 10	-20
Dissolved copper[1]	µg/L	<1.0 – 35	<1.0 – 120	-3,400 – 31	-34
Dissolved lead[1]	µg/L	<1.0 – 49	<1.0 – 80	-560 – 33	-0.44
Dissolved zinc[1]	µg/L	<2.0 – 200	<2.0 – 170	-3,400 – 69	-3.9
TPH-GRO	µg/L	<100 – <100	<100 – <100	NC	NC
TPH-DRO	mg/L	<0.001 – 52	<0.001 – 19	-41 – 93	62
PAH[2]	µg/L	<1.0 – 7.5	<1.0 – 3.6	52 – 81	64

1. Negative EMC values for dissolved metals were skewed by non-detected concentrations in the influent sample and detected concentrations in the paired effluent sample.2. Ten of 17 PAH compounds were detected only during events 4, 12, and 14. PAH SOL reduction calculated from sum of all detected PAH compounds during these three events.

NC: Not calculated.

In spite of the excessive sediment loadings, the sediment SOL data were further evaluated to assess the performance impacts of maintenance activities and events where bypass did not occur. This data indicated a 34% TSS SOL reduction for the first three events following maintenance, as compared to a 3.1% reduction for all other events. Furthermore, the data indicated a 40% SSC SOL reduction for events where bypass did not occur, compared to a 1.5% reduction for events where bypass occurred.

System Operation

The StormFilter was installed by DPW personnel, under the supervision of ECT. The installation took approximately two days. No major problems with the CBSF were noted during installation; however, pipe scaling and blockage downstream of the CBSF was detected after the CBSF was installed. Addressing this issue delayed the start of verification testing.

The CBSF was cleaned and equipped with new filter cartridges prior to the start of verification and in the spring of 2004, before verification resumed after winter demobilization, and at the end of verification. The CBSF vaults are easily accessible from the ground surface, which makes cartridge replacement and sediment removal easy. According to the vendor, spent filter cartridges weigh approximately 250 lb each, and, if mishandled, can cause damage to the PVC under-drain manifold in the vault.

The CBSF's PVC under-drain manifold was not fully assembled when it was delivered to the DPW, and became disassembled during the shakedown period. The TO dry fit the manifold components when verification testing began. The first two events were sampled with the manifold either partially disassembled or dry fit but not sealed. When SMI was informed of this condition, they responded by sending a repair technician to the DPW to properly assemble and seal the manifold.

Vendor Comments

The vendor included a chapter in the verification report asserting that the data were collected from filters that were severely impacted by exceedingly high solids loads, sampled in a completely occluded condition, and that the sediment loadings and concentrations experienced at the site were substantially higher than the range they would recommend for usage of the CBSF without site controls or pretreatment.

Quality Assurance/Quality Control

NSF personnel completed a technical systems audit during testing to ensure that the testing was in compliance with the test plan. NSF also completed a data quality audit of at least 10% of the test data to ensure that the reported data represented the data generated during testing. In addition to QA/QC audits performed by NSF, EPA personnel conducted an audit of NSF's QA Management Program.

Original signed by: *Sally Gutierrez 10/3/05*	*Original signed by:* *Robert Ferguson 10/5/05*
Sally Gutierrez Date Director National Risk Management Laboratory Office of Research and Development United States Environmental Protection Agency	Robert Ferguson Date Vice President Water Systems NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the *ETV Verification Protocol, Stormwater Source Area Treatment Technologies Draft 4.1, March 2002,* the verification statement, and the verification report (NSF Report Number 05/22/WQPC-WWF) are available from:

ETV Water Quality Protection Center Program Manager (hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140

NSF website: http://www.nsf.org/etv (electronic copy)
EPA website: http://www.epa.gov/etv (electronic copy)
Appendices are not included in the verification report, but are available from NSF upon request.

Notice

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development, has financially supported and collaborated with NSF International (NSF) under a Cooperative Agreement. The Water Quality Protection Center (WQPC), operating under the Environmental Technology Verification (ETV) Program, supported this verification effort. This document has been peer reviewed and reviewed by NSF and EPA and recommended for public release. Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use, nor does it constitute certification by NSF.

Foreword

The following is the final report on an Environmental Technology Verification (ETV) test performed for NSF International (NSF) and the United States Environmental Protection Agency (EPA). The verification test for the Stormwater Management, Inc. CatchBasin StormFilter™ Treatment System was conducted at the City of St. Clair Shores Department of Public Works (DPW) facility located in St. Clair Shores, Michigan.

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Contents

Tables

Figures

Acronyms and Abbreviations

BMP	Best management practice
CBSF	Catch Basin StormFilter
cfs	Cubic feet per second
CSF	CSF leaf media
DPW	Department of Public Works
DRO	Diesel-range organic compounds
ECT	Environmental Consulting & Technology, Inc.
EMC	Event mean concentration
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ft^2	Square feet
ft^3	Cubic feet
g	Gram
gal	Gallon
gpm	Gallon per minute
GRO	Gasoline-range organic compounds
in.	Inch
L	Liter
lb	Pound
LOD	Limit of detection
LOQ	Limit of quantification
mg	Milligram
mg/L	Milligram per liter (ppm)
mL	Milliliter
μg/L	Microgram per liter (ppb)
μm	Micron
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
PAH	Polynuclear aromatic hydrocarbons
psi	Pounds per square inch
QA	Quality assurance
QC	Quality control
RTD	Rapid transfer device
RTI	RTI Laboratories, Inc.
SMI	Stormwater Management, Inc.
SSC	Suspended sediment concentration
SOL	Sum of loads
SOP	Standard operating procedure
TO	Testing organization (ECT)
TSS	Total suspended solids
USGS	United States Geological Survey
VO	Verification organization (NSF)
WQPC	Water Quality Protection Center

Chapter 1
Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The ETV Program's goal is to further environmental protection by substantially accelerating the acceptance and use of innovative, improved, and more cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; stakeholder groups that consist of buyers, vendor organizations, consulting engineers, and regulators; and the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF) operates the Water Quality Protection Center (WQPC) in cooperation with EPA. The WQPC evaluated the performance of the Stormwater Management, Inc. (SMI) CatchBasin StormFilter™ (CBSF), a stormwater treatment device designed to remove sediments from wet weather runoff.

It is important to note that verification of this equipment does not mean that the equipment is "certified" by NSF or "accepted" by EPA. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures.

1.2 Testing Participants and Responsibilities

The ETV testing of the CBSF was a cooperative effort among the following participants:

- NSF
- EPA
- Environmental Consulting & Technology, Inc. (ECT)
- RTI Laboratories, Inc. (RTI)
- SMI

The following is a brief description of each ETV participant and its roles and responsibilities.

1.2.1 U.S. Environmental Protection Agency

The EPA Office of Research and Development, through the Urban Watershed Branch, Water Supply and Water Resources Division, NRMRL, provides administrative, technical, and QA guidance and oversight on all ETV WQPC activities. EPA reviewed and approved each phase of the verification project. EPA provides financial support for the operation of the Center and provided partial support for the cost for this verification test.

EPA's responsibilities with respect to this verification test included:

- verification test plan review and approval;
- verification report review and approval; and
- verification statement review and approval.

The key EPA contact for this program is:

Mr. Ray Frederick, ETV WQPC Project Officer
(732) 321-6627 email: Frederick.Ray@epamail.epa.gov

U.S. EPA, NRMRL
Urban Watershed Management Research Laboratory
2890 Woodbridge Avenue (MS-104)
Edison, New Jersey 08837-3679

1.2.2 NSF – Verification Organization

The WQPC is administered through a cooperative agreement between EPA and NSF. NSF is a not-for-profit testing and certification organization dedicated to public health, safety, and protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in the development of consensus standards for the protection of public health and the environment. NSF also provides testing and certification services to ensure that products bearing the NSF name, logo and/or mark meet those standards.

NSF personnel provided technical oversight throughout the verification process. NSF also provided review of the test plan and this verification report.

NSF's responsibilities as the verification organization (VO) included:

- reviewing and commenting on the test plan;
- coordinating with peer reviewers to review and comment on the test plan;
- coordinating with the EPA Project Officer and the technology vendor to approve the test plan prior to initiation of verification testing;
- reviewing the quality systems of all parties involved with the testing organization (TO), and subsequently, qualify the TO;
- overseeing the technology evaluation and associated laboratory testing;
- conducting an on-site audit of test procedures;

- providing quality assurance/quality control (QA/QC) review and support for the TO;
- overseeing the development of a verification report and verification statement; and
- coordinating with EPA to approve the verification report and verification statement.

Key contacts at NSF for the VO are:

Mr. Thomas Stevens, P.E. (734) 769-5347	Program Manager email: stevenst@nsf.org
Mr. Patrick Davison, (734) 913-5719	Project Coordinator email: davison@nsf.org
Ms. Maren Roush, (734) 827-6821	Project Coordinator email: mroush@nsf.org

NSF International
789 Dixboro Road
Ann Arbor, Michigan 48105

1.2.3 Testing Organization

The TO for the verification test was Environmental Consulting & Technology, Inc. (ECT) of Detroit, Michigan. ECT's Project Manager provided project oversight. ECT's responsibilities included:

- ensuring that the testing location and conditions allowed for the verification test to meet its stated objectives;
- preparing the test plan;
- overseeing the verification test in accordance with the test plan;
- scheduling and coordinating activities for the test participants, including establishing a communication network and providing logistical and technical support as needed;
- collecting, managing, evaluating, interpreting and reporting the test data and the performance of the technology;
- resolving any quality concerns encountered during the test; and
- reporting all findings to the VO.

The key personnel and contacts for ECT are:

Ms. Annette DeMaria, (313) 963-6600	Project Manager email: ademaria@ectinc.com
Ms. Olivia Olsztyn-Budry, (313) 963-6600	Field Manager email: oolsztyn@ectinc.com

Environmental Consulting & Technology, Inc.
719 Griswold Street, Suite 520
Detroit, Michigan 48226

1.2.4 Analytical Laboratory

RTI Laboratories, Inc. (RTI), located in Livonia, Michigan, analyzed the stormwater samples for the parameters identified in the test plan and arranged for sample pickup from the test site.

The key analytical laboratory contacts are:

Mr. David Vesey, Project Manager
(734) 422-8000 email: dvesey@rtilab.com

Mr. Lloyd Kaufman, Quality Assurance Officer
(734) 422-8000 email: lkaufman@rtilab.com

RTI Laboratories, Inc.
31628 Glendale Ave.
Livonia, Michigan 48150

1.2.5 Technology Vendor

SMI, of Portland, Oregon, is the vendor of the CBSF. SMI was responsible for supplying a field-ready CBSF and making sure that the equipment was properly installed and operated during the verification test. SMI was also responsible for providing technical support, and was available during the verification test to provide technical assistance as needed.

Specific responsibilities of the vendor during the verification period included:

- initiating the application for ETV testing;
- providing input regarding the verification testing objectives to be incorporated into the test plan;
- providing complete, field-ready equipment and the O&M manual(s) typically provided with the technology (including instructions on installation, startup, operation, and maintenance) for verification testing;
- providing any existing relevant performance data for the technology;
- providing assistance to the TO on the operation and monitoring of the technology during the verification testing, and logistical and technical support, as required;
- reviewing and approving the site-specific test plan;
- reviewing and commenting on the verification report; and
- providing funding for verification testing.

The key contact for SMI is:

Mr. James Lenhart, P.E. Senior Vice President
(800) 548-4667 email: jiml@stormwaterinc.com

Stormwater Management, Inc.
12021-B NE Airport Way
Portland, Oregon 97220

1.2.6 ETV Test Site

The CBSF was installed at the City of St. Clair Shores Department of Public Works (DPW) facility in St. Clair Shores, Michigan. DPW personnel installed and maintained the CBSF system with assistance and supervision from ECT.

The key contact for the City of St. Clair Shores DPW is:

Mr. John Chastain, Sewer Department Supervisor
(586) 445-5363 email: johnc@scsmi.net

City of St. Clair Shores Department of Public Works
19600 Pleasant Street
St. Clair Shores, Michigan 48080

Chapter 2
Technology Description

The following technology description data was supplied by the vendor and does not represent verified information.

2.1 Technology Description

The CBSF is a device designed to remove stormwater pollutants from wet-weather flows. A schematic of a single-cartridge CBSF is shown in Figure 2-1. The CBSF comes in configurations ranging from one to four cartridges. The verified CBSF was configured with four cartridges. The four-cartridge CBSF consists of a sumped inlet chamber, four filter cartridges in two separate cartridge bays, and an overflow weir, all housed in a steel catch basin structure. All of the CBSF configurations operate on the same basic principle. Runoff enters the sumped inlet chamber through a catch basin grate by sheet flow from a paved surface. The inlet chamber is equipped with an internal baffle designed to trap debris and floating oil and grease, and an overflow weir. While in the inlet chamber, heavier solids are allowed to settle through a port between the baffle and the overflow weir. Once in the cartridge chamber, polluted water ponds and percolates horizontally through the media in the filter cartridges. Treated water collects in the cartridge's center tube. From there, the treated water is directed by an under-drain manifold to the outlet pipe on the downstream side of the overflow weir and is discharged to the outlet pipe.

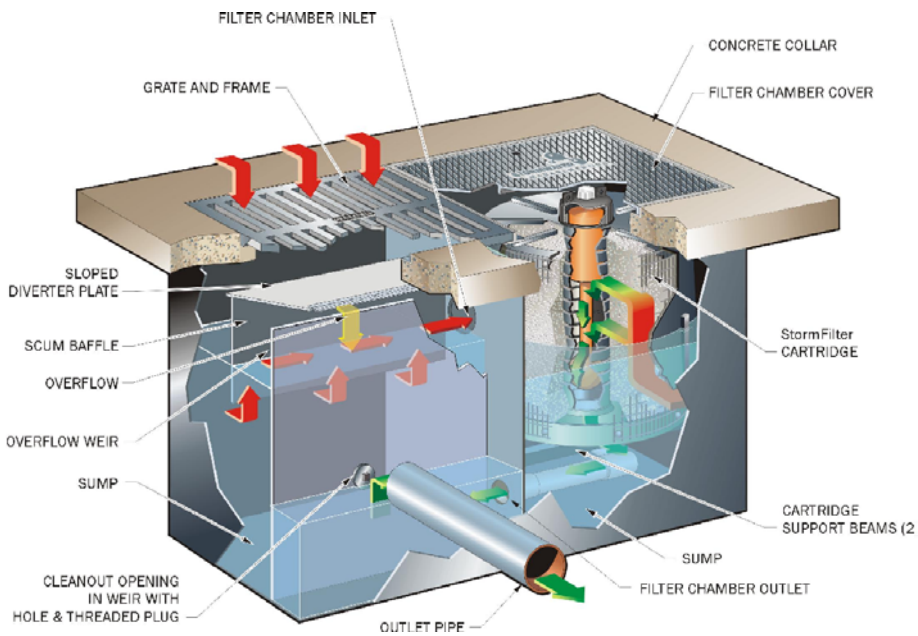

Figure 2-1. Schematic drawing of a single-cartridge CatchBasin StormFilter.

2.2 Product Specifications:

Four-cartridge CBSF:

- Housing – steel vault
- Dimensions – 10.25 ft long, 2 ft wide, 3.75 ft deep
- Peak hydraulic treatment capacity – 60 gpm (0.13 cfs), or 15 gpm per cartridge
- Bypass capacity – 448 gpm (1 cfs)
- Debris storage capacity – 1 yd^3 or 200 gal in the cartridge chamber, and 4 ft^3 or 28 gal in the inlet bay
- StormFilter cartridge sediment capacity – 25 lb per cartridge (dry solids)

2.3 Filtration Process

The filtration process works by percolating stormwater through a series of filter cartridges filled with a filter media. SMI determines the type of filter media to be used based on site-specific water quality characteristics. For the DPW site, SMI selected CSF leaf media, which is manufactured using a feedstock of deciduous leaves collected by the City of Portland, Oregon. SMI composts the leaves into mature stable humus, which is then processed into an organic granular media, which can be used to remove suspended sediments, oil and grease, and soluble metals. A diagram identifying the filter cartridge components is shown in Figure 2-2.

Stormwater enters the cartridge bay from the inlet. After entering the cartridge bay, the stormwater elevation rises and enters into the cartridge through openings in the bottom of the cartridge. Air in the cartridge is displaced by the water and purged from beneath the filter hood through a one-way check valve located on top of the cartridge. The water infiltrates through the filter media and into the center tube. Once the center tube fills with water, a float valve opens and the water in the center tube flows into the under-drain manifold, located beneath the filter cartridge. This causes the check valve to close, initiating a siphon that draws stormwater through the filter. The siphon continues until the water surface elevation drops to the elevation of the hood's scrubbing regulators. When the water drains, the float valve closes and the system resets.

The CBSF is equipped with an overflow weir designed to bypass flows exceeding the peak hydraulic treatment capacity and prevent catch basin backup and surface flooding. The bypass flow is discharged through the outlet pipe along with the treated water.

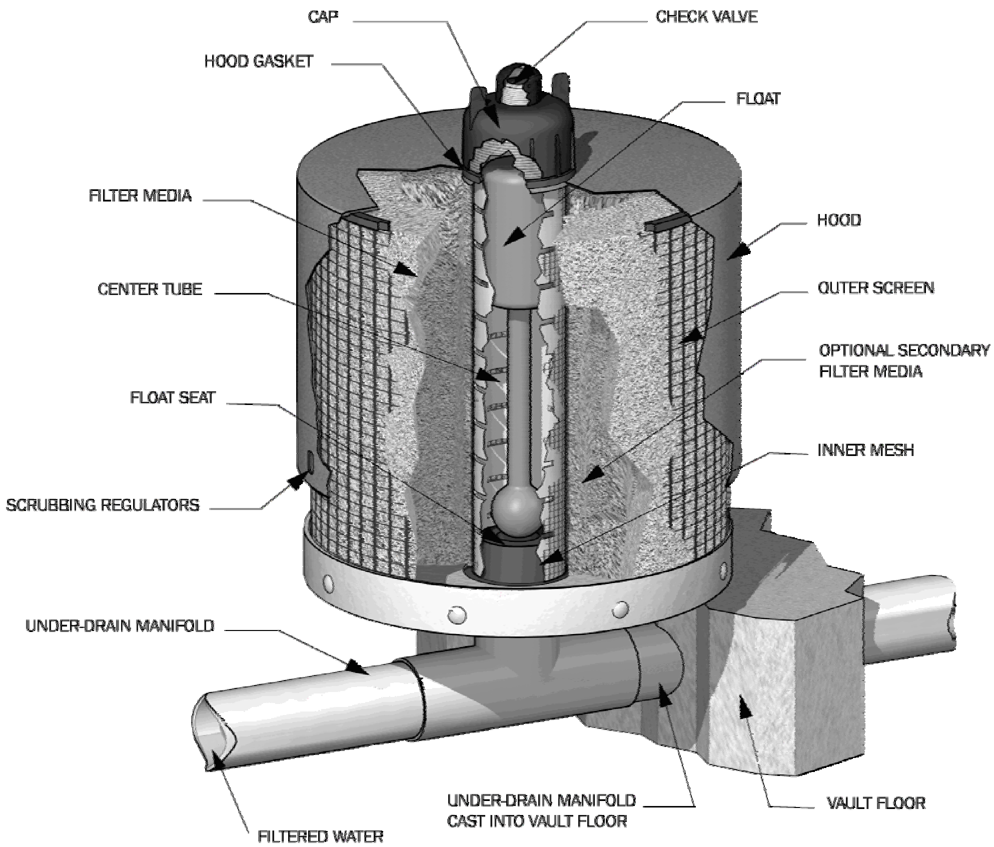

Figure 2-2. Schematic drawing of a StormFilter cartridge.

2.4 Technology Application and Limitations

CBSF systems are flexible in terms of the flows they can treat. By varying the cartridge bay size and number of filter cartridges, the treatment capacity of a CBSF can be modified to accommodate runoff from a range of watershed sizes.

CBSF systems treatment capabilities, both in terms of flow and sediment capacity, are limited by the number of filter cartridges incorporated into a particular unit. Each filter cartridge is designed with a flow rate of 15 gpm and a dry sediment capacity of 25 lb. Flows exceeding the filter cartridge's flow capacity bypass the filter cartridges and discharge directly to the outlet. The four-cartridge CBSF has a maximum bypass flow rate of 1 cfs (448 gpm), and the cartridge bays can retain one cubic yard of sediment.

2.5 Vendor Claims

SMI recognizes that stormwater treatment is a function of influent concentration and, in the case of sediment removal, particle size distribution. The performance claims for the CBSF installed at the DPW site were based on a flow rate of 15 gpm per cartridge.

2.5.1 TSS

In 2002, a New Jersey corporation verified Stormwater Management for Advanced Technology for specific TSS performance claims associated with laboratory investigations.

A single StormFilter cartridge configured to threat flows at 15 gpm using a coarse perlite media was shown to have a TSS removal efficiency of 79% with a 95% confidence limits of 78% and 80% respectively for a sandy loam material comprised of 55% sand, 45% silt, 5% clay (USDA) by mass, in laboratory studies using simulated stormwater.

When treating a 15 gpm flow, a StormFilter cartridge filled with CSF leaf media was shown to have a TSS removal efficiency of 73% with a 95% confidence limits of 68% and 79%, respectively, based on an evaluation of field and laboratory data.

2.5.2 Metals

The CSF media also acts as a chemical filter to remove dissolved ionic pollutants such as heavy metals, including lead, copper, and zinc. The mechanism of cation exchange is provided by humic substances, which are a product of the aerobic biological activity during the composing process. Heavy metal removal rates vary upon concentration and can be up to 95% total metal removal.

A single StormFilter cartridge with CSF media operating at 15 gpm should typically remove 33 to 54% of dissolved zinc for concentrations between 0.2 and 1.0 mg/L, and has the ability to remove dissolved copper through cation exchange but has not been quantified for a specific claim. Dissolved copper concentrations typically range from 0.003 to 0.02 mg/L and performance should be in the range of 25 to 50% removal. Dissolved lead concentrations had not been quantified but could be expected to have similar results as dissolved copper.

2.5.3 Oil and Grease

The high organic carbon content of the CSF media facilitates removal of oil and grease as well as some other organic compounds. When the oil and grease loadings are less than 25 mg/L, the system performs best, with a measured removal rate of 40 to 70%. Oil and grease concentrations that exceed 15 mg/L on a consistent basis may need to incorporate additional oil and grease control measures to aid removal and protect media longevity.

In tests done by SMI, the sorbent cartridge hood cover material absorbed up to 10 times its own weight in petroleum product. The cover itself weighs about a half of a pound and the dimensions are the same as the cartridge standard hood. Through testing with SAE 10W-40 motor oil, the hood cover absorbed up to five pounds of oil, and would not release captured oil after saturation.

Chapter 3
Test Site Description

3.1 Location and Land Use

The CBSF was installed in the City of St. Clair Shores DPW yard located at 19700 Pleasant Street in St. Clair Shores, Michigan. The test site is shown in Figures 3-1 and 3-2. The drainage area to the CBSF is utilized by DPW personnel as an uncovered stockpile area and transfer station, where piles of sand, gravel, concrete, asphalt and sediment are located. The sediment piles consisted of materials excavated as part of DPW maintenance projects, such as sidewalk and sewer repair, that were not used as backfill. The sediment consisted primarily of clay, with small amounts of sand, gravel, topsoil, vegetation, and construction debris. The size and composition of the stockpiles varied throughout the test period. Prior to installation of the StormFilter, a sand pile was located directly adjacent to the installation site, as noted in the test plan. This sand pile was later replaced with a sediment pile. The sediment pile was present throughout the remainder of the test period.

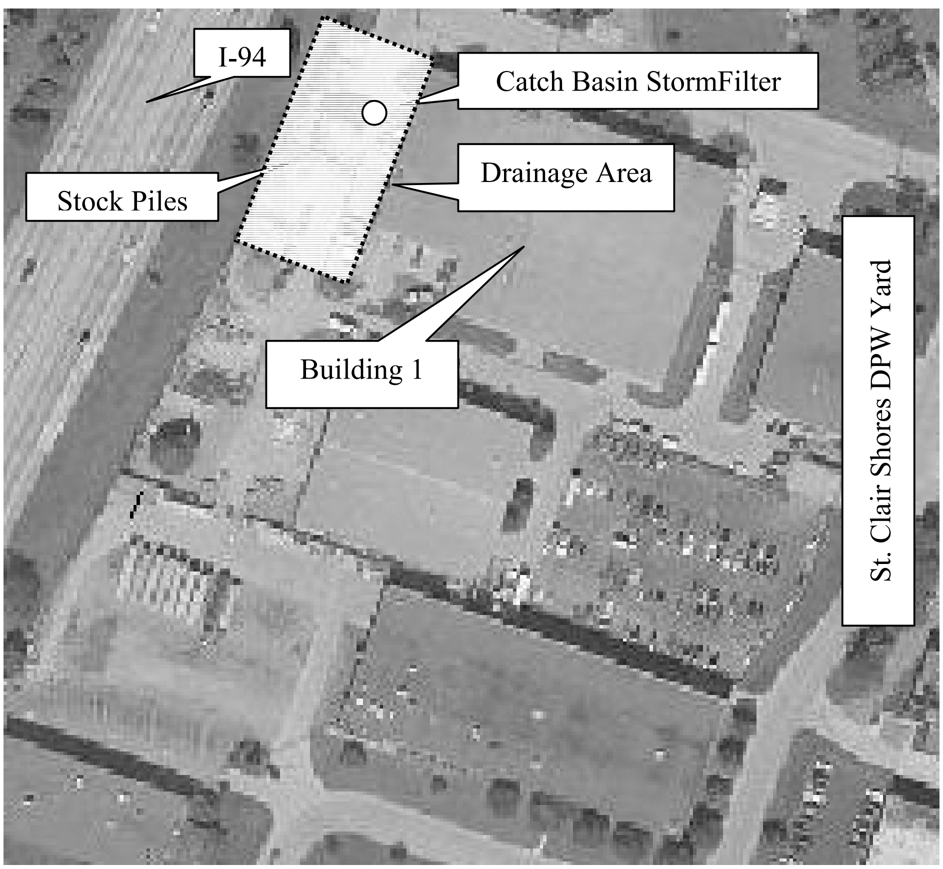

Figure 3-1. Test site location.

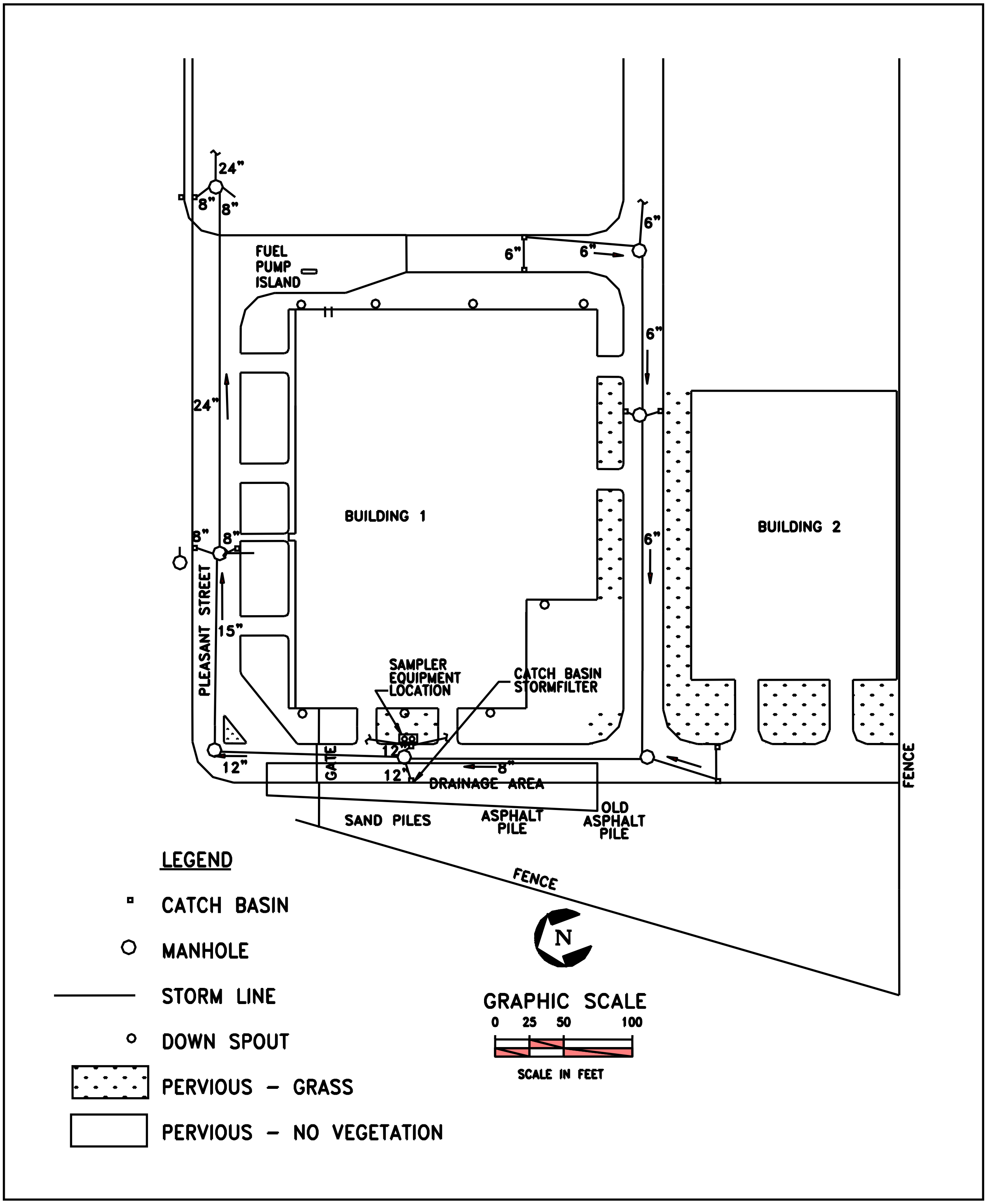

Figure 3-2. Test site.

The CBSF received runoff from approximately 0.16 acres of impervious surface west of DPW Building 1. The decking of Interstate Highway 94, on the DPW's western property boundary, is recessed below the DPW site's ground surface, so highway runoff does not impact the DPW site. The drainage area determination was based on the following information and assumptions:

- the site plan, based on a survey conducted by the DPW and TO, which provided information that was used for sizing purposes;
- the adjacent on-site storm drains were capable of capturing all the flow in their respective drainage areas, forming a hydrologic barrier; and
- on-site sewer collection system would allow for unrestricted flow.

3.2 Contaminant Sources and Site Maintenance

The main pollutant sources within the drainage area are created by the stockpiles (as shown in Figures 3-3 and 3-4), vehicular traffic, and atmospheric deposition. Traffic volume, consisting primarily of employee vehicles, city vehicles, earth-moving equipment, and dump trucks, is moderate. Dump trucks are used to haul material to and from the DPW yard. Heavy machinery, such as front-end loaders, are used to handle and maintain the stockpiles.

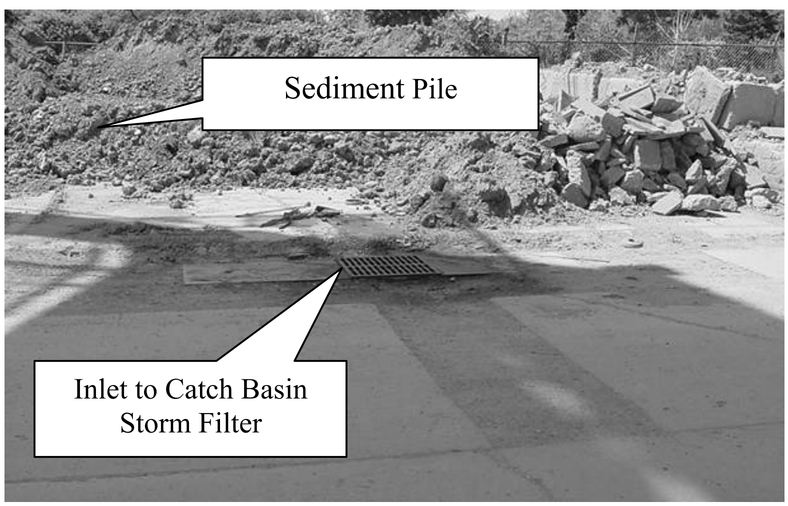

Figure 3-3. CBSF drainage area condition 2003.

Site activities, including handling the stockpiles, and loading and unloading dump trucks, contributed to a high proportion of dust and silt to settle on impervious surfaces within the runoff area. The stockpiles are not covered with tarps, and are exposed to environmental conditions. In spite of regular street sweeping and catch basin cleaning performed by DPW personnel, the dusty conditions were observed during most site visits.

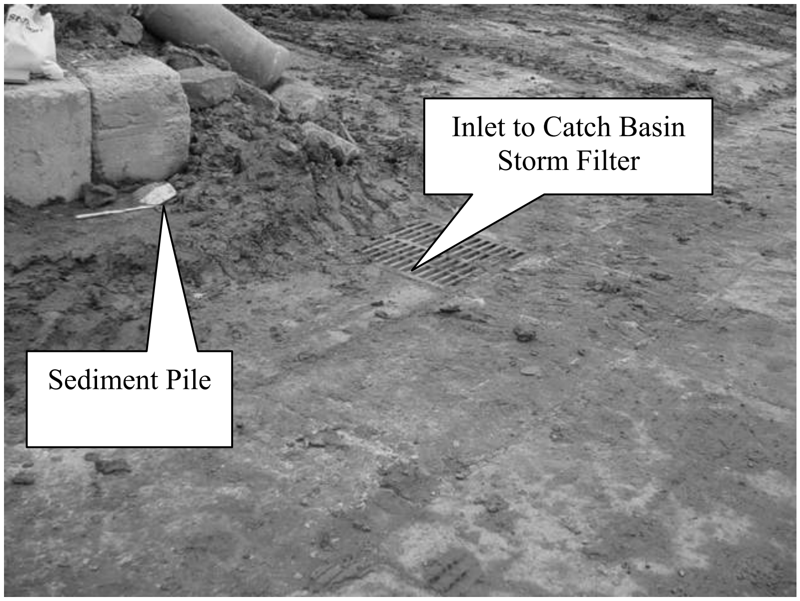

Figure 3-4. CBSF drainage area condition 2005.

3.3 Stormwater Conveyance System

The entire drainage area is served by a storm sewer collection system, which discharges to the Nine Mile Drain. The Nine Mile Drain flows east to the Eight-and-a-Half Mile Relief Drain, which discharges to the Detroit Water and Sewage Department wastewater treatment plant. During heavy rain events, stormwater is redirected to the Chapaton Retention Basin, and if the capacity of the basin is exceeded, the stormwater is discharged to Lake St. Clair.

The pipes that make up the sewer collection system on site are heavily scaled, as shown in Figure 3-5. A downstream portion of the sewer pipe was replaced prior to testing to address frequent pipe flooding and backwater effects observed during the shakedown phase. Backwater effects were not observed during the verification testing.

3.4 Rainfall and Peak Flow Calculations

The rainfall amounts for the one-, two-, and ten-year storms for the drainage area are presented in Table 3-1. The protocol specifies that 6-month data be included, however, these data were not available. Table 3-2 presents the intensities in inches per hour calculated for the given rainfall depths. These data were utilized to generate the peak flows shown in Table 3-3. The rational method was used to calculate the peak flows for the StormFilter. The rationale for these calculations was discussed in the test plan.

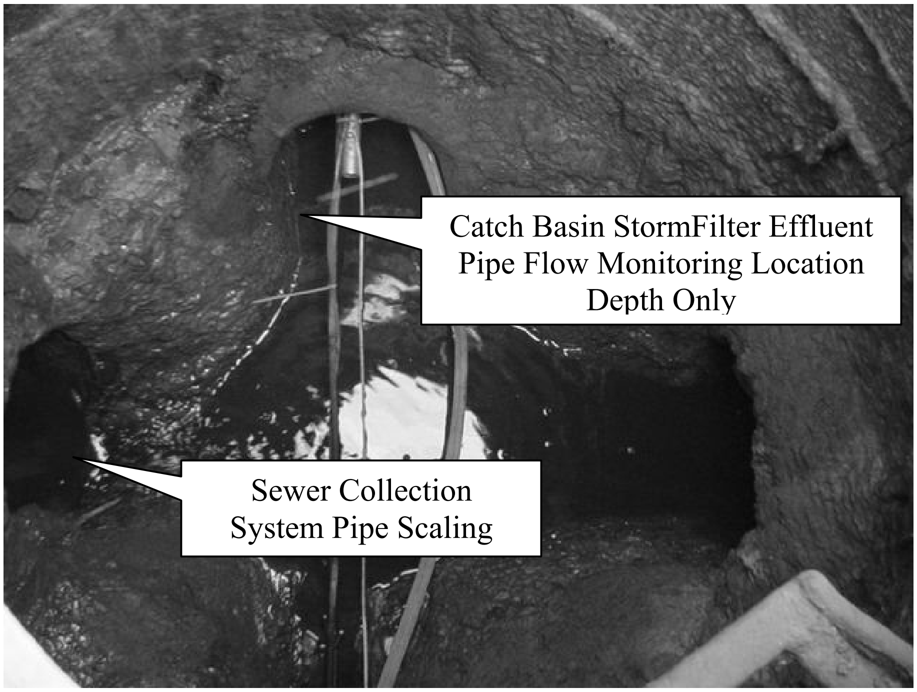

Figure 3-5. Stormwater conveyance system condition.

Table 3-1. Rainfall Depth (inches)

Duration	1-yr	2-yr	10-yr
30 min	0.8	1.0	1.4
1 hr	1.0	1.2	1.8
2 hr	1.2	1.4	2.1
12 hr	1.8	2.2	3.0
24 hr	2.1	2.4	3.2

Source: U.S. Weather Bureau, "Rainfall Frequency Atlas of the United States for Duration from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years", Technical Paper No. 40, 1961.

Table 3-2. Intensities (inches/hour)

Duration	1-yr	2-yr	10-yr
30 min	1.6	2.0	2.8
1 hr	1.0	1.2	1.8
2 hr	0.60	0.70	1.1
12 hr	0.15	0.18	0.25
24 hr	0.088	0.10	0.13

Table 3-3. Peak Flow Calculations (cfs)

Duration	1-yr	2-yr	10-yr
30 min	0.23	0.29	0.40
1 hr	0.14	0.17	0.26
2 hr	0.09	0.10	0.16
12 hr	0.02	0.03	0.04
24 hr	0.01	0.01	0.02

3.5 Local Meteorological Conditions

The test plan includes summary temperature and precipitation data from the National Weather Service. The climate of southeast Michigan is typically continental with some modification by the Great Lakes. Southeast Michigan experiences cold, snowy winters, and warm to hot summers. Average annual precipitation is approximately 37 in., with an average annual snowfall of 39 in. Temperatures range from a normal low in January of 17.8°F and a normal high of 83.4°F in July (NOAA 2005)

Weather patterns generally move from west to east across southeast Michigan. However, due to the proximity of the City of St. Clair Shores to Lake St. Clair, rain events tend to split just west of the city and proceeded north and south of the DPW yard. This phenomenon was observed by the TO throughout the ETV test and resulted in several mobilizations to the site during which insufficient rainfall was measured.

Chapter 4
Sampling Procedures and Analytical Methods

The objective of this program was to collect stormwater runoff prior to treatment by the CBSF and to collect effluent from the CBSF to verify the efficiency of the equipment. In order to accomplish this, two sampling locations were established and automatic and manual sampling methods were employed. Descriptions of the sampling locations and methods used during verification testing are summarized in the following section. Equipment specifications, test site descriptions, testing requirements, sampling procedures, and analytical methods were detailed in the *Test Plan for Stormwater Management, Inc. Storm Filter*, November 5, 2004 (Appendix A).

4.1 Sampling Locations

Two sampling locations were established to assess the treatment capability of the CBSF.

4.1.1 Influent

The influent sampling and monitoring site was selected to characterize the untreated stormwater from the drainage area entering the CBSF. Influent samples were collected using a sheet flow collector, manufactured and supplied by SMI, that fit over the entire inlet on the catch basin lip, below the catch basin grate (Figure 4-1a). Water flowed through the grate and was funneled through the insert. The sheet flow collector was equipped with suction strainers connected to the influent autosampler and manual sampler tubing. The influent sample strainer was located in the PVC outlet of the sheet flow collector (Figure 4-1b). A small weir was built into the sheet flow collector's outlet pipe to allow runoff to build up to a level sufficient to sample. The sheet flow collector's outlet pipe was cleaned out before the start of each rain event.

(a) Side view

(b) Underside view

Figure 4-1. Sheet flow collector.

4.1.2 Effluent

The effluent sampling and monitoring site was selected to characterize the water exiting the CBSF. As specified in Section 2.3, the CBSF is equipped with an overflow weir designed to bypass flows exceeding the peak hydraulic treatment capacity. Both treated and bypass flows are discharged to a single outlet pipe. Therefore, the effluent sampling site sampled both the treated and any bypassed stormwater exiting the CBSF. The effluent sampling site was located in the outlet bay of the CBSF, immediately upstream of the 8-in. outlet pipe at the level of the invert of the outlet pipe. The automatic and manual effluent sample strainers were suspended in the outlet bay, not installed in the outlet pipe, so that they would not sample material that may have accumulated in the outlet pipe, and to avoid possible cross-contamination during backwater conditions. The effluent sampling location collected a composite sample consisting of both treated effluent and untreated bypass water coming from the CBSF system, as both water streams were discharged to the same outlet pipe.

4.2 Monitoring Equipment

The specific equipment used for monitoring flow, sampling water quality, and measuring rainfall included:

- influent and effluent automatic samplers: ISCO 6712 Portable Samplers;
- rain gauge: ISCO 675 Logging Rain Gage; and
- flow monitor: ISCO 730 Bubbler Flow Meter (replaced by the ISCO 4230 Bubbler Flow Meter for sampling conducted in 2004).

The ISCO 730 Bubbler Flow Module was replaced with an ISCO 4230 Bubbler Flow Meter during remobilization in the spring of 2004. The ISCO 4230 allowed for more programming options, which reduced the number of unqualified events due to equipment communication problems. The ISCO 730 and 4230 Bubbler Flow Meters measure flow using the same basic technology.

4.3 Contaminant Constituents Analyzed

The list of constituents analyzed in the stormwater samples is shown in Table 4-1.

4.4 Sampling Schedule

The CBSF was installed on April 11, 2003. Verification testing began in July 2003 with the first event capture in September 2003. December 2003 was unseasonably warm, which allowed for sampling through January 1, 2004, after which time sampling was suspended until May 2004. Sampling was completed in October 2004. Table 4-2 summarizes the sample collection data from the storm events. These storm events met the requirements of a "qualified event," as defined in the test plan:

1. The total rainfall depth for the event, measured at the site rain gauge, was 0.2 in. (5 mm) or greater (snow fall and snow melt events did not qualify).

2. Flow through the treatment device was successfully measured and recorded over the duration of the runoff period.
3. A flow-proportional composite sample was successfully collected for both the influent and effluent over the duration of the runoff event.
4. Each composite sample collected consisted of a minimum of five aliquots, including at least two aliquots on the rising limb of the runoff hydrograph, at least one aliquot near the peak, and at least two aliquots on the falling limb of the runoff hydrograph.
5. There was a minimum of six hours between qualified sampling events.

Table 4-1. Constituent List for Water Quality Monitoring

Pollutant category	Required constituents	Laboratory method[1]	Method Detection limit
Sediment	Total suspended solids (TSS)	EPA 160.2	1.2 mg/L
	Suspended sediment concentration (SSC)	ASTM D3977-97 (b)	5 mg/L
Metals	Total zinc	EPA 200.8 or 6020	2.5 µg/L
	Dissolved zinc	EPA 200.8 or 6020	2.5 µg/L
	Total lead	EPA 200.8 or 6020	0.8 µg/L
	Dissolved lead	EPA 200.8 or 6020	0.8 µg/L
	Total copper	EPA 200.8 or 6020	0.9 µg/L
	Dissolved copper	EPA 200.8 or 6020	0.9 µg/L
	Total cadmium	EPA 200.8 or 6020	0.11 µg/L
	Dissolved cadmium	EPA 200.8 or 6020	0.11 µg/L
Petroleum hydrocarbons	Total petroleum hydrocarbons (TPH)	TPH as GRO+DRO (8015M8260+8015M8270)	0.05 µg/L
	Polynuclear aromatic hydrocarbons (PAH):		
	Acenaphthene	EPA 8270	1.2 µg/L
	Acenaphthylene	EPA 8270	1.2 µg/L
	Anthracene	EPA 8270	1.3 µg/L
	Benzo(a)anthracene	EPA 8270	1.4 µg/L
	Benzo(a)pyrene	EPA 8270	1.4 µg/L
	Benzo(b)fluoranthene	EPA 8270	1.4 µg/L
	Benzo(g,h,i)perylene	EPA 8270	1.6 µg/L
	Benzo(k)fluoranthene	EPA 8270	1.4 µg/L
	Chrysene	EPA 8270	1.3 µg/L
	Dibenz(a,h)anthracene	EPA 8270	1.6 µg/L
	Fluoranthene	EPA 8270	1.3 µg/L
	Fluorene	EPA 8270	1.3 µg/L
	Indeno(1,2,3-cd)pyrene	EPA 8270	1.6 µg/L
	Naphthalene	EPA 8270	1.1 µg/L
	Phenanthrene	EPA 8270	1.3 µg/L
	Pyrene	EPA 8270	1.4 µg/L

1. EPA, 1979; *Standard Methods*, 1986; and SW-846, 1996

Table 4-2. Summary of Events Monitored for Verification Testing

Event no.	Event date	Influent Start time	Influent End time	Effluent Start time	Effluent End time	Manual/auto no. of aliquots[1]
1	9/22/03	7:40	9:25	7:42	9:30	9/0
2	9/26/03	23:50	1:55	0:22	2:06	8/0
3	10/14/03	11:14	14:50	11:20	14:54	8/0
4	11/18/03	7:50	21:18	7:54	21:20	8/0
5	11/24/03	4:09	9:08	4:11	9:12	9/0
6	12/10/03	14:05	19:15	14:12	19:20	6/0
7	12/23/03	3:34	11:20	3:55	11:53	7/16
8	12/29/03	8:25	23:26	8:32	23:29	10/0
9	1/1/04	21:51	23:49	22:08	0:51	0/7
10	5/10/04	22:26	0:15	22:26	0:15	0/19
11	5/23/04	18:45	23:10	18:45	23:10	0/33
12	6/10/04	13:09	13:42	13:12	13:41	5/17
13	7/7/04	15:12	16:54	15:14	16:55	8/10
14	7/14/04	16:25	18:01	16:26	18:21	7/14
15	8/28/04	7:21	9:38	7:22	9:43	6/25
16	10/23/04	19:25	23:38	19:31	0:03	10/18

1. Refer to Sections 4.5.1 and 4.5.2 for information on automatic and manual aliquot collection.

Table 4-3 summarizes the storm data for the qualified events. Detailed information on each storm's runoff hydrograph and the rain depth distribution over the event period are included in Appendix B. The starting times for the collection of the influent and effluent samples varied from event to event, in addition to the number of sample aliquots collected. Both autosamplers were activated when the bubbler meter sensed flow in the outlet pipe. The peak runoff intensity exceeded the CBSF peak hydraulic treatment capacity of 60 gpm during 10 of the 16 events, which means that a portion of the flow bypassed the filtering process.

The recorded flow volumes were several times higher than the flow volumes that should have been observed, given the site characteristics. A 0.16 acre site with 90% imperviousness would generate a calculated rainfall flow volume of approximately 39 gal for each 0.01 in. of rain that fell on the drainage area. The actual volume of rain recorded by the flow monitor ranged from 1.1 to 13 times higher than the calculated flow volume from event to event, and the sum of recorded flow for all events was 4.3 times higher than the sum of calculated flow. In general, storms with higher peak intensities exhibited the highest degree of variance between the recorded flow and the calculated flow. It is possible that the flow monitor read flows higher than actual during intense storm events, or there may have been situations where rain falling outside the anticipated drainage basin flowed to the CBSF.

Table 4-3. Rainfall Summary for Monitored Events

Event No.	Date	Rainfall Amount (inches)	Rainfall Duration (hr:min)	Runoff Volume (gal)	Peak Runoff Intensity (gpm)[2]
1	9/22/03	0.31	1:45	2,990	**196**
2	9/26/03	0.26	2:00	1,510	44
3	10/14/03	0.68	6:30	2,950	41
4	11/18/03	0.44	17:45	4,940	13
5	11/24/03	0.33	10:45	17,900	**99**
6	12/10/03	0.75	7:45	19,800	**85**
7	12/23/03	0.42	10:30	11,200	**85**
8	12/29/03	0.31	7:45	2,270	9
9	1/1/04	0.20[1]	2:30	868	10
10	5/10/04	0.29	3:30	4,450	**273**
11	5/23/04	1.39	3:45	22,500	**335**
12	6/10/04	0.28	2:30	5,030	**171**
13	7/7/04	0.30	1:45	3,700	**274**
14	7/14/04	0.18	0:45	3,330	**175**
15	8/28/04	0.52	2:45	10,100	**223**
16	10/23/04	0.21	4:30	3,970	39

1. According to the ISCO rain gauge, 0.15 in of rain fell on 1/1/04. A plastic rain gauge on site, which had been emptied during the set-up activities for the anticipated event, measured over 0.20 in of rain, and other gauges were used to verify the amount of rain that fell in the area, so the TO is confident that the result obtained by the plastic gauge is accurate.
2. Peak runoff intensities that exceeded the CBSF peak treatment capacity are shown in **boldface text**.

4.5 Field Procedures for Sample Preservation and Handling

Data gathered by the autosamplers, flow meters and rain gage were accessible by the TO personnel by means of directly downloading the information to a computer, via a Rapid Transfer Device (RTD), manufactured by ISCO. The TO collected samples while inspection and sampler maintenance activities were performed by the TO and DPW personnel.

At the end of each qualified rain event, the sample aliquots were capped and removed from the sampler by TO personnel. Samples were split on site into the appropriate laboratory containers using a Teflon™ cone splitter. Samples were preserved per method requirements and analyzed within the holding times allowed by the methods.

The samples were either retained in the custody of the TO and delivered directly to the laboratory, or were picked up by laboratory representatives and relinquished to the laboratory sample custodian(s). Custody was maintained according to the laboratory's sample handling procedures. Chain-of-custody (COCs) forms were completed and accompanied each sample to establish the necessary documentation to trace sample possession from the time of collection.

4.5.1 Automatic Samples

Automatic samples were collected with ISCO autosamplers. Sampling equipment was stored above grade and across the street from where the CBSF was installed. Two ISCO Automatic Samplers and one ISCO Bubbler Flow Monitor were housed in a locked shed located next to an untested catch basin, across from the CBSF. This untested catch basin provided access to the CBSF from across the street, without interfering with the DPW's operations. A peristaltic pump on the sampler pumped water from the sampling location through Teflon™-lined tubing and into the pump head where water passed through approximately three feet of silicone tubing and into one of twenty-four 350 mL sample collection bottles. The tubing extended into the untested catch basin, through a 12-in. concrete sewer pipe and manhole located in the center of the road, and finally through the 8-in. CBSF outlet pipe, where the tubing connected to the sample intake points. One autosampler was dedicated to sampling the influent while the other was dedicated to sampling the effluent stream. TO staff members were on site during rain events to ensure that the equipment was functioning properly and to collect manual samples in conjunction with the automatic sampling.

4.5.2 Manual Samples

Adjacent to the autosampler influent and effluent sample strainers were identical manual influent and effluent sample strainers. The manual monitoring points allowed for grab samples for total petroleum hydrocarbon (TPH) gasoline-range organics (GRO), diesel-range organics (DRO), and polynuclear aromatic hydrocarbon (PAH) analysis to be collected with a peristaltic pump directly into the appropriate sample container. The manual sampling procedure was used to collect flow-weighted composite samples (using the flow and volume data indicated by the flow meter) for events sampled in 2003, due to issues associated with the operation of the autosamplers. As with the autosampler arrangement, manual samples were collected from the CBSF's influent and effluent collection points through Teflon™ pump tubing and peristaltic pumps operated by the TO personnel. The manual sample collection tubing exited the CBSF through the sheet flow collector. The manual samples were capped and numbered in order of their collection. The time of collection was recorded for all manual samples.

Chapter 5
Monitoring Results and Discussion

The monitoring results related to contaminant reduction over the verification test period are reported in two formats:

1. Efficiency ratio comparison, which evaluates the effectiveness of the system on an event mean concentration (EMC) basis.

2. Sum of loads comparison, which evaluates the effectiveness of the system on a constituent mass (concentration times volume) basis.

The test plan required that a suite of analytical parameters, including solids, organics, and metals, be tested to evaluate the vendor's performance claims. The laboratory analytical reports are included in Appendix C.

5.1 Performance Parameters

5.1.1 Concentration Efficiency Ratio

The concentration efficiency ratio reflects the treatment capability of the device using the event mean concentration (EMC) data obtained for each runoff event. The concentration efficiency ratios are calculated by:

$$\text{Efficiency ratio (ER)} = 100 \times (1-[EMC_{effluent}/EMC_{influent}]) \qquad (5\text{-}1)$$

The influent and effluent sample concentrations and calculated efficiency ratios are summarized by analytical categories: sediments (TSS and SSC); organics (TPH and PAH); and metals (total and dissolved cadmium, copper, lead, and zinc).

Sediments: The ETV protocol and test plan do not specify maximum sediment concentration in stormwater, nor did SMI's literature specify a maximum concentration for their stormwater treatment devices to function effectively. However, during the data review after testing was complete, the vendor, TO, and VO recognized that the mass and concentration of sediment loadings in this drainage basin, attributed primarily to the soil stockpiles and site activities, exceeded the capacity of the CBSF, making a valid measure of the sediment removal performance of the CBSF difficult to obtain. This is explained further in Section 5.1.2 and Chapter 7. However, the data is presented for informational purposes.

The influent and effluent sample concentrations and calculated efficiency ratios for sediment parameters are summarized in Table 5-1. The TSS inlet concentrations ranged from 1,100 to 5,200 mg/L; the outlet concentrations ranged from 570 to 8,600 mg/L; and the efficiency ratio ranged from -120 to 63 percent. The SSC inlet concentrations ranged 930 to 9,100 mg/L; the outlet concentrations ranged from 700 to 12,000 mg/L; and the efficiency ratio ranged from -44 to 53 percent.

Table 5-1. Monitoring Results and Efficiency Ratios for Sediment Parameters

		TSS			SSC		
Event No.	Date	Influent (mg/L)	Effluent (mg/L)	Efficiency Ratio (%)	Influent (mg/L)	Effluent (mg/L)	Efficiency Ratio (%)
1	9/22/03	3,000	2,900	3.7	2,900	2,800	3.4
2	9/26/03	2,600	2,900	-8.3	2,600	2,800	-7.7
3	10/14/03	2,500	1,400	43	2,500	1,200	52
4	11/18/03	3,200	3,300	-1.9	3,900	2,200	44
5	11/24/03	1,100	840	25	930	700	25
6	12/10/03	1,100	1,300	-12	1,000	1,200	-20
7	12/23/03	4,100	3,500	14	3,700	3,400	8.1
8	12/29/03	2,000	1,900	5.4	1,800	1,700	5.6
9	1/1/04	5,200	3,000	42	5,000	2,800	44
10	5/10/04	1,700	2,200	-31	1,600	2,300	-44
11	5/23/04	1,500	570	63	1,600	1,600	0
12	6/10/04	2,300	1,900	17	2,200	1,600	27
13	7/7/04	3,400	4,000	-17	3,700	4,000	-8.1
14	7/14/04	4,000	8,600	-120	9,100	12,000	-32
15	8/28/04	2,000	1,200	41	2,000	1,000	50
16	10/23/04	1,500	1,000	33	3,000	1,400	53

Both the TSS and SSC analyses measure sediment concentrations in water; however, the TSS analytical procedure requires the analyst to draw an aliquot from the sample container, while the SSC procedure uses the entire contents of the sample container. If a sample contains a high concentration of solids of a large particle size, acquiring a representative aliquot from the sample container for TSS analysis is very difficult. Therefore, there is a higher probability that a disproportionate amount of the settled solids will be left in the container during TSS analysis, and that the reported TSS concentration will be lower than the SSC concentration. Conversely, similar TSS and SSC concentrations indicate that the sediment loadings in the sample probably contains a high proportion of solids of a small particle size. Most of the influent TSS and SSC concentrations were similar, so the sediment loadings appeared to be of a small particle size.

The data show that, with the exception of event 2, a positive SSC efficiency ratio was achieved when the peak runoff intensity (Table 4-3) did not exceed the peak treatment capacity of the CBSF, while the efficiency ratio was negative for about half of the events where the peak runoff intensity exceeded the peak treatment capacity. This is further evidence that the CBSF was undersized for this particular drainage basin.

Total Metals: Since the CBSF was loaded with sediments, the ability of the CBSF to treat total metal constituents was diminished. The inlet and outlet sample concentrations and calculated efficiency ratios for total metals are summarized in Table 5-2. The total cadmium inlet concentration ranged from 0.6 to 44 µg/L, and the efficiency ratio ranged from -41 to 87 percent. The total lead inlet concentration ranged from 15 to 580 µg/L and the efficiency ratio ranged from -47 to 79 percent. The total copper inlet concentration ranged from 6 to 390 µg/L, and the efficiency ratio ranged from -64 to 42 percent. The total zinc inlet concentration ranged from 72 to 1,800 µg/L, and the efficiency ratio ranged from -82 to 70 percent.

Dissolved Metals: Since the CBSF was loaded with sediments, the ability of the CBSF to treat total metal constituents was diminished. The inlet and outlet sample concentrations and calculated efficiency ratios for dissolved metals are summarized in Table 5-3. Several dissolved metals concentration sample pairs exhibited influent concentrations close to the detection limits. When this occurred, the calculated efficiency ratio percentage exhibited a disproportionately high negative value. The dissolved cadmium inlet concentration ranged from <0.2 to 2 µg/L, and the efficiency ratio ranged from -9 to 10 percent. The dissolved lead inlet concentration ranged from <1.0 to 80 µg/L and the efficiency ratio ranged from -560 to 33 percent. The dissolved copper inlet concentration ranged from <1.0 to 35 µg/L, and the efficiency ratio ranged from -3,400 to 31 percent. The dissolved zinc inlet concentration ranged from <2.0 to 200 µg/L, and the efficiency ratio ranged from -3,400 to 69 percent.

Table 5-2. Monitoring Results and Efficiency Ratios for Total Metals

	Total Cadmium			Total Lead			Total Copper			Total Zinc		
Event No.	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)
1	2.8	2.3	18	87	91	-5	40	36	10	170	170	0
2	0.6	0.62	-3	48	59	-23	15	16	-7	72	74	-3
3	1.8	1.3	28	130	88	32	31	31	0	160	160	0
4	6.7	4.2	37	580	370	36	390	240	38	1,800	1,100	39
5	1.4	1.1	21	79	60	24	80	75	6	450	360	20
6	1.5	1.2	20	89	82	8	140	81	42	610	280	54
7	3.8	1.1	71	220	200	9	220	200	9	930	720	23
8	2.5	2.4	4	130	130	0	100	120	-20	320	360	-13
9	6.0	3.9	35	300	170	43	200	250	-25	800	590	26
10	0.8	**<0.2**	87	68	100	-47	39	64	-64	170	310	-82
11	0.6	**<0.2**	83	15	3.2	79	16	13	19	80	24	70
12	2.9	2.3	21	83	87	-5	46	53	-15	390	390	0
13	3.5	3.2	9	120	97	19	68	61	10	520	480	8
14	1.4	0.86	39	28	39	-39	6.0	6.6	-10	190	230	-21
15	2.9	4.1	-41	77	44	43	42	33	21	320	230	28
16	44	7.6	83	120	83	31	64	50	22	390	340	13

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

Table 5-3. Monitoring Results and Efficiency Ratios for Dissolved Metals

	Dissolved Cadmium			Dissolved Lead			Dissolved Copper			Dissolved Zinc		
Event No.	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)
1	2.0	1.8	10	80	80	0	35	34	3	170	170	0
2	<0.2	0.3	ND	<1.0	11	ND	8.0	11	-38	13	36	-180
3	<0.2	<0.2	ND	2.9	19	-560	21	17	19	25	100	-300
4	1.1	1.2	-9	49	42	14	33	43	-30	200	170	15
5	<0.2	<0.2	ND	<1.0	<1.0	ND	9.0	8.6	4	13	14	-8
6	<0.2	<0.2	ND	<1.0	<1.0	ND	26	18	31	13	15	-15
7	<0.2	<0.2	ND	<1.0	<1.0	ND	12	14	-17	41	23	44
8	<0.2	<0.2	ND	<1.0	<1.0	ND	19	16	16	5.3	5.8	-9
9	<0.2	<0.2	ND	<1.0	<1.0	ND	13	12	8	4.6	5.7	-24
10	<0.2	<0.2	ND	1.0	6.6	-560	12	16	-33	<2.0	31	ND
11	<0.2	<0.2	ND	8.2	5.5	33	16	13	19	43	28	35
12	<0.2	<0.2	ND	<1.0	1.9	ND	6.9	9.9	-43	4.3	3.4	21
13	<0.2	0.7	ND	<1.0	<1.0	ND	1.4	49	-3,400	2.6	90	-3,400
14	<0.2	<0.2	ND	<1.0	1.4	ND	2.5	20	-700	10	35	-250
15	<0.2	<0.2	ND	<1.0	<1.0	ND	<1.0	<1.0	ND	3.2	**<2.0**	69
16	<0.2	<0.2	ND	<1.0	<1.0	ND	<1.0	120	ND	<2.0	<2.0	ND

ND: Not determinable.
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

TPH: Since the CBSF was loaded with sediments, the ability of the CBSF to treat hydrocarbons was diminished. The inlet and outlet sample concentrations and calculated efficiency ratios are summarized in Table 5-4. TPH-GRO results were below detection limits for all events. TPH-DRO inlet concentration ranged from <0.001 to 52 mg/L, and the efficiency ratio ranged from -41 to 93 percent.

Table 5-4. Monitoring Results and Efficiency Ratios for TPH-DRO

Event No.	Influent (mg/L)	Effluent (mg/L)	Efficiency Ratio (%)
1	<0.001	<0.001	ND
2	<0.001	<0.002	ND
3	52	19	63
4	2.1	0.73	65
5	0.98	0.57	42
6	0.41	0.58	-41
7	21	6.8	68
8	2.0	2.5	-25
9	NA	NA	ND
10	NA	NA	ND
11	NA	NA	ND
12	0.31	0.40	-29
13	<0.001	<0.001	ND
14	0.71	**<0.001**	93
15	0.29	0.22	24
16	<0.001	<0.001	ND

All TPH-GRO concentrations were below detection limits
NA: Not analyzed due to low sample volume
ND: Not determinable
Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

PAH: Since the CBSF was loaded with sediments, the ability of the CBSF to treat hydrocarbons was diminished. The inlet and outlet sample concentrations and calculated efficiency ratios for detected PAH compounds are summarized in Table 5-5. Some PAH compounds were detected in low concentrations during three events, and not detected during the other events. When PAH compounds were detected, the efficiency ratios ranged from 52 to 81 percent.

Table 5-5. Monitoring Results and Efficiency Ratios for PAH Compounds

	Event 4 (11/18/03)			Event 12 (6/10/04)			Event 14 (7/14/04)		
	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)	Influent (µg/L)	Effluent (µg/L)	Efficiency Ratio (%)
Benzo(a)pyrene	<1.0	<1.0	ND	<1.0	<1.0	ND	2.3	**<1.0**	78
Benzo(b)fluoranthene	<1.0	<1.0	ND	<1.0	<1.0	ND	1.7	**<1.0**	71
Benzo(g,h,i)perylene	<1.0	<1.0	ND	<1.0	<1.0	ND	1.5	**<1.0**	67
Benzo(k)fluoranthene	<1.0	<1.0	ND	<1.0	<1.0	ND	1.6	**<1.0**	69
Chrysene	1.3	**<1.0**	62	<1.0	<1.0	ND	2.7	1.2	56
Fluoranthene	<1.0	<1.0	ND	<1.0	<1.0	ND	5.4	2.4	56
Fluorene	2.6	**<1.0**	81	<1.0	<1.0	ND	<1.0	<1.0	ND
Naphthalene	<1.0	<1.0	ND	1.4	**<1.0**	64	<1.0	<1.0	ND
Phenanthrene	2	**<1.0**	75	<1.0	<1.0	ND	1.3	**<1.0**	62
Pyrene	2	**<1.0**	75	<1.0	<1.0	ND	7.5	3.6	52

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate EMC.

5.1.2 Sum of Loads

The sum of loads (SOL) is the sum of the percent load reduction efficiencies for all the events, and provides a measure of the overall performance efficiency for the events sampled during the monitoring period. The load reduction efficiency is calculated using the following equation:

$$\text{\% Load Reduction Efficiency} = 100 \times (1 - (A / B)) \qquad (5\text{-}2)$$

Where:

A = Sum of Effluent Load = (Effluent EMC_1)(Flow $Volume_1$) + (Effluent EMC_2)(Flow $Volume_2$) + (Effluent EMC_n)(Flow $Volume_n$)

B = Sum of Influent Load = (Influent EMC_1)(Flow $Volume_1$) + (Effluent EMC_2)(Flow $Volume_2$) + (Effluent EMC_n)(Flow $Volume_n$)

n = number of qualified sampling events

Sediment: The SOL data for sediments are summarized in Table 5-6. As noted in Section 5.1.1, the vendor, TO and VO recognize that the sediment loadings exceed the treatment capacities of the CBSF, therefore a valid measure of the sediment removal performance of the CBSF could not be conducted.

Table 5-6. Sediment Sum of Loads Results – All Qualified Events

Event No.	Date	Runoff Volume (gal)	TSS Influent (lb)	TSS Effluent (lb)	SSC Influent (lb)	SSC Effluent (lb)
1	9/22/03	2,990	74.5	71.8	72.3	69.8
2	9/26/03	1,510	33.2	36.0	32.7	35.2
3	10/14/03	2,950	60.5	34.4	61.5	29.5
4	11/18/03	4,940	133	135	161	90.6
5	11/24/03	17,900	166	125	139	104
6	12/10/03	19,800	188	211	165	198
7	12/23/03	11,200	385	330	345	317
8	12/29/03	2,270	38.6	36.5	34.1	32.2
9	1/1/04	868	37.3	21.6	36.2	20.3
10	5/10/04	4,450	61.6	80.9	59.4	85.3
11	5/23/04	22,500	285	107	300	300
12	6/10/04	5,030	97.3	80.5	92.3	67.1
13	7/7/04	3,700	105	122	114	123
14	7/14/04	3,330	111	240	253	333
15	8/28/04	10,100	164	98	168	84.2
16	10/23/04	3,970	49.6	33.8	99.3	46.3
Sum of the Loads			**1,990**	**1,760**	**2,130**	**1,940**
SOL Efficiency (%)			**11**		**9.2**	

According to the vendor, the four-cartridge CBSF has a maximum sediment storage capacity of 27 ft^3 or 200 gal in the sump, plus a maximum of 100 lb in the cartridges (25 lb per cartridge). Based on SOL calculations, the sediment loadings for qualified events could have exceeded the CBSF sediment capacity after only a few events. Furthermore, since not every rain event was a qualified event, the CBSF experienced loadings during the verification period in excess of the qualified event loadings. For example, a 1.27-in. rain event occurred on September 19, 2003, after maintenance and filter cartridge replacement, but before the first qualified rain event. Had this storm been a qualified event, it would have had the second highest rainfall depth of the evaluation (behind event 11, with 1.39 in.), and could have contributed a sediment loading to the CBSF similar to that of event 11 (285 lb of TSS; and 300 lb of SSC).

The sediment SOL data can be further evaluated to examine a number of different scenarios, such as events following major maintenance activities, and events where bypass conditions occurred. This data is summarized in Table 5-7, and shows that maintenance activities are necessary to maintain higher TSS SOL efficiencies, and selecting a site with peak flows below the hydraulic capacity is important to achieve higher SSC SOL efficiencies.

Table 5-7. Sediment Sum of Loads Results – Analysis of Site Conditions

	SOL Efficiency (%)	
Condition	**TSS**	**SSC**
All events	11	9.2
First two events following maintenance (events 3, 4, 10, and 11)	34	13
Events under established conditions (all events except 3, 4, 10, and 11)	3.1	7.7
Events where 60-gpm hydraulic treatment capacity was ***not*** exceeded (see Table 4-3)	16	40
Events where 60-gpm hydraulic treatment capacity ***was*** exceeded (see Table 4-3)	11	1.5

Metals: The SOL data for total metals are summarized in Table 5-8 and dissolved metals in Table 5-9. Due to the low concentrations of total and dissolved metals in the stormwater, the metal masses are expressed in grams. The CBSF achieved a total metals reduction 20 to 52%, but achieved negligible removal efficiency for dissolved metals. In general, the dissolved metals concentrations in both the influent and effluent samples were very low. For dissolved cadmium, in particular, most concentrations were below detection limits, and the net sum of loads amounted to approximately 0.05 g in both the influent and effluent.

TPH-DRO: The SOL data for TPH-DRO are summarized in Table 5-10. The CBSF achieved a 62% removal efficiency, which is consistent with SMI's claim of 40 to 70% oil and grease removal.

PAH compounds: As noted in Section 5.1.1 PAH compounds were detected in low concentrations during three events, and not detected in the remaining 13 events. Due to the low concentrations of PAH compounds in the stormwater, the constituent masses are expressed in milligrams. The CBSF achieved a 56 to 81% removal efficiency range for detected PAH compounds, and a net PAH removal efficiency of 64% for all detected PAH compounds, which is consistent with or exceeds SMI's claim of 40 to 70% oil and grease removal.

Table 5-8. Total Metals Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Total Cadmium Influent (g)	Total Cadmium Effluent (g)	Total Lead Influent (g)	Total Lead Effluent (g)	Total Copper Influent (g)	Total Copper Effluent (g)	Total Zinc Influent (g)	Total Zinc Effluent (g)
1	9/22/03	2,990	0.032	0.026	0.98	1.03	0.453	0.407	1.92	1.92
2	9/26/03	1,510	0.003	0.004	0.27	0.34	0.086	0.091	0.412	0.423
3	10/14/03	2,950	0.020	0.015	1.45	0.98	0.346	0.346	1.79	1.79
4	11/18/03	4,940	0.125	0.079	10.8	6.92	7.29	4.49	33.7	20.6
5	11/24/03	17,900	0.095	0.075	5.35	4.07	5.42	5.08	30.5	24.4
6	12/10/03	19,800	0.112	0.090	6.67	6.15	10.5	6.07	45.7	21.0
7	12/23/03	11,200	0.161	0.047	9.33	8.48	9.33	8.48	39.4	30.5
8	12/29/03	2,270	0.021	0.021	1.12	1.12	0.859	1.03	2.75	3.09
9	1/1/04	868	0.020	0.013	0.99	0.56	0.657	0.821	2.63	1.94
10	5/10/04	4,450	0.013	**0.002**	1.15	1.68	0.657	1.08	2.86	5.22
11	5/23/04	22,500	0.050	**0.009**	1.28	0.27	1.36	1.11	6.81	2.04
12	6/10/04	5,030	0.055	0.044	1.58	1.66	0.876	1.01	7.43	7.43
13	7/7/04	3,700	0.049	0.045	1.68	1.36	0.952	0.854	7.28	6.72
14	7/14/04	3,330	0.018	0.011	0.35	0.49	0.076	0.083	2.39	2.90
15	8/28/04	10,100	0.111	0.157	2.94	1.68	1.61	1.26	12.2	8.79
16	10/23/04	3,970	0.661	0.114	1.80	1.25	0.962	0.751	5.86	5.11
Sum of the Loads			**1.55**	**0.748**	**47.8**	**38.0**	**41.4**	**33.0**	**204**	**144**
SOL Efficiency (%)			**52**		**20**		**20**		**29**	

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL.

Table 5-9. Dissolved Metals Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Dissolved Cadmium Influent (g)	Dissolved Cadmium Effluent (g)	Dissolved Lead Influent (g)	Dissolved Lead Effluent (g)	Dissolved Copper Influent (g)	Dissolved Copper Effluent (g)	Dissolved Zinc Influent (g)	Dissolved Zinc Effluent (g)
1	9/22/03	2,990	0.023	0.020	0.905	0.905	0.396	0.385	1.92	1.92
2	9/26/03	1,510	**0.0006**	0.0015	**0.003**	0.063	0.046	0.063	0.074	0.206
3	10/14/03	2,950	ND	ND	0.032	0.212	0.234	0.190	0.279	1.12
4	11/18/03	4,940	0.021	0.022	0.916	0.785	0.617	0.804	3.74	3.179
5	11/24/03	17,900	ND	ND	ND	ND	0.610	0.583	0.881	0.949
6	12/10/03	19,800	ND	ND	ND	ND	1.95	1.35	0.97	1.12
7	12/23/03	11,200	ND	ND	ND	ND	0.509	0.593	1.74	0.975
8	12/29/03	2,270	ND	ND	ND	ND	0.163	0.137	0.046	0.050
9	1/1/04	868	ND	ND	ND	ND	0.043	0.039	0.015	0.019
10	5/10/04	4,450	ND	ND	0.017	0.111	0.202	0.269	**0.017**	0.522
11	5/23/04	22,500	ND	ND	0.698	0.468	1.36	1.11	3.66	2.38
12	6/10/04	5,030	ND	ND	**0.010**	0.036	0.131	0.188	0.082	0.065
13	7/7/04	3,700	**0.001**	0.0098	ND	ND	0.020	0.686	0.036	1.26
14	7/14/04	3,330	ND	ND	0.006	0.018	0.032	0.252	0.126	0.441
15	8/28/04	10,100	ND	ND	ND	ND	0.019	0.019	0.122	**0.038**
16	10/23/04	3,970	ND	ND	ND	ND	0.008	1.803	ND	ND
Sum of the Loads			**0.045**	**0.054**	**2.59**	**2.60**	**6.34**	**8.47**	**13.7**	**14.2**
SOL Efficiency (%)			**-20**		**-0.44**		**-34**		**-3.9**	

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL.

Table 5-10. TPH-DRO Sum of Loads Results

Event No.	Date	Runoff Volume (gal)	Influent (lb)	Effluent (lb)
1	9/22/03	2,990	ND	ND
2	9/26/03	1,510	ND	ND
3	10/14/03	2,950	1.3	0.47
4	11/18/03	4,940	0.086	0.030
5	11/24/03	17,900	0.15	0.09
6	12/10/03	19,800	0.068	0.10
7	12/23/03	11,200	2.0	0.63
8	12/29/03	2,270	0.0	0.0
9	1/1/04	868	NA	NA
10	5/10/04	4,450	NA	NA
11	5/23/04	22,500	NA	NA
12	6/10/04	5,030	0.0	0.0
13	7/7/04	3,700	ND	ND
14	7/14/04	3,330	0.020	0.00001
15	8/28/04	10,100	0.024	0.019
16	10/23/04	3,970	ND	ND
Sum of the Loads			**3.6**	**1.4**
SOL Efficiency (%)			**62**	

Table 5-11. PAH Sum of Loads Results

Compound	Location	Event Number (Date) 4 (11/18/03)	12 (6/10/04)	14 (7/14/04)	Sum of Loads (mg)	Removal Efficiency (%)
Rainfall Volume (gal)		**4,940**	**5,030**	**3,330**		
Benzo(a)pyrene	Influent (mg)	ND	ND	29	29	78
	Effluent (mg)	ND	ND	**6.3**	6	
Benzo(b)fluoranthene	Influent (mg)	ND	ND	21	21	71
	Effluent (mg)	ND	ND	**6.3**	6.3	
Benzo(g,h,i)perylene	Influent (mg)	ND	ND	19	19	67
	Effluent (mg)	ND	ND	**6.3**	6.3	
Benzo(k)fluoranthene	Influent (mg)	ND	ND	20	20	69
	Effluent (mg)	ND	ND	**6.3**	6.3	
Chrysene	Influent (mg)	24	ND	34	58	58
	Effluent (mg)	**9.3**	ND	15	24	
Fluoranthene	Influent (mg)	ND	ND	68	68	56
	Effluent (mg)	ND	ND	30	30	
Fluorene	Influent (mg)	49	ND	ND	49	81
	Effluent (mg)	**9.3**	ND	ND	9.3	
Naphthalene	Influent (mg)	ND	27	ND	27	64
	Effluent (mg)	ND	**9.5**	ND	10	
Phenanthrene	Influent (mg)	37	ND	16	54	71
	Effluent (mg)	**9.3**	ND	**6.3**	16	
Pyrene	Influent (mg)	37	ND	95	130	58
	Effluent (mg)	**9.3**	ND	45	55	

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate SOL.

5.2 Particle Size Distribution

The information and data contained in this section of the report is provided by the technology vendor, SMI, and has not verified by the Testing Organization or the Verification Organization.

Particle size distribution analyses were conducted on samples collected and analyzed by the vendor on solids retained in the inlet/outlet and cartridge bays. The sample collection took place on April 10 and December 10, 2004, and coincided with CBSF maintenance activities, when VO, TO, and vendor personnel were present on the site. The hydrometer and sieve analysis (Gee and Bauder, 1986) was used to perform the particle size distribution analysis. Samples were collected from one of the soil piles close to the CBSF, while the other samples were collected from the solids retained in the CBSF after water was decanted from the retained sediments. The data, enclosed in Appendix D, is summarized in Table 5-12. Based on the particle size distribution similarity for the three samples collected on December 10, the vendor concluded that the soil pile was a primary source of material retained by the CBSF.

Table 5-12. Particle Size Distribution Analysis Results

Date	Sample location	Particle size distribution (by mass)	Soil texture	Bulk density, wet (lb/ft^3)
4/10/04	Cartridge bay	17% sand, 50% silt, 33% clay	silty clay loam	ND
12/10/04	Soil pile	50% sand, 25% silt, 25% clay	sandy clay loam	ND
12/10/04	Inlet/outlet bay	55% sand, 20% silt, 25% clay	sandy clay loam	95.6
12/10/04	Cartridge bay	25% sand, 33% silt, 40% clay	clay loam	74.1

ND: Not determined.

Chapter 6
QA/QC Results and Summary

The Quality Assurance Project Plan (QAPP) in the test plan identified critical measurements and established several QA/QC objectives. The verification test procedures and data collection were conducted in accordance with the QAPP. QA/QC summary results are reported in this section, and the full laboratory QA/QC results and supporting documents are presented in Appendix B.

6.1 Laboratory Analytical Data QA/QC

6.1.1 Bias (Field Blanks)

Field blanks were collected on three separate occasions to evaluate the potential for sample contamination throughout the verification process, including automatic sampler, sample-collection bottles, splitters, and filtering devices. Distilled water was used for the first blank. After the results were found to have elevated metals concentrations, the blank water was switched to deionized water to eliminate the possibility that the distilled water contained trace metals concentrations. Deionized water was pumped through the automatic sampler, and was collected in sample bottles. These samples were processed and analyzed in the same manner as event samples. The field blanks were collected on 10/14/03 (between events 2 and 3), 11/19/03 (between events 4 and 5), and 7/15/04 (between events 13 and 14).

Results for the field blanks are shown in Table 6-1. All but twelve analyses were below the limits of detection (LOD), and all but fifteen analyses were below the limit of quantification (LOQ). These results show that an acceptable level of contaminant control in field procedures was achieved.

Table 6-1. Field Blank Analytical Data Summary

		Sampling Date		
Parameter	**Units**	**10/20/03**	**11/19/03**	**07/15/04**
TSS	mg/L	1	<1	ND
SSC	mg/L	19	<1	ND
Total cadmium	µg/L	<0.2	<0.2	ND
Total lead	µg/L	3.5	<1	ND
Total copper	µg/L	<1.0	1.4	ND
Total zinc	µg/L	10	8.3	20
Dissolved cadmium	µg/L	<0.2	<0.2	ND
Dissolved lead	µg/L	<1.0	<1.0	ND
Dissolved copper	µg/L	<1.0	<1.0	ND
Dissolved zinc	µg/L	6.7	5.7	16
GRO	µg/L	<100	<100	ND
DRO	µg/L	3,300	600	ND

ND: Not detected.

Table 6-1. Field Blank Analytical Data Summary – continued

Parameter	Units	10/20/03 Influent	11/19/03 Influent	07/15/04 Influent
Acenaphthene	µg/L	<1.2	<1.2	ND
Acenaphthylene	µg/L	<1.2	<1.2	ND
Anthracene	µg/L	<1.2	<1.2	ND
Benzo(a)anthracene	µg/L	<1.2	<1.2	ND
Benzo(a)pyrene	µg/L	<1.2	<1.2	ND
Benzo(b)fluoranthene	µg/L	<1.2	<1.2	ND
Benzo(ghi)Perylene	µg/L	<1.2	<1.2	ND
Benzo(k)fluoranthene	µg/L	<1.2	<1.2	ND
Chrysene	µg/L	<1.2	<1.2	ND
Dibenzo(a,h)anthracene	µg/L	<1.2	<1.2	ND
Fluoranthene	µg/L	<1.2	<1.2	ND
Fluorene	µg/L	<1.2	<1.2	ND
Indeno(1,2,3-cd)pyrene	µg/L	<1.2	<1.2	ND
2-Methylnaphthalene	µg/L	<1.2	<1.2	ND
Naphthalene	µg/L	<1.2	<1.2	ND
Phenanthrene	µg/L	<1.2	<1.2	ND
Pyrene	µg/L	<1.2	<1.2	ND

ND: Not detected.

6.1.2 Replicates (Precision)

Precision measurements were performed by the collection and analysis of duplicate samples. Field duplicates were collected to monitor the overall precision of the sample collection and laboratory analyses. Duplicate inlet and outlet samples were collected during three different storm events to evaluate precision in the sampling processes. The duplicate samples were processed, delivered to the laboratory, and analyzed in the same manner as the regular samples. Relative percent difference (RPD) between the analytical results for the test samples and those for the duplicate samples was calculated to evaluate precision. RPD is calculated using the following formula:

$$\%RPD = \left(\frac{|x_1 - x_2|}{\bar{x}}\right) \times 100\% \qquad (6\text{-}1)$$

where:

x_1 = Concentration of compound in sample

x_2 = Concentration of compound in duplicate

$\bar{x}$ = Mean value of x_1 and x_2

Three field duplicates were analyzed, and are summarized in Table 6-2. Overall, the results show good duplication. Below is a discussion of the results from selected parameters.

TSS and SSC: All duplicates were within the target limits.

Metals: For dissolved metals, five samples had a high RPD (low precision) and seven samples had low RPD (high precision). Most of the total metals results were within the target limits. In two instances where the RPD was above the target limit, the results were obtained for the effluent duplicate, where concentrations were typically lower than influent concentrations.

TPH- GRO and DRO: All results were below the target limit for both parameters. However, in most cases during the sampling period, GRO was not detected and DRO was detected in very few cases.

PAH: All results were below the target limit for both parameters. However, constituents of the PAHs were not detected for most events. In addition, for the last duplicate sampling round, not enough volume was captured for processing of PAHs.

Table 6-2. Field Duplicate Sample RPD Data Summary

			October 14, 2003			December 29, 2003			May 10, 2004		
Parameter	**Unit**		**Rep 1**	**Rep 2**	**RPD (%)**	**Rep 1**	**Rep 2**	**RPD (%)**	**Rep 1**	**Rep 2**	**RPD (%)**
TSS	mg/L	Influent	2,460	-	-	2,040	-	-	1,660	1,590	4
	mg/L	Effluent	1,400	1,430	2	1,930	1,770	9	2,180	-	-
SSC	mg/L	Influent	2,500	2,300	8	1,800	-	-	1,600	1,600	0
	mg/L	Effluent	1,200	-	-	1,700	2,200	26	2,300	-	-
Total Cadmium	µg/L	Influent	1.8	-	-	2.5	-	-	0.78	-	-
	µg/L	Effluent	1.3	1.2	8	2.4	2.2	9	**0.1**	1.4	173
Total Lead	µg/L	Influent	130	-	-	130	-	-	68	-	-
	µg/L	Effluent	88	85	3	130	120	8	100	91	9
Total Copper	µg/L	Influent	31	-	-	100	-	-	39	-	-
	µg/L	Effluent	31	30	3	120	160	29	64	55	15
Total Zinc	µg/L	Influent	160	-	-	320	-	-	170	-	-
	µg/L	Effluent	160	170	6	360	340	6	310	280	10
Dissolved Cadmium	µg/L	Influent	**0.1**	**0.1**	0	**0.1**	-	-	**0.1**	-	-
	µg/L	Effluent	**0.1**	-	-	**0.1**	**0.1**	0	**0.1**	**0.1**	0
Dissolved Lead	µg/L	Influent	2.9	8.5	98	**0.5**	-	-	1	-	-
	µg/L	Effluent	19	-	-	**0.5**	**0.5**	0	6.6	8.1	20
Dissolved Copper	µg/L	Influent	21	15	33	19	-	-	12	-	-
	µg/L	Effluent	17	-	-	16	18	12	16	18	12
Dissolved Zinc	µg/L	Influent	25	77	102	5.3	-	-	**1**	-	-
	µg/L	Effluent	100	-	-	5.8	7.7	28	31	8	118
TPH-GRO	µg/L	Influent	**50**	-	-	**50**	**50**	0	**50**	-	-
	µg/L	Effluent	**50**	**50**	0	**50**	-	-	**50**	**55**	10
TPH-DRO	µg/L	Influent	52,000	-	-	2,000	1,800	11	**55**	-	-
	µg/L	Effluent	19,000	16,000	17	2,500	-	-	**55**	**55**	0

Values in **boldface text** represent results where one-half the method detection limit was substituted for values below detection limits to calculate RPD.

Table 6-2. Field Duplicate Sample Relative Percent Difference Data Summary – continued

			October 14, 2003			December 29, 2003		
Parameter	**Unit**		**Rep 1**	**Rep 2**	**RPD (%)**	**Rep 1**	**Rep 2**	**RPD (%)**
Acenaphthene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Acenaphthylene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Anthracene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Benzo(a)anthracene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Benzo(a)pyrene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Benzo(b)fluoranthene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Benzo(ghi)Perylene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Benzo(k)fluoranthene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Chrysene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Dibenzo(a,h)anthracene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Fluoranthene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Fluorene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Indeno(1,2,3-cd)pyrene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
2-Methylnaphthalene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Naphthalene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Phenanthrene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-
Pyrene	µg/L	Influent	<1.0		-	<1.0		0
	µg/L	Effluent	<1.0	<1.0	0	<1.0	<1.0	-

6.1.3 Accuracy

Method accuracy was determined and monitored using a combination of matrix spike/matrix spike duplicates (MS/MSD) and laboratory control samples (known concentration in blank water). The MS/MSD data are evaluated by calculating the deviation from perfect recovery (100%) and measuring possible interferences with recovery due to sample matrix. Laboratory control data are evaluated by calculating the deviation from the laboratory control concentration. Accuracy was in control throughout the verification test. Tables 6-3 and 6-4 summarize the matrix spikes and lab control sample recovery data, respectively.

Table 6-3. Laboratory MS/MSD Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Std. Dev. (%)	Range (%)
Acenaphthylene	6	85.0	94	56	15.2	70-130
Anthracene	4	79.8	84	74.6	4.22	70-130
Benzo(a)anthracene	4	79.2	80.8	77.6	1.46	70-130
Benzo(a)pyrene	4	107	126	91.2	18.7	70-130
Benzo(b)fluoranthene	4	101	112	88.8	12.3	70-130
Benzo(ghi)Perylene	4	106	117	91.6	13.3	70-130
Benzo(k)fluoranthene	4	97.0	113	84.4	12.7	70-130
Chrysene	4	101	112	91.6	10.3	70-130
Dibenzo(a,h)anthracene	4	116	126	104	11.0	70-130
Fluoranthene	4	100	113	88.4	12.0	70-130
Fluorene	4	103	124	85.2	18.0	70-130
Indeno(1,2,3-cd)pyrene	4	86.6	89.2	84.4	2.20	70-130
2-Methylnaphthalene	4	105.3	117	94	11.9	70-130
Naphthalene	4	80.8	82.8	79.2	1.57	70-130
Phenanthrene	4	89.1	91.2	87.2	1.65	70-130
Pyrene	6	95.9	125	64	23.9	70-130
Total cadmium	8	102	111	91.4	6.80	75-125
Total lead	8	101	110	85.5	8.66	75-126
Total copper	8	93.8	109	81.5	8.74	75-127
Total zinc	8	98.4	114	70.5	13.9	75-128
Dissolved cadmium	6	103	112	85.5	9.86	75-129
Dissolved lead	6	103	110	90	7.67	75-130
Dissolved copper	6	99.2	115	90	8.60	75-131
Dissolved zinc	6	105	113	90	8.61	75-132

Table 6-4. Laboratory Control Sample Data Summary

Parameter	Count	Average (%)	Maximum (%)	Minimum (%)	Std. Dev. (%)
Acenaphthylene	12	85.3	115.00	54.0	20.6
Anthracene	5	84.9	96.4	70.8	11.6
Benzo(a)anthracene	5	86.4	102	70.8	14.4
Benzo(a)pyrene	5	112	124	98.8	11.6
Benzo(b)fluoranthene	5	101	107	84.4	9.35
Benzo(ghi)Perylene	5	107	116	92.0	9.74
Benzo(k)fluoranthene	5	107	121	82.0	15.8
Chrysene	5	101	107	88.0	7.64
Dibenzo(a,h)anthracene	5	115	126	105	9.37
Fluoranthene	5	106	121	89.2	11.6
Fluorene	5	105	120	92.4	13.1
Indeno(1,2,3-cd)pyrene	5	94.2	113	80.4	12.5
2-Methylnaphthalene	5	109	120	93.2	9.68
Naphthalene	5	92.1	106	80.1	12.4
Phenanthrene	5	94.3	104	77.6	10.9
Pyrene	12	87.1	116	56.0	18.5
Total cadmium	5	103	111	97.1	5.58
Total lead	5	103	110	96.1	5.60
Total copper	4	97.0	105	92.0	6.28
Total zinc	4	106	111	100	4.57
Dissolved cadmium	4	99.5	104	96.0	3.42
Dissolved lead	4	98.5	102	92.0	4.73
Dissolved copper	4	93.5	104	84.0	9.98
Dissolved zinc	4	97.3	104	90.0	5.74
TSS	5	100	106	98.2	3.29

6.1.4 Representativeness

The field procedures were designed to ensure that representative samples were collected of both influent and effluent stormwater. Field duplicate samples and supervisor oversight provided assurance that procedures were being followed. The challenge in sampling stormwater is obtaining representative samples. The data indicated that while individual sample variability might occur, the long-term trend in the data was representative of the concentrations in the stormwater, and repeatable methods of evaluating key constituent loadings in the stormwater were utilized to compensate for the variability of the laboratory data.

The laboratory used standard analytical methods, with written SOPs for each method, to provide a consistent approach to all analyses. Sample handling, storage, and analytical methodology were reviewed to verify that standard procedures were being followed. The use of standard methodology, supported by proper quality control information and audits, ensured that the analytical data were representative of actual stormwater conditions.

To obtain representativeness of the sub-samples (aliquots) necessary to analyze the various parameters from the event sample, a cone splitter was used. Because the site was located near municipal stockpiles of dirt, it was suspected that the sediment levels in the sample water would be very high. The churn splitter, which is typically used in this application, has limited accuracy when splitting samples high in sediment. According to the USGS Office of Water Quality National Field Manual, a churn splitter is accurate for splitting samples with a suspended sediment concentration up to 1,000 mg/L. The cone splitter can be used for suspended sediment concentrations up to 10,000 mg/L. For this reason, the cone splitter, which has a higher accuracy for sample splitting with high sediment loads, was selected.

6.1.5 Completeness

The flow data and analytical records for the verification study are 100% complete. However, hydrocarbon (TPH and PAH) was not conducted during three events (9, 10 and 11) due to insufficient sample volume.

RTI did not achieve the GRO and DRO detection limits originally specified in the test plan. RTI was concerned that reporting values at the detection limits requested by the test plan would increase the likelihood that interferences and instrumentation error could result in false positive reports being reported.

6.2 Flow Measurement Calibration

The flow was calibrated by TO field crews checking the depth of water in the pipe and correlating it to the value reported by the flow meter. The ISCO 4230 and 730 Bubbler Flow Meters used in the testing measure only the depth of water, so a weir plate was used as a primary calibration device for the flow meters. The primary device was calibrated by the manufacturer (ISCO) at the factory. ISCO also provided information regarding the relationships between depths of water and flow, which were programmed into the sampling equipment. To calibrate the depth, field crews measured the depth of water behind the primary device to ensure that the flow meter was reading the same depth. This was done prior to the start of rain at every other event. At no time was there a difference in the depth of water of more than 0.1 inch.

6.2.1 Flow Pacing

During 2003, the TO used an ISCO 730 Bubbler Flow Meter to pace the samplers. The flow meter was programmed to read the flow at the CBSF and, based on a series of pulses, dictated when the influent sampler collected samples. The effluent sampler was also programmed to collect a sample based on pulses coming from the influent sampler. This should have led to an influent sample being collected first, followed by the collection of an effluent sample. However samples in the effluent sampler were not being properly collected. Even after assistance from the manufacturer, it was determined that the use of the 730 Bubbler in this configuration would not work.

To remedy this, the 730 Bubbler was replaced with a stand-alone ISCO 4230 Bubbler flow meter. Each sampler was directly connected to the flow meter and the effluent sampler was programmed to run on a 50-gal delay from the influent sampler. Once the equipment was changed, there were very few disqualified events because of equipment problems.

However, for event 12, on June 10, 2004, the flow pacing was inaccurate. According to the report collected by the flow meter, effluent aliquots 19 through 24 were collected at the same time or one to two minutes prior to the influent samples. It is believed that this was because the samplers were collecting samples every one to two minutes and the flow rate was high enough that the sampler collection process did not catch up with the program's command to collect a sample.

Prior to collecting a sample, the sampler runs through a purge and rinse cycle. This cycle can last from approximately 30 to 60 seconds, depending upon the length of suction line. The influent suction line was 53 ft and the effluent suction line was 43 ft. This difference in length most likely caused a very slight increase in time for the purge, rinse and collection cycle for the influent sampler, as compared to the effluent sampler. This difference may have caused the effluent sampler to complete its collection process slightly faster than the influent sampler, allowing the effluent sampler to start the collection process for the next sample before the influent had completed the collection process for the previous sample. The flow rate and the difference in tubing lengths, is expected to explain why the effluent samples were collected before the influent samples during event 12.

6.2.2 Inlet – Outlet Volume Comparison

The CBSF is an offline system. For this project, the only influent water was surface runoff that entered the CBSF through the storm grate. It was assumed that the volume entering the storm grate was the same as that leaving the CBSF. Therefore, only one flow meter, installed at the outlet, was used. The CBSF unit retains a certain volume of water between events, but since this retained volume is essentially constant between events, the net runoff volume into the unit should equal the net runoff volume exiting the unit.

Chapter 7
Operation and Maintenance Activities

7.1 System Operation and Maintenance

Installation of the CBSF was completed in April 2003. During summer 2003, the system was placed into operation and adjustments to the system were completed, ETV monitoring began in September 2003. A summary of the O&M activities for the CBSF during the test, including the activity completed and the personnel time and cost to complete the activity, is summarized in Table 7-1.

Table 7-1. Operation and Maintenance During Verification Testing

Date	Activity	Personnel Time/Cost
April 11, 2003	CBSF was installed.	ECT: 1 staff, 1 day SCS DPW: 3-5 staff, 2 days
Sept. 10, 2003	CBSF major maintenance. The cartridges were replaced and the sediment was removed from the CBSF. A total of 13 in. from the central chamber and 17 in. from the cartridge chambers of sediment were removed. Once the sediment was removed, it was evident that the PVC manifold piping was disconnected. ECT staff dry-fit the manifold and replaced the cartridges.	ECT: 2 staff, 1 day SCS DPW: 2 staff, 1 day
Sept 28 through Oct. 1, 2003	ECT contacted SMI regarding the cloudiness of the effluent sample, indicating the manifold may be leaking. SMI came on site on 10/1/03 to inspect and repair the PVC manifold. The chambers were opened and the cartridges removed. SMI staff used PVC glue to repair the PVC manifold.	ECT: 2 staff, 1 day SMI: 1 staff, 1 day
Nov. 21, 2003	Several events were disqualified because insufficient volume was collected in the effluent sampler. SMI installed the automatic effluent strainer, located at the invert of the CBSF outlet. During the rain events, field crews determined that the strainer was not submerged in the flow. To ameliorate this, a tubing elbow was installed to angle the strainer downward in the effluent bay of the CBSF.	ECT: 2 staff, 1 day

Table 7-1. Operation and Maintenance During Verification Testing - continued

Date	Activity	Personnel Time/Cost
Jan. 13, 2004	Decommission of sampling equipment for the winter began with the removal of tubing and influent tray.	ECT: 1 staff, 1 day
Jan. 19, 2004	Decommission of sampling equipment continued with the removal of flow meter and automatic samplers. All equipment was stored in the SCS DPW storage facility.	ECT: 1 staff, 1 day SCS DPW: 2 staff, 1 day
April 6, 2004	Inspection of CBSF prior to sampling commencement. It was determined by ECT and NSF that a major maintenance was needed, based on sediment measurements.	ECT: 2 staff, 1 day NSF: 1 staff, 1 day
April 10, 2004	Major maintenance of the CBSF was performed. The old cartridges were removed and the unit was cleaned using a vacuum truck and water from the SCS DPW. New cartridges were installed and the unit was set up for sampling, including autosampler programming and calibrating, and changing the sample tubing.	ECT: 2 staff, 1 day NSF: 1 staff, 1 day SMI: 2 staff, 1 day SCS DPW: 3 staff, 1 day
Dec. 8-10, 2004	Site was decommissioned and all sampling equipment was removed.	ECT: 2 staff, 2 days
Dec. 10, 2004	Final major maintenance performed on the CBSF. Cartridges were removed and sediment removed. Caps were placed on the PVC manifold because new cartridges were not installed. The PVC manifold was cracked by a DPW employee mishandling a spent filter cartridge.	ECT: 1 staff, 1 day SMI: 1 staff, 1 day NSF: 2 staff, 1 day SCS DPW: 2 staff, 1 day

7.2 Retained Solids Analysis

Based on the measurements of the 43% retained solids in the CBSF recorded by the VO, and the bulk density analyses conducted by the vendor's laboratory, an estimate of the dry mass of retained solids inside the CBSF at the time of the two maintenance activities can be made, and are summarized in Table 7-2. The calculated mass of retained solids shows that the CBSF had retained substantially more sediment than its rated specification of 100 lb and one cubic yard of sediment.

Table 7-2. Estimated Dry Mass of Retained Solids in CBSF

Description	Sediment depth (in)	Calculated dry volume (ft^3)	Calculated dry mass (lb)
April 10, 2004			
Left cartridge chamber	16	49	3,700
Right cartridge chamber	13	40	3,000
Inlet/outlet chamber	28	55	5,300
Total		**144**	**12,000**
December 10, 2004			
Left cartridge chamber	11	40	2,500
Right cartridge chamber	9	28	2,100
Inlet/outlet chamber	26	51	4,900
Total		**119**	**9,500**

7.3 System Schedule of Activities

Between April when the CBSF was installed and September when the first sampling occurred, the drain pipes downstream of the CBSF became blocked. Although the CBSF did not discharge directly to this drain, the flow meter used for the CBSF verification test was installed in a manhole that was part of the blocked drain, causing flooding conditions in the manhole where the flow meter was located. These conditions led to inaccurate flow measurement. The DPW cleared the blockage in early September. Once the testing started, sampling crews mobilized 28 times, successfully sampling a total of 17 rain events. Of the mobilizations that did not result in a qualified event, five were due to equipment problems, and six were due to an insufficient rain depth. Temperature gradients associated with the cooler air over Lake St. Clair appeared to redirect rain events to the north or south of the DPW. This had not been expected to happen at the beginning of the project, but was evident through observation of the TO.

Chapter 8
Vendor-Supplied Information

The information and data contained in this section of the report is provided by the technology vendor, SMI, and has not verified by the Testing Organization or the Verification Organization.

The testing performed on the SMI CBSF located at the City of St. Clair Shores Department of Public Works Yard was conducted under conditions that lie outside any performance claim or operational envelope for the CBSF. Due to the inherent property of filter occlusion as the solids load to a filter exceeds the capacity of the filter, the filter will cease to function until maintenance or replacement occurs. The results obtained from the testing at St. Clair Shores Department of Public Works Yard represents data collected from filters that were severely impacted by exceedingly high solids loads, sampled in a completely occluded condition. To support the above statements we present the following supporting points:

- The test plan states that the material stored on the site would be sand, asphalt or concrete, or a concrete sand mix. In reality, what was stored was a sandy clay loam (see Section 5.2). The finer particle-size material caused the filter media to become clogged and blind more rapidly than a more coarse sediment would have caused.

- SMI originally sized the four-cartridge CBSF for this drainage area on the assumption that the soil piles would not significantly contribute sediments into the drainage area, based on Figure 4-1 in the test plan (Appendix A).

- At times, mounds of soil were piled immediately adjacent to the CBSF with heavy equipment operating directly on top of and around the CBSF, causing excavated material to directly enter the inlet bay through the surface grate (see Figures 3-3 and 3-4).

- For "typical" stormwater, the TSS concentrations published in literature are on the order of 100 mg/L, whereas the TSS concentrations for this project are consistently in the thousands of mg/L, with a maximum of 5,200 mg/L and an average of 3,000 mg/L. Such TSS concentrations are not representative of typical stormwater runoff and are outside the bounds of any usage that SMI recommends for the CBSF. SMI attempts to make it clear that this technology is not appropriate for an erosion control situation or other heavy sediment conditions similar to the situation at this site.

- A cartridge solids load analysis by SMI indicates that, due to the extreme solids loading conditions induced by the piles of excavated materials, the filters would have required on the order of 50 maintenance cycles during the monitoring period (see Section 8.1).

- Of the 16 storms sampled, 10 have flows in excess of the system design flow, further exacerbating the issue with flows to bypass the filtration system. Additionally, during intense storm events, it appears that the CBSF was receiving a contribution of stormwater from outside the originally-specified drainage area, and operating in excess of the design flow.

In conclusion, SMI believes that this project does not represent a meaningful evaluation of the CBSF. However, SMI understands that there is a risk taken when working with multiple variables beyond the scope or control of the investigation that have significant influence on the results.

8.1 Sediment Loading Analysis

The objective of this analysis is to estimate the cumulative influent solids load, cumulative cartridge loading capacity, and number of maintenances required based on the 25-lb rated capacity of the StormFilter cartridge during each of the sampling periods after maintenance of the four cartridge CBSF system installed at the St. Clair Shores DPW yard.

The following steps were used to analyze the rate at which sediment was loaded into the CBSF, which is summarized in Table 8-1 and graphically in Figure 8-1:

1. Determine the relationship of rainfall to runoff for periods between maintenance events (April 10 and December 10, 2004), using TSS data collected by the VO;
2. Produce cumulative runoff for storms greater than 0.2 in., including storms that were not sampled, using rainfall data collected by nearby rainfall stations maintained by the Southeast Michigan Council of Governments, which would provide a reasonable estimate for the total rain that fell at the test site;
3. Calculate the average influent TSS influent concentration for the qualified storm events, using data collected by the VO;
4. Calculate daily influent solids load, using calculated average TSS and daily cumulative runoff volume;
5. Calculate the daily CBSF mass loading, using a 90% runoff rate, an estimated CBSF pre-treatment efficiency of 10%, and a StormFilter cartridge treatment efficiency of 50%; and
6. Determine cumulative influent solids load, cumulative cartridge loading capacity, and number maintenances required for each of the testing.

Table 8-1. Estimated Sediment Loading Results

Description	Date range	
	9/03 to 4/04	**5/04 to 11/04**
Cumulative precipitation (in)	18.7	37.3
Cumulative influent solids load (lb)	16,900	34,000
Cumulative cartridge loading capacity (%)	2,500	2,600
Determined number of maintenances required	25	26
Number of events sampled prior to first required maintenance	0	0

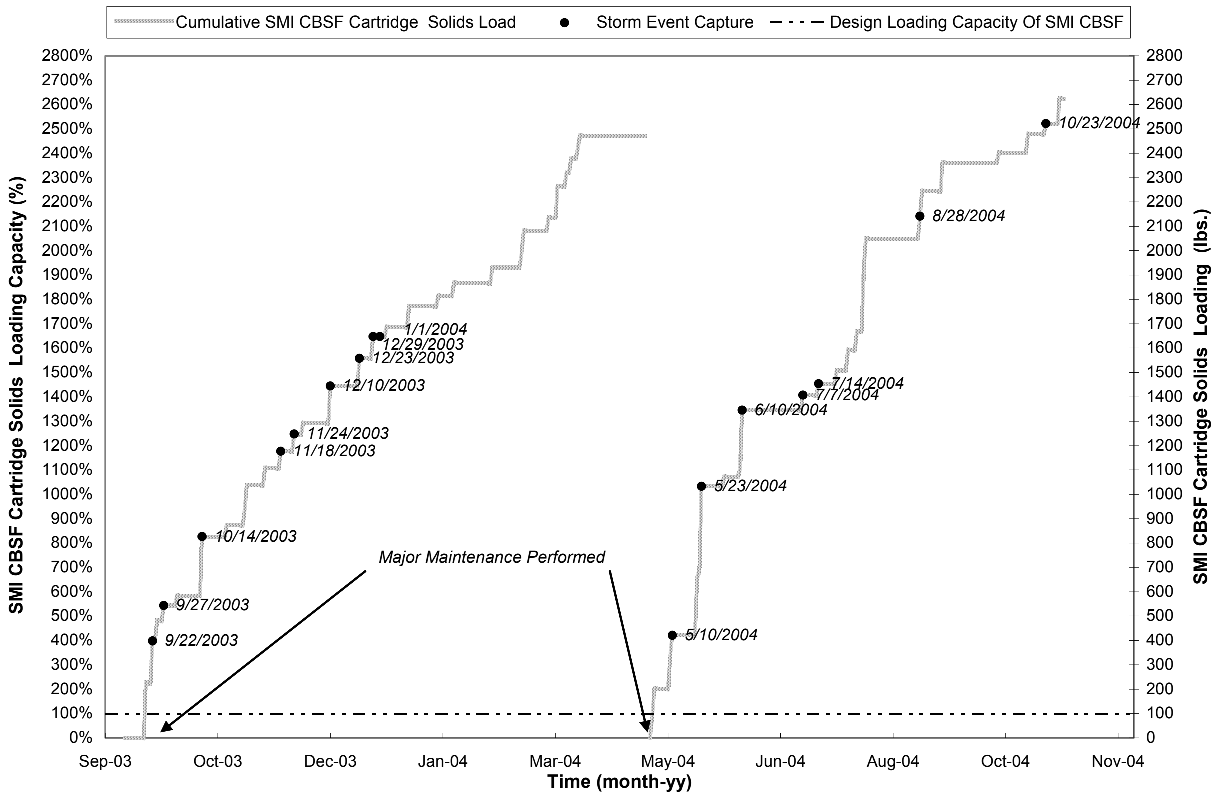

Figure 8-1. St. Clair Shores SMI CBSF cartridge solids loading capacity versus time.

The calculated cumulative CBSF cartridge solids loads for both periods prior to the sampling of the first storm event during each period was calculated to be 400 lb for the first period and 420 lb for the second period. The rated solids loading capacity of each StormFilter cartridge is 25 lb, thus the capacity for the four-cartridge CBSF is 100 lb. Therefore, each qualified event contributed a mass loading that was four times greater than the rated capacity of the CBSF. These calculations were made without taking into account the loading that might have taken place on a daily basis due to dry weather activities in and around the CBSF.

Appendices

Glossary

Accuracy - a measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a quantitative term that expresses confidence that all necessary data have been included.

Precision - a measure of the agreement between replicate measurements of the same property made under similar conditions.

Protocol – a written document that clearly states the objectives, goals, scope and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program.

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

Residuals – the waste streams, excluding final effluent, which are retained by or discharged from the technology.

Representativeness - a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point, a process condition, or environmental condition.

Wet-Weather Flows Stakeholder Advisory Group - a group of individuals consisting of any or all of the following: buyers and users of in drain removal and other technologies, developers and Vendors, consulting engineers, the finance and export communities, and permit writers and regulators.

Standard Operating Procedure – a written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Technology Panel - a group of individuals with expertise and knowledge of stormwater treatment technologies.

Testing Organization – an independent organization qualified by the Verification Organization to conduct studies and testing of mercury amalgam removal technologies in accordance with protocols and Test planans.

Vendor – a business that assembles or sells treatment equipment.

Verification – to establish evidence on the performance of in drain treatment technologies under specific conditions, following a predetermined study protocol(s) and Test planan(s).

Verification Organization – an organization qualified by USEPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

Verification Report – a written document containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results. The Test planan(s) shall be included as part of this document.

Verification Statement – a document that summarizes the Verification Report reviewed and approved and signed by USEPA and NSF.

Verification Test planan – A written document prepared to describe the procedures for conducting a test or study according to the verification protocol requirements for the application of in drain treatment technology. At a minimum, the Test planan shall include detailed instructions for sample and data collection, sample handling and preservation, precision, accuracy, goals, and quality assurance and quality control requirements relevant to the technology and application.

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