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Environmental Technology Verification Report

Stormwater Source Area Treatment Device

The Stormwater Management StormFilter® Using ZPG Filter Media

Prepared by

NSF International

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

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 STORMFILTER® USING ZPG FILTER MEDIA**	
TEST LOCATION:	**MILWAUKEE, WISCONSIN**	
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 EPA, operates the Water Quality Protection Center (WQPC), one of six centers under ETV. The WQPC recently evaluated the performance of the Stormwater Management StormFilter® (StormFilter) using ZPG filter media manufactured by Stormwater Management, Inc. (SMI). The system was installed at the “Riverwalk” site in Milwaukee, Wisconsin. Earth Tech, Inc. and the United States Geologic Survey (USGS) performed the testing.

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 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 StormFilter was provided by the vendor and does not represent verified information.

The StormFilter installed at the Riverwalk site consists of an inlet bay, flow spreader, cartridge bay, overflow baffle, and outlet bay, housed in a 12 foot by 6 foot pre-cast concrete 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 0.29 cubic feet per second (cfs). Flows greater than the maximum flow rate would pass the overflow baffle to the discharge pipe, bypassing the filter media.

The StormFilter contains filter cartridges filled with ZPG filter media (a mixture of zeolite, perlite, and granular activated carbon), which are designed to remove sediments, metals, and 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 vendor claims that the treatment system can remove 50 to 85 percent of the suspended solids in stormwater, along with removal of total phosphorus, total and dissolved zinc, and total and dissolved copper in ranges from 20 to 60 percent.

VERIFICATION TESTING DESCRIPTION

Methods and Procedures

The test methods and procedures used during the study are described in the *Test Plan for Verification of Stormwater Management, Inc. StormFilter® Treatment System Using ZPG Media, "Riverwalk Site," Milwaukee, Wisconsin* (NSF International and Earth Tech, March 2004) (VTP). The StormFilter treats runoff collected from a 0.19-acre portion of the eastbound highway surface of Interstate 794. Milwaukee receives an average of nearly 33 inches of precipitation, approximately 31 percent of which occurs during the summer months.

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 inches (5 mm) or greater (snow fall and snow melt events do 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 sample monitoring and collection devices were installed and programmed to collect composite samples from the influent, the treated effluent, and the untreated bypass during qualified flow events. 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)
- total dissolved solids (TDS)
- suspended sediment concentration (SSC)
- particle size analysis

Metals

- total and dissolved cadmium, lead, copper and zinc

Nutrients

- total and dissolved phosphorus

Water Quality Parameters

- chemical oxygen demand (COD)
- dissolved chloride
- total calcium and magnesium

VERIFICATION OF PERFORMANCE

Verification testing of the StormFilter lasted approximately 16 months, and coincided with testing conducted by USGS and the Wisconsin Department of Natural Resources. A total of 20 storm events were sampled. Conditions during certain storm events prevented sampling for some parameters. However, samples were successfully taken and analyzed for all parameters for at least 15 of the 20 total storm events.

Test Results

The precipitation data for the 20 rain events are summarized in Table 1.

Table 1. Rainfall Data Summary

Event Number	Start Date	Start Time	Rainfall Amount (inches)	Rainfall Duration (hr:min)	Runoff Volume (ft^3)[1]	Peak Discharge Rate (gpm)[1]
1	6/21/02	6:54	0.52	0:23	420	447
2	7/8/02	21:16	1.5	2:04	1,610	651
3	8/21/02	20:08	1.7	15:59	1,620	671
4	9/2/02	5:24	1.2	3:24	1,180	164
5	9/18/02	5:25	0.37	4:54	350	136
6	9/29/02	0:49	0.74	7:54	730	70.9
7	12/18/02	1:18	0.37	3:47	300	61.0
8	4/19/03	5:39	0.55	10:00	340	96.9
9	5/4/03	21:21	0.90	11:44	540	73.2
10	5/30/03	18:55	0.54	4:06	320	83.9
11	6/8/03	3:26	0.62	11:09	450	140
12	6/27/03	17:30	0.57	13:25	460	107
13	7/4/03	7:25	0.53	40:43	550	143
14	7/8/03	9:49	0.33	3:37	260	62.8
15	9/12/03	15:33	0.22	1:55	150	21.5
16	9/14/03	5:22	0.47	6:35	340	264
17	9/22/03	2:28	0.27	2:09	270	104
18	10/14/03	1:03	0.25	2:07	220	56.5
19	10/24/03	16:46	0.71	15:07	410	75.8
20	11/4/03	16:14	0.60	2:09	560	906

[1] Runoff volume and peak discharge volume was measured at the outlet monitoring point.

The monitoring results were evaluated using event mean concentration (EMC) and sum of loads (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 15 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 2. Analytical Data, EMC Range, and SOL Reduction Results

Parameter[1]	Units	Inlet Range	Outlet Range	EMC Range (percent)	SOL Reduction (percent)
TSS	mg/L	29 – 780	20 – 380	-33 – 95	46
SSC	mg/L	51 – 5,600	12 – 370	3 – 99	92
TDS	mg/L	<50 – 600	<50 – 4,200[2]	-600 – 10	-170[2]
Total phosphorus	mg/L as P	0.05 – 0.63	0.03 – 0.30	0 – 70	38
Dissolved phosphorus	mg/L as P	0.01 – 0.20	0.01 – 0.19	-35 – 38	6
Total magnesium	mg/L	4.0 – 174	1.1 – 26	53 – 96	85
Total calcium	mg/L	9.4 – 430	4.0 – 68	26 – 93	79
Total copper	µg/L	15 – 440	7.0 – 140	8.3 – 96	59
Total lead	µg/L	<31 – 280	<31 – 94	33 – 91	64
Total zinc	µg/L	77 – 1,400	28 – 540	20 – 89	64
Dissolved copper	µg/L	<5 – 58	<5 – 42	-47 – 64	16
Dissolved zinc	µg/L	26 – 360	16 – 160	-86 – 56	17
COD	mg/L	18 – 320	17 – 190	-91 – 47	16
Dissolved chloride	mg/L	3.2 – 470	3.3 – 2,600[2]	-740 – 24	-242[2]

[1] Total and dissolved cadmium and dissolved lead concentrations were below method detection limits for every storm event.

[2] Dissolved chloride and TDS results were heavily influenced by a December storm event when road salt was applied to melt snow and ice.

Based on the SOL evaluation method, the TSS reductions nearly met the vendor's performance claim, while SSC reductions exceeded the vendor's performance claim of 50 to 85 percent solids reduction. The StormFilter also met or exceeded the performance claim for total and dissolved phosphorus, total copper, and total zinc. The StormFilter did not meet the performance claim for dissolved copper or dissolved zinc, both of which were 20 to 40 percent reduction, and had no performance claims for any other parameters.

The TDS and dissolved chloride values were heavily influenced by a single event (December 18, 2002), where high TDS and dissolved chloride concentrations were detected in the effluent. The event was likely influenced by application of road salt on the freeway. When this event is omitted from the SOL calculation, the SOL value is -37 percent for TDS and -31 percent for dissolved chloride.

Particle size distribution analysis was conducted on samples when adequate sample volume was collected. The analysis identified that the runoff entering the StormFilter contained a large proportion of coarse sediment. The effluent contained a larger proportion of fine sediment, which passed through the pores within the filter cartridges. For example, 20 percent of the sediment in the inlet samples was less than 62.5 µm in size, while 78 percent of the sediment in the outlet samples was less than 62.5 µm in size.

System Operation

The StormFilter was installed prior to verification testing, so verification of installation procedures on the system was not documented.

The StormFilter was cleaned and equipped with new filter cartridges prior to the start of verification. During the verification period, two inspections were conducted as recommended by the manufacturer. Based on visual observations, the inspectors concluded that a major maintenance event, consisting of cleaning the vault and replacing the filter cartridges, was not required. After the verification was complete, a major maintenance event was conducted, and approximately 570 pounds (dry weight) of sediment was removed from the StormFilter's sediment collection chamber.

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 percent 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
Lawrence W. Reiter, Ph. D. September 21, 2004
Lawrence W. Reiter, Ph. D. Date
Acting Director
National Risk Management Laboratory
Office of Research and Development
United States Environmental Protection Agency

Original Signed by
Gordon E. Bellen September 23, 2004
Gordon E. Bellen Date
Vice President
Research
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 04/17/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.

Environmental Technology Verification Report

Stormwater Source Area Treatment Device

The Stormwater Management StormFilter® Using ZPG Filter Media

Prepared for:
NSF International
Ann Arbor, MI 48105

Prepared by
Earth Tech Inc.
Madison, Wisconsin

With assistance from:
United States Geologic Survey (Wisconsin Division)
Wisconsin Department of Natural Resources

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

Raymond Frederick, Project Officer
ETV Water Quality Protection Center
National Risk Management Research Laboratory
Water Supply and Water Resources Division
U.S. Environmental Protection Agency
Edison, New Jersey

July 2004

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.

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 StormFilter® using ZPG Media was conducted at a testing site in downtown Milwaukee, Wisconsin, maintained by Wisconsin Department of Transportation (WisDOT).

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.

Lawrence W. Reiter, Acting Director
National Risk Management Research Laboratory

Contents

Verification Statement .... VS-i
Notice i
Foreword ii
Contents iii
Figures iv
Tables iv
Abbreviations and Acronyms vi
Chapter 1 Introduction 1
  1.1 ETV Purpose and Program Operation 1
  1.2 Testing Participants and Responsibilities 1
    1.2.1 U.S. Environmental Protection Agency 2
    1.2.2 Verification Organization 2
    1.2.3 Testing Organization 3
    1.2.4 Analytical Laboratories 4
    1.2.5 Vendor 4
    1.2.6 Verification Testing Site 4
Chapter 2 Technology Description 6
  2.1 Treatment System Description 6
  2.2 Filtration Process 7
  2.3 Technology Application and Limitations 8
  2.4 Performance Claim 8
Chapter 3 Test Site Description 9
  3.1 Location and Land Use 9
  3.2 Contaminant Sources and Site Maintenance 10
  3.3 Stormwater Conveyance System 11
  3.4 Water Quality/Water Resources 11
  3.5 Local Meteorological Conditions 11
Chapter 4 Sampling Procedures and Analytical Methods 12
  4.1 Sampling Locations 12
    4.1.1 Site 1 - Influent 12
    4.1.2 Site 2 - Treated Effluent 12
    4.1.3 Other Monitoring Locations 13
  4.2 Monitoring Equipment 14
  4.3 Contaminant Constituents Analyzed 15
  4.4 Sampling Schedule 16
  4.5 Field Procedures for Sample Handling and Preservation 18
Chapter 5 Monitoring Results and Discussion 20
  5.1 Monitoring Results: Performance Parameters 20
    5.1.1 Concentration Efficiency Ratio 20
    5.1.2 Sum of Loads 27
  5.2 Particle Size Distribution 33
Chapter 6 QA/QC Results and Summary 35
  6.1 Laboratory/Analytical Data QA/QC 35
    6.1.1 Bias (Field Blanks) 35
    6.1.2 Replicates (Precision) 36

6.1.3 Accuracy 38
6.1.4 Representativeness 40
6.1.5 Completeness 40
6.2 Flow Measurement Calibration 41
6.2.1 Inlet – Outlet Volume Comparison 41
6.2.2 Gauge Height Calibration 44
6.2.3 Point Velocity Correction 44
6.2.4 Correction for Missing Velocity Data 44
Chapter 7 Operations and Maintenance Activities 47
7.1 System Operation and Maintenance 47
7.1.1 Major Maintenance Procedure 48
Chapter 8 References 49
Glossary 50
Appendices 52
A Verification Test Plan 52
B Event Hydrographs and Rain Distribution 52
C Analytical Data Reports 52

Figures

Figure 2-1. Schematic drawing of a typical StormFilter system. 6
Figure 2-2. Schematic drawing of a StormFilter cartridge. 7
Figure 3-1. Location of test site. 9
Figure 3-2. Drainage area detail 10
Figure 3-3. StormFilter drainage area condition. 10
Figure 4-1. View of monitoring station. 12
Figure 4-2. View of ISCO samplers. 13
Figure 4-3. View of datalogger. 13
Figure 4-4. View of rain gauge. 14
Figure 6-1. Calibration curves used to correct flow measurements 42
Figure 6-2. Event 2 example hydrograph showing period of missing velocity data. 45

Tables

Table 2-1. StormFilter Performance Claims 8
Table 4-1. Field Monitoring Equipment 14
Table 4-2. Constituent List for Water Quality Monitoring 15
Table 4-3. Summary of Events Monitored for Verification Testing 17
Table 4-4. Rainfall Summary for Monitored Events 18
Table 5-1. Monitoring Results and Efficiency Ratios for Sediment Parameters 21
Table 5-2. Monitoring Results and Efficiency Ratios for Nutrient Parameters 23
Table 5-3. Monitoring Results and Efficiency Ratios for Metals 24
Table 5-4. Monitoring Results and Efficiency Ratios for Water Quality Parameters 26
Table 5-5. Sediment Sum of Loads Efficiencies Calculated Using Various Flow Volumes 28
Table 5-6. Sediment Sum of Loads Results 29

Table 5-7. Nutrient Sum of Loads Results 30
Table 5-8. Metals Sum of Loads Results 31
Table 5-9. Water Quality Parameter Sum of Loads Results 32
Table 5-10. Particle Size Distribution Analysis Results 34
Table 6-1. Field Blank Analytical Data Summary 35
Table 6-2. Field Duplicate Sample Relative Percent Difference Data Summary 37
Table 6-3. Laboratory Duplicate Sample Relative Percent Difference Data Summary 38
Table 6-4. Laboratory MS/MSD Data Summary 39
Table 6-5. Laboratory Control Sample Data Summary 39
Table 6-6. Comparison of Inlet and Outlet Event Runoff Volumes 43
Table 6-7. Gauge Corrections for Flow Measurements at the Inlet 44
Table 6-8. Missing Sample Aliquots Due to Missing Inlet Velocity Data 46
Table 7-1. Operation and Maintenance During Verification Testing 47

Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
BMP	Best Management Practice
cfs	Cubic feet per second
COD	Chemical oxygen demand
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
in	Inch
kg	Kilogram
L	Liters
lb	Pound
LOD	Limit of detection
LOQ	Limit of quantification
NRMRL	National Risk Management Research Laboratory
µg/L	Microgram per liter (ppb)
µm	Micron
mg/L	Milligram per liter
NSF	NSF International, formerly known as National Sanitation Foundation
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
SMI	Stormwater Management, Inc.
SSC	Suspended sediment concentration
SOL	Sum of loads
SOP	Standard Operating Procedure
TDS	Total dissolved solids
TO	Testing Organization
TP	Total phosphorus
TSS	Total suspended solids
USGS	United States Geological Survey
VA	Visual accumulator
VO	Verification Organization (NSF)
VTP	Verification test plan
WDNR	Wisconsin Department of Natural Resources
WQPC	Water Quality Protection Center
WisDOT	Wisconsin Department of Transportation
WSLH	Wisconsin State Laboratory of Hygiene
ZPG	ZPG media, a mixture of zeolite, perlite, and granular activated carbon

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 goal of the ETV program is to further environmental protection by substantially 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.

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NSF International (NSF), in cooperation with the EPA, operates the Water Quality Protection Center (WQPC). The WQPC evaluated the performance of The Stormwater Management StormFilter® using ZPG Filter Media (StormFilter), a stormwater treatment device designed to remove suspended solids, metals, and other stormwater pollutants from wet weather runoff.

It is important to note that verification of the equipment does not mean that the equipment is “certified” by NSF or “accepted” by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the Testing Organization (TO).

1.2 Testing Participants and Responsibilities

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

- U.S. Environmental Protection Agency
- NSF International
- U.S. Geologic Survey (USGS)
- Wisconsin Department of Transportation (WisDOT)
- Wisconsin Department of Natural Resources (WDNR)
- Wisconsin State Laboratory of Hygiene (WSLH)
- USGS Sediment Laboratory
- Earth Tech, Inc.
- Stormwater Management, Inc. (SMI)

The following is a brief description of each ETV participant and their 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, National Risk Management Research Laboratory (NRMRL), provides administrative, technical, and quality assurance guidance and oversight on all ETV Water Quality Protection Center activities. In addition, EPA provides financial support for operation of the Center and partial support for the cost of testing for this verification.

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 Verification Organization

NSF is the verification organization (VO) administering the WQPC in partnership with EPA. 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 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 of the verification process. NSF also provided review of the verification test plan (VTP) and this verification report. NSF's responsibilities as the VO include:

- Review and comment on the VTP;
- Review quality systems of all parties involved with the TO, and qualify the TO;
- Oversee TO activities related to the technology evaluation and associated laboratory testing;
- Conduct an on-site audit of test procedures;
- Provide quality assurance/quality control (QA/QC) review and support for the TO;
- Oversee the development of the verification report and verification statement; and,
- Coordinate with EPA to approve the verification report and verification statement.

Key contacts at NSF are:

Mr. Thomas Stevens, Program Manager	Mr. Patrick Davison, Project Coordinator
(734) 769-5347	(734) 913-5719
email: stevenst@nsf.org	email: davison@nsf.org

NSF International
789 North Dixboro Road
Ann Arbor, Michigan 48105
(734) 769-8010

1.2.3 Testing Organization

The TO for the verification testing was Earth Tech, Inc. of Madison, Wisconsin (Earth Tech), which was assisted by the U.S. Geological Service (USGS), located in Middleton, Wisconsin. USGS provided testing equipment, helped to define field procedures, conducted the field testing, coordinated with the analytical laboratories, and conducted initial data analyses.

The TO provided all needed logistical support, established a communications network, and scheduled and coordinated activities of all participants. The TO was responsible for ensuring that the testing location and conditions allowed for the verification testing to meet its stated objectives. The TO prepared the VTP; oversaw the testing; and managed, evaluated, interpreted and reported on the data generated by the testing, as well as evaluated and reported on the performance of the technology. TO employees set test conditions, and measured and recorded data during the testing. The TO's Project Manager provided project oversight.

The key personnel and contacts for the TO are:

Earth Tech, Inc.:

Mr. Jim Bachhuber P.H.
(608) 828-8121
email: jim_bachhuber@earthtech.com

Earth Tech, Inc.
1210 Fourier Drive
Madison, Wisconsin 53717

United States Geologic Survey:

Ms. Judy Horwatich
(608) 821-3874
email: jawierl@usgs.gov

USGS
8505 Research Way
Middleton, Wisconsin 53562

1.2.4 Analytical Laboratories

The Wisconsin State Laboratory of Hygiene (WSLH), located in Madison, Wisconsin, analyzed the stormwater samples for the parameters identified in the VTP, except for suspended sediment concentration and particle size. The USGS Sediment Laboratory, located in Iowa City, Iowa, performed the suspended sediment concentration separations and particle size analyses.

The key analytical laboratory contacts are:

Mr. George Bowman
(608) 224-6279
email: gtb@mail.slh.wisc.edu

WSLH
2601 Agriculture Drive
Madison, Wisconsin 53718

Ms. Pam Smith
(319) 358-3602
email: pksmith@usgs.gov

USGS Sediment Laboratory
Federal Building Room 269
400 South Clinton Street
Iowa City, Iowa 52240

1.2.5 Vendor

Stormwater Management, Inc. (SMI) of Portland, Oregon, is the vendor of the StormFilter, and was responsible for supplying a field-ready system. SMI was also responsible for providing technical support, and was available during the tests to provide technical assistance as needed.

The key contact for SMI is:

Mr. James Lenhart, P.E.
(800) 548-5667
email: jiml@stormwaterinc.com

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

1.2.6 Verification Testing Site

The StormFilter was installed in a parking lot under Interstate 794 on the east side of the Milwaukee River in downtown Milwaukee, Wisconsin. The StormFilter treated storm water collected from the decking of Interstate 794. The unit was installed in cooperation with the Wisconsin Department of Transportation (WisDOT), which is the current owner/operator of the system.

The key contact for WisDOT is:

Mr. Robert Pearson
(608) 266-7980
email: robert.pearson@dot.state.wi.us

Bureau of Environment
Wisconsin Department of Transportation
4802 Sheboygan Avenue, Room 451
Madison, Wisconsin 53707

Chapter 2
Technology Description

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

2.1 Treatment System Description

The Stormwater Management StormFilter® using ZPG Media (StormFilter) is designed to remove sediments, metals, and other roadway pollutants from stormwater. The StormFilter device under test was designed to treat storm water with a maximum flow rate of 0.29 cubic feet per second (cfs). The unit consisted of an inlet bay, flow spreader, cartridge bay, an overflow baffle, and outlet bay, all housed in a 12 ft by 6 ft pre-cast concrete vault. A 2 ft by 6 ft inlet bay served as a grit chamber and provided for flow transition into the 7.4 ft by 6 ft cartridge bay. The flow spreader provided for the trapping of floatables, oil, and surface scum. The unit also included nine filter cartridges filled with ZPG filter media (a mixture of zeolite, perlite, and granular activated carbon), installed inline with the storm drain lines. The cartridge bay provided for sediment storage of 0.87 cubic yards. A schematic of the StormFilter and a detail of the filter cartridge are shown in Figures 2-1 and 2-2.

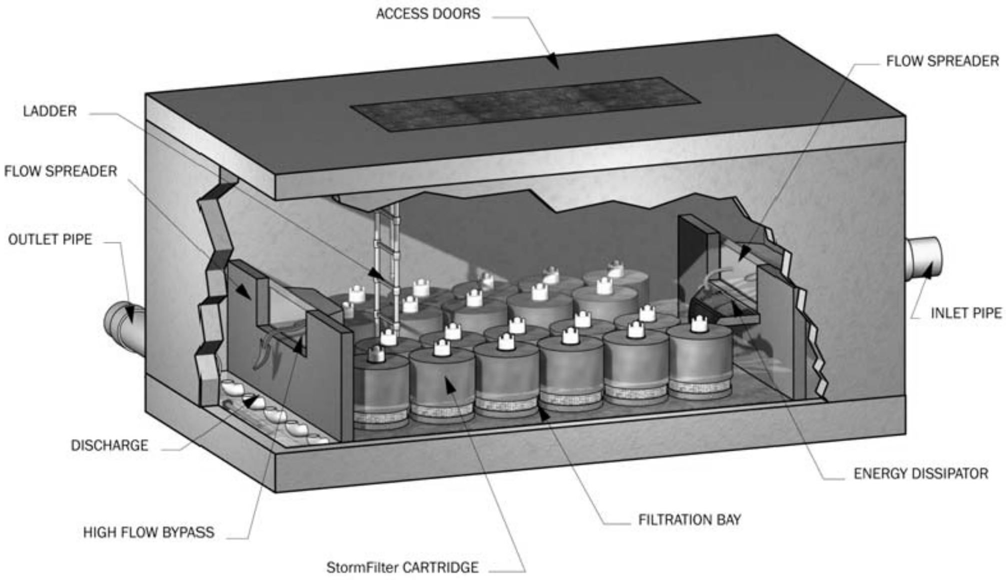


Figure 2-1. Schematic drawing of a typical StormFilter system.

Additional equipment specifications, test site descriptions, testing requirements, sampling procedures, and analytical methods were detailed in the *Test Plan for the Verification of the StormFilter® Treatment System using ZPG Media, "Riverwalk" Site, Version 4.3.* The verification test plan (VTP) is included in Appendix A.

2.2 Filtration Process

The filtration process works by percolating storm water through a series of filter cartridges filled with ZPG media, which is a mixture of zeolite, perlite, and granular activated carbon. The filter media traps particulates and adsorbs materials such as suspended solids and petroleum hydrocarbons. The media will also trap pollutants such as phosphorus, nitrogen, and metals that commonly bind to sediment particulates. A diagram identifying the filter cartridge components is shown in Figure 2-2.

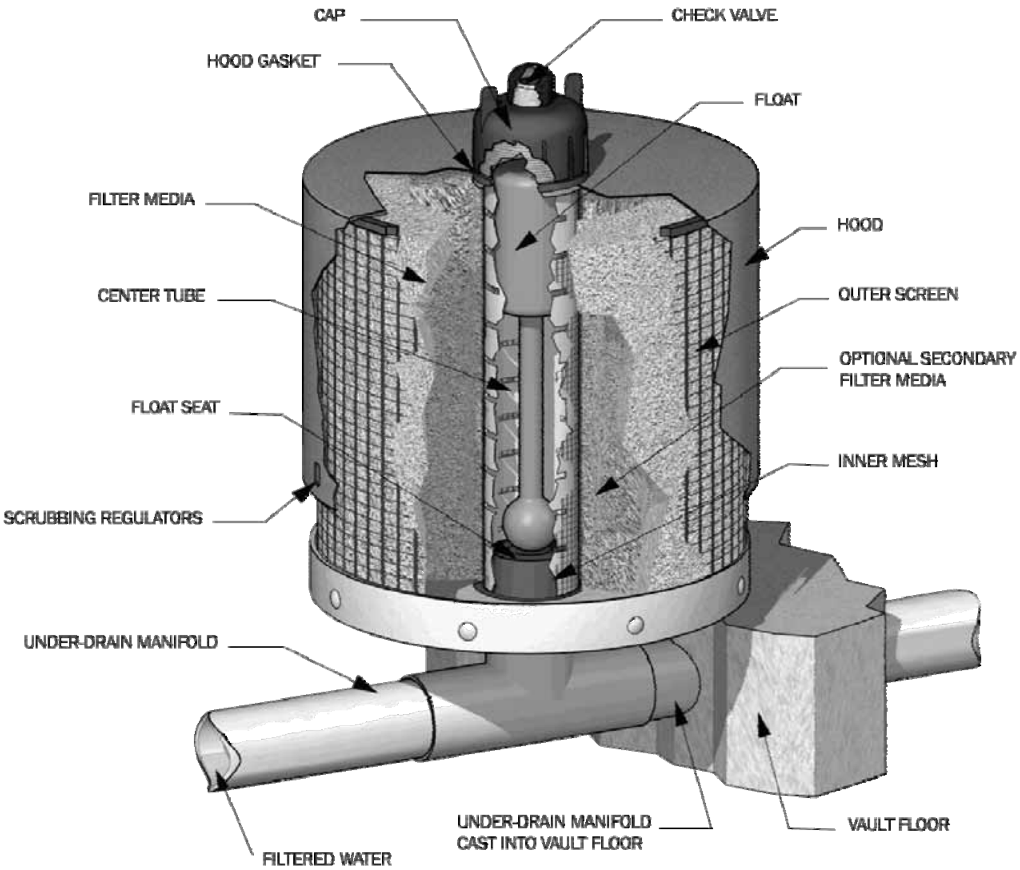


Figure 2-2. Schematic drawing of a StormFilter cartridge.

Storm water enters the cartridge bay through the flow spreader, where it ponds. Air in the cartridge is displaced by the water and purged from beneath the filter hood through the one-way check valve located on top of the cap. 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 storm water 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 StormFilter is equipped with an overflow baffle designed to bypass flows and prevent catch basin backup and surface flooding. The bypass flow is discharged through the outlet pipe along with the treated water.

2.3 Technology Application and Limitations

StormFilter Treatment Systems are flexible in terms of the flow it can treat. By varying the holding tank size, and number of filter cartridges, the treatment capacity can be modified to accommodate runoff from various size watersheds. The filtration systems can be designed to receive runoff from all rainstorm events, or they can be designed with a high flow bypass system.

The StormFilter installed at the Riverwalk site was designed to receive all the runoff from the drainage area.

2.4 Performance Claim

SMI recognizes that stormwater treatment is a function of influent concentration and particle size distribution in the case of sediment removal. The performance claims for the StormFilter unit installed at the Riverwalk site are summarized in Table 2-1. SMI does not provide any additional removal claims for constituents other than those specified in Table 2-1.

Table 2-1. StormFilter Performance Claims

Constituent	Removal Efficiency Range (Percent)
Total suspended solids (TSS)	50 – 85
Total phosphorus	30 – 45
Dissolved phosphorus	Negligible
Total zinc	30 – 60
Dissolved zinc	20 – 40
Total copper	30 – 60
Dissolved copper	20 – 40

Chapter 3
Test Site Description

3.1 Location and Land Use

The StormFilter system is located in a municipal parking lot beneath an elevated freeway (I-794) and just east of the Milwaukee River, in downtown Milwaukee Wisconsin. The parking lot is located is just west of Water Street, between Clybourn Street and St. Paul Avenue. Figure 3-1 shows the location of the test site, and Figure 3-2 details the drainage area.

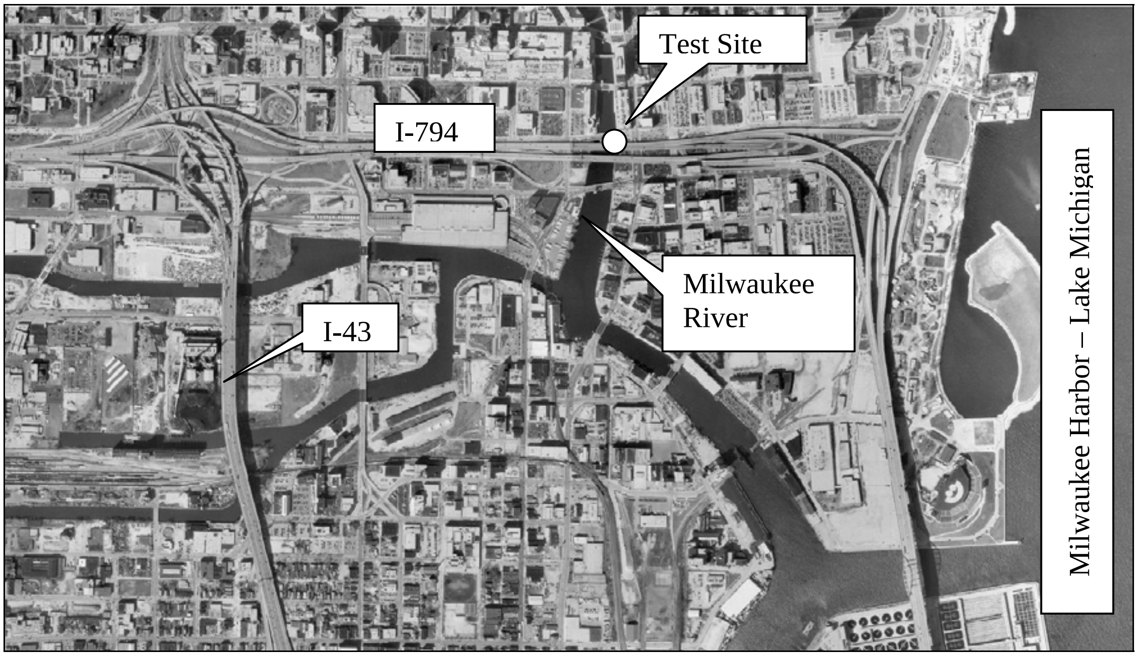


Figure 3-1. Location of test site.

The StormFilter receives runoff from 0.187 acres of the eastbound highway surface of Interstate 794. Surface inlets on the highway collect the runoff and convey the water to the treatment device via downspouts from the deck surface to beneath the parking lot below the highway deck, as shown in Figure 3-3. The drainage area determination was based on the following information and assumptions:

1. WisDOT design plans for Interstate 794 dated 1966 (scale: 1 inch equals 20 feet) and rehabilitation plans dated 1994;
2. The assumption that resurfacing the deck did not change the basic slope or relative drainage area to each inlet; and
3. The assumption that adjacent storm drains were capable of capturing all the flow in their respective drainage areas, forming a hydrologic barrier.

The drainage site is not impacted by surrounding land uses due to its elevated highway decking.

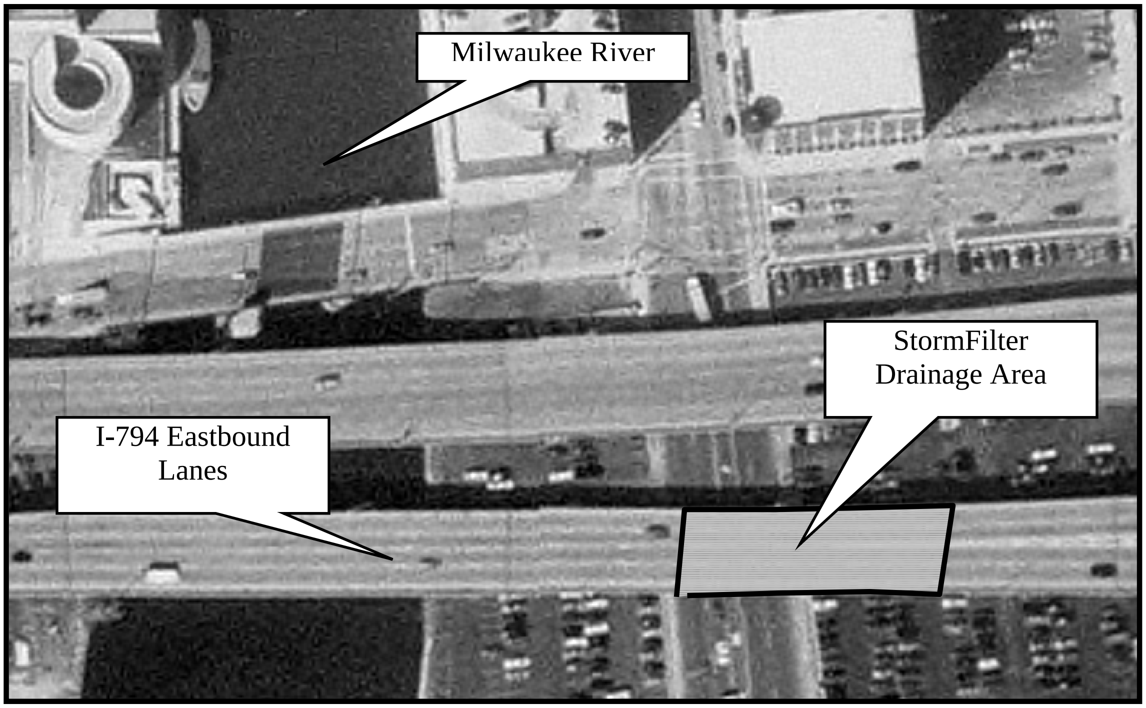


Figure 3-2. Drainage area detail.

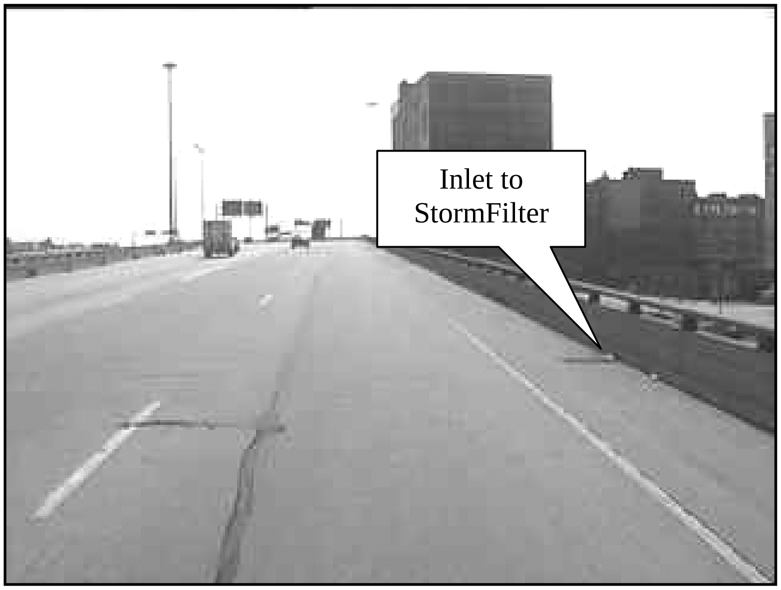


Figure 3-3. StormFilter drainage area condition.

3.2 Contaminant Sources and Site Maintenance

The main pollutant sources within the drainage area are created by vehicular traffic, atmospheric deposition, and, winter salt applications that are applied as conditions require.

The storm sewer catch basins do not have sumps. Conventional (mechanical) street sweeping is done on a monthly basis in the summer months (June through August). There are no other stormwater best management practices (BMPs) within the drainage area.

3.3 Stormwater Conveyance System

The entire drainage area is served by a storm sewer collection system. Before installation of the StormFilter system, the drainage area discharged storm water directly to the Milwaukee River through the system under the parking lot.

The highway deck is about 15 feet above the parking lot. Thus, the storm sewer conveyance system drops vertically through an 8-inch pipe to a point below the parking lot surface, then travels about 6.5 feet horizontally to the inlet monitoring (flow and quality) site, and another two feet to the StormFilter. The StormFilter outlet is connected to an 8-inch pipe that discharges without further treatment to the Milwaukee River.

3.4 Water Quality/Water Resources

Stormwater from the site is discharged directly to the Milwaukee River, just upstream of the mouth to Milwaukee Harbor, and then into Lake Michigan. The river and harbor have had a history of severe water quality impacts from various sources including contaminated river sediments, urban non-point source runoff, rural non-point sources (higher upstream in the watershed), and point source discharges. The water quality in the river suffers from low dissolved oxygen, high nutrient, metals, bacteria levels, and toxic contamination.

Most of the urban communities within the Milwaukee River watershed, including the City of Milwaukee, are under the State of Wisconsin stormwater permitting program (NR 216). This program meets or exceeds the requirements of EPA’s Phase I stormwater regulations.

3.5 Local Meteorological Conditions

The VTP (Appendix A) includes summary temperature and precipitation data from the National Weather Service station from the Mitchell Field Airport in Milwaukee. The statistical rainfalls for a series of recurrence and duration precipitation events are presented in the VTP (Hull et al., 1992). The climate of Milwaukee, and in Wisconsin in general, is typically continental with some modification by Lakes Michigan and Superior. Milwaukee experiences cold snowy winters, and warm to hot summers. Average annual precipitation is approximately 33 inches, with an average annual snowfall of 50.3 inches.

Chapter 4
Sampling Procedures and Analytical Methods

Descriptions of the sampling locations and methods used during verification testing are summarized in this section. Additional detail may be found in the VTP (Appendix A).

4.1 Sampling Locations

Two locations in the test site storm sewer system were selected as sampling and monitoring sites to determine the treatment capability of the StormFilter.

4.1.1 Site 1 - Influent

This sampling and monitoring site was selected to characterize the untreated stormwater from the entire drainage area. A velocity/stage meter and sampler suction tubing were located in the influent pipe, upstream from the StormFilter so that potential backwater effects of the treatment device would not affect the velocity measurements. The monitoring station (Figure 4-1) and test equipment (Figure 4-2 and 4-3) are shown below.

Figure 4-1. View of monitoring station.

4.1.2 Site 2 - Treated Effluent

This sampling and monitoring site was selected to characterize the stormwater treated by the StormFilter. A velocity/stage meter and sampler suction tubing, connected to the automated sampling equipment, were located in an eight-inch diameter plastic pipe downstream from the StormFilter.

Figure 4-2. View of ISCO samplers.

Figure 4-3. View of datalogger.

4.1.3 Other Monitoring Locations

In addition to the two sampling and monitoring sites, a water-level recording device was installed in the StormFilter vault. The data from this device were used to verify the occurrence of bypass conditions.

A rain gauge was located adjacent to the drainage area to monitor the depth of precipitation from storm events. The data were used to characterize the events to determine if they met the requirements for a qualified storm event. The rain gauge is shown in Figure 4-4.

Figure 4-4. View of rain gauge.

4.2 Monitoring Equipment

The specific equipment used for monitoring flow, sampling water quality, and measuring rainfall is listed in Table 4-1.

Table 4-1. Field Monitoring Equipment

Equipment	Site 1	Site 2	Rain Gauge	StormFilter Vault
Water Quality Sampler	ISCO 3700 refrigerated automatic sampler (4, 10 L sample bottles)	ISCO 3700 refrigerated automatic sampler (4, 10 L sample bottles)		
Velocity Measurement	Marsh-McBirney Velocity Meter Model 270	Marsh-McBirney Velocity Meter Model 270		
Stage Meter	Marsh-McBirney Velocity Meter Model 270	Marsh-McBirney Velocity Meter Model 270		Campbell Scientific Inc. SWD1
Datalogger	Campbell Scientific Inc. CR10X datalogger	Campbell Scientific Inc. CR10X datalogger		Campbell Scientific Inc. CR10X datalogger
Rain Gauge			Rain-O-Matic	

4.3 Contaminant Constituents Analyzed

The list of constituents analyzed in the stormwater samples is shown in Table 4-2. The vendor's performance claim addresses reductions of sediments, nutrients (total phosphorus) and heavy metals from the runoff water.

Table 4-2. Constituent List for Water Quality Monitoring

Parameter	Reporting Units	Limit of Detection	Limit of Quantification	Method[1]
Total dissolved solids (TDS)	mg/L	50	167	SM 2540C
Total suspended solids (TSS)	mg/L	2	7	EPA 160.2
Total phosphorus	mg/L as P	0.005	0.016	EPA 365.1
Suspended sediment concentration (SSC)	mg/L	0.1	0.5	ASTM D3977-97
Total calcium	mg/L	0.2	0.7	EPA 200.7
Total copper	μg/L	1	3	SM 3113B
Dissolved copper	μg/L	1	3	SM 3113B
Total magnesium	mg/L	0.2	0.7	EPA 200.7
Dissolved zinc	μg/L	16	50	EPA 200.7
Total zinc	μg/L	16	50	EPA 200.7
Dissolved phosphorus	mg/L as P	0.005	0.016	EPA 365.1
Dissolved cadmium	μg/L	6	20	EPA 200.7
Total cadmium	μg/L	6	20	EPA 200.7
Total lead	μg/L	31	100	EPA 200.7
Dissolved lead	μg/L	31	100	EPA 200.7
Dissolved chloride	mg/L	0.6	2	EPA 325.2
Chemical oxygen demand (COD)	mg/L	9	28	ASTM D1252-88(B)
Sand-silt split	NA	NA	NA	Fishman *et al.*
Five point sedigraph	NA	NA	NA	Fishman *et al.*
Sand fractionation	NA	NA	NA	Fishman *et al.*

[1] EPA: *EPA Methods and Guidance for the Analysis of Water* procedures; SM: *Standard Methods for the Examination of Water and Wastewater (19th edition)* procedures; ASTM: American Society of Testing and Materials procedures; Fishman et al.: *Approved Inorganic and Organic Methods for the Analysis of Water and Fluvial Sediment* procedures.

4.4 Sampling Schedule

USGS personnel installed the monitoring equipment under a contract with the WDNR.

The monitoring equipment was installed in the December of 2001. In March through May 2002, several trial events were monitored and the equipment tested and calibrated. Verification testing began in June 2002, and ended in November 2003. Table 4-3 summarizes the sample collection data from the storm events. These storm events met the requirements of a “qualified event,” as defined in the VTP:

1. The total rainfall depth for the event, measured at the site rain gauge, was 0.2 inches (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 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.

5. There was a minimum of six hours between qualified sampling events.

Table 4-4 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 sample collection starting times for the influent and effluent samples, as well as the number of sample aliquots collected, varied from event to event. The influent sampler was activated when the influent velocity meter sensed flow in the pipe. The effluent sampler was activated when the filtration process discharged treated effluent.

Twenty events are reported in this verification, as shown in Tables 4-3 and 4-4. At the onset of the monitoring program, the site was not monitored under the ETV program. Both TSS and SSC were being analyzed, but due to budgetary concerns, TSS was discontinued and not sampled for five events (events 3 through 7). Once the monitoring program was entered into the ETV program, the TSS parameter was reinstated, and the monitoring program was extended so that TSS and SSC data was collected for 15 events. The extension of the verification program resulted in the collection of flow data for 20 events and analytical data for other parameters for 15 or more events.

Table 4-3. Summary of Events Monitored for Verification Testing

	Inlet Sampling Point (Site 1)					Outlet Sampling Point (Site 2)				
Event Number	Start Date	Start Time	End Date	End Time	No. of Aliquots	Start Date	Start Time	End Date	End Time	No. of Aliquots
1	6/21/02	6:54	6/21/02	7:40	7	6/21/02	6:57	6/21/02	7:34	7
2	7/8/02	21:21	7/8/02	23:41	29	7/8/02	21:24	7/8/02	23:26	29
3	8/21/02	20:12	8/22/02	12:37	30	8/21/02	20:27	8/22/02	12:21	16
4	9/2/02	5:25	9/2/02	9:48	21	9/2/02	5:30	9/2/02	9:12	24
5	9/18/02	5:31	9/18/02	10:25	10	9/18/02	5:54	9/18/02	10:49	8
6	9/29/02	2:52	9/29/02	9:27	9	9/29/02	3:19	9/29/02	9:33	16
7	12/18/02	1:19	12/18/02	6:02	18	12/18/02	1:44	12/18/02	6:05	9
8	4/19/03	5:56	4/19/03	15:55	18	4/19/03	6:04	4/19/03	15:57	15
9	5/4/03	21:28	5/5/03	7:18	23	5/4/03	21:35	5/5/03	7:18	26
10	5/30/03	19:00	5/30/03	23:22	13	5/30/03	19:05	5/30/03	23:59	15
11	6/8/03	3:30	6/8/03	14:55	14	6/8/03	3:32	6/8/03	15:10	20
12	6/27/03	17:32	6/28/03	11:01	18	6/27/03	17:43	6/28/03	11:34	22
13	7/4/03	7:27	7/6/03	9:47	19	7/4/03	7:30	7/6/03	10:26	26
14	7/8/03	9:52	7/8/03	13:45	8	7/8/03	9:59	7/8/03	14:06	11
15	9/12/03	15:35	9/12/03	17:31	8	9/12/03	16:12	9/12/03	18:23	7
16	9/14/03	5:34	9/14/03	12:05	15	9/14/03	6:11	9/14/03	12:10	11
17	9/22/03	2:29	9/22/03	4:54	8	9/22/03	2:36	9/22/03	4:35	13
18	10/14/03	1:11	10/14/03	3:21	15	10/14/03	1:25	10/14/03	3:34	10
19	10/24/03	16:59	10/24/03	21:49	20	10/24/03	17:10	10/24/03	22:19	20
20	11/4/03	15:58	11/4/03	19:20	10	11/4/03	16:18	11/4/03	19:48	14

Table 4-4. Rainfall Summary for Monitored Events

Event Number	Start Date	Start Time	End Date	End Time	Rainfall Amount (inches)	Rainfall Duration (hr:min)	Runoff Volume $(ft^3)^1$	Peak Discharge Rate $(gpm)^1$
1	6/21/02	6:54	6/21/02	7:17	0.52	0:23	420	447
2	7/8/02	21:16	7/8/02	23:20	1.5	2:04	1,610	651
3	8/21/02	20:08	8/22/02	12:07	1.7	15:59	1,620	671
4	9/2/02	5:24	9/2/02	8:48	1.2	3:24	1,180	164
5	9/18/02	5:25	9/18/02	10:19	0.37	4:54	350	136
6	9/29/02	0:49	9/29/02	8:43	0.74	7:54	730	70.9
7	12/18/02	1:18	12/18/02	5:05	0.37	3:47	300	61.0
8	4/19/03	5:39	4/19/03	15:39	0.55	10:00	340	96.9
9	5/4/03	21:21	5/5/03	9:05	0.90	11:44	540	73.2
10	5/30/03	18:55	5/30/03	23:01	0.54	4:06	320	83.9
11	6/8/03	3:26	6/8/03	14:35	0.62	11:09	450	140
12	6/27/03	17:30	6/28/03	10:55	0.57	13:25	460	107
13	7/4/03	7:25	7/6/03	10:08	0.53	40:43	550	143
14	7/8/03	9:49	7/8/03	13:26	0.33	3:37	260	62.8
15	9/12/03	15:33	9/12/03	17:28	0.22	1:55	150	21.5
16	9/14/03	5:22	9/14/03	11:57	0.47	6:35	340	264
17	9/22/03	2:28	9/22/03	4:37	0.27	2:09	270	104
18	10/14/03	1:03	10/14/03	3:10	0.25	2:07	220	56.5
19	10/24/03	16:46	10/24/03	11:53	0.71	15:07	410	75.8
20	11/4/03	16:14	11/4/03	18:23	0.60	2:09	560	906

[1] Runoff volume and peak discharge volume measured at the outlet monitoring point.

4.5 Field Procedures for Sample Handling and Preservation

Data gathered by the on-site datalogger were accessible to USGS personnel by means of a modem and phone-line hookup. USGS personnel collected samples and performed a system inspection after storm events.

Water samples were collected with ISCO automatic samplers programmed to collect one-liter aliquots during each sample cycle. A peristaltic pump on the sampler pumped water from the sampling location through Teflon™-lined sample tubing to the pump head where water passed through approximately three feet of silicone tubing and into one of four 10-liter sample collection bottles. Samples were capped and removed from the sampler after the event by the WisDOT or USGS personnel depending upon the schedule of the staff. The samples were forwarded to USGS personnel if the WisDOT personnel collected them. The samples were then transported to the USGS field office in Madison, Wisconsin, where they were split into multiple aliquots using a 20-liter Teflon-lined churn splitter. When more than 20 liters (two 10-liter sample collection bottles) of sample were collected by the autosamplers, the contents of the two full sample containers would be poured into the churn, a portion of the sample in the churn would be discarded, and a proportional volume from the third sample container would be poured into the churn. The analytical laboratories provided sample bottles. Samples were preserved per method requirements and analyzed within the holding times allowed by the methods. Particle size and SSC samples were shipped to the USGS sediment laboratory in Iowa City, Iowa (after event 2, SSC samples were analyzed at WSLH). All other samples were hand-delivered to WSLH.

The samples were maintained in the custody of the sample collectors, delivered directly to the laboratory, and relinquished to the laboratory sample custodian(s). Custody was maintained according to the laboratory’s sample handling procedures. To establish the necessary documentation to trace sample possession from the time of collection, field forms and lab forms (see Appendix B of the VTP) were completed and accompanied each sample.

Chapter 5
Monitoring Results and Discussion

The monitoring results related to contaminant reduction over the events 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 (SOL) comparison, which evaluates the effectiveness of the system on a constituent mass (concentration times volume) basis.

The StormFilter is designed to remove suspended solids from wet-weather flows. The VTP required that a suite of analytical parameters, including solids, metals, and nutrients, be evaluated because of the vendor's performance claim.

5.1 Monitoring Results: 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:

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

The influent and effluent sample concentrations and calculated efficiency ratios are summarized by analytical parameter categories: sediments (TSS, SSC, and TDS); nutrients (total and dissolved phosphorus); metals (total and dissolved copper, total and dissolved zinc, total lead and total cadmium); and water quality parameters (COD, dissolved chloride, total calcium and total magnesium). The water quality parameters were not specified in the vendors' performance claim and were monitored for other reasons outside the scope of the ETV program.

Sediments: The influent and effluent sample concentrations and calculated efficiency ratios for sediment parameters are summarized in Table 5-1. As discussed in Section 4.4, TSS analysis was not conducted on the samples collected from events 3 through 7. The TSS inlet concentrations ranged from 29 to 780 mg/L the outlet concentrations ranged from 20 to 380 mg/L, and the efficiency ratio ranged from -33 to 95 percent. The SSC inlet concentrations ranged 51 to 5,600 mg/L, the outlet concentrations ranged from 12 to 370 mg/L, and the efficiency ratio ranged from 3 to 99 percent.

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

		TSS			SSC			TDS		
Event No.	Rainfall (in)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)
1[1]	0.52	71	83	-17	370	63	83	<50	<50	-
2[1]	1.5	51	28	45	310	20	94	<50	<50	-
3	1.7	NA	NA	-	65	19	71	<50	<50	-
4	1.2	NA	NA	-	320	13	96	39	38	3
5	0.37	NA	NA	-	120	43	64	NA	NA	-
6	0.74	NA	NA	-	140	12	91	<50	<50	-
7	0.37	NA	NA	-	770	130	83	600	4,200	-600
8	0.55	780	380	51	5,600	370	93	520	720	-38
9	0.90	73	34	53	830	34	96	78	90	-15
10	0.54	110	70	36	1,300	68	95	66	130	-91
11	0.62	60	40	33	420	40	90	<50	76	-
12	0.57	77	46	40	370	47	87	90	160	-80
13	0.53	29	30	-3	51	32	37	60	110	-83
14	0.33	57	24	58	74	23	69	82	110	-34
15	0.22	700	36	95	3,800	29	99	210	190	10
16	0.47	50	49	2	410	49	88	<50	60	-
17	0.27	37	31	16	480	21	96	50	80	-60
18	0.25	35	20	43	410	21	95	50	74	-48
19	0.71	67	36	46	420	33	92	<50	60	-
20	0.60	55	73	-33	100	97	3	<50	<50	-

[1] SSC analyzed at USGS Sediment Laboratory; all other parameters analyzed at WSLH

NA: Not Analyzed

The results show a large difference between inlet TSS and SSC concentrations. In each event where both parameters are analyzed, inlet SSC concentrations range from 30 percent to almost 1,200 percent higher than the equivalent TSS concentration. Both the TSS and SSC analytical parameters 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 requires use of the entire contents of the sample container. If a sample contains a high concentration of settleable (large particle size) solids, acquiring a representative aliquot from the sample container is very difficult. Therefore a disproportionate amount of the settled solids may be left in the container, and the reported TSS concentration would be lower than SSC.

The highest concentrations of influent TDS concentrations were observed from events 7 and 8. These two events occurred during the winter (12/18/02 and 4/19/03 respectively) and were likely influenced by road salting operations. This explanation is supported by the high chloride concentrations observed in the inlet samples for these two events (see Table 5-4).

Nutrients: The inlet and outlet sample concentrations and calculated efficiency ratios are summarized in Table 5-2. The total phosphorus inlet concentration ranged from 0.05 mg/L to 0.63 mg/L, and the dissolved phosphorus inlet concentration ranged from 0.014 mg/L to 0.20 mg/L. Reductions in total phosphorus EMCs ranged from 0 to 70 percent. Dissolved phosphorus EMCs ranged from –35 to 38 percent. Most of the inlet and outlet dissolved phosphorus concentrations were close to the 0.005 mg/L (as P) detection limit, with little, if any, differences between inlet and outlet concentrations.

Metals: The inlet and outlet sample concentrations and calculated efficiency ratios are summarized in Table 5-3. Reductions in metal EMCs followed a similar pattern as the phosphorus results, in that the total fraction all showed higher concentrations and greater EMC reductions than the dissolved faction. The total copper inlet concentration ranged from 15 to 440 µg/L, and the EMC reduction ranged from 8 to 96 percent. The total zinc inlet concentration ranged from 77 to 1,400 µg/L, and the EMC reduction ranged from 20 to 89 percent. Total zinc and total copper inlet concentrations exhibited field precision, as measured by a statistical analysis of field duplicate samples, that was outside a range identified as acceptable in the test plan. This is explained in greater detail in Section 6.1.2. The dissolved copper inlet concentration ranged from less than 5 to 58 µg/L, and the EMC reduction ranged from –47 to 64 percent. The dissolved zinc inlet concentration ranged from 26 to 360 µg/L, and the EMC reduction ranged from -86 to 56 percent. The total and dissolved cadmium and dissolved lead concentrations in both the inlet and outlet samples were below detection limits for every sampled storm event. Total lead concentrations were below detection limits in both the inlet and outlet samples for nine of the sampled events, while the EMC ranged from 33 to 91 percent for the seven events where total lead was detected in the inlet sample.

Water quality parameters: inlet and outlet sample concentrations and calculated efficiency ratios for water quality parameters are summarized in Table 5-4. High dissolved chloride concentrations in both the inlet and outlet were observed for events 7 and 8 (12/18/02 and 4/19/03). The likely source of the chloride is the winter application of road salt to the highway. Aside from these two events, dissolved chloride concentrations in the inlet and outlet samples were relatively low, and the StormFilter system did not remove dissolved chloride.

Table 5-2. Monitoring Results and Efficiency Ratios for Nutrient Parameters

	Total Phosphorus			Dissolved Phosphorus		
Event No.[1]	**Inlet (mg/L as P)**	**Outlet (mg/L as P)**	**Reduction (Percent)**	**Inlet (mg/L as P)**	**Outlet (mg/L as P)**	**Reduction (Percent)**
1	0.14	0.10	29	0.041	0.039	4.9
2	0.11	0.08	27	0.041	0.037	9.8
3	0.05	0.04	20	0.014	0.013	7.1
4	0.10	0.05	50	0.030	0.032	-6.7
5	0.14	0.10	29	0.059	0.046	22
6	0.10	0.03	70	0.021	0.021	0.0
7	0.33	0.20	39	0.035	0.029	17
8	0.50	0.29	42	0.027	0.017	37
9	0.17	0.08	53	0.057	0.043	25
10	0.20	0.14	30	0.045	0.028	38
11	0.19	0.08	58	0.023	0.028	-22
12	0.24	0.19	21	0.061	0.059	3.3
14	0.16	0.11	31	0.048	0.049	-2.1
15	0.63	0.30	52	0.20	0.19	5.0
16	0.10	0.10	0	0.020	0.027	-35
17	0.15	0.10	33	0.043	0.054	-26
18	0.15	0.10	33	0.040	0.046	-15

[1] Phosphorus parameters were not analyzed during events 13, 19 or 20.

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

	Total Copper			Dissolved Copper			Total Zinc			Dissolved Zinc		
Event No.[1]	Inlet[2] (µg/L)	Outlet (µg/L)	Reduction (Percent)	Inlet (µg/L)	Outlet (µg/L)	Reduction (Percent)	Inlet[2] (µg/L)	Outlet (µg/L)	Reduction (Percent)	Inlet (µg/L)	Outlet (µg/L)	Reduction (Percent)
1	41	28	32	<5	<5	-	220	140	36	60	34	43
2	34	19	44	10	8.8	12	200	76	62	59	51	14
3	15	10	33	6.1	5.4	11	180	39	78	27	20	26
4	29	10	66	7.7	7.0	9	200	56	72	49	43	12
5	130	30	77	21	14	33	680	110	84	87	51	41
6	16	7	56	5.0	4.5	10	77	28	64	26	16	38
7	130	78	40	14	20	-47	390	300	23	59	110	-86
8	280	140	50	28	27	3	1,400	540	61	110	84	24
9	44	20	55	11	8.7	24	230	91	60	64	45	30
10	79	42	47	17	15	10	240	140	42	67	70	-4
11	36	23	36	18	7.6	58	120	84	30	37	32	14
12	48	44	8	20	23	-13	200	160	20	81	96	-19
14	36	29	19	13	15	-14	230	79	66	57	42	26
15	330	69	79	58	42	27	1,400	210	85	360	160	56
16	32	21	34	5.5	6.2	-13	180	110	39	26	30	-15
17	440	18	96	9.0	11	-17	650	69	89	42	47	-12
18	46	15	67	50	18	64	300	66	78	46	42	9

[1] Metals parameters were not analyzed during events 13, 19 or 20.

[2] Total copper and total lead inlet data exhibited precision (field duplicates) outside the targeted goal of 25 percent (see discussion in Section 6.1.2).

Table 5-3 (cont'd).

	Total Cadmium			Dissolved Cadmium			Total Lead			Dissolved Lead		
Event No.[1]	Inlet (µg/L)	Outlet (µg/L)	Reduction (percent)	Inlet (µg/L)	Outlet (µg/L)	Reduction (percent)	Inlet (µg/L)	Outlet (µg/L)	Reduction (percent)	Inlet (µg/L)	Outlet (µg/L)	Reduction (percent)
1	<6	NA	-	<6	NA	-	<31	NA	-	<31	NA	-
2	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
3	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
4	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
5	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
6	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
7	<6	<6	-	<6	<6	-	130	72	45	<31	<31	-
8	<6	<6	-	<6	<6	-	190	<31	91	<31	<31	-
9	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
10	<6	<6	-	<6	<6	-	53	32	40	<31	<31	-
11	<6	<6	-	<6	<6	-	33	<31	52	<31	<31	-
12	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
14	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-
15	<6	<6	-	<6	<6	-	280	37	87	<31	<31	-
16	<6	<6	-	<6	<6	-	140	94	33	<31	<31	-
17	<6	<6	-	<6	<6	-	110	53	52	<31	<31	-
18	<6	<6	-	<6	<6	-	<31	<31	-	<31	<31	-

[1] Metals parameters were not analyzed during events 13, 19 or 20.
NA: Not analyzed

Table 5-4. Monitoring Results and Efficiency Ratios for Water Quality Parameters

Event No.[1]	Chemical Oxygen Demand			Dissolved Chloride			Total Calcium			Total Magnesium		
	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)	Inlet (mg/L)	Outlet (mg/L)	Reduction (Percent)
1	42	37	12	5.8	5.2	10	42	15	64	21	5.8	72
2	39	25	36	4.6	4.6	0	28	6	79	14	1.9	86
3	18	24	-33	4.5	3.4	24	9.7	4.4	55	4.2	1.6	62
4	29	24	17	3.2	3.3	-3	55	4.4	92	26	1.4	95
5	80	78	2.5	NA	NA	-	17	9.7	43	7.3	3.2	56
6	28	17	39	3.6	4.0	-11	9.4	4	57	4.0	1.1	73
7	68	130	-91	310	2,600	-740	130	48	63	56	8.5	85
8	320	190	41	470	660	-40	430	68	84	174	26	85
9	53	38	28	25	31	-24	62	11	82	28	2.8	90
10	67	61	9.0	14	32	-130	40	17	58	18	4.8	73
11	41	36	12	9.4	17	-81	37	9.6	74	18	3.0	83
12	85	81	4.7	17	35	-110	29	17	41	11	4.2	62
14	63	53	16	20	22	-10	12	8.9	26	4.9	2.3	53
15	300	160	47	34	35	-3	230	16	93	120	4.4	96
16	38	34	11	6.1	9.7	-59	41	8.8	79	20	3.7	82
17	48	72	-50	9	16	-78	73	8.3	89	36	2.5	93
18	51	50	2.0	5.4	NA	-	60	7	88	22	1.9	91

[1] Parameters were not analyzed during events 13, 19 or 20.
NA: Not Analyzed

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

Flow calibration: Before the flow and concentration results could be used for calculating the inlet and outlet sediment loads, the flow rate calculations were modified based on calibration of the flow meters, correction to the velocity data, and corrections for the gauge heights. A discussion describing these calibration procedures is in Chapter 6. These modifications made significant changes to the volumes used for the inlet and outlet of the StormFilter. After these adjustments were made to the velocity and flow measurements, the event volumes at the inlet and outlet sites were compared. Low variability was observed between the inlet and outlet volumes for each storm. Differences between the volumes were 15 percent or less for 17 of the 20 storms. The average difference between the inlet and outlet volumes was 11 percent. There was not a trend as to whether the inlet or outlet flow volumes were larger.

Although the volumes were close, the differences could still influence the SOL calculations. With perfect measurements, the inlet and outlet volumes should be exactly the same, since there is no place the water could be lost in the treatment system. It was decided that the outlet volumes would best represent the flows at both the outlet and inlet. The outlet volumes are considered more accurate because the inlet experienced most of the missing velocity data (see Section 6.2). If the missing velocity data was the result of higher solids concentrations and/or much higher velocities at the inlet, these characteristics could make the inlet flow measurements less reliable than the outlet measurements. Air entrapment caused by high velocities over the top of the velocity probe could also cause a disturbance in the probe's electromagnetic signal.

To demonstrate the impact of using the volume calculations at each site, all three possible combinations for the sediment results are presented below: using outlet volumes to calculate loads at both sites; using inlet volumes to calculate loads at each site, and using the respective inlet and outlet volumes to calculate loads at each site. Table 5-5 demonstrates that using the different load calculation methods had little impact on the resulting SOL calculations for the sediment parameters. For this reason, the loads for the remaining parameters (metals, nutrients, and other parameters) are calculated only using the outlet volumes for each site.

Table 5-5. Sediment Sum of Loads Efficiencies Calculated Using Various Flow Volumes

Flow Location	Load Reduction Efficiency (Percent)[1] TSS	SSC	TDS
Inlet only	47	92	-45
Outlet only	46	92	-46
Inlet and Outlet	50	93	-38

[1] Load reduction efficiencies were calculated without data from events 3 through 7, when no TSS samples were collected (see Section 4.4).

Sediment: Table 5-6 summarizes results for the SOL calculations analysis using three approaches: all events reported and all parameters; results for SSC samples for those events with data from TSS, TDS and SSC parameters (does not include events 3 through 7); and results for TDS samples for all events except for an apparent outlier (event 7, likely influenced by application of road salt). These results show no significant difference between the SOL reductions of SSC. By eliminating event 7 from the TDS SOL calculations, the SOL reduction improves from –170 percent to –37 percent.

The SOL analyses indicate a TSS reduction of 47 to 50 percent, and SSC reduction of 92 to 93 percent. The TSS load reduction nearly meets SMI's performance claim of 50 to 85 percent TSS reduction, while SSC reduction exceeds the performance claim.

The large discrepancy in TSS versus SSC is likely due to the large particle sizes found in the runoff (see Section 5.2) and the methodology difference between the two analytical procedures. Analytical procedures for TSS require an aliquot to be removed from the sample container. When larger sediment particles are in the sample container, it is unlikely (even when the container is stirred) that the larger particles will be evenly distributed throughout the container, making the aliquot not representative of the sediment in the sample. SSC analytical procedures require the entire volume of sample to be analyzed for sediment volume, eliminating this issue.

Nutrients: The SOL data for nutrients are summarized in Table 5-7. The total phosphorus load reduction of 38 percent met SMI's performance claim of 30 to 45 percent reduction. Additionally, the dissolved phosphorus load reduction of six percent also met SMI's performance claim of negligible dissolved phosphorus removal.

Table 5-6. Sediment Sum of Loads Results

		TSS				**SSC**				**TDS**			
Event No	**Runoff Volume (ft^3)**	**Inlet (mg/L)**	**Inlet (lb)**	**Outlet (mg/L)**	**Outlet (lb)**	**Inlet (mg/L)**	**Inlet (lb)**	**Outlet (mg/L)**	**Outlet (lb)**	**Inlet (mg/L)**	**Inlet (lb)**	**Outlet (mg/L)**	**Outlet (lb)**
1*	420	71	1.9	83	2.2	370	9.8	63	1.7	<50	*0.7*	<50	*0.7*
2*	1,610	51	5.2	28	2.8	310	32	20	2.0	<50	*2.5*	<50	*2.5*
3	1,620	NA	-	NA	-	65	6.6	19	1.9	<50	*2.5*	<50	*2.5*
4	1,180	NA	-	NA	-	320	24	13	1.0	39	2.9	38	2.8
5	350	NA	-	NA	-	120	2.6	43	0.9	NA	-	NA	-
6	730	NA	-	NA	-	140	6.3	12	0.6	<50	*1.1*	<50	*1.1*
7	300	NA	-	NA	-	770	14	130	2.4	600	11	4,200	79
8	340	780	17	380	8.1	5,600	120	370	8.0	520	11	720	15
9	540	73	2.5	34	1.2	820	28	34	1.2	78	2.6	90	3.1
10	320	110	2.3	70	1.4	1,300	26	68	1.4	66	1.3	130	2.5
11	450	60	1.7	40	1.1	420	12	40	1.1	<50	*0.7*	76	2.1
12	460	77	2.2	46	1.3	370	11	47	1.4	90	2.6	160	4.7
13	550	29	1.0	30	1.0	51	1.8	32	1.1	60	2.1	110	3.8
14	260	57	0.9	24	0.4	74	1.2	23	0.4	82	1.3	110	1.8
15	150	700	6.6	36	0.3	3,800	35	29	0.3	210	2.0	190	1.8
16	340	50	1.1	49	1.0	400	8.7	49	1.0	<50	*0.5*	60	1.3
17	270	37	0.6	31	0.5	480	8.2	21	0.4	50	0.8	80	1.4
18	220	35	0.5	20	0.3	410	5.7	21	0.3	50	0.7	74	1.0
19	410	67	1.7	36	0.9	420	11	33	0.9	<50	*0.6*	60	1.5
20	560	55	1.9	73	2.6	100	3.6	97	3.4	<50	*0.9*	<50	*0.9*
Total (all events monitored)			**47**		**25**		**370**		**31**		**48**		**130**
Load Reduction Efficiency (Percent)					**46**				**92**				**-170**
SSC Total (omitting events 3-7)							**314**		**24**				
Load Reduction Efficiency (Percent)									**92**				
TDS Total (omitting event 7)											**37**		**51**
Load Reduction Efficiency (Percent)													**-37**

* SSC Analyzed at USGS Sediment Laboratory　　NA Not Analyzed

Italicized numbers represent results where one-half the method detection limit was substituted for values below detection limits.

Table 5-7. Nutrient Sum of Loads Results

	Total Phosphorus (g)		Dissolved Phosphorus (g)	
Event No.	**Inlet**	**Outlet**	**Inlet**	**Outlet**
1	1.7	1.2	0.49	0.47
2	4.8	3.6	1.87	1.68
3	2.1	1.7	0.64	0.60
4	3.3	1.6	1.00	1.06
5	1.4	1.0	0.59	0.46
6	2.0	0.67	0.44	0.44
7	2.8	1.7	0.30	0.25
8	4.8	2.8	0.26	0.16
9	2.6	1.2	0.88	0.66
10	1.8	1.3	0.41	0.25
11	2.5	1.0	0.29	0.36
12	3.0	2.5	0.79	0.77
14	1.2	0.79	0.35	0.36
15	2.6	1.2	0.83	0.80
16	1.0	0.91	0.19	0.26
17	1.2	0.74	0.33	0.41
18	0.91	0.60	0.24	0.28
Total:	40	24	9.9	9.3
Load Reduction Efficiency (Percent):		**38**		**6**

Metals: The SOL data for metals are summarized in Table 5-8. The total zinc (64 percent) and total copper (60 percent) load reductions met or exceeded the 30 to 60 percent performance claim for these constituents. Total zinc and total copper inlet concentrations exhibited field precision, as measured by a statistical analysis of field duplicate samples, that was outside a range identified as acceptable in the test plan. This is explained in greater detail in Section 6.1.2. The dissolved zinc (17 percent) and dissolved copper (16 percent) load reduction were lower than the 20 to 40 percent performance claim for these constituents. The dissolved zinc and copper influent concentrations were relatively low for most events. Load reduction for dissolved zinc with influent concentrations greater than 100 µg/L was 42 percent and load reduction dissolved copper with influent concentrations greater than 50 µg/L was 50 percent. There were no performance claims reported for total lead or total cadmium.

Table 5-8. Metals Sum of Loads Results

Event No.	Total Copper (g)		Dissolved Copper (g)		Total Zinc (g)		Dissolved Zinc (g)		Total Lead (g)	
	Inlet[1]	Outlet	Inlet	Outlet	Inlet[1]	Outlet	Inlet	Outlet	Inlet	Outlet
1	4.9	3.4	-	-	27	17	0.73	0.41	-	-
2	16	8.6	0.37	0.32	92	35	2.17	1.9	-	-
3	6.9	4.6	0.24	0.21	81	18	1.1	0.79	-	-
4	9.6	3.3	0.21	0.19	66	19	1.3	1.2	-	-
5	13	3.0	0.18	0.12	68	11	0.76	0.45	-	-
6	3.3	1.5	0.09	0.08	16	5.8	0.46	0.28	-	-
7	11	6.7	0.12	0.18	34	26	0.52	0.97	-	-
8	26	13	0.36	0.35	130	51	1.4	1.1	1.1	0.63
9	6.8	3.1	0.23	0.18	36	14	1.4	0.96	2.5	*0.20*
10	7.2	3.8	0.22	0.19	22	13	0.85	0.89	-	-
11	4.6	2.9	0.26	0.11	15	11	0.54	0.47	0.67	0.41
12	6.2	5.7	0.27	0.31	26	21	1.1	1.3	0.49	*0.23*
14	2.6	2.1	0.10	0.12	17	5.8	0.45	0.33	-	-
15	14	2.9	0.30	0.21	57	8.9	1.8	0.82	-	-
16	3.1	2.0	0.06	0.07	18	10	0.29	0.33	1.4	0.19
17	33	1.4	0.06	0.07	49	5.2	0.27	0.31	1.5	1.0
18	2.8	0.9	0.30	0.11	18	4.0	0.27	0.25	0.72	0.34
Total:	**171**	**69**	**3.4**	**2.8**	**771**	**274**	**15**	**12**	**8.5**	**3.0**
Load Reduction Efficiency (Percent):		**59**		**16**		**64**		**17**		**64**

[2] Total copper and total lead inlet data exhibited precision (field duplicates) outside the targeted goal of 25 percent (see discussion in Section 6.1.2).

Italicized numbers represent results where one-half the method detection limit was substituted for values below detection limits.

Note: total and dissolved cadmium and dissolved lead SOL calculations were not conducted because all values were below detection limits.

Water quality parameters: The SOL data for water quality parameters are summarized in Table 5-9. The StormFilter system achieved a 16 percent load reduction for COD, a 79 percent load reduction for total calcium, and an 85 percent load reduction for total magnesium. The negative load reduction (-242 percent) for dissolved chloride was influenced by high effluent concentrations during events 7 and 8 (December 2002 and April 2003). These events were likely biased by earlier applications of road salt for deicing. SMI did not make any performance claims for these parameters.

Table 5-9. Water Quality Parameter Sum of Loads Results

Event No.	**COD (lb)**		**Dissolved Chloride (lb)**		**Total Calcium (lb)**		**Total Magnesium (lb)**	
	Inlet	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**
1	1.1	1.0	0.15	0.14	1.1	0.39	0.56	0.15
2	3.9	2.5	0.46	0.46	2.8	0.61	1.4	0.19
3	1.8	2.5	0.46	0.35	0.99	0.45	0.43	0.16
4	2.1	1.8	0.24	0.24	4.0	0.32	1.9	0.10
5	1.8	1.7	NA	NA	0.38	0.22	0.16	0.07
6	1.3	0.8	0.17	0.18	0.43	0.18	0.18	0.05
7	1.3	2.5	5.93	49	2.5	0.90	1.1	0.16
8	6.7	4.0	9.9	14	9.2	1.4	3.7	0.55
9	1.8	1.3	0.86	1.1	2.1	0.36	0.94	0.10
10	1.3	1.2	0.29	0.65	0.8	0.33	0.36	0.10
11	1.2	1.0	0.27	0.49	1.1	0.27	0.51	0.08
12	2.4	2.3	0.48	1.00	0.84	0.50	0.32	0.12
14	1.0	0.9	0.32	0.36	0.20	0.15	0.08	0.04
15	2.8	1.5	0.32	0.32	2.2	0.15	1.1	0.04
16	0.8	0.7	0.13	0.21	0.86	0.19	0.42	0.08
17	0.8	1.2	0.15	0.27	1.2	0.14	0.61	0.04
18	0.7	0.7	0.07	NA	0.81	0.10	0.30	0.03
Total:	**33**	**28**	**20**	**69**	**31.5**	**6.70**	**14.1**	**2.1**
Load Reduction Efficiency (Percent):		**16**		**-240**		**79**		**85**
Dissolved Chloride Total and Reduction Efficiency (omitting events 7 and 8)			**4.4**	**5.7** **-31**				

NA: not analyzed

5.2 Particle Size Distribution

Particle size distribution analysis was conducted on selected events. Three types of analyses were conducted. The ability of the lab to conduct the specific analysis depended on the available sample volume, the sediment concentration, and the particle sizes in the sample. The ISCO samplers did not always collect an adequate volume of sample to conduct the full suite of particle size analyses.

1. A “sand/silt split” analysis determined the percentage of sediment (by weight) larger than 62 µm (defined as sand) and less than 62 µm (defined as silt). This analysis was performed on the outlet samples of events 3 4, 6, 15, and 16.

2. A Visual Accumulator (VA) tube analysis (Fishman et al., 1994) defined the percent of sediment (by weight) sized less than 1000, 500, 250, 125, and 62 µm. The analyses were conducted on the inlet and outlet samples of events 1, 2, and 9, and on the inlet samples of events 4, 6, 15, and 16.

3. A pipette analysis (Fishman et al., 1994) was conducted to further define the silt portion of a sample as the percent of sediment (by weight) sized less than 31, 16, 8, 4, and 2 µm. This analysis was conducted on the inlet and outlet samples of events 7 and 8.

The particle size distribution results are summarized in Table 5-10. In each event where particle size analysis was conducted, the outlet samples had a higher percentage of particles in the silt category (<62.5 µm) than the equivalent inlet sample. This is a result of the filtering mechanism of the StormFilter removing a higher percentage of the larger sediment particles.

Table 5-10. Particle Size Distribution Analysis Results

		Percent Less Than Particle Size (µm)									
Event No,	**Location**	**<1000**	**<500**	**<250**	**<125**	**<62.5**	**<31**	**<16**	**<8**	**<4**	**<2**
1	Inlet	80	64	36	22	18					
	Outlet	100	100	98	93	91					
2	Inlet	52	45	25	12	12					
	Outlet	100	100	100	96	88					
3	Inlet	100	73	42	32	32					
	Outlet					82					
4	Inlet	71	52	17	9	8					
	Outlet					92					
6	Inlet	93	93	58	39	32					
	Outlet					91					
7	Inlet	90	61	47	42	40	38	33	25	16	10
	Outlet					100	97	96	86	78	66
8	Inlet	90	77	49	34	30	26	20	14	11	8
	Outlet					100	96	86	66	55	48
9	Inlet	92	81	34	19	15					
	Outlet	100	81	57	50	44					
15	Inlet	90	75	23	4	4					
	Outlet[1]										
16	Inlet	72	44	23	15	13					
	Outlet					92					

[1] No data reported due to laboratory error.

Chapter 6
QA/QC Results and Summary

The Quality Assurance Project Plan (QAPP) in the VTP identified critical measurements and established several QA/QC objectives. The verification test procedures and data collection followed 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 C.

6.1 Laboratory/Analytical Data QA/QC

6.1.1 Bias (Field Blanks)

Field blanks were collected at both the inlet and outlet samplers on three separate occasions to evaluate the potential for sample contamination through the entire sampling process, including automatic sampler, sample-collection bottles, splitters, and filtering devices. "Milli-Q" reagent water was pumped through the automatic sampler, and collected samples were processed and analyzed in the same manner as event samples. The first field blank was collected on 04/02/02 (before the first event was sampled), allowing the USGS to review the results early in the monitoring schedule. The second and third field blanks were collected on 11/11/02 (between events 6 and 7) and 6/30/03 (between events 12 and 13), respectively.

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

Table 6-1. Field Blank Analytical Data Summary

Parameter	Units	Blank 1 (4/2/2002)		Blank 2 (11/11/2002)		Blank 3 (6/30/2003)			
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	LOD	LOQ
TSS	mg/L	<2	<2	--	--	<2	<2	2	7
SSC	mg/L	--	--	--	--	<2	<2	2	7
TDS	mg/L	<50	<50	<50	<50	<50	<50	50	167
COD	mg/L	<9	<9	<9	<9	12	14	9	28
Dissolved copper	µg/L	<5	<5	<1	<1	1.7	2.3	1	3
Total copper	µg/L	<5	<5	<1	<1	2	2	1	3
Dissolved zinc	µg/L	<16	<16	<16	<16	<16	<16	16	50
Total zinc	µg/L	<16	<16	<16	<16	<16	<16	16	50
Dissolved phosphorus	mg/L	--	--	<0.005	<0.005	<0.005	<0.005	0.005	0.016
Total phosphorus	mg/L	<0.005	<0.005	0.025	<0.005	<0.005	<0.005	0.005	0.016
Dissolved chloride	mg/L	3.3	<0.6	<0.6	<0.6	0.8	<0.6	2	3.3
Total calcium	mg/L	0.7	<0.2	<0.2	<0.2	0.2	<0.2	0.2	0.7
Total magnesium	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	0.7

6.1.2 Replicates (Precision)

Precision measurements were performed by the collection and analysis of duplicate samples. The relative percent difference (RPD) recorded from the sample analyses 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

Field precision: Field duplicates were collected to monitor the overall precision of the sample collection procedures. Duplicate inlet and outlet samples were collected during five different storm events to evaluate precision in the sampling process and analysis. The duplicate samples were processed, delivered to the laboratory, and analyzed in the same manner as the regular samples. Summaries of the field duplicate data are presented in Table 6-2.

Overall, the results show good field precision. Below is a discussion on the results from selected parameters.

<u>TSS and SSC</u>: Most results were within targeted limits. Outlet samples (lower concentrations and smaller particle sizes) showed higher precision. The SSC inlet sampling had two occurrences of percent RPD exceeding the limit. The poorer precision for the inlet samples could be due to the sample handling and splitting procedures, or sampling handling for analysis, or a combination of factors. Tests conducted by Horowitz, et al. (2001) on the sample splitting capabilities of a churn splitter showed the bias and the precision of the splits is compromised with increasing sediment concentrations and particle size. The tests identified the upper particle size limits for the churn splitter is between 250 and 500 microns (Horowitz, et al, 2001). According to the data summarized in Table 5-10, 63 percent of the particles in inlet samples were greater than 250 microns.

<u>Dissolved constituents (sediment, phosphorus, and metals)</u>: These parameters consistently had very low RPD (very high precision). This supports the idea that the sample splitting operation may be the source of higher RPD in the high particulate samples.

<u>Total metals</u>: The total zinc and total copper data generally had the highest discrepancies (highest RPD, or lowest precision). Similar to the particulate sediment results, the highest RPDs occurred in the inlet samples, which had higher particulate concentrations. The total calcium and total magnesium data showed higher precision.

<u>Total phosphorus</u>: This parameter was consistently below or near the acceptable RPD value of 30 percent. Again, the highest discrepancies occurred at the inlet analyses, with very good duplicate agreement at the outlet samples.

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

			9/19/2002			4/19/2003			6/27/2003			9/12/2003			10/14/2003		
Parameter	**Unit**		**Rep 1a**	**Rep 1b**	**RPD (Pct)**	**Rep 2a**	**Rep 2b**	**RPD (Pct)**	**Rep 3a**	**Rep 3b**	**RPD (Pct)**	**Rep 4a**	**Rep 4b**	**RPD (Pct)**	**Rep 5a**	**Rep 5b**	**RPD (Pct)**
TSS	mg/L	Inlet	-	-	-	780	840	**7**	77	96	**22**	700	820	**16**	35	44	**23**
		Outlet	-	-	-	380	380	**0**	46	47	**2**	36	31	**15**	20	25	**22**
SSC	mg/L	Inlet	500	680	**30**	5,600	4,900	**14**	370	210	**54**	3,800	2,400	**44**	410	310	**29**
		Outlet	39	39	**0**	370	370	**0**	47	48	**2**	29	32	**10**	21	22	**5**
TDS	mg/L	Inlet	<50	52	**NA**	520	520	**0**	90	86	**5**	210	220	**6**	50	<50	**0**
		Outlet	<50	<50	**0**	720	730	**1**	162	160	**1**	190	190	**0**	74	58	**24**
Dissolved copper	µg/L	Inlet	8.9	9.5	**7**	28	28	**0**	20	21	**6**	58	59	**2**	50	170	**108**
		Outlet	6.8	8.4	**21**	27	26	**5**	23	23	**0**	42	41	**2**	18	19	**6**
Total copper	µg/L	Inlet	140	35	**120**	280	370	**29**	48	52	**8**	330	260	**25**	46	130	**97**
		Outlet	17	18	**6**	140	140	**0**	44	46	**4**	69	68	**1**	15	15	**0**
Dissolved zinc	µg/L	Inlet	35	31	**12**	110	120	**6**	81	77	**5**	360	350	**1**	46	47	**2**
		Outlet	22	22	**0**	84	91	**8**	96	92	**4**	160	150	**3**	42	43	**2**
Total zinc	µg/L	Inlet	134	328	**84**	1,400	2,200	**46**	200	320	**48**	1,400	1,700	**21**	300	280	**5**
		Outlet	61	63	**3**	540	540	**0**	160	160	**0**	220	210	**3**	66	67	**2**
Dissolved phosphorus	mg/L	Inlet	0.03	0.031	**3**	0.027	0.025	**8**	0.061	0.063	**3**	0.20	0.21	**3**	0.040	0.039	**3**
		Outlet	0.027	0.026	**4**	0.017	0.016	**6**	0.059	0.058	**2**	0.19	0.19	**0**	0.046	0.046	**0**
Total phosphorus	mg/L	Inlet	0.16	0.11	**37**	0.50	0.56	**10**	0.235	0.32	**31**	0.63	0.58	**7**	0.15	0.11	**35**
		Outlet	0.067	0.065	**3**	0.29	0.30	**3**	0.19	0.19	**0**	0.30	0.29	**4**	0.098	0.098	**0**
Total calcium	mg/L	Inlet	16	20	**23**	430	480	**9**	29	32	**9**	230	220	**7**	60	62	**4**
		Outlet	6.1	6.2	**2**	68	68	**0**	17	18	**2**	16	16	**0**	7.0	7.1	**1**
Total magnesium	mg/L	Inlet	7.8	10	**26**	170	200	**14**	11	12	**3**	120	110	**9**	22	27	**20**
		Outlet	2.5	2.5	**0**	26	26	**0**	4.2	4.2	**0**	4.4	4.2	**5**	1.9	2.0	**5**

Single dash indicates no sample processed for event

Laboratory precision: The WSLH analyzed duplicate samples from aliquots drawn from the same sample container as part of their QA/QC program. Summaries of the field duplicate data are presented in Table 6-3.

Table 6-3. Laboratory Duplicate Sample Relative Percent Difference Data Summary

Parameter[1]	Count[2]	Average (percent)	Maximum (percent)	Minimum (percent)	Std. Dev. (percent)	Objective (percent)
Total calcium	19	1.7	4.6	0.19	1.2	25
Dissolved chloride	21	0.69	2.4	0.03	0.60	25
Dissolved copper	12	2.1	8.7	0.03	2.9	25
Total copper	21	1.8	4.6	0.09	1.5	25
Total magnesium	19	1.2	3.6	0.01	1.2	25
TSS	16	1.3	3.5	0	1.1	30
Dissolved phosphorus	18	1.3	1.6	0	0.51	30
TDS	18	3.3	12	0	3.3	30
Total phosphorus	20	1.4	6.4	0	1.6	30
Dissolved zinc	17	1.5	5.6	0.09	1.4	25
Total zinc	18	1.7	3.8	0	1.2	25

1 Laboratory precision may also be evaluated based on absolute difference between duplicate measurements when concentrations are low. For data quality objective purposes, the absolute difference may not be larger than twice the method detection limit.

2 Analyses where both samples were below detection limits were omitted from this evaluation.

The data show that laboratory precision was maintained throughout the course of the verification project.

The field and analytical precision data combined suggest that the solids load and larger particle sizes in the inlet samples are the likely cause of poor precision, and apart from the field sample splitting procedures for inlet samples, the verification program maintained high precision.

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 percent), while laboratory control data are evaluated by calculating the absolute value of deviation from the laboratory control concentration. Accuracy was in control throughout the verification test. Tables 6-4 and 6-5 summarize the matrix spikes and lab control sample recovery data, respectively.

Table 6-4. Laboratory MS/MSD Data Summary

Parameter	Count	Average (percent)	Maximum (percent)	Minimum (percent)	Std. Dev. (percent)	Range (Pct)
Total calcium	22	96.5	113	90.8	5.1	85 – 115
COD	20	97.9	119	79.4	10.3	75 – 125
Dissolved chloride	21	101	108	97.3	2.4	90 – 110
Total copper	22	101	116	91.3	7.7	80 – 120
Dissolved copper	14	98.5	113	90.8	6.1	85 – 115
Total magnesium	22	97.5	102	93.0	2.5	85 – 115
Dissolved phosphorus	19	102	106	96.9	2.3	90 – 110
Total phosphorus	19	102	109	97.3	3.2	90 – 110
Total zinc	22	94.9	101	91.0	2.6	85 – 115
Dissolved zinc	19	97.9	114	91.8	5.0	85 – 115

The balance used for solids (TSS, TDS, and total solids) analyses was calibrated routinely with weights that were NIST traceable. The laboratory maintained calibration records. The temperature of the drying oven was also monitored using a thermometer that was calibrated with an NIST traceable thermometer.

Table 6-5. Laboratory Control Sample Data Summary

Parameter	Count	Mean (percent)	Maximum (percent)	Minimum (percent)	Std. Dev. (percent)
Total calcium	18	97	105	93	2.8
COD	20	101	107	923	3.4
Dissolved chloride	48	100	110	92	2.8
Total copper	21	99	106	91	4.5
Dissolved copper	36	102	110	94	3.5
Total magnesium	18	98	103	94	1.9
SSC	13	99	108	87	6.2
TSS	12	99	120	86	9.9
Dissolved phosphorus	6	101	102	100	0.5
TDS	18	106	122	94	7.1
Total phosphorus	24	101	108	96	2.3
Total zinc	19	97	103	94	2.1
Dissolved zinc	9	99	102	97	1.8

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 redundant methods of evaluating key constituent loadings in the stormwater were utilized to compensate for the variability of the laboratory data.

The laboratories 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.

Regarding flow (velocity and stage) measurements, representativeness is achieved in three ways:

1. The meter was installed by experienced USGS field monitoring personnel familiar with the equipment, in accordance with the manufacturer's instructions;

2. The meter's individual area and velocity measurements were converted to a representation of the flow area using manufacturer's conversion procedures (see Chapter 9 of Marsh-McBirney's O&M Manual in Appendix A of the VTP);

3. The flow calculated from the velocity/stage measurements was calibrated using the procedure described in Section 6.2

To obtain representativeness of the sub-samples (aliquots) necessary to analyze the various parameters from the event sample, a churn splitter was used. As noted in Radtke, et al. (1999), the churn splitter is the industry standard for splitting water samples into sub-samples. However, inconsistencies were noted in the sub-samples, especially when the sample contained high concentrations of large-sized sediments. The even distribution of the larger particulates becomes problematic, even with the agitation action of the churn within the splitter (Horowitz, et al, 2001). The issue of the potential for uneven distribution of particulates has not been fully resolved to date.

6.1.5 Completeness

The flow data and analytical records for the verification study are 100 percent complete. There were instances of velocity "dropouts" during some events. A discussion of the calibration procedures for flow data (velocity and stage measurements), including how velocity dropouts were addressed, is provided in Section 6.2.

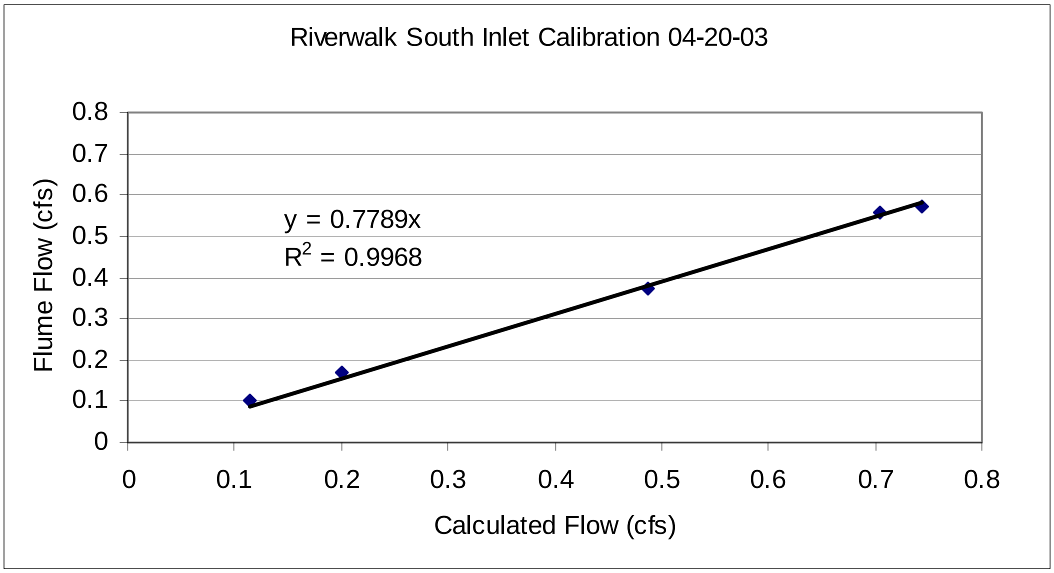
6.2 Flow Measurement Calibration

Flow meters at the inlet and outlet of the StormFilter were calibrated on April 20, 2003 and November 8, 2003 using similar procedures. A truck-mounted three-inch Parshall flume was used to calibrate the flow meter at the inlet and outlet pipes. Three 5-horsepower pumps were used to supply water from the Milwaukee River to the flume. Water was pumped into a chamber box before the flume approach to minimize turbulence. The discharge point of the flume was connected to the clean-out access on the storm inlet downspout. Connecting to the access point created some head for flow before it entered the StormFilter system's inlet pipe. Four different pumping rates produced different flow rates, ranging from 0.02 to 0.55 cfs, into the pipe. Even though a large flume was used, its capacity was only sufficient to fill the pipe to about three quarters full.

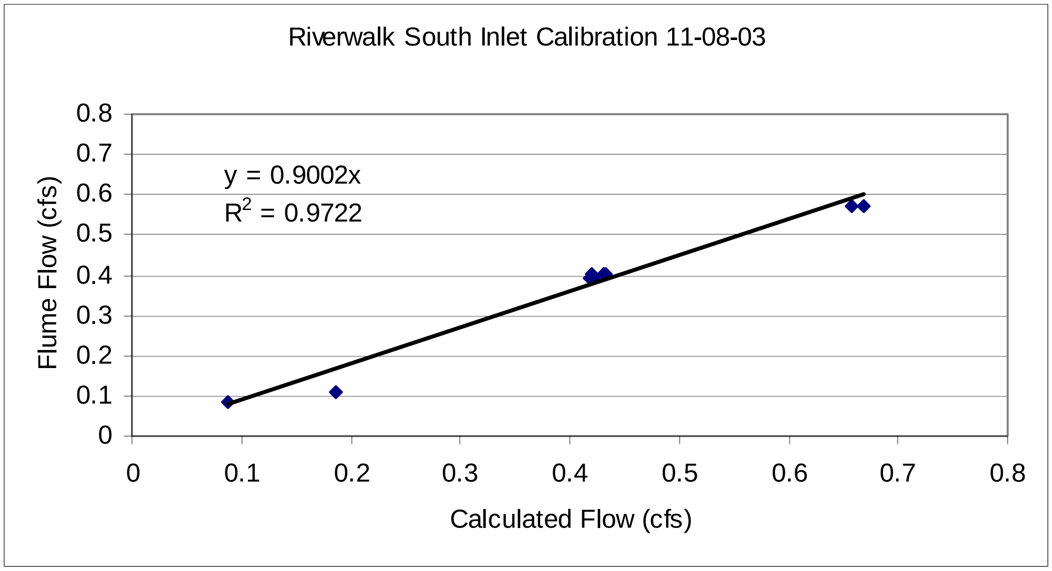
A plot of flume versus flow meter flow rates was created for both the inlet and the outlet, as shown in Figure 6-1. These plots were used to adjust the recorded flow rates. The correction reduced the inlet and outlet flows by 16 percent and 17 percent, respectively.

6.2.1 Inlet – Outlet Volume Comparison

This StormFilter configuration did not have an external bypass mechanism, so the calculated influent and effluent event volumes should ideally be the same, and a comparison of the calculated influent and effluent volumes can be used to ensure both flow monitors worked properly. The StormFilter unit does retain a certain amount of water between events, but since this retained volume is constant between events, the net runoff volume into the unit should equal the net runoff volume exiting the unit.. Good agreement was observed between the inlet and outlet volumes for each storm. Differences between the inlet and outlet volumes were 15 percent or less for 17 of the 20 storms. The average difference between the volumes was 11 percent. There was not a trend as to which volume was larger for each storm. Table 6-6 summarizes the volume comparisons for each event.



(a) April 20, 2003



(b) November 8, 2003

Figure 6-1. Calibration curves used to correct flow measurements.

Table 6-6. Comparison of Inlet and Outlet Event Runoff Volumes

	Event Volumes[1]		
Event No.	Inlet (ft^3)	Outlet (ft^3)	Difference (percent)
1	290	420	-45
2	1,700	1,600	6
3	1,600	1,600	0
4	1,000	1,200	-20
5	390	350	10
6	730	730	0
7	270	300	-11
8	400	340	15
9	610	540	11
10	340	320	6
11	500	450	10
12	420	460	-10
13	530	550	-4
14	290	260	10
15	160	150	6
16	350	340	3
17	220	270	-23
18	210	220	-5
19	410	410	0
20	680	560	18

[1] Corrected for point vs. area coefficient, flow calibration, and velocity dropouts.

The outlet volumes were considered most accurate because the inlet site experienced the majority of the missing velocity data. Possible reasons for the missing data points could be higher solids concentrations interferes with the velocity meter's capabilities, higher flow velocities at the inlet, or air entrapment at the inlet creating a disturbance in the probe's electromagnetic signal. Because of the more complete velocity data coverage at the outlet site, the outlet volumes were used for the SOL calculations (although SOL calculations for the sediment data are presented for inlet only, outlet only, and inlet and outlet). Section 6.2.4 discusses the corrections applied for the velocity dropout conditions in greater detail.

6.2.2 Gauge Height Calibration

Static gauge height measurements were made at the inlet and outlet pipes by constricting the pipe to a steady-state water level. An inflatable ball was used to block the pipe. Water level readings from a measuring tape inside the pipe were compared to the water surface level recorded by the flow meters (located within the inlet and outlet pipes, as described in Section 4). Gauge heights were checked four times during the project. A gauge height correction curve with three gauge height points—bottom, middle, and top (approximately 0.0 ft, 0.3 ft, and 0.6 ft above the invert pipe elevation)—was developed for each pipe, as shown in Table 6-7. Most of the correction factors for the inlet lowered the recorded gauge height by approximately five percent. Corrections for the outlet pipe were also small (less than ±0.05).

Table 6-7. Gauge Corrections for Flow Measurements at the Inlet

Date	Gauge Height Point 1		Gauge Height Point 2		Gauge Height Point 3	
	Gauge Height (ft)	Correction (unitless)	Gauge Height (ft)	Correction (unitless)	Gauge Height (ft)	Correction (unitless)
4/01/02	0.0	0.0	0.318	-0.035	0.636	-0.036
4/11/03	0.0	0.0	0.318	-0.035	0.635	-0.036
4/11/03	0.0	0.002	0.350	0.002	0.635	0.002
8/14/03	0.0	0.015	0.250	0.025	0.500	0.033
8/14/03	0.0	-0.005	0.350	-0.005	0.635	-0.005
11/8/03	0.0	-0.005	0.350	-0.005	0.635	-0.005

6.2.3 Point Velocity Correction

Equations have been developed by the flow monitoring equipment manufacturer to correct for velocity measurements recorded at a single point. A point velocity can be different than the average velocity over the entire depth of the water in the pipe. The equation for the flow equipment lowered all the measured velocities by approximately 10 percent.

6.2.4 Correction for Missing Velocity Data

For reasons that are not completely understood, the velocity readings at the inlet and outlet pipes would occasionally drop to zero. This occurred at the inlet meter during five events (events 2, 3, 6, 10, and 14) and at the outlet meter during one event (event 2). The missing velocity data for events 2, 3, 6, 10, and 14 amounted to 35, 15, 7, 10, and 6 percent of the total event data, respectively, based on storm flow volume.

The velocity dropout occurrences were corrected in the following manner, as demonstrated with the inlet velocity data from event 2. The meter failed to record approximately eight minutes of the 135 minutes of runoff during one of the flow peaks (see Figure 6-2). Since the gauge heights were available during the missing velocity period, the gauge heights could be used to calculate the missing velocity data. This was done by creating regression relationships between gauge height and velocity.

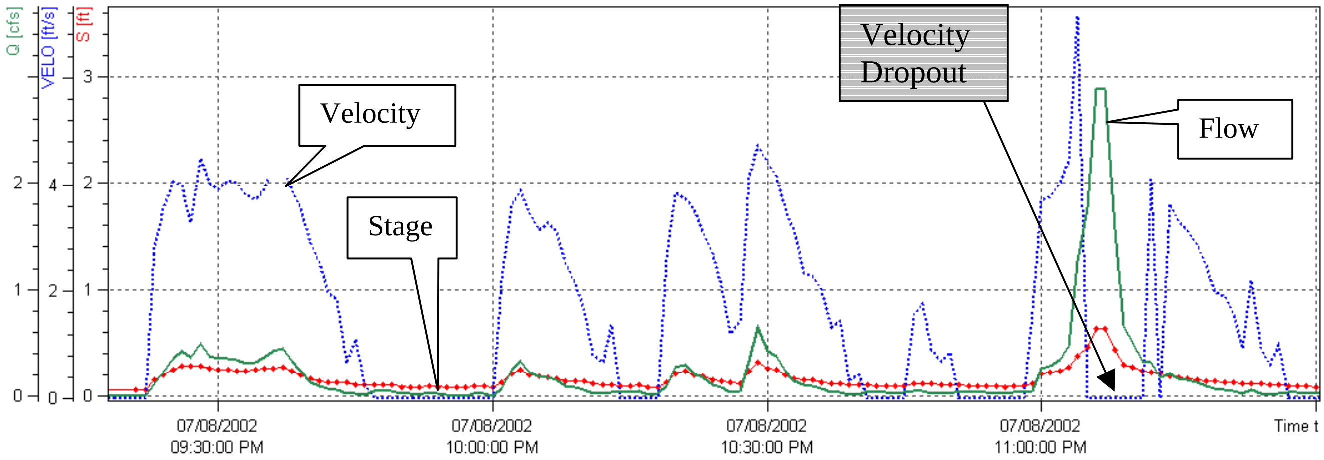


Figure 6-2. Event 2 example hydrograph showing period of missing velocity data.

By filling in the missing velocity data, the increases in volumes at the inlets for the five storms ranged from 6 to 35 percent, with an average increase of 15 percent.

The criterion for a qualified event includes successfully recording flow data throughout the duration of the event (see Section 4.4). An important part of deciding whether to qualify or reject an event is determining the amount of missing data from the event. The velocity measurements trigger the data logger to collect samples, so no samples would be collected when the velocity meter recorded zero velocity. It is possible to use the estimated flow data to determine the number of samples that should have been collected when the velocity dropped to zero, as shown in Table 6-8. The VTP included a completeness goal of 85 percent, which was used as the criteria for determining whether sufficient data was collected from a particular event. A number of storms were eliminated from the verification of the StormFilter, because they were missing more than 15 percent of the aliquots.

Some storms also had some missing velocity data near the end of the hydrograph. It appears that zero velocity was recorded when the water did not cover the velocity probe. A gauge height was still available for this part of most storms. A gauge height relationship with flow was estimated for these very low flows and the relationship was used to estimate the missing volume. This added a small amount of volume to each storm.

Table 6-8. Missing Sample Aliquots Due to Missing Inlet Velocity Data

Event No.	Number of Missing Aliquots	Total Aliquots Collected and Missing for Storm	Missing Aliquots (Percent)
2	4	33	12
3	3	33	9
4	4	25	16
10	1	14	7
17	1	9	11

In spite of the missing aliquots, each composite sample collected 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 therefore met the qualified event criteria as stated in the protocol

Chapter 7
Operations and Maintenance Activities

7.1 System Operation and Maintenance

SMI recommends initially scheduling one minor inspection and one major maintenance activity per year at the for a typical installation. A minor maintenance activity and inspection consists of visually inspecting the unit and removing trash and debris. During this activity, the need for major maintenance should be determined. A major maintenance consists of pumping accumulated sediment and water from the vault and replacing the filter cartridges. SMI indicates that the sedimentation rate is the primary factor for determining maintenance frequency, and that a maintenance schedule should be based on site-specific sedimentation conditions.

The TO followed the manufacturer's guidelines for maintenance on the StormFilter system during the verification testing. Installation of the StormFilter was completed in December 2001. In the spring of 2002, the system was placed into operation and adjustments to the system were completed, ETV monitoring of the system began in June, 2003.

Table 7-1. Operation and Maintenance During Verification Testing

Date	Activity	Personnel Time/Cost
June, 19, 2002 (Major maintenance)	StormFilter unit was cleaned of accumulated sediment and filter cartridges were replaced.	Earth Tech, USGS; WDNR; SMI; total of 3 staff days.
November 7, 2002 (Minor maintenance)	StormFilter visual inspection by WisDOT. Reported observing the following: 1) 0.20 ft of standing water in the filter vault; 2) no measurable accumulation of sediment in tank bottom; 3) less than 5 percent of water surface area contained floating debris (scum, leaves, cigarette butts; pieces of Styrofoam, etc.) 4) observed a slight oil sheen.	WisDOT: 2 staff hours
April 24, 2003 (Minor maintenance)	USGS assessed need for major maintenance. Concluded major maintenance not required at the time based on following observations: 1) TSS from a 4/4/03 event showed good reductions (Inlet: 736 mg/l; Outlet: 31 mg/l). Note: this was not an ETV qualified event. 2) the tank calibration plot from 4/18/03 showed discharge from device through the filters at a gage height of 1.25; 3) observed filter media; and color was not black, but a light gray.	4 staff hours.

Table 7-1 (cont'd).

Date	Activity	Personnel Time/Cost
January 27, 2004 (Major maintenance)	Post-monitoring clean out. The procedure is summarized in Section 7.1.1.	Staff time: 40 hours Lab costs (drying & weighing canisters): $1,200.00

7.1.1 Major Maintenance Procedure

As noted in Table 7-1, major maintenance, consisting of removing the sediments collected in the StormFilter and replacing the filter cartridges, was conducted after the final storm event. During the major maintenance event, water collected in the StormFilter was pumped into a 400-gallon tank, and the settled sediments were collected, dried and weighed, and the filter cartridges were replaced. The following procedures were undertaken during the major maintenance event.

<u>Inlet Bay Cleaning Procedure</u>

1. Removed plastic flow diverter
2. Removed sediment slurry with trash pump into 400-gallon cleaning tank
3. Removed plastic manifold and shoveled heavy sediment into 9 5-gallon buckets (mostly sand sized particles)

<u>Canister Bay Cleaning Procedure</u>

1. Removed as much of wet slurry as possible to 400-gallon cleaning tank with trash pump
2. Removed heavy sediment into 5-gallon bucket and dumped into 400-gallon tank
3. Removed canisters with boom truck and capped outlet
4. Removed sediment from under canisters
5. Replaced old canisters with pre-weighed clean canisters (ZPG media)

<u>400-Gallon Cleaning Tank</u>

1. Tank had about 150 gallons of water and sediment (water was left to settle sediment)
2. Used lab pump to decant liquid off the top. Filled about 4 buckets and rest went to sanitary sewer (about 130 gallons)
3. Used an ash shovel connected to a doll to scoop up the organics and sediment into 5-gallon buckets
4. Tap water was used to rinse out remainder of sediment in tank (put into buckets)

The wet slurry collected from the StormFilter was transported off-site for drying. The dry weight of the solids collected in the StormFitler was approximately 570 pounds.

SMI recommends that the cartridge filter media be characterized and disposed of in accordance with applicable regulations, and that the remaining cartridge components be shipped back to SMI's Portland, Oregon facility for cleaning and reuse.

Chapter 8
References

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3. Huff, F. A., Angel, J. R. *Rainfall Frequency Atlas of the Midwest*, Midwestern Climate Center, National Oceanic and Atmospheric Administration, and Illinois State Water Survey, Illinois Department of Energy and Natural Resources. Bulletin 71, 1992.

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5. NSF International and Earth Tech, Inc. *Test Plan for the Verification of Stormwater Management, Inc. StormFilter® Treatment System Using ZPG Filter Media, "Riverwalk Site" Milwaukee, Wisconsin.* March 22, 2004.

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7. Radtke, D.B. et al., *National Field Manual for the Collection of Water-Quality Data, Raw Samples 5.1*. U.S. Geological Survey Techniques of Water-Resources Investigations Book 9, Chapter A5, pp 24-26, 1999.

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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 Plans.

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 Plan(s).

Verification Organization – an organization qualified by EPA 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 Plan(s) shall be included as part of this document.

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

Verification Test Plan – 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 Plan 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.

Appendices

A **Verification Test Plan**
B **Event Hydrographs and Rain Distribution**
C **Analytical Data Reports**