Test Plan for the Verification of Downstream Defender®
“Madison Water Utility Administration Building Site” Madison, Wisconsin

EPA Environmental Technology Verification Program

September 30, 2005

Prepared for:	**NSF International** **Ann Arbor, MI**
Prepared by:	**Earth Tech Inc.** **Madison, WI**
In Cooperation with:	**Hydro International** **U.S. Geological Survey** **Wisconsin Department of Natural Resources**

VERIFICATION TEST PLAN

DOWNSTREAM DEFENDER®

Madison Water Utility Administration Building Site, Madison, Wisconsin

September, 2005

For

EPA/NSF Environmental Technology Verification Program
Water Quality Protection Center

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Acronyms and Abbreviations

BMP	Best Management Practice
°C	Degrees Celsius
cfs	Cubic feet per second
DQI	Data quality indicators
DOT	Department of Transportation
EMC	Event mean concentration
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
°F	Degrees Fahrenheit
ft^2	Square foot (feet)
ft^3	Cubic feet
g	Gram
gal	Gallon
gpm	Gallon per minute
hr	Hour
in.	Inch or inches
kg	Kilogram
L	Liter
lb	Pound
NRMRL	National Risk Management Research Laboratory
μg/L	Microgram per liter
μm	Micron
mg/L	Milligram per liter
mL	Milliliter
NSF	NSF International
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
psi	Pounds per square inch
QA	Quality assurance
QC	Quality control
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)
VSS	Volatile suspended solids
WDNR	Wisconsin Department of Natural Resources
WQPC	Water Quality Protection Center
WSLH	Wisconsin State Laboratory of Hygiene

Chapter 1
Introduction

1.1 Overview of the Environmental Technology Verification (ETV) Program

The United States Environmental Protection Agency (EPA) instituted an Environmental Technology Verification Program (ETV) to verify the performance of innovative technical solutions to various problems that threaten human health or the environment. EPA's Office of Research and Development manages the ETV program. ETV verifies commercial-ready, private sector technologies designed for environmental protection. This plan describes the testing of a pollution control technology (defined as "source control") for uncontrolled stormwater discharge. "Source control technologies" are defined as pollution control devices that treat stormwater pollution before the stormwater enters a public conveyance system.

The ETV program has developed verification testing protocols and approaches that serve as templates for conducting verification tests for various technologies. The goal of the verification testing process is to generate high quality data for verification of equipment performance.

The ETV Program is made up of six Centers, one of which is the Water Quality Protection Center (WQPC). The WQPC focuses on technologies addressing wet weather flows, source water protection, and homeland security issues. The WQPC also includes the verification testing of decentralized wastewater treatment systems that are installed at locations without access to wastewater collection treatment systems and that provide protection for groundwater and surface water sources.

NSF International (NSF) is the verification partner with EPA for operation of the WQPC, which is managed by the EPA Urban Watershed Branch, Water Supply and Resources Division, located in Edison, New Jersey. The role of NSF is to provide technical and administrative leadership in conducting the testing.

It is important to note that verification of the equipment does not mean that the equipment is "certified" or "approved" by NSF or EPA. Instead, the verification testing projects are a formal mechanism by which the performance of equipment can be determined by these two agencies, culminating in the issuance of a verification statement and report by NSF and EPA.

1.2 Purpose of the Verification Test Plan

This test plan provides a full description of the proposed monitoring program for the Downstream Defender®. The vendor for the Downstream Defender® is Hydro International of Portland, Maine. It is written based upon the *ETV Verification Protocol Stormwater Source Area Treatment Technologies* (Draft 4.0).

The results of the monitoring effort will be analyzed, documented and reported to NSF and EPA. It is understood that the results are intended for use by the EPA to post on an ETV web site for access by professionals in the field of stormwater pollution control.

1.3 Overview and Objectives of the Test Plan

A 6-foot diameter Downstream Defender® was installed in the parking lot of the Madison Water Utility Administration Building in Madison, Wisconsin, in a cooperative effort with the National Sanitation Foundation, Cities in the Waukesha Permit Group, United States Geological Survey (USGS), Wisconsin Department of Natural Resources (WNDR), and the City of Madison. The system receives surface runoff from the parking lot, small landscaped areas and rooftop. The system was installed expressly for the purpose of testing the effectiveness of the treatment system in capturing nonpoint source pollution from the drainage area.

Total influent, treated effluent, and total effluent stormwater volumes and constituent concentrations will be measured. . The field testing organization (TO) is Earth Tech, Inc. of Madison, Wisconsin. The United States Geological Survey (USGS) is conducting the field monitoring under a contract with the WDNR. The USGS will provide the results of the monitoring to the TO to prepare the verification report. Event mean concentrations, together with the mass of sediment captured within the device and event pollutant loads from the monitoring points will be calculated and compared to assess the sediment control efficiency of the system. Performance estimates will be based on net load reduction over the monitoring period (not individual storm performance).

1.4 Verification Test Plan Outline

This test plan addresses the following topics:

- Roles and responsibilities of participants;
- Description of the source control technology;
- Site conditions;
- Monitoring plan;
- Quality assurance plan;
- Data management;
- Data analysis and reporting; and
- Field safety and security.

1.5 Verification Test Plan Preparation Process

This plan was developed by Earth Tech Inc. using information provided by the City of Madison Water Utility, USGS, WDNR, the Wisconsin State Laboratory of Hygiene, and Hydro International.

Chapter 2
Roles and Responsibilities of Participants

Table 2-1 identifies each party (public and private) involved in verification testing of the Downstream Defender® at the Madison Water Utility Administration Building site in Madison, Wisconsin, and describes their respective roles, responsibilities, and contact people.

Table 2-1. Participant Roles and Responsibilities

Agency/Company	Contact Person(s)	Role/Responsibility
United States Environmental Protection Agency (EPA)	Ray Frederick USEPA/NRMRL, MS-104, Urban Watershed Branch, Water Supply and Water Resources Division Edison, NJ 08837-3679 (732)-321-6627 frederick.ray@epa.gov	Agency with primary responsibility for overall ETV program. The EPA's National Risk Management Research Laboratory provides administrative, technical, and quality assurance guidance and oversight on all WQPC activities. The EPA has review and approval over the Test Plan, verification report, and the verification statement. EPA also posts the verification report and statement on the EPA website.
NSF International	Thomas Stevens 789 N. Dixboro Road Ann Arbor, MI 48113 (734) 769-5347 fax: (734) 769-5195 stevenst@nsf.org	NSF is the EPA's verification partner in the WQPC. Advisor and reviewer for all aspects of monitoring project. Oversight of Quality Assurance. Approve final Test Plan and verification report. Prepare/ disseminate verification statement.
Madison Water Utility	Alan Larson 119 East Olin Avenue Madison, WI 53713 608-266-4651 allarson@madisonwater.org	Primary representative of owner. Maintenance will be conducted by City of Madison Engineering Department.
United States Geologic Survey (USGS)	Judy Horwatich 8505 Research Way Middleton, WI 53562 (608) 821-3874 jawierl@usgs.gov	The USGS is responsible for conducting the monitoring project. Judy Horwatich is the primary contact and responsible person for the field components of the testing project including: field procedures, QC/QA, coordination with laboratory, data analysis, and reporting.

Agency/Company	Contact Person(s)	Role/Responsibility
Wisconsin Department of Natural Resources (WDNR)	Roger Bannerman 101 South Webster Madison, WI 53705 (608) 266-9278 banner@dnr.state.wi.us	Advisor and reviewer for monitoring procedures, data analysis, and reporting. Also serves on NSF ETV Technology Panel. The WDNR is also partially funding the monitoring project under contract with USGS.
Wisconsin State Laboratory of Hygiene (WSLH)	George Bowman 2601 Agriculture Drive Madison, WI 53718 (608) 224-6278 gtb@mail.slh.wisc.edu	Primary responsibility for analyzing the collected stormwater samples for parameters identified in monitoring plan. Provide information on sample handling, preservation, and chain of custody procedures. Certifications for this laboratory are provided in Chapter 6.
Hydro International	Lisa Glennon 94 Hutchins Drive Portland, ME 04102 Phone: (207) 756-6200 Fax: (207) 756-6212 lglennon@hil-tech.com	Vendor of the treatment technology. Primary contact for technical issues regarding the treatment equipment, function, capabilities, and maintenance needs. Review and approval of the Test Plan. Hydro International will also review and comment on the draft verification report and Verification Statement. Provide partial funding for monitoring project.
Earth Tech, Inc.	Jim Bachhuber or Jennifer Hurlebaus 1210 Fourier Drive, Suite 100 Madison, WI 53717 (608) 836-9800 fax: (608) 836-9767 jim.bachhuber@earthtech.com jennifer.hurlebaus@earthtech.com	Earth Tech is the TO. Primary contact for overall testing program. Advisor on testing plan development and monitoring equipment installation. Earth Tech will prepare the verification report utilizing data results provided by the USGS.

Chapter 3
Description of Source Control Technology

3.1 Technology Description (generic)

The information provided in this section was provided by the vendor and has not been verified by the TO. The information is a generic description of the product being tested and is not specific to the Madison Water Utility site.

The Downstream Defender® is an advanced hydrodynamic vortex separator designed to remove settleable solids (and their associated pollutants), oil, and floatables from stormwater runoff. Its flow-modifying internal components have been developed from extensive full-scale testing, computational fluid dynamics modeling and over thirty years of hydrodynamic separation experience in wastewater, combined sewer, and stormwater applications. The internal components distinguish the Downstream Defender® from simple swirl-type devices and conventional oil/grit separators by minimizing turbulence and headlosses, enhancing separation, and preventing re-suspension of previously stored pollutants.

The Downstream Defender® has no moving parts and no external power requirements. It consists of a cylindrical concrete vessel, with plastic internal components and a 304 stainless steel support frame and connecting hardware. The concrete vessel is a standard precast cylindrical manhole with a tangential inlet pipe installed below ground. Two ports at ground level provide access for inspection and clean out of stored floatables and sediment. The internal components consist of two concentric hollow cylinders (the dip plate and center shaft), an inverted cone (the center cone), a benching skirt, and a floatables lid. The Downstream Defender's® key components are illustrated in Figure 3-1.

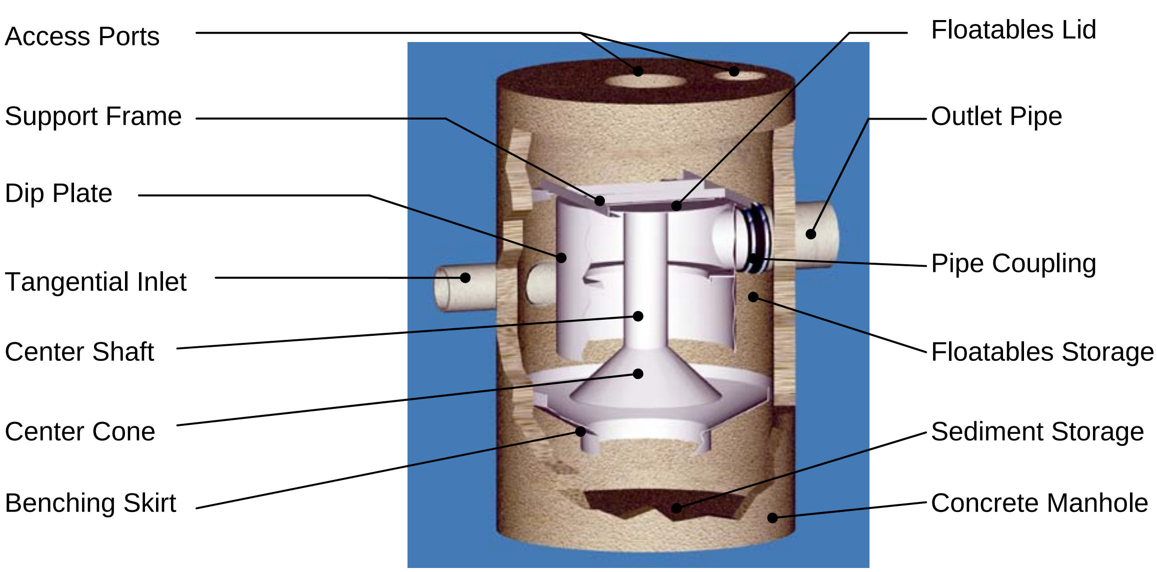


Figure 3-1. Downstream Defender® interior view (generic depiction).

The Downstream Defender® is self-activating, and operates on simple fluid dynamics. The geometry of the internal components and placement of the inlet and outlet pipes are designed to direct the flow in a pre-determined path through the vessel.

Stormwater is introduced tangentially into the side of the vessel, initially spiraling around the perimeter in the outer annular space between the dip plate cylinder and manhole wall. Oil and floatables rise to the water surface and are trapped by the dip plate in the outer annular space. As the flow continues to rotate about the vertical axis, it travels down towards the bottom of the dip plate. Low energy vortex motion directs sediment toward the center and base of the vessel. Flow passes under the dip plate and up through the inner annular space, between the dip plate and center shaft, as a narrower spiraling column rotating at a slower velocity than the outer downward flow.

The outlet of the Downstream Defender® is a single central discharge from the top water level in the inner annulus. Discharging from the inner annulus forces each fluid element to pass through a long spiral path from the inlet, downward through the outer annulus, then upward through the inner annulus before it can be released. This increases the retention time for the separation of settleable solids and floatables.

The Downstream Defender® is designed to collect accumulated pollutants outside the treatment flow path. This prevents re-entrainment into the effluent during major storms or surcharge conditions. Furthermore, removal and retention efficiencies are maintained because pollutants such as sediment, floatables, and oils accumulate between clean-outs and are collected and stored in isolated storage zones over a period of several months.

A section view of the Downstream Defender® is shown in Figure 3-2 to illustrate isolated pollutant storage locations and the purpose of the offset inlet and outlet inverts. The Downstream Defender® is designed with a submerged inlet. The crown of the inlet pipe where it connects to the unit is at the same elevation as the invert of the outlet pipe. The outlet pipe invert is placed on the hydraulic profile to maintain a static water level in the Downstream Defender® equal to the invert elevation of the outlet pipe. During a storm event, the submerged inlet introduces flow below the unit's static water surface, forcing floatables to rise into the outer annular region between the dip plate and concrete manhole. Submerging the inlet aids in stabilizing the flow regime over the unit's entire flow range. This enhances the removal efficiency and prevents re-suspension and washout (re-entrainment) of previously stored pollutants.

Headlosses of the Downstream Defender® are primarily a function of the inlet pipe diameter. The larger the inlet pipe diameter, the lower the headlosses. Headlosses can be decreased by increasing the inlet pipe diameter up to the diameter of the outlet pipe.

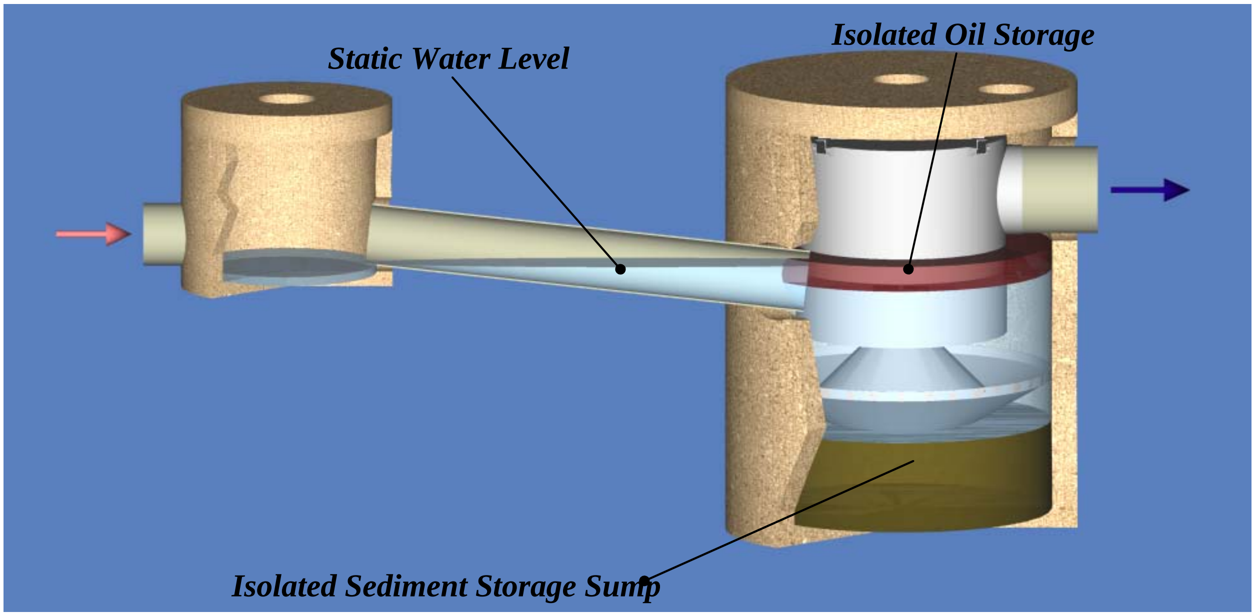


Figure 3-2. Downstream Defender® submerged inlet and isolated pollutant storage locations.

As the rotating flow spirals downward in the outer annular space, the benching skirt directs sediment toward the center and base of the vessel where it is collected in the sediment storage facility, beneath the vortex chamber. The center cone protects stored sediment and redirects the main flow upwards and inwards under the dip plate into the inner annular space. The dip plate is located at the shear zone (the interface between the outer downward circulation and the inner upward circulation where a marked difference in velocities encourages solids separation.) A floatables lid covers the effluent area in the inner annular space between the dip plate and center shaft to keep oil and floatables stored in the outer annulus separate from the treated effluent. Figure 3-3 summarizes how the internal components of the Downstream Defender® address storing pollutants within the same vessel without compromising removal efficiencies due to re-suspension and/or washout (re-entrainment).

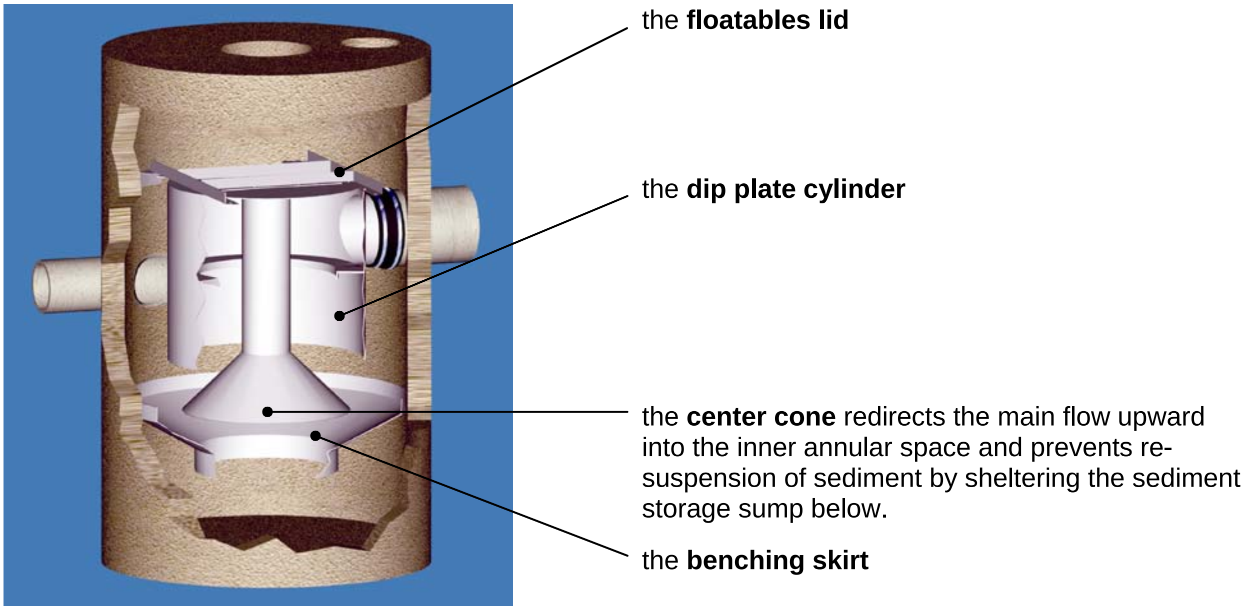


Figure 3-3. Downstream Defender® – internal components.

The Downstream Defender® can be used in the following applications:

- New developments and retrofits;
- Construction sites;
- Streets and roadways;
- Parking lots;
- Vehicle maintenance wash-down yards;
- Industrial and commercial facilities;
- Wetlands protection; and
- Pre-treatment for filter and other polishing systems.

The unit should be installed in a location that is easily accessible for a maintenance vehicle, preferably in a flat area close to a roadway or parking area.

3.2 Technology Desciption (site specific)

Specific information on the Downstream Defender® installed at the test site is presented in this section. All pipe sizes were measured by Earth Tech and USGS at an inspection trip on June 22, 2005. All pipe diameters are inside diameters. The field measured pipe diameters do not always match the sizes shown on Figures 3-4, 3-5, and 3-6. These differences may be for the following reasons:

1) some field measurements were very difficult to obtain because of the location of the pipe. The field measurements should be considered ±0.5 in.;
2) the pipes' shapes may be deflected during the construction process and round pipes are now slightly difference in shape; or
3) the size pipe installed was not the same as the pipe size shown in the drawings.

A 6-ft diameter Downstream Defender® was installed at the Madison Water Utility site in the fall of 2004. Two clean out/access ports at grade level are located above the Downstream Defender®. A flow diversion structure is located approximately 13 ft north of the Downstream Defender®. Flow from the drainage area is received to the diversion structure through a 13.5-in. PVC inlet pipe. The Downstream Defender® has a 12-in. PVC inlet pipe and a 16.5-in. PVC outlet pipe. A weir in the diversion manhole has a crest elevation approximately 14 in. above the invert of the inlet pipe. The outlet pipe from the diversion manhole to the site's wet detention pond is 13 in. in diameter.

Figures 3-4, 3-5, and 3-6 detail the planned design for the Downstream Defender® at the Madison Water Utility site. The pipe diameters shown on the drawings are not consistent with diameters measured in the field. Elevations on the device and the inlet and outlet pipes have not been field verified. Elevations and principal dimensions will be field verified prior to commencement of monitoring.

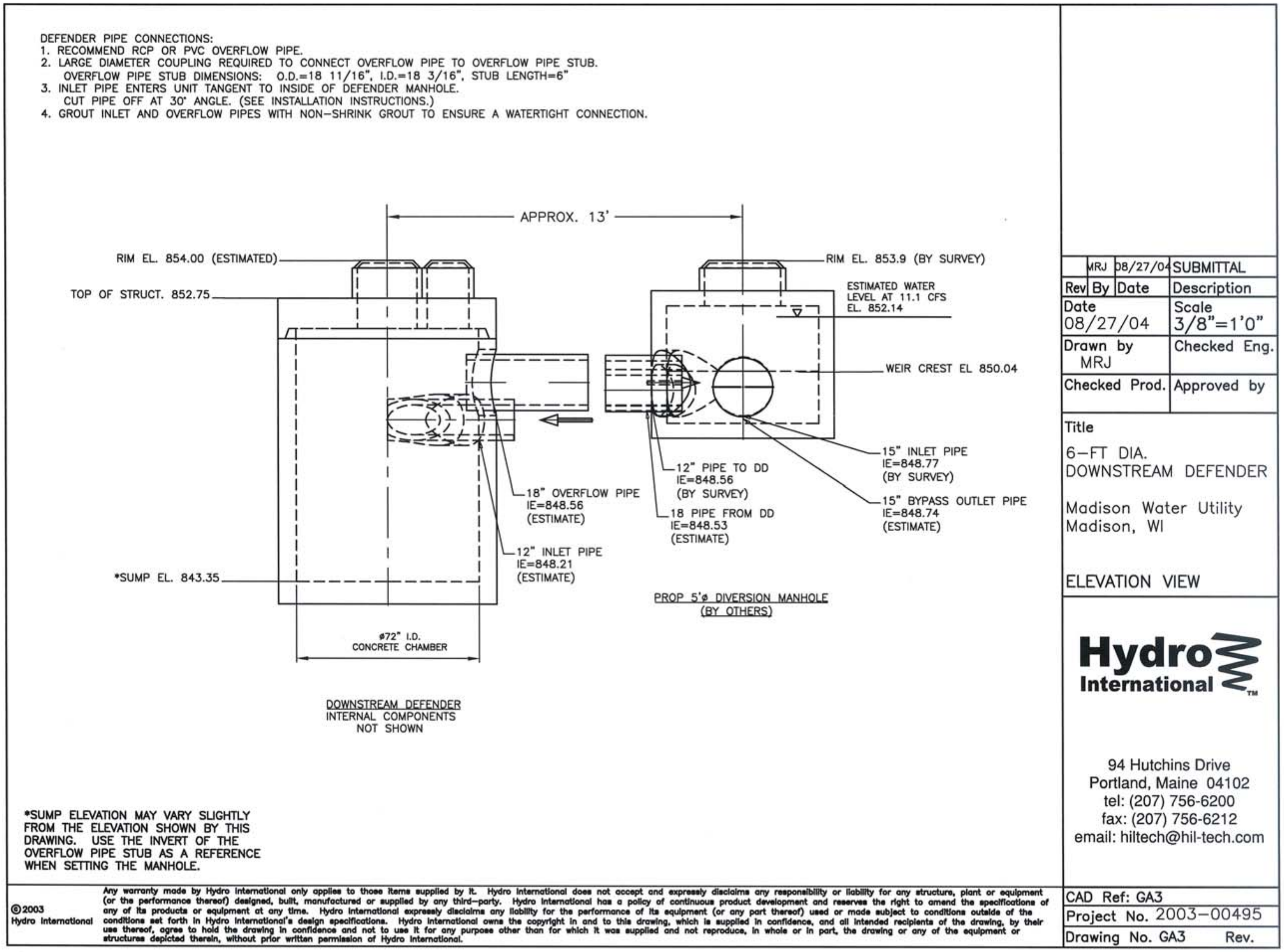


Figure 3-4. Elevation View of the Downstream Defender, Madison, WI

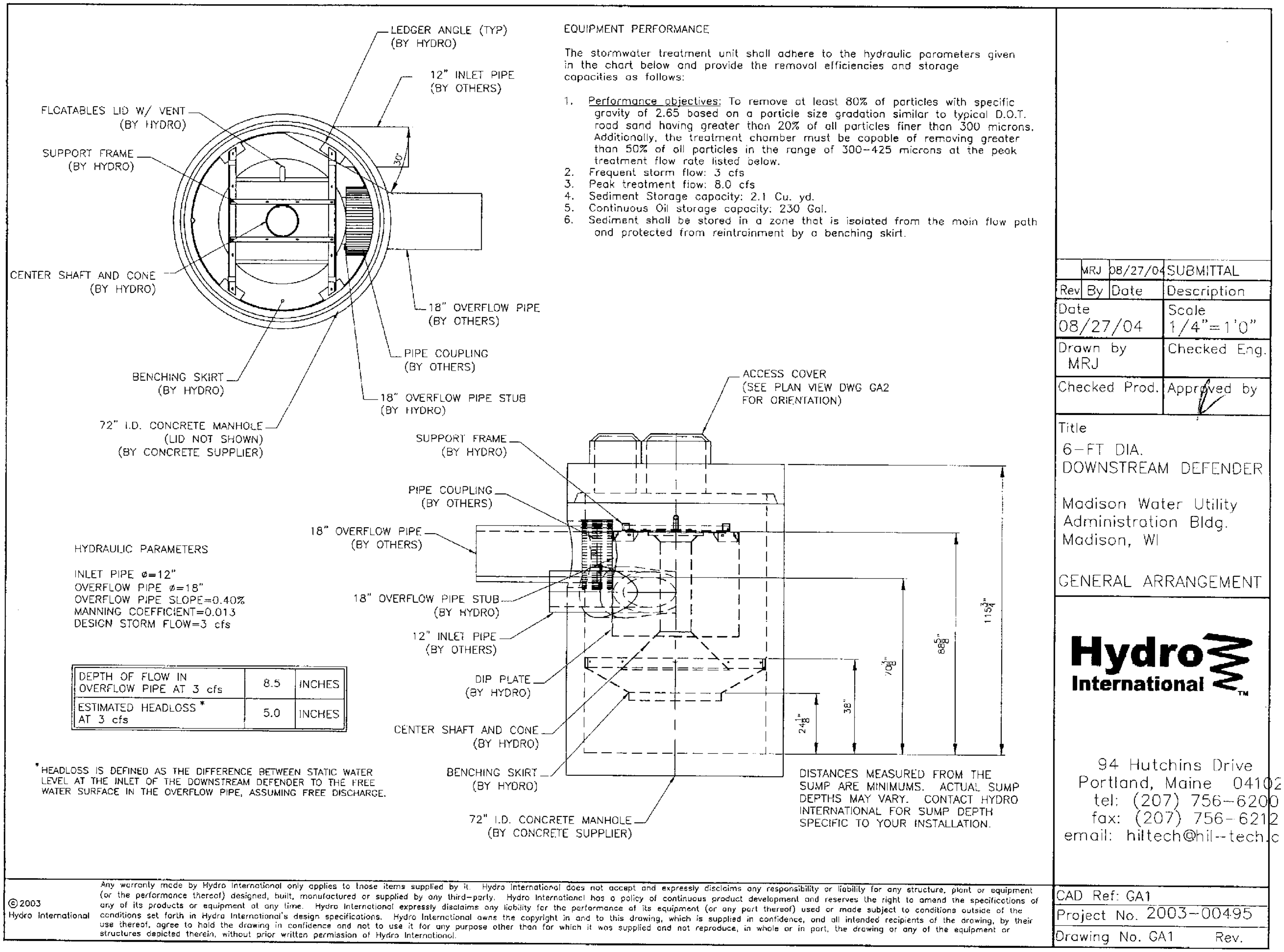


Figure 3-5. General Arrangement of the Downstream Defender®, Madison, WI.

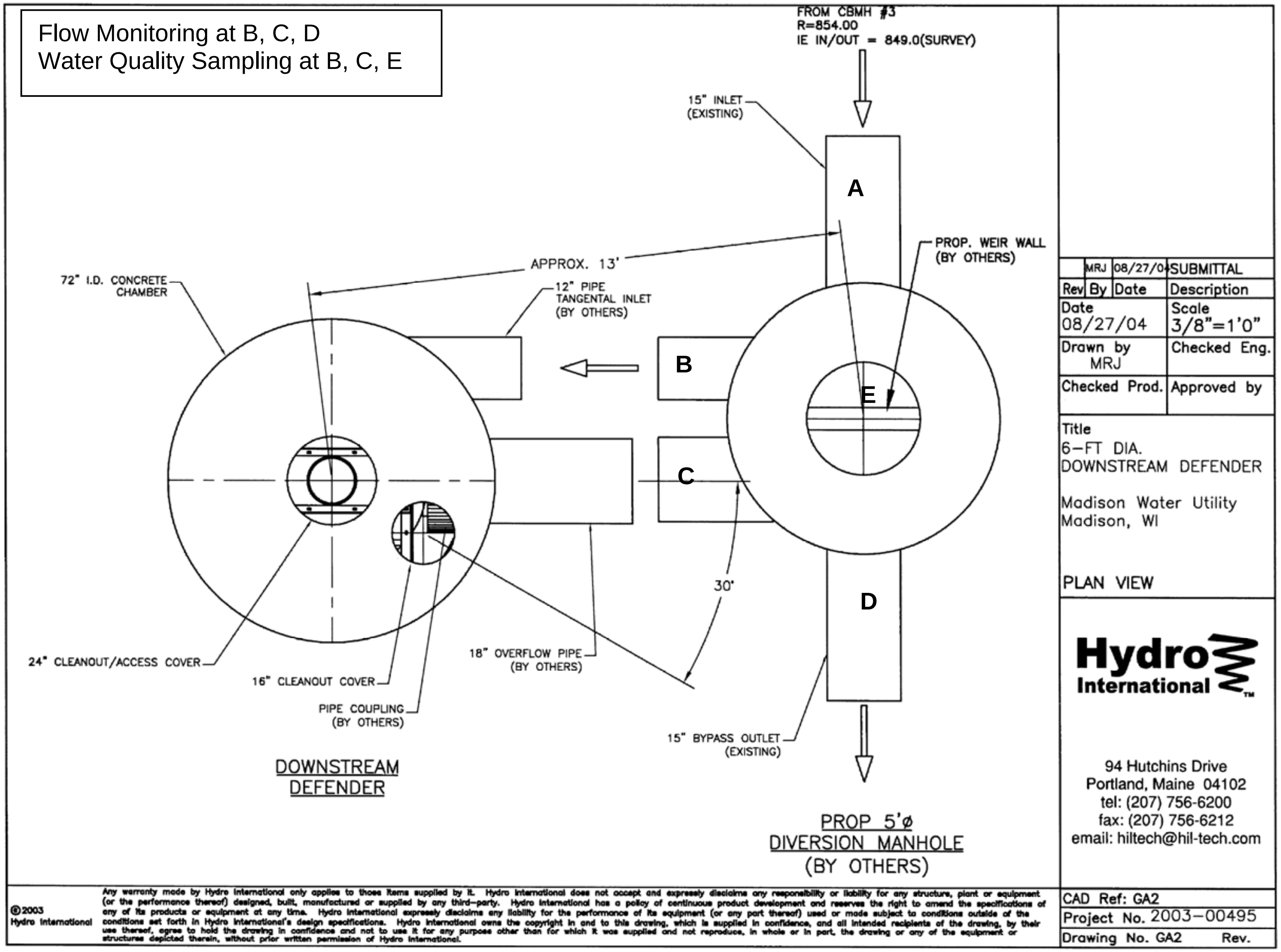


Figure 3-6. Plan View of the Downstream Defender®, Madison, WI.

3.3 Operation and Maintenance

Hydro International provided the following guidance and information on the operation and maintenance of the system.

The Downstream Defender® operates on simple fluid hydraulics. It is self-activating, has no moving parts, no external power requirement and is fabricated with durable non-corrosive components. Therefore, no procedures are required to operate the unit and maintenance is limited to monitoring accumulations of stored pollutants and periodic clean-outs. The Downstream Defender® has been designed to allow for easy and safe access for inspection/monitoring and clean-out procedures. Entry into the unit or removal of the internal components is not necessary for maintenance so that safety concerns related to confined-space-entry are avoided.

The internal components of the Downstream Defender® have been designed to protect the oil, floatables and sediment storage volumes so that treatment capacities are not reduced as pollutants accumulate between clean-outs. Additionally, the Downstream Defender® is designed and installed into the storm drain system so that the vessel remains wet between storm events. Oil and floatables are stored on the water surface in the outer annulus separate from the sediment storage volume in the sump of the unit providing the option for separate oil immobilization, removal and disposal (such as the use of absorbent pads). Since the oil/floatables and sediment storage volumes are isolated from the active separation region, the potential for re-suspension and washout of stored pollutants between clean-outs is minimized.

Keeping the unit wet also prevents stored sediment from solidifying in the base of the unit. The clean-out procedure becomes much more difficult and labor intensive if a stormwater treatment system allows fine sediment to dry-out and consolidate. When this occurs, clean-out crews must enter the chamber and manually remove the sediment; a labor intensive operation in a potentially hazardous environment.

A sump-vacuum is used to remove captured sediment and floatables. Access ports are located in the top of the manhole. The floatables access port is above the area between the concrete manhole wall and the dip plate. The sediment removal access port is located directly over the hollow center shaft. The frequency of the sump vacuum procedure is determined in the field after installation. During the first year of operation, the unit should be inspected every six months to determine the rate of sediment and floatables accumulation. A simple probe can be used to determine the level of solids in the sediment storage facility. This information can be recorded in maintenance logs to establish a routine maintenance schedule. Maximum pollutant storage capacities are provided in Table 3-1. To prevent floatables and oils from entering the sediment sump storage volume, it is recommended that oil and floatables are removed prior to removing sediment.

Table 3-1 Downstream Defender® Pollutant Storage Capacities and Maximum Clean-out Depths

Unit Diameter (ft)	Total Oil Storage (gal)	Oil Clean-Out Depth (in.)	Total Sediment Storage (gal)	Sediment Clean-Out Depth (in.)	Total Volume Removed (gal)
4	70	< 16	141	< 18	384
6	230	< 23	424	< 24	1,240
8	525	< 33	939	< 30	2,890
10	1,050	< 42	1,760	< 36	5,550

Maintenance records will be maintained during testing and included in the verification report. A copy of the inspection report is attached as Appendix A.

3.4 Performance Claims

This section was prepared by Hydro International.

The following are performance claims made by Hydro International regarding the Downstream Defender® stormwater quality treatment unit installed at the Madison Water Utility Administration Building Site in Madison, WI.

The Downstream Defender® is designed to remove and prevent washout (re-entrainment) of settleable solids and floatables from stormwater runoff. In addition, with proper maintenance, treatment capacities are not reduced as pollutants accumulate between clean-outs.

3.4.1 Total Suspended Solids

The 6-ft Downstream Defender® installed at the Madison Water Utility Administration Building Site is designed to remove settleable solids from stormwater runoff. Generally, the removal efficiency of the Downstream Defender® decreases with increasing flow rates, finer particles and cooler water temperatures. For runoff at 15 C°, the Downstream Defender® will remove over 80% of settleable solids with a specific gravity of 2.65 with a particle size distribution similar to Maine DOT road sand (see Figure 3-7) at flow rates up to 3 cfs (see Figure 3-8). Hydro International defines "settleable sediment" as particles greater than 62 µm in size.

Performance of the Downstream Defender®, in terms of sediment removals, depends on the incoming flow rate, particle size distribution, specific gravity and runoff temperature. Figure 3-7 shows two example particle size distributions (for Maine DOT road sand and F-110 silica sand).

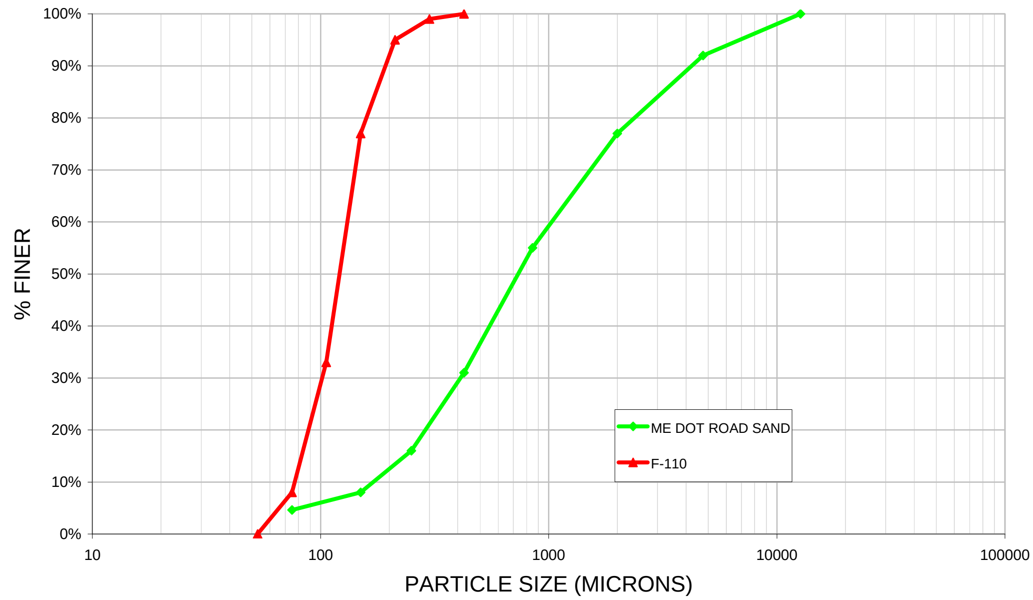


Figure 3.7 Particle Size Distribution for ME DOT Road Sand and F-110 Silica Sand.

The range of removals for the particle size distributions shown in Figure 3.7 at different flow rates for a water temperature of 15 °C is shown in Figure 3.8.

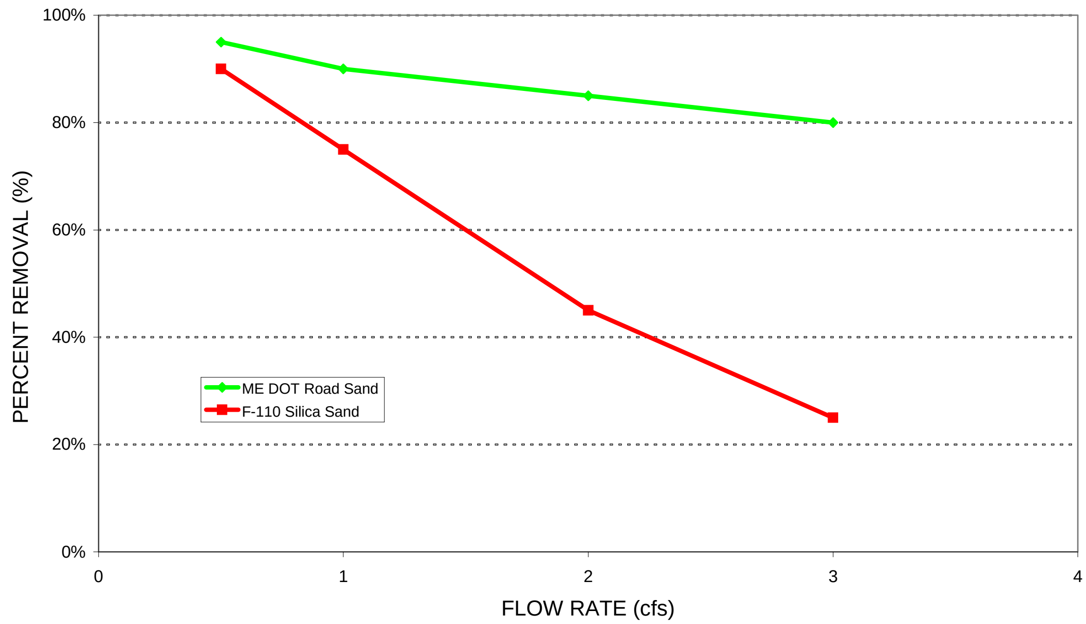


Figure 3.8 Removal Efficiencies for Differing Sediment Gradations at 15 °C.

3.4.2 Metals and Nutrients

Significant levels of metals and nutrients have been detected in the sediment removed by the Downstream Defender® during tests conducted at other locations. Removal of metals and nutrients depends on the portion of these contaminants that are attached to the particulates. Therefore, no specific removal claims are made.

3.4.3 Hydrocarbons

Even though the Downstream Defender® is designed to treat petroleum hydrocarbons in stormwater, Hydro International did not make specific performance claims for petroleum hydrocarbons to be verified by ETV testing, and this test plan will not include provisions to verify the Downstream Defender® hydrocarbon treatment capability.

3.4.4 Floatables

Up to 100% floatables removal has been observed visually in the Downstream Defender®. However, the ETV protocol has no provisions for monitoring floatables. Therefore, no specific performance claims are made.

Chapter 4
Site Description

4.1 Location and Land Use

The Downstream Defender® is located in the parking lot at the Madison Water Utility Administration Building at 119 East Olin Avenue in Madison, Wisconsin. The latitude and longitude coordinates are 43° 3'9" N and 89° 22'55" W. The device receives direct stormwater runoff from the parking lot and rooftops through a storm sewer collection system. Figure 4-1 shows the location of the test site.

The Madison Water Utility Building grounds cover about 5.5 acres. Figure 4-2 shows the site conditions with the drainage area and storm sewer collection system delineated. The drainage area tributary to the device is 1.9 acres in size. Table 4-1 shows a breakout of the land uses within the drainage area.

Table 4-1. Drainage Area Land Use

	Walkways/ Sidewalks	Parking Lot/ Road	Building (Roof)	Landscape	Total Area
Area (acres)	0.08	1.05	0.49	0.29	1.91

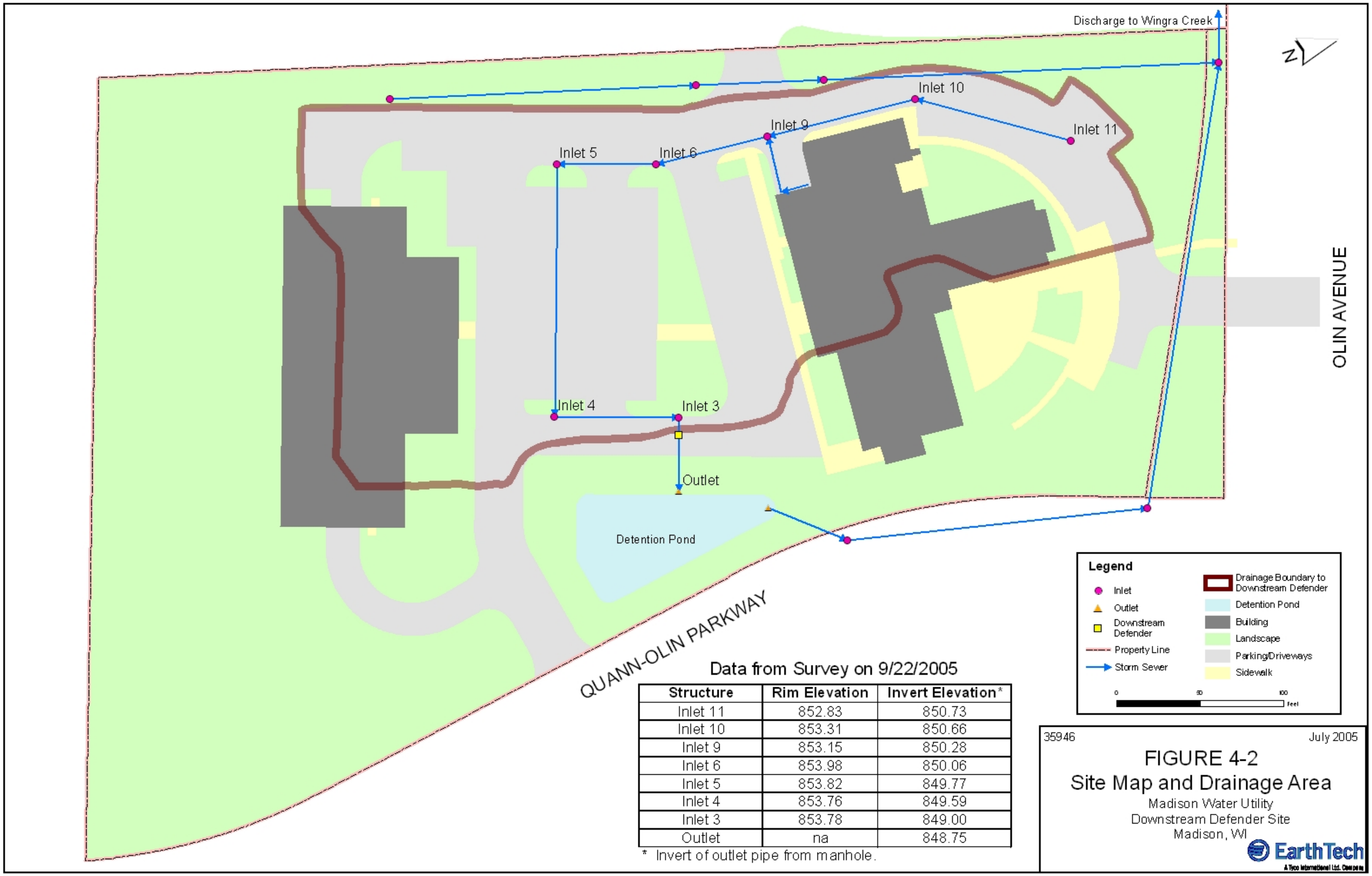
The property adjacent to the Madison Water Utility (to the west) is a City of Madison recycling facility with outside storage of yard and brush waste. Currently, drainage from this site enters the Madison Water Utility parking lot and may into the monitored system. The City of Madison will construct a speed bump diversion to keep this runoff from entering the monitored area. This diversion will also prevent yard waste from entering into the monitored system.

4.2 Pollutant Sources and Site Maintenance

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

The storm sewer catch basins do not have sumps. There are no other stormwater best management practice (BMP) devices within the drainage area.


Lake Mendota
Lake Monona
Lake Wingra
Site Boundary
Wingra (Murphy) Creek
35946
July 2005
FIGURE 4-1
Site Location
Madison Water Utility
Downstream Defender Site
Madison, WI
EarthTech
A Tyco International Ltd. Company



Data from Survey on 9/22/2005

Structure	Rim Elevation	Invert Elevation*
Inlet 11	852.83	850.73
Inlet 10	853.31	850.66
Inlet 9	853.15	850.28
Inlet 6	853.98	850.06
Inlet 5	853.82	849.77
Inlet 4	853.76	849.59
Inlet 3	853.78	849.00
Outlet	na	848.75

* Invert of outlet pipe from manhole.

35946 July 2005

FIGURE 4-2
Site Map and Drainage Area
Madison Water Utility
Downstream Defender Site
Madison, WI

EarthTech

4.3 Stormwater Conveyance System

The site is drained by a storm sewer collection system. An 18 in. storm sewer runs along the north edge of the site, collects runoff from part of the main building, parking lot and landscaped areas, and discharges to Wingra Creek. The storm sewer system consists of 12- and 15-in. diameter concrete pipe. The storm sewer collects stormwater from the buildings and parking lot and conveys it to the Downstream Defender®. From the Downstream Defender®, the treated stormwater (and bypass flow) enters a wet detention pond (located at the Water Utility property) and subsequently to the city's storm sewer system.

The storm sewer collection system that conveys stormwater to the Downstream Defender® and the bypass structure, was surveyed on September 22, 2005 by Earth Tech. Surface elevations and pipe invert elevations for the inlets were measured. Measurements were also taken at the flow diversion manhole of the Downstream Defender®. The City of Madison provided benchmark elevations on the site. The benchmark used for the survey was located on the top of the fire hydrant on the west edge of the site and it has an elevation of 856.47 ft. The survey results are shown on Figures 3-4, 3-5, and 4-2.

4.4 Water Quality/Water Resources

The receiving water of the site's runoff is Wingra Creek, which is a tributary to Lake Monona. Wingra Creek is on the WDNR 303(d) impaired waters list. Wingra Creek's impairments are aquatic toxicity and contaminated sediment.

Most of the urban communities within the Yahara watershed including the City of Madison 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.

4.5 Local Meteorological Conditions

Madison, Wisconsin has the typical continental climate of interior North America with a large annual temperature range and with frequent short period temperature changes. Madison experiences cold snowy winters, and warm to hot summers. Average annual precipitation is approximately 33 in., with an average annual snowfall of 44 in. Summary temperature and precipitation data from the Madison area are presented below in Tables 4-2 and 4-3. These data are from the National Weather Service station from the Dane County Regional Airport in Madison, Wisconsin. Figure 4-3 shows the average monthly distribution of precipitation by month for Madison. This figure shows that approximately 37% (12.31 in.) of the annual precipitation occurs during the summer months (June, July, and August). Table 4-4 presents the statistical rainfalls for a series of recurrence and duration precipitation events. This data is from *Rainfall Frequency Atlas of the Midwest*; Huff and Angel; 1992.

Table 4-2. Temperature Summary, National Weather Service Station (Station 474961 Madison WSO Airport)

Month	High Mean °F	Year	Low Mean° F	Year	1-Day Max °F	Date	1-Day Min °F	Date
Jan	28.6	1990	3.7	1977	56	1/31/1989	-37	1/30/1951
Feb	33.5	1998	11.7	1979	64	2/25/2000	-29	2/3/1996
Mar	41.6	1973	18.4	1960	82	3/31/1981	-29	3/1/1962
Apr	53.1	1955	39.5	1950	94	4/22/1980	0	4/7/1982
May	65.2	1977	50.2	1967	93	5/1/1952	19	5/1/1978
Jun	72.0	1995	59.5	1969	101	6/20/1988	31	6/10/1972
Jul	78.1	1955	67.1	1967	104	7/10/1976	36	7/6/1965
Aug	77.9	1947	62.0	1967	102	8/16/1988	35	8/29/1965
Sep	65.7	1948	56.7	1993	99	9/1/1953	25	9/29/1949
Oct	59.8	1947	43.4	1987	90	10/6/1963	13	10/30/1988
Nov	46.1	2001	27.1	1959	76	11/3/1964	-11	11/30/1947
Dec	31.3	1998	10.8	1983	64	12/5/2001	-25	12/19/1983
Seasonal Summaries:								
Annual	49.9	1998	43	1972	104	7/10/1976	-37	1/30/1951
Winter	28.2	1998	12.8	1977	64	12/5/1901	-37	1/30/1951
Spring	52.3	1977	40.5	1960	94	4/22/1980	-29	3/1/1962
Summer	74.6	1995	65.1	1967	104	7/10/1976	31	6/10/1972
Fall	52.8	1953	43.3	1976	99	9/1/1953	-11	11/30/1947

Table 4-3. Precipitation Summary, National Weather Service Station (Station 474961 Madison WSO Airport)

Month	High (in.)	Year	Low (in.)	Year	1-Day Max (in.)	Date
Jan	2.53	1996	0.14	1981	1.15	1/26/1974
Feb	2.77	1953	0.06	1995	1.61	2/27/1948
Mar	5.46	1998	0.28	1978	2.78	3/30/1998
Apr	7.11	1973	0.96	1946	1.91	4/28/1975
May	9.63	2000	0.64	1981	3.64	5/23/1966
Jun	9.95	1978	0.81	1973	4.51	6/17/1996
Jul	10.93	1950	1.38	1946	3.89	7/3/1975
Aug	9.49	1980	0.7	1948	3.4	8/2/2001
Sep	9.22	1965	0.11	1979	2.7	9/12/1961
Oct	5.63	1984	0.06	1952	2.78	10/18/1984
Nov	5.13	1985	0.11	1976	2.3	11/1/1971
Dec	4.09	1987	0.25	1960	2.19	12/3/1990
Seasonal Summaries:						
Annual	43.34	1993	21.08	1976	4.51	6/17/1996
Winter	6.44	1983	1.45	1961	2.19	12/3/1990
Spring	17.42	1973	4.36	1994	3.64	5/23/1966
Summer	21.58	1993	4.83	1976	4.51	6/17/1996
Fall	15.61	1961	2.1	1976	2.78	10/18/1984

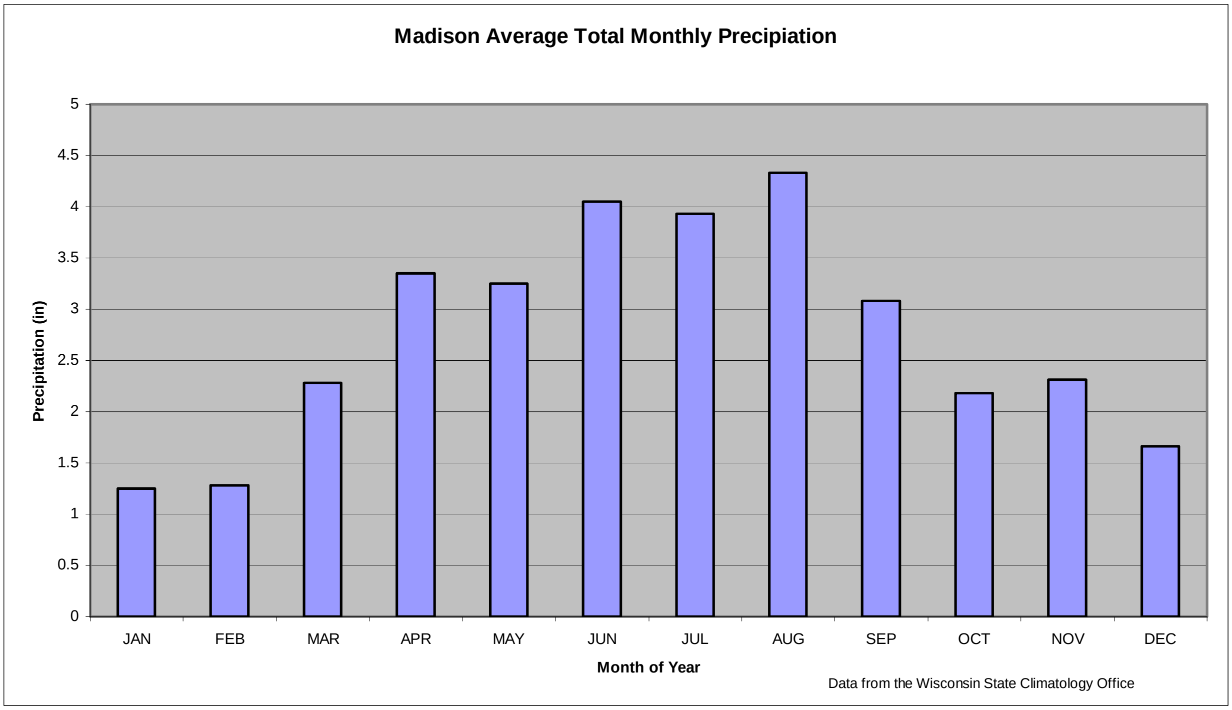


Figure 4-3. Distribution of average annual precipitation for Madison.

Table 4-4. Design Storm Data, "Area 8" (South Central Wisconsin – Madison)

	Rainfall Amount (in.)[1]				
Duration:	**2-month**	**6-month**	**1-year**	**2-year**	**10-year**
30 min	0.46	0.67	0.83	1.03	1.55
1 hr	0.58	0.86	1.06	1.31	1.97
2 hr	0.71	1.05	1.30	1.61	2.44
6 hr	0.93	1.37	1.69	2.09	3.15
12 hr	1.08	1.59	1.96	2.42	3.65
24 hr	1.24	1.82	2.25	2.78	4.20

1. Source: Table 9 for Area 8; Huff and Angel 1992

4.6 Hydrology of the Site

The Downstream Defender® installed at the Madison Water Utility site was sized to treat flows up to 3 cfs. The system includes an upstream diversion chamber with a bulkhead set at an elevation to by-pass flows in excess of 3 cfs.

Peak flows from the project site under various precipitation conditions were calculated using XP SWMM Runoff methodology. The peak flow results are shown on Table 4-5. The reported flows are the runoff from the drainage area.

Table 4-5. Peak Flow Calculations for Project Area Runoff

	Peak Flow Calculations (cfs)				
Duration	2-month	6-month	1-year	2-year	10-year
30 min	0.82	1.84	2.75	3.99	7.56
1 hr	0.77	1.63	2.30	3.21	6.31
2 hr	0.59	1.21	1.87	2.76	5.31
6 hr	0.39	0.82	1.17	1.61	2.82
12 hr	0.28	0.48	0.63	0.82	1.31
24 hr	0.21	0.34	0.43	0.55	0.85

Note: Shaded results indicate flows greater than 3 cfs.

Based on the information provided by Hydro International, bypassing occurs when flows reach 3 cfs. The SWMM model was built to account for the Downstream Defender® treating 3 cfs and the rest of the flow going over the bulkhead. Table 4-6 shows the percentage of the flow volume that bypasses the Downstream Defender® according to the modeling conducted.

Table 4-6. Percent Flow Volume Bypassed

	Flow Volume Bypass Calculations[1]				
Duration:	2-month	6-month	1-year	2-year	10-year
30 min	--	--	--	6%	31%
1 hr	--	--	--	1%	23%
2 hr	--	--	--	--	11%
6 hr	--	--	--	--	--
12 hr	--	--	--	--	--
24 hr	--	--	--	--	--

1. Information based on bypassing occurring at flows greater than 3 cfs.

Chapter 5
Monitoring Plan

5.1 Selection of Sampling Locations

Flow and water quality will be monitored to determine the changes in water quality that occurs due to treatment by the Downstream Defender®. The locations of the monitoring sites are designated as A through E on Figure 3-6. Flow monitoring will occur at location B (inlet pipe to Downstream Defender®); C (outlet pipe from Downstream Defender®) and D (outlet pipe from flow splitter box). Flow measurement at site A was considered but rejected due to predicted excessively turbulent flow conditions.

Water quality sampling will be conducted at locations B, C, and E. For sample site E, the sample line will be placed on the upstream side of the bulkhead, about one inch below the top. This location was selected to provide enough water covering the sampling tube to collect a sample. A pressure transducer located in the flow diversion structure (upstream from the bulkhead) will activate the sampler at E when the stage exceeds the sampler tube elevation. When the sampler at E is activated, a flow weighted sample will be taken when the runoff volume at D exceeds the volume at B by a pre-determined value. Every time this pre-determined volume is exceeded during the course of an event, a sample will be taken at E. This method will be evaluated during the initial sampling period and modified if necessary.

5.2 Pollutant Constituent Selection

The constituents to be analyzed as part of verification include:

- Suspended Sediment Concentration (SSC)
- Total suspended solids (TSS)
- Particle Size Distribution
- Volatile Suspended Solids (VSS)
- Temperature (measured by the auto sampler)

The Vendor's sediment removal claims are based on "Maine DOT road sand" and "F110 silica sand" with a specific particle size distribution, specific gravity and concentration. (see Section 3.4.1) This verification test will not verify the Downstream Defender's® performance relative to Maine DOT road sand. This test will verify the performance of the Downstream Defender® relative to the stormwater sediment characteristics found at the test site.

Where applicable, the Verification Report will correlate the performance claims based on Maine DOT road sand and F110 silica sand to the particle size distribution of sediment taken from the influent, effluent and sump of the test unit.

5.3 Sampling Schedule

The monitoring effort will begin in September or October of 2005. A continuous-recording flow gauging station will be installed to monitor discharge. Automatic samplers will collect water quality samples (see below for details). Fifteen qualified runoff events with will be sampled. For a rainfall event to be considered a qualified sampling event, the following conditions must be met:

- The total rainfall depth for the event, measured at the site, shall be 0.2 in. (5 mm) or greater;
- Flow through the treatment device and bypass shall be successfully measured and recorded over the duration of the runoff period;
- A flow-proportional composite sample shall be successfully collected for both the influent and effluent over the duration of the runoff event; and a sample will be taken at the outlet of the system if bypassing occurs.
- Each composite sample collected shall comprise of a minimum of five aliquots including at least two aliquots in 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. The samplers will be programmed, based on a flow-weighted measurement, to capture as many aliquots as possible throughout the event; and
- There shall be a minimum of six hours between qualified sampling events. That is, there shall be a minimum of six hours between the termination of measured effluent during one event and the start of measured influent to the stormwater technology during the subsequent rainfall event.

The water quality and discharge data collected will be used to calculate mass loadings for the various constituents going into and out of the Downstream Defender®. These mass loadings will be used to calculate efficiencies of the Downstream Defender® at removing and retaining sediment.

5.4 Water Quality Data Collection Methods

The USGS is the primary responsible party for collecting samples. Monitoring flow and water quality will be conducted using completely automated techniques to minimize labor and errors inherent in manual sampling techniques. Flow will be monitored on a continuous basis, and samples for water quality analysis will be collected during runoff events.

During the initial period of monitoring (or "shake down period"), the equipment will be checked for proper functioning and sampling. It is very likely that the first several events will not be acceptable as "qualifying" events because of equipment adjustments. Also during this period, the sampler intake lines will be inspected by USGS to make sure they are not inundated with sediment or other debris.

Also, prior to the monitoring period, the storm sewer system the flow splitting box, and the Downstream Defender® will be inspected and sediment, oils, floatables and other gross pollutants will be cleaned out.

5.4.1 Monitoring Equipment

A monitoring system will be installed to monitor temperature and flow and collect water quality samples automatically during runoff events. The monitoring system will be designed to monitor locations as described in Section 5.1. Figure 5-1 shows a schematic layout of a generic monitoring station. The following equipment will be used:

- One Campbell Scientific CR10X datalogger-serves as the station controller;
- One Campbell Scientific COM200 modem and telephone for external communications;
- Three ISCO 2150 flow meters;
- Three ISCO 3700 refrigerated automatic water-quality samplers each equipped with:

- Four 10-L sample collection bottles;
- Peristaltic pump; and,
- Teflon™ lined sample collection tubing.

- One Design Analysis H-310 Pressure Transducer and Temperature Probe
- One Design Analysis H340SPI tipping bucket rain gauge. SDI-12 output

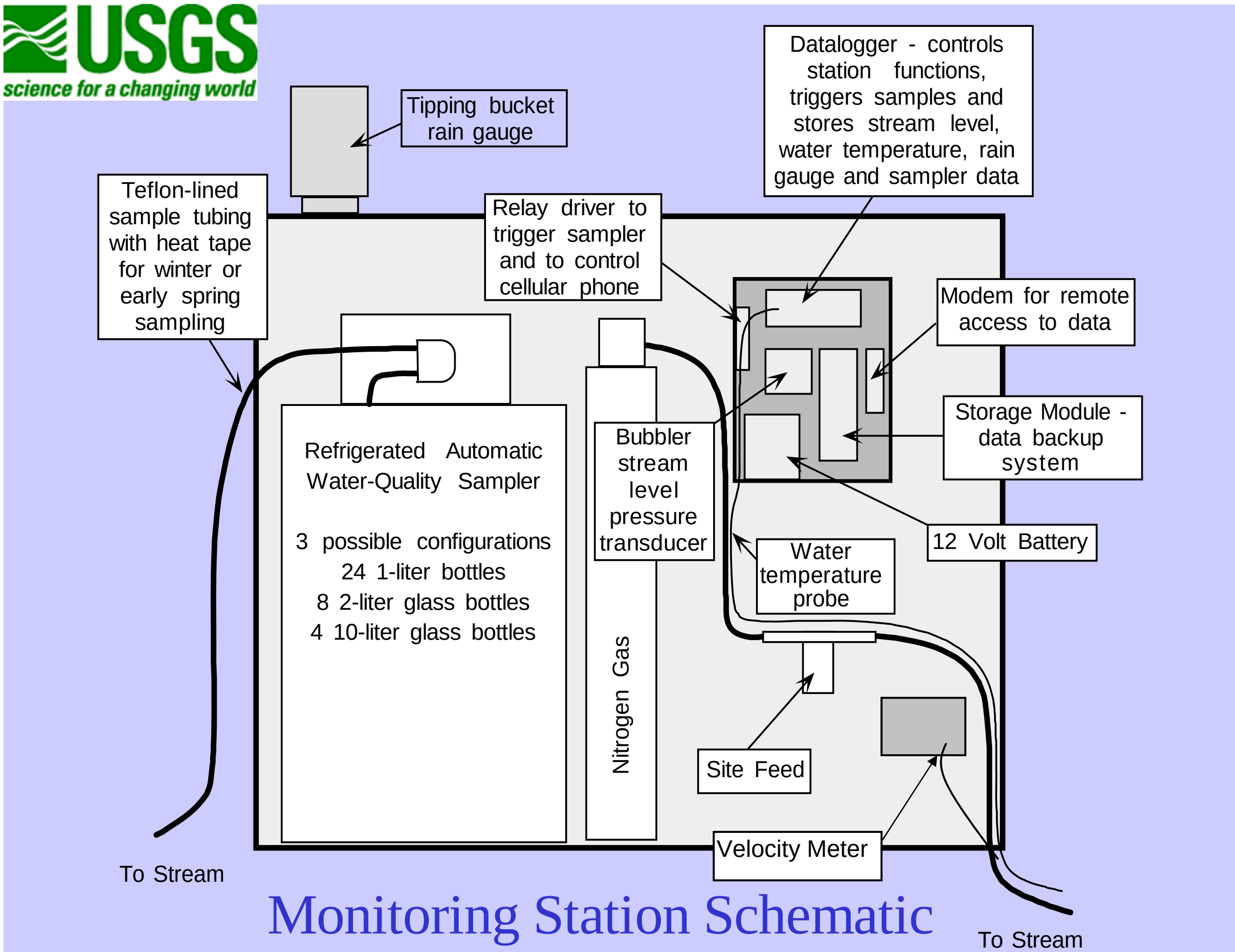


Figure 5-1. Schematic diagram of monitoring station instrumentation.

5.4.2 Placement of Sample Intake Line

Location of the intake line for sampling points B and C (Figure 3-6) is critical in order to obtain a representative sample of the stormwater. The sampling intake tube is located about one inch above the invert of the pipe. The location of the intake line at E is described in Section 5.1.

5.4.3 Number of Aliquots Per Event

Automatic samplers can be programmed to collect samples based on time, stream stage or flow. For this project, samples will be collected based on flow. Sample frequency increases or decreases to reflect the magnitude of flow. Sampling frequency will be a maximum at peak flow increasing the likelihood of collecting samples at or near this time. Sampling with respect to flow allows for compositing sub-samples throughout the hydrograph (Figure 5-2). This compositing allows for the calculation of a single flow-weighted average concentration for each event.

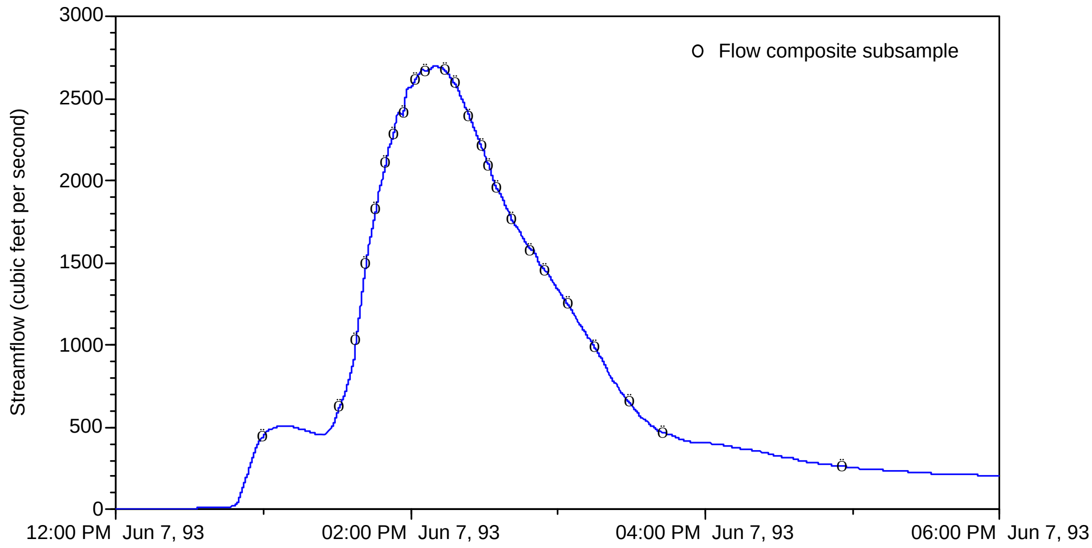


Figure 5-2. Example of aliquot distribution over a hydrograph.

The number of aliquots per event will depend on the volume of each individual event. The monitoring station will be programmed to collect a sub-sample for a predefined volume of flow. Larger volume events will collect a larger number of sub-samples than smaller volume events. The volume between sub-samples will be determined such that a minimum of five one-liter aliquots will be collected for each event. Also, five liters is the minimum volume of sample required to meet the volume requirements for laboratory analysis of the parameter list. The auto sampler has the capacity to collect a maximum of 40 one-liter aliquots.

A large volume of sample is required to conduct particle size distribution analyses. When ten liters or more of sample are collected, the sample will be analyzed for particle size distribution analysis. This will likely occur only during large storm events.

5.4.4 Estimated Total Number of Samples

Based on the proposed sampling schedule, an estimated total of 50 samples will be analyzed for the sediment constituent. This includes one inlet and one outlet sample for each of the 15 storm events, one system outlet sample for 7 storm events (estimated) when bypassing occurs, plus seven replicate samples and six blank samples.

Sediment samples will be taken two (2) times over the course of monitoring program from the sump of the Downstream Defender®:

1. During the Fall 2005 season prior to initial clean-out,
2. At the end of the Winter 2005-2006 season, and
3. At the end of the Spring 2006 season.

The samples will be analyzed for specific gravity, particle size distribution and volatile solids fraction. The final sump cleanout and analysis is described in Section 5.8.

5.4.5 Sample Handling

Water samples will be collected with automatic samplers. A peristaltic pump on the sampler will pump water from the sampling location through Teflon™ lined sample tubing to the pump head where the water will pass through about three feet of silicone tubing and deposited in one of four 10-L sample collection bottles. Samples will be capped and removed from the sampler after the event by USGS personnel. The samples will be transported to the USGS field office in Madison, Wisconsin where they will be split into multiple bottles for analysis using a 20-L Teflon™-lined Churn Splitter. All bottles will be rinsed with sample water, filled, capped and then chilled. Water chemistry samples will be delivered by hand in iced coolers to the WSLH.

5.4.6 Sampler Maintenance

The sampler will be checked to ensure that it is functioning properly after each event. The volume per aliquot will be evaluated. Sample bottles will be cleaned after each sampling event as outlined in the QA/QC section.

5.4.7 Field Sheets

A field sheet will be filled out during each site visit for documentation of the field monitoring activities. All activities during the site visit will be recorded. Field sheets (sample retrieval log sheets) will be filled out each time that samples are collected after an event.

5.5 Flow Measurement Methods

Accurate measurement of water level and subsequent calculation of flow will depend on the physical characteristics of the inlet and outlet monitoring sites. The standardized methods employed by the USGS in water-quality sampling and flow monitoring will allow for reliably consistent data for each site.

The site will have an electronic datalogger programmed to initiate water level and precipitation measurements. To track the rapidly changing flows the datalogger will be programmed to take measurements every 60 seconds.

5.5.1 Monitoring Equipment

A monitoring system will be installed at each water quality sampling site to collect velocity data also. The following equipment will be used:

- One pressure transducer measures water levels at the bulkhead to determine if bypass has occurred.
- One velocity meter at the inlet and outlet of the system. The velocity meter is about one foot upstream from the sample intake line.

5.5.2 Flow Measurement Calibration

Calibration techniques include utilization of dye/dilution, an area/velocity meter, or volumetric measurements. The area-velocity measurements will be verified by either dye/dilution or volumetric measurements. The water level measurement will be checked with manual measurements.

5.5.3 Flow Equipment Maintenance

The velocity meter will be inspected visually and debris will be removed when necessary. The amount of debris removal required will be documented in the operation and maintenance (O&M) portion of the verification report. This will also be documented in the O&M portion of the verification report.

5.6 Automated Data Recording

Continuous monitoring data will be recorded using the internal memory of the datalogger and a backup storage module. In the event of a datalogger failure, the storage module contains nonvolatile memory to minimize loss of data. Data from the past day will be transferred each morning during dry conditions and every six hours during event periods via modem to a USGS computer and uploaded into a USGS database as described in the “Data Management and Accessibility” section.

5.7 Precipitation Measurement

Rainfall will be measured with a tipping bucket rain gage and recorded by the datalogger. Rainfall data is recorded every 60 seconds. To insure that the rain gage is functioning properly, it will be calibrated with a volumetric rain calibrator at the beginning and the end of the monitoring period. Also, the total rain depths will be checked after each event by comparing to nearby rainfall data from USGS and/or other weather service sites.

5.8 Additional Monitoring

At the end of the monitoring period, the Downstream Defender® sump will be cleaned out and estimates of the amount of material retained in the will be made. The material will be removed from the sump and dried. The dry material will be weighed. Where feasible particle size analysis, specific gravity of the captured sediment and volatile solids fraction will be determined.

Chapter 6
Quality Assurance Project Plan

6.1 General Requirements

This quality assurance project plan (QAPP) specifies the procedures that will be followed to ensure the validity of test data and their use as the basis for equipment performance verification. This protocol establishes minimum requirements for the collection and analysis of certain QA/QC samples. This QAPP addresses the activities of Earth Tech, USGS and WSLH in verification testing.

The objective of QA/QC is to ensure that strict methods and procedures are followed during sampling and analysis so that the data obtained are valid for use in the verification of a technology. In addition, QA/QC ensures that the conditions under which data is obtained, will be properly recorded so as to be directly linked to the data. This information may be needed should a question arise as to the data validity.

6.2 Data Quality Indicators

Several Data Quality Indicators (DQIs) have been identified as key factors in assessing the quality of data and in supporting the verification process. These indicators include:

- Precision
- Accuracy
- Representativeness
- Comparability
- Completeness

Each DQI is described below and the goals for each DQI are specified. Performance measurements will be verified using statistical analysis of the data for the quantitative DQI's of precision and accuracy. If any QA objective is not met during the tests, an investigation of the causes will be initiated. Corrective action will be taken as needed to resolve the difficulties. Data failing to meet any of the QA objectives will be flagged in the verification report, and a full discussion of the issues impacting the QA objectives will be presented.

6.2.1 Precision

Precision refers to the degree of mutual agreement among individual measurement and provides an estimate of random error. Analytical precision is a measurement of how far an individual measurement may deviate from a mean of replicate measurements. Precision is evaluated from analysis of field and laboratory duplicates and spiked duplicates. The standard deviation (SD), relative standard deviation (RSD), relative percent difference (RPD), or range (absolute difference) methods used to quantify precision. Relative percent difference is calculated by 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 duplicates will be collected of both influent and effluent samples. The field duplicates will be collected a minimum of three times during the test. The laboratory will run duplicate samples as part of the laboratory QA program. Duplicates are analyzed on a frequency of one duplicate for every ten samples analyzed. The data quality objective for precision is based on the type of analysis performed. Table 6-1 shows the laboratory precision that has been established for each analytical method.

6.2.2 Accuracy

Accuracy is defined for water quality analyses as the difference between the measured value or calculated sample value and the true value of the sample. Spiking a sample matrix with a known amount of a constituent and measuring the recovery obtained in the analysis is a method of determining accuracy. Using laboratory performance samples with a known concentration in a specific matrix can also monitor the accuracy of an analytical method for measuring a constituent in a given matrix. Accuracy is usually expressed as the percent recovery of a compound from a sample. The following equation will be used to calculate Percent Recovery:

$$\text{Percent Recovery} = [(A_T - A_i) / A_s] \times 100\% \qquad (6\text{-}2)$$

where:

A_T = Total amount measured in the spiked sample
A_i = Amount measured in the un-spiked sample
A_s = Spiked amount added to the sample

During the verification test, the laboratory will run matrix spike samples at frequency of one spiked sample for every 10 samples analyzed. The laboratory will also analyze liquid samples of known concentration as lab control samples. The accuracy objectives by parameter or method are shown in Table 6-1.

Table 6-1. Accuracy and Precision Objectives

Constituent	Precision[1] (Percent)	Accuracy[2] (Percent)
TSS	30	75-125[3]
VSS	30	75-125[3]
SSC	ND	ND

[1] Laboratory-Based Precision. Note: 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] Laboratory Based Accuracy
[3] Based on recovery of quality control sample
ND not determined

6.2.3 Comparability

Comparability will be achieved by using consistent and standardized sampling and analytical methods. All analyses will be performed using EPA or other published methods as listed in the analytical section. Any deviations from these methods will be fully described and reported as part of the QA report for the data. Comparability will also be achieved by using National Institute of Standards (NIST) traceable standards including the use of traceable measuring devices for volume and weight. All standards used in the analytical testing will be traceable to verified standards through the purchase of verifiable standards, and maintaining a standards logbook for all dilutions and preparation of working standards. Comparability will be monitored through QA/QC audits and review of the test procedures used and the traceability of all reference materials used in the laboratory.

6.2.4 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic population, parameter at a sampling point, a process condition, or an environmental condition. The test plan design calls for composite samples of influent and effluent to be collected and then analyzed as flow-weighted composites. The sampling locations for the samples are designed for easy access and are directly attached to the pipes that carry the raw stormwater, or treated stormwater. This design will help ensure that a representative sample of the flow is obtained in each composite sample bottle. The sample handling procedure includes a thorough mixing of the composite container prior to pouring the samples into the individual containers via means of a churn or cone splitter. The laboratory will follow set procedures (in accordance with good laboratory practice) for thorough mixing of any samples prior to sub-sampling in order to ensure that samples are homogenous and representative of the whole sample.

The Downstream Defender® will be operated in a manner consistent with the supplied O&M manual, so that the operating conditions will be representative of a normal installation and operation for this equipment.

Representativeness will be monitored through QA/QC audits (both field and laboratory), including review of the laboratory procedures for sample handling and storage, review and observation of the sample collection, and review of the operating logs maintained at the test site. At least one field and one lab audit will be performed by the Verification Organization or their representative

Obtaining representative samples for stormwater is fundamentally a difficult challenge, and attention to details during sample collection, handling and analysis are required. Proper system design, sampler selection, flow meter selection, location of inlet tube, mixing sample container handling, and splitting will help maximize the representativeness of stormwater samples.

6.2.5 Completeness

Completeness is a measure of the number of valid samples and measurements that are obtained during a test period. Completeness will be measured by tracking the number of valid data results against the specified requirements in the test plan.

Completeness will be calculated by the following equation:

$$\text{Completeness} = (V / T) \times 100\% \qquad (6\text{-}3)$$

where:

V = number of valid measurements
T = total number of measurements planned in the test

The goal for this data quality objective will be to achieve minimum 85% completeness for samples scheduled in the test plan.

6.3 Field Quality Assurance

Sampling procedures are defined in Chapter 5. The sampling schedule was developed to provide a sample that is representative of the seasonal and meteorological conditions of the site.

Efforts will be made to maintain high sampling efficiency by providing sampling personnel with written procedures and training to assure the samples are properly collected, handled, and transported to the lab.

Sampling and flow measurement equipment will be calibrated and maintained in accordance to manufacturer's recommendations. Refer to Appendix D for sampler operation and maintenance procedures and Appendix C for flow meter operation and maintenance procedures information.

All sampling equipment will be decontaminated prior to use. Decontamination procedures consist of scrubbing the composite bottles with Liqui-Nox™ and rinsing with deionized water prior to use. Bottles will then be rinsed with five percent hydrochloric acid solution followed by three rinses of deionized water. Following sample collection, clean composite bottles will be placed in the sampler, and the used bottles will be brought back to the USGS office for decontamination.

The sample bottles will be obtained from the sampler, placed in a cooler with ice, and shipped to the appropriate laboratory for analysis. USGS will split the sample using a churn or cone splitter into appropriate sample containers for its analyses. The samples will be maintained in the custody of the sample collectors, delivered directly to the laboratory and relinquished to the laboratory sample custodian(s). Custody will be 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) will be filled out and will accompany each sample. Field forms will record date and time of sample collection, number of samples, and personnel conducting the sample collection. Samples will not be left unattended unless placed in a secure and sealed container with the field forms inside the container. When received by WSLH, the field forms and sample bottles receive a bar code sticker, which identifies the sample, date, time, and verifies receipt by the laboratory.

6.3.1 Field Blanks

Field blanks are necessary to evaluate whether contamination is introduced during field sampling activities. A minimum of two rounds of field blanks will be conducted. Field blanks will be collected before the initial runoff event, or at the earliest time possible by passing deionized water through the samplers. The samples will be delivered to the laboratory as "blinds" with the first sampling event samples. The second set of field blanks will be conducted at or near the midpoint of the testing (between event numbers 7 and 8) by following the same procedure.

6.3.2 Duplicates

Field duplicates are used to assess variability attributable to collection handling, shipping, storage and/or laboratory handling and analysis. Duplicates for composite sampling will be obtained by splitting a composite sample of adequate volume into two separate samples.

A minimum of three rounds of field duplicates will be conducted. Two of the three rounds will sample the inlet and outlet locations only. The other round of field duplicates will sample at all three locations: inlet, outlet, and system outlet. Field duplicates will be obtained:

- During the initial runoff event, or at the earliest time possible;
- At or near the mid point of the testing (between event numbers 7 and 8 if adequate volume is available);
- During one of the last three sampling events.

6.4 Equipment Maintenance and Calibration

The samplers, flow meters, and rain gauge will be calibrated, inspected and cleaned according to the manufacturer's specifications. Refer to Appendix C for the flow meter operation and maintenance manual and Appendix D for the sampler operation and maintenance manual.

6.5 Laboratory Quality Assurance

Comparability of the data is achieved by using standardized analytical techniques and reporting the data in professionally accepted units for concentrations, flow, and loadings. For this study, each lab will test the precision of the analyses and the precision will be expressed in terms of standard deviation calculated from replicate samples. The accuracy of the analyses used for this study will be based on statistical analysis of spiked sample testing results.

Each laboratory has internal procedures in place to minimize the chances of laboratory personnel mishandling samples resulting in loss of data.

All analyses will be performed at the WSLH, which is a full service environmental laboratory with the following certifications:

- Water Microbiology. EPA certification # 105-000415.
- State Laboratory Certification (NR 149). The full list of certified constituents can be found on the following web site: http://www.dnr.state.wi.us/org/es/science/lc/
- National Laboratory Accreditation Program. The full list of certified constituents can be found on the following web site: http://www.slh.wisc.edu/ehd/sections.html
- EPA Certification. The full list of certified constituents can be found on the following web site: http://www.slh.wisc.edu/ehd/sections.html

The WSLH routinely participate in USGS and EPA quality assurance programs. All analyses will be done using standard methods (APHA, 1995; EPA, 1983; EPA, 1991; EPA, 1995; Fishman, M.J.; and others).

Analytical methodologies and detection limits for each constituent to be analyzed are summarized in Table 6-2.

Table 6-2. Constituent List Limits of Detection and Analytical Methods

Parameter	Units	Limit of Detection	Limit of Quantification	Method[1]
TSS	mg/L	2	7	EPA 160.2
VSS	mg/L	2	7	EPA 160.2
SSC	--	--	--	ASTM D3977-97 A&B
Particle Size	--	--	--	References: 1. Burton, Jr., GA and R.E. Pitt. 2002. Stormwater Effects Handbook: A Toolbox for Watershed Managers; 2. ASTM D3977-C

[1] EPA, 1979, SM (Standard Methods), 1986, and SW (SW846, 1996)

6.6 Quality Control Procedures

Sources of variability and bias introduced by sample collection and stream flow measurement affect the interpretation of concentration data and calculated constituent loads. The following are quality-assurance and quality control (QA/QC) procedures that apply to the sampling of water chemistry and to the measurement of stream flow and precipitation. Standard USGS QA/QC methods and definitions for sample collection are published in Wilde et al, 1999.

6.6.1 Field Blanks

Any sampling or analytical source of contamination will be well documented and minimized using field and laboratory blank samples on a regular basis. A total of two field blanks will be collected at each site to evaluate contamination in the entire sampling process, which includes all equipment (automatic sampler, sample-collection bottles, and splitters), filtering procedures, and analytical procedures. "Milli-Q" reagent water will be pumped through the automatic sampler and processed and analyzed in the same manner as event samples will be processed. The first field blank will be collected at the initial storm. This will allow results at the earliest possible time in the monitoring schedule to make adjustments if necessary. The next field blank will be taken at the mid point of the sampling schedule (event 7 or 8).

6.6.2 Replicates

During the monitoring period, three replicate samples from the inlet and outlet monitoring points and one replicate sample from the system outlet will be collected to evaluate precision in the sampling process and analysis. The samples will be taken from the composite sample collected at each site for each event and split into two separate samples. They will be processed, delivered to the laboratory, and analyzed in the same manner as the regular samples. Variability in results from a series of these replicates will give an indication of precision in the process. The first replicate will be collected at the initial event. This will allow results at the earliest possible time in the monitoring schedule to make adjustments if necessary. The next replicate will be taken at the mid point of the sampling schedule (event 7 or 8).

6.6.3 Precipitation Measurement

The tipping bucket rain gauge will be calibrated for accuracy prior to field installation and at the end of the project. Event rainfall depths will be compared to data from other nearby rainfall gauges on a regular basis to insure proper rainfall measurement. Periodically the rain gauge will be checked for debris and cleaned if necessary.

6.6.4 Flow Measurement

The methods used by the USGS have many inherent processes that ensure accuracy in flow measurement. Comprehensive descriptions of USGS flow measurement techniques can be found in Rantz and others (1982, vol. 1 and 2). For this project, ISCO 2150 area-velocity meters are used to measure velocity and water level in the storm sewer at the three locations (inlet, outlet, and system outlet). The water level will be measured manually and compared to values recorded in the datalogger. Values in the datalogger will be adjusted when necessary.

6.7 Shipment to Laboratory

Samples are shipped in coolers with wet ice to keep transit temperatures between 0 and 4 ^{o}C. Holding/transit time between sampling and analysis will not exceed published standards in keeping with the certified laboratory's QA/QC requirements, and will generally be less than 24 hours. All preservation requirements are set by the certified laboratory's QA/QC requirements.

Date and time of sample collection and test setup and arrival temperature are recorded. Appropriate field forms, logs, and sheets are completed on site at the time of sample collection. All entries shall be written in waterproof ink, signed and dated. The analytical laboratory is the ultimate destination and repository for samples. To assure that data produced from the analysis of such samples are scientifically defensible, it is incumbent on laboratory personnel to maintain complete documentation of sample receipt and analytical processing until such time as a final analytical report has been produced.

6.8 Sampling Equipment Cleaning Procedures

Sample collection and processing equipment, such as equipment and field collection bottles used for collecting and processing water samples are glass bottles, soaked in phosphate-free detergent solution, scrubbed with a bottle brush, rinsed with tap water, rinsed with deionized water two times, rinsed with a five percent hydrochloric acid solution, rinsed with deionized water three times, and air dried before use. This same procedure will be used to clean the sample splitters between samples except that they will not be air dried.

Automatic samplers are run through a rinsing cycle before each sample is collected. The sequence of events for each sampling cycle is as follows:

1. The sample tubing is purged;
2. The pump draws stream water into the sample tubing to a point just before the pump head;
3. The sample tubing is purged again (at this point, the rinse cycle is complete); and,
4. The sub-sample is collected. See the procedures outlined in Section 6.6.1 for the QA of the automatic sampler.

6.9 General QA/QC Documentation and Reviews

All QA/QC results will be tabulated to represent results. Where problems are identified, these data will be highlighted.

QA samples will be reviewed when they are returned from the lab by the USGS and corrective actions will be implemented immediately if results warrant changes to procedures. QA problems and corrective actions will be summarized in progress reports and the verification report.

6.9.1 Quality Assurance Reports

Quality Assurance Reports will be included as part of the verification report. The Quality Assurance Reports shall include findings, results, and any corrective measures conducted as outlined in the QA/QC section. The reports will consist of QA/QC reports from the laboratories, maintenance records, and written documentation maintained throughout the testing period.

The laboratory will report all results with all associated QC data. The results will include all volume and weight measurements for the samples, field blank results, method blanks, spike and spike duplicate results, results of standard check samples and special QC samples, and appropriate calibration results. All work will be performed within the established QA/QC protocol as outlined in the laboratory SOPs and the laboratory QA/QC Plan. Methods must be either EPA approved methods or from Standard Methods, 20th edition. All QA/QC including accuracy, precision, calibrations frequency and evaluation must meet the minimum EPA requirements. Any deviations from the standard test procedures or difficulties encountered during the analyses will be documented and reported with the data.

6.9.2 Quality Assurance Assessments

At least one field audit will be conducted by the VO (NSF WQPC Manager, NSF QA/QC staff or designee) during the test. The audit(s) will be to observe the sample collection procedures being used, to observe operation of the unit, condition of the test site, and to review the field logbook(s). A written report will be prepared by the auditor and submitted to the NSF QA/QC Officer and the WQPC Manager. At least one lab audit will be performed by the VO to observe sample receipt, handling, storage, and to confirm proper analytical methods, QA/QC procedures and calibrations are being used.

The WSLH has assessment programs that include internal and external audits, quality reports to management, and other internal checks are part of the system used to ensure that the QA/QC procedures are being implemented and maintained. The assessment procedures will be part of the QA/QC program, and will be followed during the time the analytical work is being performed for the verification test.

Field related activities encountered by USGS during sampling trips that could require corrective action should be noted and forwarded to the TO. This would include problems with sample collection, labeling, and improper entries or missed entries in logbooks, or operational problems. The primary person responsible for monitoring these activities will be Jim Bachhuber, with external audits by NSF-designated staff. If a problem occurs, the problem will be noted in the field logbook and the TO will notify NSF, and the vendor in the case of unit operating issues. The problem, once identified, will be corrected. If a change in field protocol related to sample collection or handling is needed, the change will be approved by the VO. All corrective action will be thoroughly documented and discussed in the verification report.

The laboratories will take corrective action whenever:

- There is a non-conformance with sample receiving or handling procedures;
- The QA/QC data indicates any analysis is out of the established control limits;
- Audit findings indicate a problem has occurred; or
- Data reporting or calculations are determined to be incorrect.

The WSLH has a corrective action plan as part of the laboratory QA/QC Manual. These procedures will be followed, including notifying the laboratory QA/QC Manager and the TO. All corrective action will be thoroughly documented and reported to the TO. All data impacted by a correction will be so noted and a discussion of the problem and corrective action will be included with the data report.

All corrective actions, either in the field or in the laboratory, will be reported to the VO Project Coordinator. The VO will review the cause of the problem and the corrective action taken by the TO. The review will include consideration of the impact of the problem on the integrity of the test, and a determination will be made if the test can continue or if additional action is needed. Additional action could include adding additional days to the test period, re-starting the test at day one, or other appropriate action as determined by the VO. The VO will respond, in writing, to any notification of corrective action within twenty-four hours of being notified of the problem. This response can be to continue the testing, cease testing until further notice, or other appropriate communication regarding the problem.

Chapter 7
Data Management and Accessibility

Stream flow data across the United States are currently being collected by the USGS for more than 7,000 stations. More than 4,000 of these stations have telephone or satellite communications for transmittal of data to USGS. All data from these monitoring stations is being stored in the USGS National Water Information System (NWIS) database. NWIS also contains historical stream flow or water quality data for more than 19,000 locations in the United States. This is the primary database system used by the USGS, and is instrumental in the processing of final data records. NWIS will be the primary repository for the physical (stream flow, precipitation) and water quality data collected during this project.

7.1 Data Storage Systems

Continuous monitoring data (water level and precipitation) is initially stored in the internal memory of the datalogger. A USGS computer retrieves the data via modem on a daily basis during nonevent periods and every six hours during event periods. The data is uploaded directly into NWIS at this time. Graphs of the past seven days of provisional data for these stations are available to the public through the web. Examples of these graphs can be found at the following website: http://wi.waterdata.usgs.gov/nwis/current?type=flow

Data from WSLH are downloaded automatically through the Internet using automated file transfer programs. These data are then processed and entered into the NWIS database.

7.2 Data Corrections

Water level and precipitation data will be processed using field calibration and verification data. Manual water level measurements will be compared to measurements recorded by the datalogger. Corrections will be applied if needed. After water level corrections have been made, final values for flow will be calculated using the established water level-flow relationship.

Rain gauge calibration measurements will be used to apply corrections to precipitation data. The measured precipitation depths will be multiplied by a simple ratio between the true calibration volume and the measured calibration volume to determine the final precipitation.

Water quality data will be used directly from values reported by the laboratories.

7.3 Accessibility

All original data will be stored in the NWIS database and will be available upon request. This data will include constituent concentrations, storm flow volumes, event precipitation depth and duration, and constituent loadings for all three monitoring sites.

Chapter 8
Data Analysis and Reporting

8.1 Verification Report

Earth Tech will be responsible for producing the verification report. The report will follow the format and requirements of the ETV program as described in this chapter. The USGS will conduct the data analyses, including event mean concentrations, and loading calculations, from the monitoring sites. These calculations will be forwarded to Earth Tech for incorporation into the report. The verification report will initially be reviewed by NSF and EPA, and then forwarded to Hydro International., for comment, before finalizing the document. The verification report will include the following major sections:

- Introduction
- Executive Summary
- Description and Identification of Product Tested
- Procedures and Methods Used in Testing
- Results and Discussion
- References
- Appendices, including raw and analyzed test data.

8.2 Methods for Evaluating Source Technology

Completion of the monitoring will result in a comprehensive database documenting constituent loadings, concentrations, and storm flow for each event at each of the two sites. This data will be used in determining the effectiveness of the system. Results from the upstream site (Site 1), and the downstream site (Site 2) will be compared to determine differences in loading to the receiving storm sewer. The effectiveness will be analyzed based on the approaches described below.

8.2.1 Efficiency Ratio

The first method is an efficiency ratio (ER) based on the average event-mean concentrations (EMCs). The average of the outlet concentrations is compared to the inlet concentrations. The EMC for the monitoring period will be based on the flow weighted EMC's for each event.

$$\text{ER} = 100 \times (1\text{-(outlet EMC)/(inlet EMC)}) \quad (8\text{-}1)$$

8.2.2 Sum of Loads

The second method is called the sum of loads (SOL). The pollutant removal efficiency of the source area device is based on comparing the sum of the treated and total (treated plus bypass) outlet loads to the sum of the inlet loads. The SOL analysis will be conducted for the parameter list; plus a calculation of the particles above and below the sand/silt split (62.5 µm).

$$\text{SOL} = 100 \times (1\text{-(sum of the outlet loads)/(sum of the inlet loads)}) \quad (8\text{-}2)$$

The locations of the flow and water quality sampling tubes were selected to calculate loads relevant to the sum of loads calculations (refer to Figure 3-6):

The Downstream Defender® inlet load will be calculated using the following equation:

$$SOL = (\text{event volume at B}) \times (\text{EMC at B}) \quad (8\text{-}3)$$

The Downstream Defender® outlet load will be calculated using the following equation:

$$SOL = (\text{event volume at C}) \times (\text{EMC at C}) \quad (8\text{-}4)$$

The bypass load not treated by Downstream Defender® will be calculated using the following equation:

$$SOL = ((\text{event volume at D}) - (\text{event volume at B})) \times (\text{EMC at E}) \quad (8\text{-}5)$$

8.3 Results of QA/QC Analysis

The results from the field and laboratory duplicates will be summarized and presented in summary tables in the report. Laboratory data for accuracy (spiked sample and control sample results) will be summarized and presented in the report as well. All individual analytical precision and accuracy results from the qualified events will be included with the raw data in the appendix of report.

Any corrective actions required during sample collection and any analyses not meeting the data quality objectives (Table 6.2) will be discussed in narrative form in the report. Analytical data not meeting the QC objectives will be flagged and discussed in the QC section of the final report. This discussion will address any impact these flagged data set(s) may have on the overall results for event mean concentration and the sum of the load calculations.

8.4 Presentation of Results

The verification report will include at least the following tables:

8.4.1 Event Mean Concentration

The EMC data will be reported as shown in Table 8-1, and will be completed for each monitored constituent.

Table 8-1. Example of Data Summary – Event Mean Concentration

Event	Start Date/ Time	End Date/ Time	Event Rainfall Depth (in.)	Maximum Hourly Rainfall Intensity (in./hr)	Runoff Volume Through Device (ft^3)	Runoff Volume Bypassing Device (ft^3)	EMC: Constituent 1 (mg/l unless otherwise noted)		EMC: Constituent 2 (mg/l unless otherwise noted)	
							Inlet	Outlet	Inlet	Outlet
Event 1										
Event 2										
Event 3										
Event 4										
Event 5...15										

8.4.2 Sum of Loads

The sum of loads data will be reported as shown in Table 8-2 and will be completed for each monitored constituent.

Table 8-2. Example of Data Summary – Sum of Loads

Event	Inlet Load	Outlet Load
1		
2		
3		
4		
5 - 15		
Total	Sum of Events	Sum of Events
Load Reduction Efficiency (Percent)[1]		

1. Load Reduction Efficiency = 100 * [1-(Sum($OL_{1...15}$)/ Sum ($IL_{1...15}$))]

8.4.3 Particle Size Distribution

The results of this analysis should be presented by "percent of total particle mass" by particle size categories. As an example, the Milwaukee NURP Volume I Report (Bannerman et al, 1984) uses the following particle size categories:

- < 0.025 mm
- 0.025 to 0.038 mm
- 0.0380 to 0.063 mm
- 0.0630 to 0.125 mm
- 0.125 to 0.250 mm
- > 0.250 mm

The particle size distribution will be reported as shown in Table 8-3.

Table 8-3. Example of Particle Size Distribution Results

Particle Size (µm)	Raw Stormwater (Site 1) Mean (%)	Std. Dev.	Max. (%)	Min. (%)	Treated Stormwater (Site 2) Mean (%)	Std. Dev.	Max. (%)	Min. (%)

Particle Size (µm)	Sediment in Downstream Defender® Sump (Site 3) Mean (%)	Std. Dev.	Max. (%)	Min. (%)

8.4.4 Rainfall Data

The verification report will include rainfall hyetographs for each measured rainfall during the monitoring period. The hyetographs shall show rainfall amounts for the minimum increment of time recorded by the gauge and a cumulative rainfall curve.

8.4.5 Flow Data

For each qualified sampling event, a runoff hydrograph (flow [cfs] vs. time) shall be developed using the flow data collected at either the inlet and/or the outlet of the treatment technology over the duration of the sampling event. In addition to the flow, the hydrograph shall show the starting and ending point of the rainfall event, and the points at which water quality sample collection started and ended.

Flow data from one monitoring location (either inlet or outlet) will be used to represent each storm. This flow data will also be used for calculating all of the pollutant loads (inlet and outlet) for each storm. The selection of which data to use (inlet or outlet) will be based on the review of the flow records to determine which monitoring location provides the best overall data for a given event.

8.4.6 Verification Statement

NSF and EPA shall prepare a verification statement that briefly summarizes the verification report for issuance to the vendor. The verification statement shall provide a brief description of the testing conducted and a synopsis of the performance results. The statement is intended to provide verified vendors a tool by which to promote the strengths and benefits of their product.

8.4.7 Appendices

At a minimum, the verification report appendices will include:

- Downstream Defender® Test Plan and Appendices
- Raw data in a tabulated (spreadsheet) format
- QA/QC reports, along with corrective actions, if any
- Downstream Defender® O&M Manual

Chapter 9
Field Safety and Security

9.1 Confined Space Entry Protocol

All personnel that will be entering a confined space situation for this project will be required to be certified in confined space entry protocol and will be required to follow this protocol as defined by the American National Standards Institute.

9.2 Field First Aid Equipment

All vehicles used to service the monitoring site will be equipped with USGS-approved first aid kits.

9.3 Protection Against Vandalism

Monitoring sites in an urban setting are at risk from vandalism. All equipment will be secured with heavy-duty lock systems to avoid equipment damage from vandalism. The outside of all structures will be washed of aesthetic vandalism in a prompt manner.

9.4 Notification Process in Case of Injury

Project personnel will carry health service cards and information sufficient for notification of a family member or friend and the USGS project manager in case of injury.

9.5 Site Access

The USGS and WDNR will develop a site access protocol with owner/operator of the site parking lot. The protocol will specify access points, parking space, notification procedures, and other logistics relative to the field monitoring activities.

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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.

Source Control Technology – pollution control devices that treat stormwater pollution before the stormwater enters a public conveyance system.

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 USEPA to verify environmental technologies and to issue Verification Statements and Verification Reports.

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

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

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 Downstream Defender® Product Design Manual
B Example of Lab Field Sheet
C ISCO 2150 Area Velocity Flow Meter O&M Manual (Available from NSF International or Earth Tech)
D ISCO 3700 Sampler O&M Manual (Available from NSF International or Earth Tech)