Verification Test Plan
for
Hydro International, Inc.

Up-Flo™ Filter for Stormwater Treatment

Prepared for
NSF International
Ann Arbor, Michigan
And
The Environmental Technology Verification Program
of the
US Environmental Protection Agency
Edison, New Jersey

By

Penn State Harrisburg
Middletown, Pennsylvania

February 2006

Signature Page

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For

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Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
°C	Celsius degrees
COD	Chemical oxygen demand
DQI	Data Quality Indicators
EPA	U.S. Environmental Protection Agency
ETV	Environmental Technology Verification
ft^2	Square foot (feet)
g	Gram
gal	Gallons
gpm	Gallon(s) per minute
HDPE	High-density polyethylene
Kg	Kilogram(s)
L	Liters
Lb	Pounds
MDL	Minimum Detection Level
NRMRL	National Risk Management Research Laboratory
NPDES	National Pollutant Discharge Elimination System
NURP	National Urban Runoff Program
µg/L	Microgram per liter (ppb)
mg/L	Milligram per liter
mL	Milliliter
NSF	NSF International, formerly known as National Sanitation Foundation
NIST	National Institute of Standards and Technology
O&M	Operations and Maintenance
P	Phosphorus
PM	Project Manager for the Testing Organization (TO)
QA	Quality assurance
QC	Quality control
RP	Reactive phosphorus
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SSC	Suspended sediment concentration
TCLP	Toxicity Characteristic Leaching Procedure
TP	Total phosphorus
TO	Testing Organization
TSS	Total suspended solids
VO	Verification Organization (NSF)
WQPC	Water Quality Protection Center

Chapter 1
Introduction and Objectives

1.1 Introduction

This document contains the technology specific test plan to be used for the verification testing of the Hydro International Up-Flo™ Filter for challenge water treatment. The Up-Flo™ Filter is a patented up-flow filter that includes sediment containment, filtration media, and overflow protection through a bypass siphon. The unit is designed for use in catch basins as an in-drain or in-line treatment technology. This test plan has been prepared in accordance with the Protocol for the Verification of In-Drain Treatment Technologies (April 2001) (protocol) developed under the United States Environmental Protection Agency (EPA) Environmental Technologies Verification (ETV) program's Water Quality Protection Center (WQPC).

The ETV Program is intended to:
- Evaluate the performance of innovative and commercially available environmental technologies;
- Provide permit writers, buyers and users, among others, with objective information about technology performance; and,
- Facilitate "real world" implementation of promising technologies.

The ETV program has developed verification testing protocols that are intended to serve as templates for conducting verification tests for various technologies. The protocol was published as the guidance document for test plan development for verification testing of in-drain treatment units used in challenge water collection systems. This test plan was developed in accordance with the guidance document. The goal of the verification testing process is to generate high quality data for verification of equipment performance.

NSF International (NSF) oversees the verification testing pilot project for in-drain treatment technologies under the sponsorship of the EPA Urban Watershed Branch, Water Supply and Resources Division. 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 pilot projects are a formal mechanism by which the performance of equipment can be determined by these two agencies, and which can result in the issuance of a verification report by NSF and EPA.

1.2 Objectives

Hydro International, plc (Hydro International) manufactures the Up-Flo™ Filter, a high rate, modular filtration system designed to remove floatables, gross debris, and suspended sediment and associated pollutants from challenge water runoff. The Up-Flo™ Filter is intended for use as an in-line or in-drain technology. The treatment unit that will be tested in this verification program is a full scale, commercially available unit. This unit will be tested for its sediment and phosphorus removal efficiency from simulated challenge water runoff.

Verification testing of in-drain treatment systems under the ETV WQPC is designed to verify the contaminant treatment capabilities and operational and maintenance procedures of commercial-ready systems, following sound protocols and appropriate quality assurance and control. A primary objective of the ETV is to measure the performance of these technologies through a well-defined test plan that includes measurement of various contaminants, typically present in maintenance areas, parking lots, gasoline stations, truck stops and the "first flush" from challenge water, before and after application of the treatment technology.

The objective of this test plan is to determine the performance that is attained by the Up-Flo™ Filter when used to treat water containing a variety of solid materials and particulate phosphorus. Reduction in contaminant loads will be evaluated to determine the effectiveness of the system to remove suspended solids, solids in particular size ranges, as well as total and reactive phosphorus.

The objective will be achieved by implementing testing procedures presented in this test plan. A synthesized challenge water containing solids and particulate phosphorus will be prepared. This challenge mixture will include hydrocarbon concentrations in the range of typical urban runoff. Detergent ingredients will be added in concentrations typical of drain water since no data on detergent concentrations in stormwater are available. The treatment system will be challenged under a variety of hydraulic loading conditions and contaminate loads. Influent and effluent samples from the unit will be measured for various contaminants as determined by indicator and chemical tests (total suspended solids, suspended sediment concentration, total phosphorus, and reactive phosphorus). The results will be used to calculate removal efficiencies, system capacities, and to determine the system treatment effectiveness.

The treatment system will also be monitored for operation and maintenance characteristics, including the performance and reliability of the equipment and the level of operator maintenance required. Data will be collected on the generation of residues. At the end of each test period, solids accumulated in the sump of the unit will be collected and measured. The filtration media will also be changed at the end of certain phases of testing and will be measured for weight and volume.

Chapter 2
Verification Testing Responsibilities

EPA sponsors the ETV Program, which is implemented through contracted verification organizations (VOs). NSF is the VO for the WQPC. The VO is responsible to provide oversight for the testing program and for selection of the Testing Organization (TO) for each technology to be verified. NSF reviews all test plans and oversees all of the participants in the testing program to ensure there is no bias or conflict of interest that could influence the test results. Penn State Harrisburg will act as the TO. NSF will provide oversight and review of the testing operation, as required under the audit program requirements outlined in the test plan and contract documents.

2.1 EPA

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 WQPC activities. The EPA will review and approve each phase of the verification project. The EPA's responsibilities will include:

- Test plan review and approval;
- Verification report review and approval; and
- Verification statement review and approval.

The key EPA contact for this program is:

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

EPA, NRMRL
Urban Watershed Management Research Laboratory
2890 Woodbridge Ave. (MS-104)
Edison, NJ 08837-3679

2.2 NSF - Verification Organization

The ETV WQPC is administered through a cooperative agreement between EPA and NSF its verification partner organization. NSF administers the WQPC, and the development and implementation of the test plan.

NSF's responsibilities as the VO include:

- Review and comment on the test plan;
- Coordinate with peer-reviewers to review and comment on the test plan;

- Coordinate with the EPA Program Manager and the technology vendor to approve the test plan prior to the initiation of verification testing;
- Review the quality systems of all parties involved with the TO and subsequently, qualify the TO;
- Oversee the technology evaluation and associated laboratory testing;
- Carry out an on-site audit of test procedures;
- Oversee the development of a verification report and verification statement;
- Coordinate with EPA to approve the verification report and verification statement;
- Provide QA/QC review and support for the TO.

Key contacts at NSF are:

Mr. Thomas Stevens, Program Manager
(734) 769-5347 email: Stevenst@nsf.org

Mr. Patrick Davison, Project Coordinator
(734) 913-5719 email: Davison@nsf.org

NSF International
789 Dixboro Road
Ann Arbor, Michigan 48105

2.3 PSH - Testing Organization

The TO for the verification testing is the Environmental Engineering Program at Penn State Harrisburg (PSH). The PSH physical laboratory has the space and large-scale equipment (tanks, pumps, etc.) to perform the testing on the Up-Flo™ Filter unit, and the PSH chemical laboratory has the equipment and experience to perform the analytical work for this test plan.

Dr. Shirley Clark will be the Project Manager (PM) for the TO and will be responsible for the successful completion of the verification project. Dr. Clark will have responsibility for obtaining all of the information needed to plan and execute the test plan, managing the data collected during the test period, overseeing the preparation of the draft verification report, and providing technical guidance. Dr. Clark and her team also will prepare the test plan and draft verification report.

PSH will provide the laboratory services for the testing program. PSH will be responsible for all quality assurance for the test plan through its QA protocols and test-specific procedures. NSF will provide administrative and technical support for review of the test plan and the Final Report. The QA and data reports prepared by PSH will be reviewed by the NSF QA group or their designee. The laboratory is familiar with EPA QA requirements and performs many projects to EPA QA specifications.

The TO's responsibilities include:

- Preparing the test plan;
- Conducting testing according to the test plan;
- Installation, operation, and maintenance of the Up-Flo™ Filter unit in accordance with the vendor's O&M manual(s);
- Controlling access to the area where verification testing is being carried out;
- Maintaining safe conditions at the test site for the health and safety of all personnel involved with verification testing;
- Scheduling and coordinating the activities of all verification testing participants, including establishing a communication network and providing logistical and technical support;
- Resolving any quality concerns that may be encountered and report all findings to the VO;
- Managing, evaluating, interpreting and reporting on data generated by verification testing;
- Evaluation and reporting on the performance of the technology; and,
- If necessary, document changes in plans for testing and analysis, and notify the VO of any and all such changes before changes are executed.

The key personnel and contacts for the TO are:

Dr. Shirley E. Clark
Assistant Professor of Environmental Engineering
(717) 948-6127 email: seclark@psu.edu

PSH Environmental Engineering
777 W. Harrisburg Pike
Science & Technology Building
Middletown, PA 17057

2.4 Technology Vendor

The Up-Flo™ Filter is manufactured and distributed by Hydro International. The vendor will be responsible for supplying the equipment needed for the test plan and will support the TO in ensuring that the equipment is properly installed and operated during the verification test period. Specific responsibilities of the vendor include:

- Initiate application for ETV testing;
- Provide input to the verification testing objectives to be incorporated into the test plan;
- Provide complete ready to operate equipment, and the operations and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, operation and maintenance) for verification testing;
- Provide any existing relevant performance data for the technology if it has been tested/operated at other locations;
- Provide logistical and technical support as required;
- Provide assistance to the TO on the operation and monitoring of the Technology during the verification testing;
- Review and approve the test plan;
- Review and comment on the verification report; and
- Provide funding for verification testing.

The key contacts for Hydro International will be:

Dr. Robert Andoh, Group Technical Director
(207) 756-6200 email: bandoh@hil-tech.com

Ms. Lisa Glennon, Research and Development Manager
(207) 756-6200 email: lglennon@hil-tech.com

Hydro International
94 Hutchins Drive
Portland, ME 04102

2.5 ETV Test Site

The verification test will be performed at the Penn State Harrisburg Environmental Engineering laboratories. The physical laboratory will be the location of the test setup and operation of the Up-Flo™ Filter. This laboratory group will be responsible for record keeping and providing information on activities that may affect the characterization and verification test results. These responsibilities include:

- Provide space and utilities for the test setup;
- Provide equipment, piping, pumps, valves, flow meters, tanks, etc. needed to setup the test and run water to the Up-Flo™ Filter unit;
- Install the equipment and wet test the system to ensure the system is operational;
- Perform the testing of the equipment in accordance with the test plan;
- Collect samples and record flow rates for each phase of testing; and
- Maintain records and information on the operation of the unit.

Chapter 3
Description of the Up-Flo™ Filter System

3.1 Technology Overview

The Up-Flo™ Filter is a passive, modular filtration system that incorporates multiple elements of a treatment train into a single, small-footprint device. The Up-Flo™ Filter uses a sedimentation sump and screening system to pretreat runoff before it flows up through the filter media where final polishing occurs. A high-capacity, siphonic bypass safeguards against upstream ponding during high-flow events. The siphon also serves as a floatables baffle to prevent the escape of floatable trash and debris from the Up-Flo™ Filter chamber.

3.1.1 Up-Flo™ Filter Components

The Up-Flo™ Filter has no moving parts and no external power requirements. It consists of a cylindrical concrete vessel with plastic internal components and a stainless steel support frame. The concrete vessel is a standard cylindrical manhole with an inlet pipe or a grate opening. An inspection port at ground level provides access to the sump for sediment removal. The internal components consist of angled stainless steel screens, wedge-shaped Filter Modules, a bypass siphon with a floatables baffle, and an Outlet Module. The base of the Outlet Module is equipped with a Drain-Down Port design that enables standing water to drain out of the filter media between storm events, preventing the re-release of captured pollutants. The Up-Flo™ Filter components are shown in Figure 3-1.

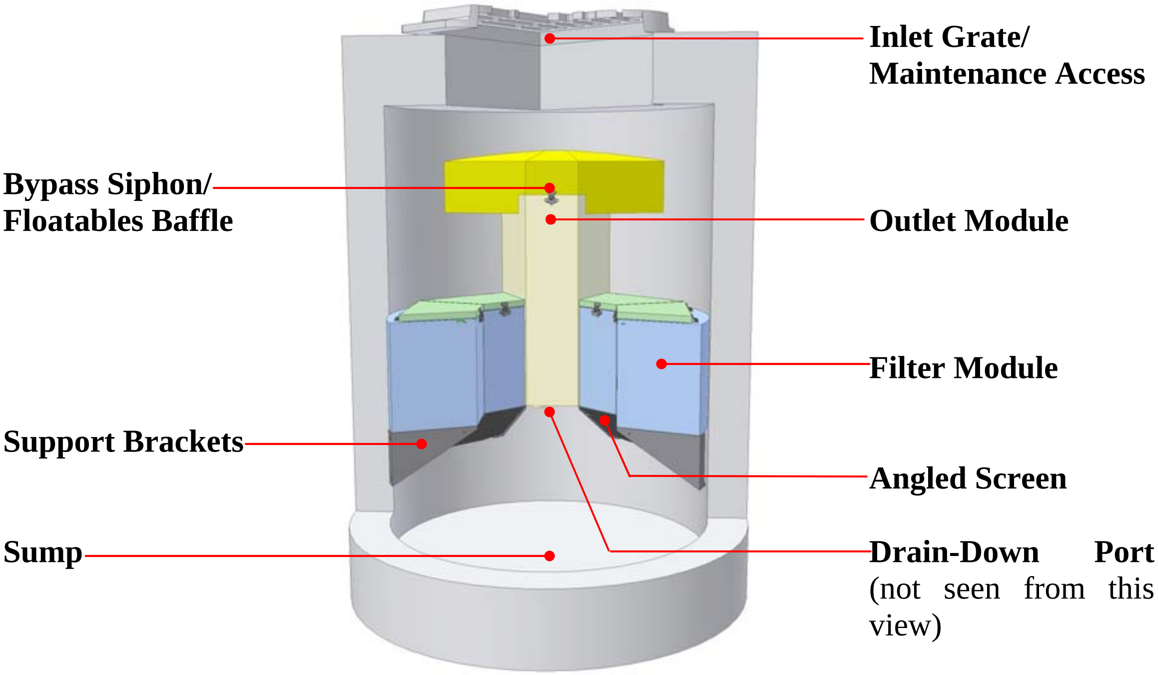

Figure 3-1. Up-Flo™ Filter components.

The Filter Module houses the Media Pack. The Media Pack consists of two (2) filter media bags and two (2) layers of flow distributing media. The internal components of the Filter Module are shown in Figure 3-2.

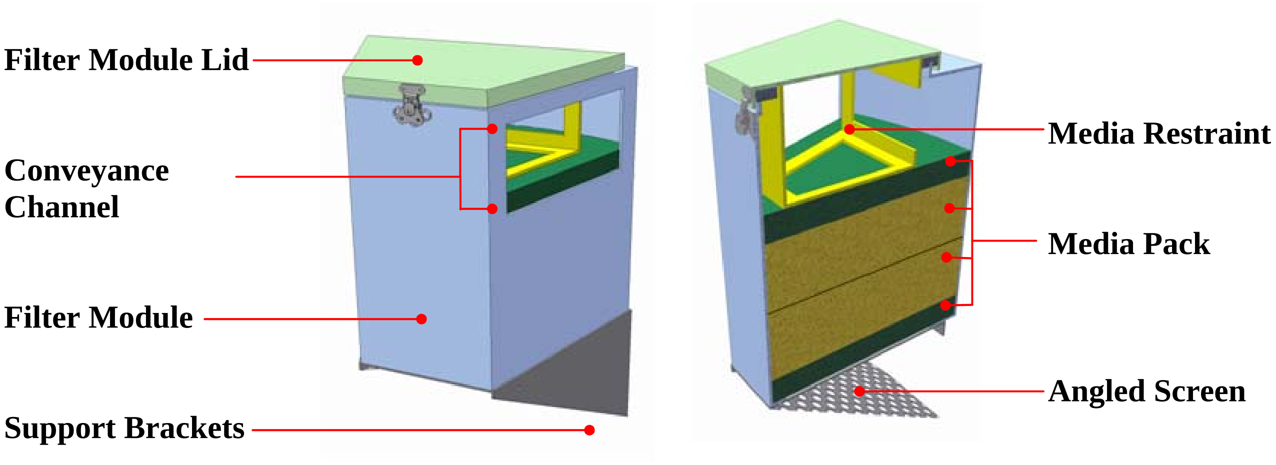

Figure 3-2. Filter module components.

3.2 Hydraulic Flow Path

The Up-Flo™ Filter is self-activating and operates on simple fluid hydraulics. The configuration of the internal components directs the flow in a pre-determined path through the vessel as described below.

3.3 Flow Conditions

3.3.1 Operating Flow Conditions

Challenge water enters the chamber from an inlet pipe or an overhead grate and flows into the sump region where gross debris and coarse grit are removed by settling. Runoff continues to fill the chamber until there is enough driving head to initiate flow through the filter media. At this point, the water flows up through the Angled Screen into the Filter Module. In the module, flow passes up through the filter media and is conveyed to the Outlet Module via the Flow Conveyance Channel. The flow path through the Up-Flo™ Filter during normal operating conditions is illustrated in Figure 3-3.

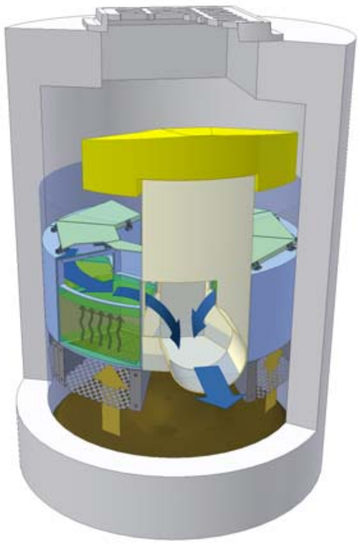

Figure 3-3. Flow path during normal operating conditions.

3.3.2 Bypass Flow Conditions

Flows in excess of the filtration capacity are discharged directly to the outlet module by the siphonic bypass. The siphon also serves as a floatables baffle to prevent the escape of buoyant litter and debris. The flow path through the Up-Flo™ Filter during bypass flow conditions is shown below in Figure 3-4.

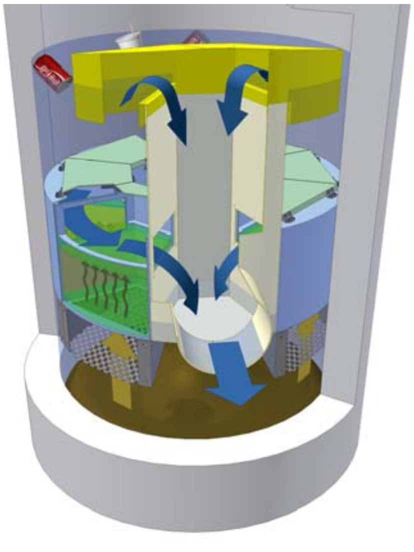

Figure 3-4. Flow path during bypass flow conditions.

3.3.3 Drain Down

Filter media continuously submerged in water can become anoxic, producing an environment that promotes bacterial growth and the release of other harmful leachates. The Up-Flo™ Filter has been designed with a drain-down mechanism to ensure that the filter media sits above the standing water level between storm events. As a storm event subsides, water slowly drains out of the chamber through the Drain-Down Port located at the base of the outlet module. The Drain-Down Ports are covered with a layer of filter fabric to provide treatment to the drain-down flows. The flow path for the drain down mechanism is shown in Figure 3-5.

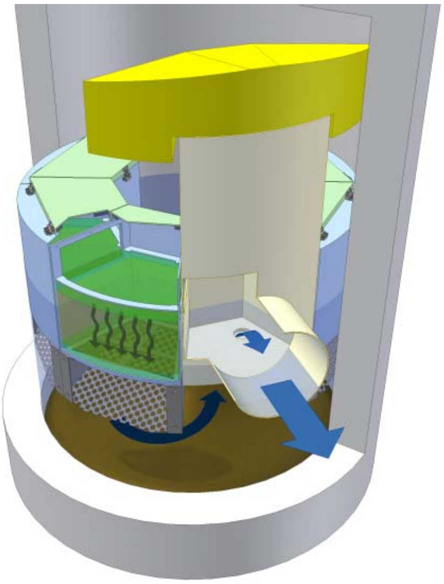

Figure 3-5. Flow path during drain down conditions.

3.4 Sizing and Hydraulic Capacity

The Up-Flo™ Filter is sized to treat the peak treatment flow of a water quality design storm. The peak flow is determined from calculations based on the contributing watershed hydrology and from a design storm magnitude set by the local challenge water management agency. The number of Filter Modules included in an Up-Flo™ Filter is determined by the peak treatment flow.

The flow rate through each filter module depends on the nature and type of media within the module and the water level in the Up-Flo™ Filter chamber. By adjusting media blends, each Filter Module can be engineered to have a range of treatment flow rates from 10 gpm to an excess of 25 gpm. The flow rate through each Filter Module will determine the number of modules needed to treat the peak treatment flow of the storm event.

The Up-Flo™ Filter is equipped with a Bypass Siphon designed to discharge flows in excess of the treatment flow. When influent flows exceed the filtration capacity, the water level in the

Up-Flo™ Filter chamber rises until it reaches the height of the internal weir of the siphon. Once water starts to flow over the weir, the Bypass Siphon begins drawing water out of the chamber discharging the excess flows through the Outlet Module to the outlet pipe.

The height of the bypass can be adjusted to accommodate shallow retrofits or restrictive hydraulic profiles. The standard Up-Flo™ Filter bypasses in excess of 7 cfs with 2.5 feet of hydraulic drop. A shallow unit, depicted in Figure 3-6, has a bypass capacity in excess of 4 cfs with a significantly reduced hydraulic drop.

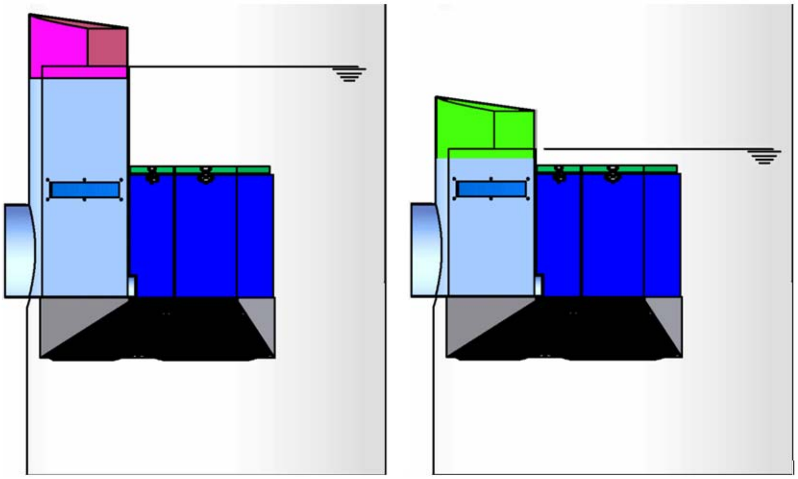

Figure 3-6. Bypass water levels for standard Up-Flo™ Filter (left) and shallow Up-Flo™ Filter.

3.5 Test Unit Specifications and Test Setup Description

The unit to be tested is a full scale, commercially available Catch Basin system. For the standard Catch Basin configuration, the Up-Flo™ Filter is comprised of one to six Filter Modules. In normal business practice, the number of Filter Modules included in an Up-Flo™ Filter system is dependent upon the required peak treatment flow rate. It is important to characterize the Up-Flo™ Filter on a per-Module basis because it is sized on a per-Module basis. TSS, Phosphorus and Hydraulic Capacity performance claims will be verified on a one-module Catch Basin Up-Flo™ Filter setup. Sizing claims will be verified by benchmarking the hydraulic capacity of a two-module set up to the capacity of the one-module set-up. The two-module Catch Basin Up-Flo™ Filter set up is shown in Figure 3-7, Figure 3-8, and Figure 3-9.

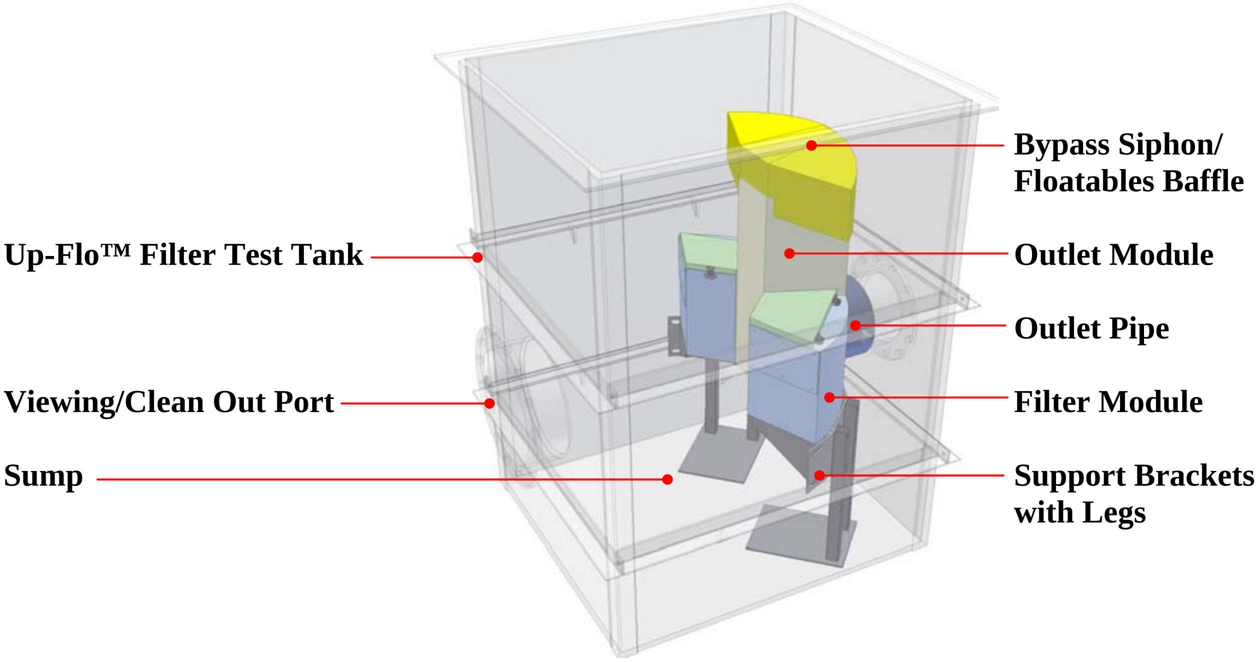

Figure 3-7. Up-Flo™ Filter test unit isometric view.

The test unit has a 24-inch sump depth, a 12-inch outlet, and an 18-inch acrylic viewing port. The height of the bypass is set so that there can be 21 inches of driving head acting on the Up-Flo™ Filter before bypass levels are reached. The test tank will be set up such that inflows pour into the chamber through the open top, replicating a grated-inlet field installation.

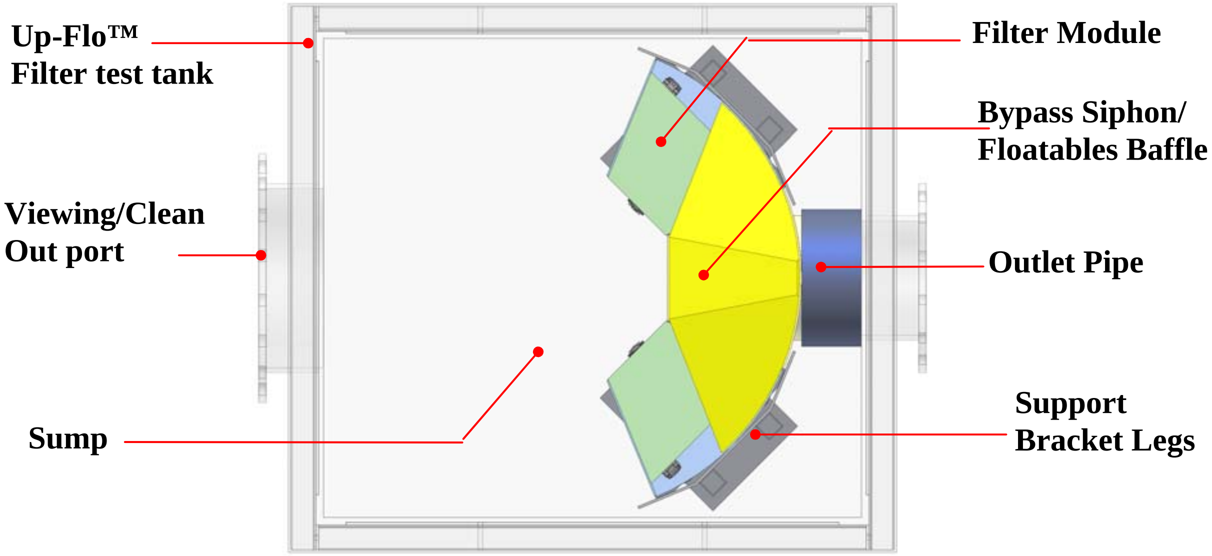

Figure 3-8. Up-Flo™ Filter test unit plan view.

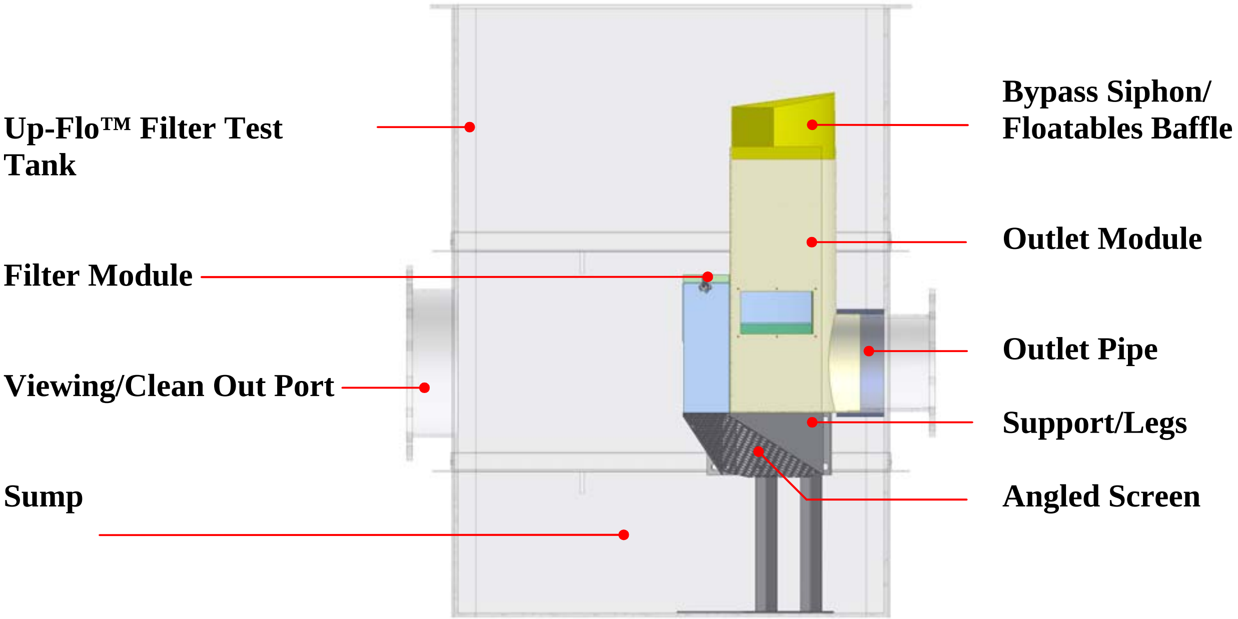

Figure 3-9. Section view of Up-Flo™ Filter test unit.

The tests will be performed at PSH's Environmental Engineering physical testing laboratory. The PSH laboratory is set up to handle testing of this type with physical facilities that includes a water supply up to 50 gpm, tanks, mixers, and pumps to store and feed the synthetic water, and all other associated piping, controls and related equipment. The Up-Flo™ Filter is a passive unit that does not require any utility connections to operate. Therefore, there will be no electrical requirements needed for operation of the unit. There will be water and electrical needs for the laboratory to supply the synthetic test water to the unit, operate pumps, mixers, and sampling equipment, etc. However, none of these requirements would be needed in a field application. There will be no special permitting needed to operate the unit or the test facility equipment for this verification.

The synthetic challenge water described later in this test plan will contain simulated challenge water solids and a source of particulate phosphorus (as described later in this plan). The levels of these contaminants in the synthetic water will be similar to those found in challenge water runoff, based on data generated both during the Nationwide Urban Runoff Program (NURP) and the more-recent analysis of outfall data. While it is anticipated that all the effluent water will meet the requirements of both the sanitary pre-treatment program and the NPDES permit, it is planned that this water will be captured in a holding area and the solids allowed more time to settle. The solids that accumulate will be solid waste that require disposal during the test. Based on the manufacturer's data and general information regarding the contaminants that most likely will be removed and present in the residues, these solids wastes should be acceptable for disposal in a standard municipal landfill. The residues will be tested prior to disposal to ensure they are not regulated materials that require special disposal. In addition, a carbon filter will be used to treat the discharge water after the effluent settling tank to ensure that the organic pollutants are removed to acceptable levels prior to discharge to either the storm drain system or the sanitary sewer system.

The unit will be installed at the PSH water/wastewater laboratory such that water will enter and exit the unit by gravity as would occur in a typical field installation. Figure 3-10 shows a schematic process flow diagram for the test setup at the laboratory.

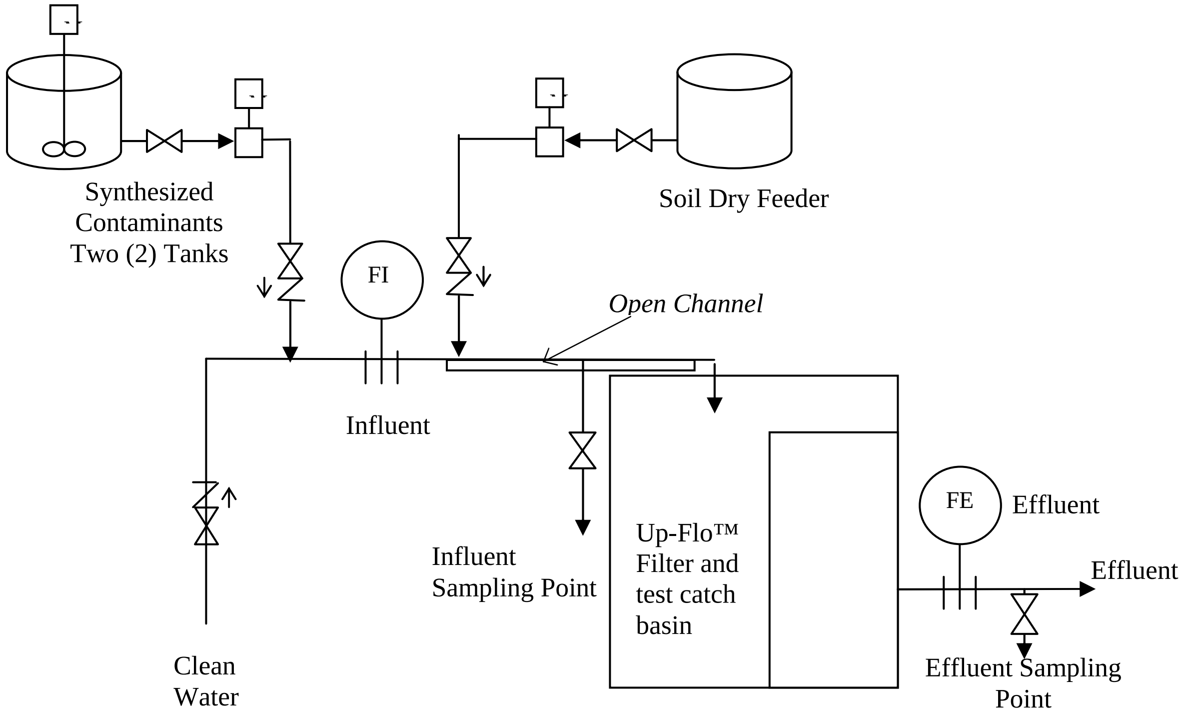

Figure 3-10. Process schematic of test system setup.

3.6 Up-Flo™ Filter Capabilities and Claims

3.6.1 System Capability

The Up-Flo™ Filter is a compact treatment-train device that targets the wide range of constituents typically found in challenge water runoff. Each Up-Flo™ Filter includes a sedimentation sump, coarse screens and filtration media. Coarse grit and gross debris will be removed by settling in the sump, neutrally buoyant debris will be removed by screening, and fine suspended sediment will be removed by filtration. The filter media may be customized to target other site-specific pollutants such as nutrients, metals and organics.

Two filter media will be used in this verification program. The first media will be Hydro International's CPZ Mix™, which is made up of activated carbon, manganese-coated zeolite and peat. Granular activated carbon is a traditional filter media for targeting organic chemicals, pesticides and herbicides. The manganese-coated zeolite targets TSS, iron, manganese and ammonium in challenge water runoff. The small fraction of peat targets the removal of organics and metals. The second media to be tested will be Filpro® 0.35 grade filter sand. Filpro® 0.35 is a commercially available grade of filter sand that is certified by NSF International under NSF Standard 61 and is sized and graded to meet the specifications of AWWA B-100 and the ANSI standards for consistently uniform and chemically inert filter media. The filter sand targets the removal of TSS and associate pollutants such as particle-bound phosphorus.

Each Filter Module with the CPZ Mix™ will have a flow rate of 20-25 gpm when the water level in the chamber provides 20 inches of driving head. Each module with filter sand will pass 18 to 20 gpm under 20 inches of driving head. The filtration rate will decrease as driving head decreases. Filtration will occur until the driving head in the chamber falls to zero inches. When the inflows exceed the filtration capacity, the excess flows will discharge through the Bypass Siphon directly to the outlet module. The Bypass has been designed to accommodate 7 cfs of excess flows. This high-capacity Bypass Siphon ensures that head-loss and flow-restrictions due to the filter media will not cause collection system backups and ponding on the surface during events with high flow rates.

Maintenance of the sump and replacement of the filter bags is important for the successful long-term operation of the Up-Flo™ Filter. The filtration rate of the Up-Flo™ Filter will decrease as captured pollutants accumulate in the filtration media. The filter bags should be replaced once a year (or as needed) to ensure that fine sediment build up is not allowed to accumulate such that the flow rate of the filter will be significantly reduced. Sediment and gross debris must also be periodically removed from the sump to ensure that accumulated sediment does not block the intake of the Filter Module.

This test plan is designed to meet the basic protocol requirements and will focus on the treatment capability of the unit to remove sediment and particulate phosphorus from synthetic challenge water. The experimental design and sampling and analysis plan presented in the following sections provide details on the test protocol and the constituents targeted for this verification.

3.6.2 Vendor Claims

The Up-Flo™ Filter is designed to incorporate multiple elements of a treatment train into a single, small-footprint device. The Up-Flo™ Filter utilizes settling, screening and filtration to remove gross debris and suspended sediment from challenge water runoff. Specifically, the Up-Flo™ Filter will remove over 80% of fine total suspended solids (TSS) from challenge water runoff, and it will also remove a portion of total phosphorus and other pollutants commonly found sorbed to the surface of suspended sediment particles such as metals and organics.. Verification of the removals of metals, organics (except that measured as chemical oxygen demand [COD]), and other pollutants is not included as part of this test plan.

Regular maintenance events are necessary to ensure optimal performance of the Up-Flo™ Filter. In-field maintenance includes removing floatables, sediment and other pollutants from the sump and changing out the Media Packs. In-field inspection should occur regularly. In-field Media Pack replacement should occur once a year or as needed. The in-field maintenance of each catch basin Up-Flo™ Filter unit should take a half-hour or less. Maintenance on the Up-Flo™ Filter test unit will occur after each phase of performance testing. The side of the Up-Flo™ Filter test tank is equipped with an 18-inch access port to facilitate sump cleanout (see Figure 3-7). To replace media packs, entry into the test tank is necessary. The tank is spacious enough to provide comfortable access for one maintenance person. It is not anticipated that confined space issues will need to be addressed during this testing since the test tank will be open to the atmosphere.

To properly maintain the Up-Flo™ Filter, follow the steps detailed in the Up-Flo™ Filter Operation & Maintenance Manual (Appendix A).

3.7 Performance Measures for the Verification Test

The performance capabilities of the Up-Flo™ Filter unit will be assessed both quantitatively and qualitatively. Sampling and analysis of the influent, effluent, and residues will provide data to determine the treatment efficiency of the unit with quantitative data. Recording of visual observations, operational issues and maintenance requirements will provide a basis for qualitatively assessing the unit's performance. The entire test plan, including the Experimental Design, Sampling and Analysis Plan, and Quality Assurance Project Plan, is focused on obtaining performance-based data that will serve as the foundation of the verification report and the verification statement.

3.7.1 Contaminant Selection and Monitoring for Performance

The Up-Flo™ Filter unit is designed to remove solids and solids-associated pollutants, such as particulate-bound phosphorus in runoff. Based on the unit's capabilities a list of targeted contaminants that will be monitored for removal by the unit has been selected. The targeted list is as follows:

Targeted Contaminant List

- Suspended sediment concentration (SSC)
- Total suspended solids (TSS)
- Particle size distribution (PSD)
- Total phosphorus (TP)
- Reactive phosphorus (RP)

These constituents, in addition to COD [as a surrogate for the added organics], will be measured in influent and effluent samples in accordance with the experimental design and the Sampling and Analysis Plan. The results will provide data for determining the performance capability of the unit to remove targeted contaminants and provide data on the additional and secondary contaminants as well. All of these data will be reported in the verification report as part of the quantitative performance measurements.

3.7.2 System Component Operation and Maintenance Performance

The overall system performance will be measured both quantitatively and qualitatively. Quantitative measurements will include determination of the range of hydraulic flow conditions that can be handled by the unit. The hydraulic capacity of the unit will be determined by measuring the hydraulic flow rate in volume of water treated and flow rate handled. The experimental design includes both hydraulic loading tests and loading of contaminants to the unit. The filter media will be stressed to exhaustion and spike loads will be charged to the unit at high flow rates. The mass removal of contaminants will be determined.

Qualitative measures will be assessed by observations of and experience with the unit during the setup and testing phases. Records will be maintained on the ease and time of installation, the time and ease of maintenance for cleanout and absorption medium replacement, and other operating observations. The unit is a simple design with no controls, instrumentation, alarms, or other mechanical or electrical devices that will require operation. The unit will be monitored for solids or debris buildup, clogging of entry paths, and other related operational issues. The Operations and Maintenance (O&M) Manual provided by Hydro International will be reviewed for its specificity and completeness. These observations, experiences, records and review will be the basis for evaluating the system performance in terms of operation and maintenance.

3.7.3 Quantification of Residuals

Testing the Up-Flo™ Filter will create residual material, such as removed contaminants, sediments, and spent filter media. The quantity of residual materials requiring disposal is a factor in performance measurements. Refer to Section 4.5 of this test plan for a discussion of how residual materials will be quantified during the tests.

Chapter 4
Experimental Design

4.1 Introduction

The experimental design described in this test plan is designed to obtain quantitative and qualitative data on the performance capabilities of the test equipment. The data collected will serve as the basis for determining the effectiveness of the treatment unit to reduce constituent loads in the influent synthetic challenge water. The data collected in accordance with the experimental design and Sampling and Analysis Plan will be presented in the verification report and serve as the basis for the verification statement for this technology.

The experimental design follows the methods and procedures defined in the protocol. The design incorporates all of the elements described in the protocol and includes all of the phases of testing prescribed. There are three deviations or exceptions from the protocol as understood by the Testing Organization. These deviations are:

1. The measurement of head loss is not directly applicable due to the design of the Up-Flo™ Filter; and
2. The synthetic challenge water concentrations are set to reflect actual challenge water concentrations and the particle size distribution will be selected based on those required by New Jersey Department of Environmental Protection challenge water device evaluation protocols.

The verification test will be a controlled test. The testing will be performed on a full-scale unit set up in the PSH laboratory. The PSH laboratory is a physical testing laboratory with space, tanks, piping, utilities, etc., to perform medium-to-large scale (10 – 50 gpm) testing of this type. A synthetic challenge water will be used for the testing. The synthetic challenge water will be made as described later in this section and dosed to the unit as prescribed in the protocol.

4.2 Test Site and Setup

The test site will be the PSH Environmental Engineering water/wastewater laboratory at the facility in Middletown, Pennsylvania. The physical laboratory is setup to handle large flow testing and full-scale unit testing. The facility has space to setup several large tanks and piping to convey the challenge water to the full-scale test unit. The lab can supply up to 50 gpm of city water as a main feed during the testing and has ample electrical service to run all pumps, controllers, samplers, and associated equipment.

As stated earlier, the Up-Flo™ Filter unit used for the verification test will be that of a full scale commercially available one-module catch basin configuration. It will be the standard one-module configuration sold for catch basin applications used for this in-drain application. The unit will be placed in a tank that simulates a catch basin. Influent to the unit will be pumped into the same elevation as the grate inlet (relative to the unit) so that flow can move through the system by gravity and the driving head in a manner similar to a field application. Effluent from the unit will flow by siphon out of the side of the test unit in the same manner that the flow exits the unit in the field.

Figure 3-10 shows the process flow diagram and equipment configuration for the test setup. City water will serve as the main water feed with a maximum flow rate of up to 50 gpm. A flow control valve will control the flow. The flow rate of the water will be measured using a standard "paddle wheel" style flow meter that will show flow rate (gpm) and will totalize the volume processed (gallons).

Synthetic challenge water will be made by adding pre-mixed and sized solids, with a specific amount of a particulate phosphorus source (potting soil with compost) to the city water. One tank will be used to hold stock solution of these materials. A dry feeder will be used to feed a mixture of clay, topsoil, and sand to the city water. Initial tests in the lab found that the sand could not be kept in suspension even in a stirred sample bottle. Therefore, the dry feeder will be used to feed the solids into the pipe with sufficient mixing area available in the pipe between the solids-addition point and the entry to the device. The sieve size analysis of the selected solids mix is shown below, as specified by a New Jersey testing plan, is provided in Table 4.1, and is displayed graphically in Figure 4-1.

Table 4-1. Particle Size Distribution

Description	Particle Size (µm)	Sandy loam (percent by mass)
Coarse sand	500 – 1,000	5
Medium sand	250 – 500	5
Fine sand	100 – 250	30
Very fine sand	50 – 100	15
Silt	8 – 50	25
Fine Silt	2 – 8	15
Clay	1 – 2	5

This distribution can be approximated by mixing a pre-sieved concrete plant sand with the Sil-Co-Sil 250 to be purchased from U.S. Silica, Inc. (or one of its distributors). The mix is 42.5% sand and 57.5% Sil-Co-Sil 250.

In addition, Miracle-Gro™ topsoil will be added to this particle mixture to generate the required additional phosphorus (above that supplied by the STPP in the organic mixture). Testing at PSH on this topsoil showed that the phosphorus content measured as total phosphorus (TP) is approximately 0.4 mg TP/g Miracle-Gro™. Prior to the onset of testing, the phosphorus content will be determined in a solution of well-mixed challenge water.

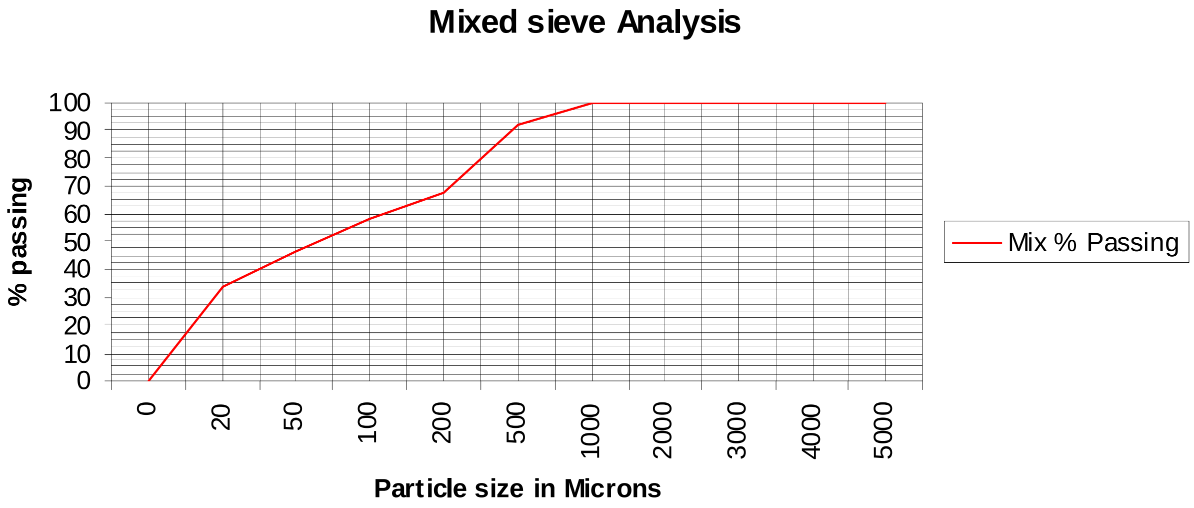

Figure 4-1. Sediment particle size distribution graph.

All sampling will be performed manually for all test sequences. This eliminates the concern regarding the collection of representative solids when using automatic sampling equipment.

The synthetic challenge water will enter the treatment unit through the open top of the device grating, flow through the sump/sediment collection section, and pass over/through the absorbent materials. The treated water will exit through the outlet pipe along the side of the unit (see earlier figures). Flow rates will be measured both at the beginning and outlet of the system. A sampling port will be located in the effluent pipe that will be set up for collection of manual grab samples. All sampling will be performed manually for all test sequences.

4.3 Test Phases – Hydraulic Loading

The unit will be tested under varying hydraulic load conditions to simulate typical conditions found in wash water applications (i.e., catch basins and drain inlets in streets, parking lots, etc.) and during challenge water flows. The primary operational characteristics will be tested to determine:

- Performance under intermittent flow conditions;
- Performance under different hydraulic loadings, including peak flow;
- Performance at different contaminant loadings; and
- Capacity of the unit to contain contaminants.

The testing will be done in four phases that will include conditions designed to test all of the above-mentioned operating scenarios. The Phases described below follow the same Phases that are discussed in the protocol. The actual order in which this testing is accomplished may change, but all four phases will be completed.

4.3.1 Phase I - Performance under Intermittent Flow Conditions

In Phase I the system will be operated intermittently to simulate actual in-drain treatment applications during intermittent loadings at flow rates that are typical average flow rates over a period of time. The Up-Flo™ Filter catch basin unit, with one to six filter modules, is designed to treat flow rates of up to approximately 20 gpm per filter module before any water is bypassed through the overflows. A more typical average flow rate at a catch basin or drain inlet is expected to be in the 10-15 gpm range. A flow rate of approximately 10 gpm will be used for the Phase I five day test.

The intermittent tests will be run for a five day period. Each twenty-four hour period will consist of an eight-hour ON cycle, followed by a 16-hour OFF cycle. During the eight-hour ON cycle, the unit will receive flow for 15 minutes, followed by a 15-minute period with no flow. The result will be 16 flow periods in the eight-hour ON cycle (two 15 minute flow periods per hour for 8 hours). The flow will be constant during the dosing periods at a flow rate of approximately 10 gpm.

The well-mixed stock solution tanks will be filled prior to the test and the volume recorded. The chemical feed pumps will be calibrated prior to the start of the testing and set to the appropriate feed rates. The test will be started by opening the flow control valve for the main water supply and turning on the chemical feed pumps. Flow rates will be checked and recorded. The flow will be maintained for a 15-minute period and then the water supply and chemical feed pumps turned off for 15 minutes. This cycle will be repeated for the eight-hour ON test period. The entire cycle will be repeated for five days.

Samples of both the influent and the effluent will be collected by manual grab samples. Samples will only be collected of the influent and effluent when flow is being sent to the unit. The parameters being monitored will be composites over the operating day. Samples for both the solids and phosphorus analysis will be collected manually with one liter of sample collected every 500 gallons (approximately once every two hours), and these individual grabs will be composited once the samples are returned to the laboratory. Table 5-1 in the Sampling and Analysis Plan Section provides a summary of all sampling and analysis schedules for verification test.

On the first and third day of intermittent cycling, a special sampling program will include one-hour composites (8 total) for TSS, particle size distribution (PSD), and total and reactive phosphorus. Grab samples will be collected during each of the two 15 minute flow cycles each hour and composited into a single sample for analysis. On these two days, the eight-hour flow weighted composite for TSS, PSD and total and reactive phosphorus (described above) will not be collected and analyzed. The TSS analysis will follow the same special procedure. The entire volume of sample from the grab samples will be filtered for the solids test. This will ensure that the heavier particles (sand) are contained in the sample being filtered and not left in the sample bottle. This procedure is described further in Section 5.

Flow rates will be monitored throughout the test period on a minimum of a once per hour basis. Cumulative volumes processed during the test will be monitored based on the flow rates and the totalizing flow meters. All flows (influent, stock solution feeds, effluent) will be recorded in a permanent logbook. The logbook will also be used to record observations made during the test runs. Observations will include a physical description of the effluent water with respect to color, oil sheen, etc. The unit will be observed for any evidence of clogging, change in operating head or head loss, flow patterns, or any evidence of bypass or short-circuiting.

The protocol calls for the measurement of head loss as part of the monitoring of flow conditions in the unit. Head loss is a concern for in-drain units that are inserted into the drain and have no bypass or ability to overflow. If head loss is high, then the drainage system capacity is limited and flooding can occur on surface areas. The Up-Flo™ Filter unit, however, is designed to bypass any flow that does not pass through the absorption media. The unit has a bypass design capacity that is greater than the typical inlet grate. By designing the unit bypass capacity larger than the inlet grate capacity, it is ensured that flooding cannot occur due to a backup or plugging of the absorption media.

Given that the unit is fed by gravity, is open at the top, and has an overflow capacity greater than the inlet, it is not possible to measure head loss on the influent stream to the unit. An approximation of the depth of water over the filter media in the treatment chamber will be monitored by noting whether water is bypassing the treatment media, and reported as an estimate of the head loss through the media. This head loss, however, only impacts the capacity of the unit to treat water and does not impact the concern regarding flooded conditions.

As described in Section 4.2, the unit will be fed by gravity in a similar manner to the flow conditions expected in the field applications. The flow will enter the top of the unit and flow by gravity into the unit. All effluent will flow out of the unit by gravity and exit via the open channel leaving the test unit. The intermittent flow cycles will simulate conditions that can be expected during small rain events or during flows from a commercial/industrial operation that might reach a storm drain inlet or catch basin.

The unit has a relatively large capacity (approximately 40 cubic feet) for holding sediment (settled solids). The challenge water will have approximately 300 mg/L of sediment. Assuming 100% removal from a flow of 12,000 gallons and a 90 pounds per cubic foot bulk density, the retained sediment would occupy 0.2 cubic feet. Therefore, sediment cleanout is not anticipated until the Phase I test is completed. The vendor has indicated that the unit will most likely reach capacity for this synthetic water due to blinding of the filter media by the fine sediment and soils. The estimate is that the unit will handle in the range of 1.2 million gallons of water containing 300 mg/L of solids. Based on these initial estimates, it is not expected that the unit will require maintenance or changing of the absorbents during the Phase I test period.

At the end of the Phase I period, the unit will be inspected to determine the condition of the sediment chamber and the absorbents. Observation of an increase in water depth in the test tank during the test run will provide an indication if the media is beginning to blind or plug. If the media and sediment chamber are in good operating condition, the media will be removed, drained, weighed and returned to the unit for the capacity study. If the sediment chamber appears to be filling quicker than expected or the media is beginning to plug as indicated by water draining through the bypass holes during the low-flow testing, the unit will be cleaned and the media pack will be replaced as described in Section 4.5.

4.3.2 Phase II – Determination of the Capacity of the Unit

The objective of the Phase II testing will be to run the unit to “exhaustion” with respect to the capacity of the absorbent material to remove suspended solids and/or phosphorus. During this phase of testing, the unit will be operated under continuous flow conditions for 16 hours a day until the unit plugs with solids or the absorption capacity is exceeded. The protocol calls for continuous operation during the capacity test. However, the test set up is based on manual operation and observation. The high water flow rates and manual operation require that a technician be present at all times to ensure water overflows or other problems do not occur. The PSH lab normally operates on an 8-hour day but will extend to 12-hour operation for this test. It is not practical to operate twenty four hours per day. Further, it would be highly unusual for an in-drain unit to flow at near maximum flow continuously until exhaustion occurred. Therefore, operating on a 12-hour basis should not have any impact on the overall capacity results or the applicability to the real world.

If the unit is in good operating condition after Phase I, the loading placed on the unit sediment chamber and filter media will be incorporated into the capacity test as provided for in the protocol. The total loading from Phase I will be added to Phase II data to calculate total capacity. If the unit has shown signs of plugging or reaching capacity in the Phase I test, then the unit will be cleaned and fresh absorbent will be placed in the unit prior to the start of the test. The flow rate for this test will be set at 16 gpm, which is approximately 80% of the maximum rated flow capacity of 20 gpm.

Based on vendor information, it is not expected that capacity of the absorbent will be exceeded before the loading of suspended solids begins to plug the filter media and causes the unit to overflow through the bypass openings. The filter media is expected to “blind off” due to the presence of the small sediment particles and high solids loading. It is not known how much loading the unit can receive before the capacity is exceeded. If the unit capacity has not been exceeded in the first 12 hour run (about 11,500 gallons of water), the unit will be operated for a second 12 hour period on day two or until the solids capacity is reached. If after the second 12-hour period indicates exhaustion has not been achieved, then the unit will be started again and will continue to be dosed on a 12 hour run schedule until the maximum absorption capacity is reached.

Samples will be collected on a grab sample basis. Samples from the influent and effluent will be collected at the start of the test and after approximately each 10,000 gallons of influent flow, and analyzed for the primary constituents (TSS, SSC, COD, TP, RP). During the second 12-hour test period (day two), the same sampling schedule will be maintained. Samples will only be analyzed for water volumes up to the time that unit begins to blind off and cannot pass the all of the influent through the filter/absorption media. If the capacity of the unit is found to be larger than 23,000 gallons (two 12-hour feed days), samples will continue to be collected until the capacity is achieved.

Flow rates will be monitored throughout the test period on a minimum of a once per hour basis. Cumulative volumes processed during the test will be monitored based on the flow rates. All flows (influent, stock solution feeds, effluent) will be recorded in a permanent logbook. The logbook will also be used to record observations made during the test runs. The water depth over the filter media will be monitored and recorded. Increasing depth at the set flow will be an indication that plugging is starting to occur. When the media begin to plug, the water depth will increase and eventually the challenge water will begin to exit through the bypass. At that time, the unit will be assumed to have reached capacity. Observations will include physical description of the effluent water with respect to color, oil sheen, etc.

At the end of the Phase II test, the unit will be cleaned and the media pack will be replaced as described in Section 4.5.

4.3.3 Phase III Performance Under Varied Hydraulic and Concentration Conditions

This phase of testing will focus on determining the unit's hydraulic capacity and how well it handles spike loads of constituents. Phase III will have three distinct parts.

4.3.3.1 Part 1: Hydraulic Capacity with Clean Water

The vendor has stated that one Filter Module has a rated capacity of 20 gpm for treating water. Flows above 20 gpm are bypassed through the bypass openings in the top of the unit. In order to confirm the rated treatment capacity the unit will be challenged with increasing flow rates using clean water in the Part I test.

The test will start with a clean unit containing fresh media. Only the clean water line will be used for this test. The Drain-Down Port on the base of the Outlet Module will be plugged prior to testing. Flow will start at 10 gpm of fresh water for a period of 15 minutes. After 15 minutes, the flow will be increased to 15 gpm for a period of 15 minutes. Flow will continue to be increased by an additional 5 gpm (20, 25, 30, etc.) in 15-minute increments until flow begins through the bypass. The maximum flow rate achieved, before bypass and after bypass occurs, will be recorded in the logbook. After achieving the maximum treated rate, the flow will continue to be increased to challenge the bypass system. Flow will continue until the maximum available fresh water rate is reached. All flow rates and operating observations will be recorded in the logbook along with any physical observations regarding the unit response during the test.

As discussed in Section 4.3.1, the protocol calls for the measurement of head loss during several phases of testing. The design of this unit however does not lend itself to head loss determination, and head loss in the unit itself is not a cause for concern with respect to flooding. There will be no head loss due to the unit on the entry line, as the water will flow by gravity into the unit. It is not expected that the unit will actually go to bypass at any time during this test. The unit capacity for overflow described earlier is much higher than the maximum flow rate of water available to the laboratory. Observations of the water elevation at various flows will be made so that estimates of media head loss can be made. The overflow will be monitored and water height at various bypass flow rates will be recorded.

4.3.3.2 Part 2: Hydraulic Throughput with Synthetic Challenge Water

The Part 2 testing will follow the same approach as the Part 1 testing except that the synthetic challenge water will be used as the influent water. In this part, the chemical feed pumps and dry feeder will be used to add the stock solutions to the fresh water. At each increase in flow rate, the pumps and feeder will be increased in rate in ratio to the fresh water feed to maintain a constant concentration of constituents in the synthetic challenge water.

The test will be conducted after the Part 1 test and will use the same filter media that was used for the Part 1 test. Flow will start at 10 gpm for a period of 15 minutes. After 15 minutes, the flow will be increased to 15 gpm for a period of 15 minutes. Flow will continue to be increased by an additional 5 gpm (20, 25, 30, etc.) in 15-minute increments until flow begins through the bypass holes. The maximum flow rate achieved before bypass and after bypass begins will be recorded in the logbook. After achieving the maximum treated rate, the flow will continue to be increased to challenge the bypass system. Flow will continue to be increased until either, the bypass is at capacity and the unit begins to flood, or until the maximum available fresh water rate is reached. All flow rates and operating observations will be recorded in the logbook along with any physical observations regarding the unit response during the test.

Grab samples of the influent and effluent will be collected at each flow rate condition until the unit floods or the maximum available feed water capacity is reached. All samples will be analyzed for the complete list of constituents (solids and phosphorus).

During this part as in all test runs, all flow rates and operating observations will be recorded in the logbook, along with any physical observations regarding the unit response during the test.

4.3.3.3 Part 3: Impacts of Spike Concentration Loadings

Part 3 is a test series designed to evaluate the impact that spike loadings may have on the unit's ability to remove key constituents. The key constituents for the Up-Flo™ Filter are TSS, SSC, PSD, TP and RP. The test protocol for Part 2 will be used to increase the hydraulic loading to the unit, and increasing the concentration of solids (including total phosphorus particulates) will increase the concentration of the parameters in the synthetic challenge water.

Using the same unit (no cleanout or media pack) as for Part 2, the test procedure will start at a flow rate of approximately 10 gpm. The chemical feed pump rates of the stock solutions and dry feeder will be set at a factor of four times higher than used in the previous tests. This will increase the concentration of constituents by a factor of four. After 15 minutes, the flow will be increased to 15 gpm for a period of 15 minutes. Flow will continue to be increased by an additional 5 gpm (20, 25, 30, etc.) in 15-minute increments until flow begins through the bypass mechanism. The maximum flow rate achieved before bypass and after bypass begins will be recorded in the logbook. After achieving the maximum treated rate, the flow will continue to be increased to challenge the bypass system. Flow will continue to be increased until either, the bypass is at capacity and the unit begins to flood, or until the maximum available fresh water rate is reached. All flow rates and operating observations will be recorded in the logbook along with any physical observations regarding the unit response during the test.

Grab samples of the influent and effluent will be collected at each flow rate condition until the unit floods or the maximum available feed water capacity is reached. All samples will be analyzed for all constituents of interest.

At the end of the Phase III tests, the unit will be cleaned and the media pack will be replaced as described in Section 4.5.

4.3.4 Phase IV: Contaminant Capacities at High Hydraulic Throughput

The influence on treatment efficiency of high hydraulic loads on the unit will be tested in Phase IV. The Phase IV test will be a capacity or "exhaustion test" similar to Phase II, except the unit will be under higher hydraulic loads typical of a very large flow event. The Up-Flo™ Filter unit is somewhat unique in that it will treat all of the water that can pass through the treatment chambers and then bypass the remaining water. Thus, at higher flows (above treatment capacity) it will not backup and flood an area around the inlet, but rather will treat a set flow, about 20 gpm/ft^2 of filter media, and the additional flow will be bypassed to the catch basin outlet and enter the collection system. Only if the bypass flow rate capacity and treatment capacity are exceeded will water begin to backup and flood. Under this high flow rate test, the unit will be operated above the rated treatment capacity with the bypass flowing and removing the extra flow. It is expected that the flow rate will be approximately 40 gpm (approximately 20 gpm to treatment; 20 gpm to bypass), which is above the treatment capacity and about 80% of the available flow rate at the laboratory. The test will demonstrate the system's treatment capability when it is operating in bypass mode. Flow to the unit will be on a continuous basis for a 12-hour period. This time may need adjustment depending on the capacity determined during the Phase II test. The test will start with a clean unit with fresh absorbent.

Prior to starting the Phase IV test, the capacity of the unit will have been determined during Phase II and the anticipated run time to reach "breakthrough" will be recalculated. If a longer run is needed the unit will be operated for additional time or until capacity is achieved.

Observation of the flow rates through the treatment unit and the bypass will be used as the primary indicator that solids capacity has been reached. When flow rates in the treatment section decrease by 25% or more for 30 minutes, capacity will be considered to have been reached. If for any reason the results after the two 16-hour periods (or alternative time determined in Phase II) indicate exhaustion has not been achieved, then the unit will be started again and will continue to be dosed on the 16-hour schedule until the maximum capacity is reached.

Samples will be collected on a grab sample basis. Samples from the influent and effluent will be collected at the start of the test and after every 10,000 gallons of water treated and analyzed for the primary constituents. If additional 12-hour test period(s) are needed, the same sampling schedule will be maintained. Samples will only be analyzed for water volumes up to the time that unit begins to blind off and the treated water through the filter/absorption media decreases by 25% or more.

Flow rates will be monitored throughout the test period on a minimum of a once per hour basis. Cumulative volumes processed during the test will be monitored based on the flow rates. All flows (influent, stock solution feeds, effluent) will be recorded in a permanent logbook, which will also be used to record observations made during the test runs. Observations will include physical description of the effluent water with respect to color, oil sheen, etc. The unit will be observed for any evidence of clogging, change in operating head or head loss, flow patterns, or any evidence of bypass or short-circuiting.

At the end of the Phase IV test, the unit will be cleaned and media pack will be replaced as described in Section 4.5.

4.4 Influent Characterization

4.4.1 Synthetic Challenge Water

The verification test will be performed using synthetic water made from a mixture of solids – one of which will provide the particulate phosphorus required by the test plan. As described in the protocol, this water is intended to simulate actual products that may be present in runoff waters entering a drainage system. The following products will be used to make the synthetic challenge water:

- Regular unleaded gasoline;
- Diesel fuel;
- 10W-30 motor oil;
- Brake fluid;
- Antifreeze (glycol based);
- Vehicle washing detergent (specific chemical addition – see below);
- Windshield washer fluid;
- Sil-Co-Sil 250;
- Miracle Gro™ Topsoil sieved to remove visible large twigs, etc.; and
- Concrete plant sand sieved to a size of all passing through 5,000 µm.

These products or materials will be purchased and the same material/product will be used for all tests. Sil-Co-Sil is supplied by U.S. Silica, Inc. and is sold for use in abrasive applications. The total phosphorus content of the mixture will be supplied by a potting soil/topsoil amended with compost. It will be purchased from a local home improvement store. The concrete plant mix sand will be purchased from a local concrete products manufacturer.

Table 4-2. Revised Synthetic Challenge Water Concentrations

Parameter	Concentration (mg/L)
SSC	300
TSS	300
Total phosphorus (as P)	5
Reactive phosphorus (as P)	1 - 2
TPH	10 - 20

A formula using a mix of the above named products/materials has been made and tested in the laboratory to determine the conformance to these specifications. The synthetic mix that was prepared and tested is shown in Table 4-3. The results of testing the topsoil/potting soil for phosphorus content is 0.4 mg TP/g Miracle-Gro™ topsoil The addition of topsoil is in such small concentrations that the sieve size analysis of the mixture of Sil-Co-Sil, concrete-plant sand and topsoil is identical to the solids mixture sieve analysis shown in Figure 4-1.

Table 4-3. Synthetic Challenge Water Mix Stock Concentrations

Product or Material	Concentration in Water (mg/L)
Regular unleaded gasoline	0.08
Truck diesel fuel	3.9
10W-30 motor oil	19
Brake fluid	0.97
Antifreeze (glycol based)	10
Dodecylbenzenesulfonic acid (LAS)	10
Sodium tripolyphosphate (STPP)	2
Windshield washer fluid	10
Topsoil and Sil-Co-Sil 250 mixture	300

The product concentrations in Table 4-3 represent a deviation in the constituent concentrations identified in the protocol. The hydrocarbon concentrations specified in the protocol were not achievable in prior testing due to the insolubility of hydrocarbons with water. For this test plan, the VO agreed that the hydrocarbon concentrations could be decreased further (to a targeted concentration range of 10 to 20 mg/L) since the vendor makes no specific claims for hydrocarbon treatment. Also, no sufficient challenge product to increase the metals concentrations to those specified in the protocol have been identified, so the metals will be contributed from those present in the clean water source plus the trace metals present in the sediment mixture. Since the vendor did specify a performance claim for phosphorus treatment, a topsoil fortified with fertilizer shall be used to increase phosphorus concentrations to approximately 5 mg/L. The VO, TO, and vendor agree that the materials that comprise the synthetic challenge water should provide a condition suitable to adequately verify the performance of the Up-Flo™ Filter against the protocol requirements.

4.4.2 *Stock Solutions*

The standard mix determined above (Table 4-2) will be used for all of the verification tests. The Sil-Co-Sil, topsoil, and sand will be fed from the dry feeder and set to meet the concentration targets in the established mix. The solids will be premixed prior to filling the dry feeder hopper to homogenize the solids feed. The hopper will be refilled frequently to ensure that the solids do not separate during the test.

The remaining products will be mixed into two separate solutions. One solution will include the hydrocarbon-based products (gasoline, diesel fuel, motor oil, and brake fluid), while the other solution will include the water-soluble products (antifreeze, LAS, STPP, and windshield washer fluid). The two solutions shall be prepared using the following specifications:

- Hydrocarbon mixture (fed into the water at a rate of 0.03 mL per liter of water):
    - 10 grams (g) motor oil
    - 2 g diesel fuel
    - 0.05 g gasoline
    - 0.5 g brake fluid

- Water-soluble mixture (fed into the water at a rate of 0.1 mL per liter of water):
    - 10 g windshield washer fluid
    - 10 g antifreeze
    - 10 g LAS
    - 2 g STPP
    - Mixture diluted to 100 mL with tap water

4.4.3 *Influent Characterization during the Verification Testing*

The influent synthetic challenge water will be sampled and analyzed during all of the various test conditions described in Phases I – IV in Section 4.3. While the generic protocol allowed for single daily samples of the influent in several test cases, the approach used in the test plan is to match influent and effluent samples as often as possible for all sampling periods. This will ensure that the actual influent concentrations will be known for all test conditions.

Because of the large water volumes needed for these tests it was not practical to make a single large daily batch of synthetic water to supply the entire day's flow. Instead, the system will use more concentrated stock solutions that will be injected into the fresh water flow in the open channel section. Given the potential for some variation in the actual mixed influent water, the test plan calls for influent samples, both grab and composites from the manual grabs, to be matched with the effluent samples. This will serve as a check on the feed systems and insure representative influent data is available for determining unit treatment and removal efficiencies. Table 5-1 in the Sampling and Analysis Plan shows a summary of all samples being collected during each phase of testing.

4.4.4 *Solids Characterization during the Verification Testing*

Influent and effluent solids will be characterized using the Coulter Counter Particle Size Analyzer for particles in the range of 0.6 µm up to 220 µm. Particles above 220 µm will be characterized by sieving the samples through a stainless steel sieve with a mesh size of 220 µm. The combination of the Coulter Counter results and the sieve analysis for the large particles will allow for a complete characterization of the influent and effluent particle distribution between 0.6 µm and 5,000 µm. The results for the solids analysis will be subdivided into removal for the following particle size ranges:

- 0.6 - 3 µm
- 3 - 12 µm
- 12 - 30 µm
- 30 - 60 µm
- 60 - 120 µm
- 120 - 220 µm
- > 220 µm

4.5 Effluent Characterization

The effluent quality will be monitored during all Phases of testing except during the fresh water hydraulic test in Phase III, Part 1. Treated effluent grab samples and samples composited from manual grab samples will be collected. The sampling plan shows the details of the actual samples being collected in Table 5-1. The sampling and analysis approach focuses frequent sample collection and analysis on the key parameters for evaluating the Up-Flo™ Filter unit as described previously. Less frequent sampling and analysis is scheduled for secondary parameters.

The primary parameters will be used to evaluate the efficiency of treatment by providing a sound basis for comparing influent water quality with effluent water quality. In addition, these parameters will also provide information on the unit's capability to remove these constituents and will also provide general information on their fate as they pass through the unit. This is particularly true for nutrients, which the unit will only remove if they are in the insoluble form and settle with the solids or if they are bound to organic materials that are absorbed as part of the petroleum hydrocarbon absorption process.

Specific details on the sampling and analysis frequency and parameter list are provided in the Sampling and Analysis Plan Section and in the previous sections describing the test phases.

4.6 Residue Management

Residues, including sediment in the settling chamber and the absorbent media, will be removed from the unit at the end of some phases of testing as described in Section 4.3. Measurements will include the volume of residues/media collected and the wet weight of residues/media collected. These data will be used to provide information on typical cleanout volume and weights that can be expected from normal operation.

Solid residues will be collected from the sedimentation chamber in the unit. The sediment will be removed using a vacuum system (wet/dry shop vacuum) to simulate the typical removal system used in the field (vacuum truck). The content of the shop vacuum reservoir will be removed using scoops, spatulas, scrapers, etc. to remove as much material as possible. These solids will be measured for wet weight and volume in order to evaluate the amount of solids that can be expected to be generated and cleaned out of the unit on a volume throughput/loading basis. Samples of the solids will also be measured for solids content so that a dry weight of solids produced can also be calculated. Three sub samples of the sediment will be collected and percent solids measured. The weight of solids collected will be used to relate the accumulation rate of solids to total water treated.

One representative sample of the spent filter media and retained solids will be analyzed using the Toxicity Characteristic Leachate Procedure (TCLP) prior to disposal. The leachate will be analyzed for metals and for applicable organic materials. The spent filter media will also be generated as a residue. The media packs will be drained and weighed to determine the weight and volume of material that will require disposal.

4.7 Operation and Maintenance Observations

The Up-Flo™ Filter unit will be installed and operated by PSH during the test period. The vendor supplied Operations and Maintenance Manual is presented in Appendix A. Hydro International will also provide consultation on installation and operation of the unit.

Installation of the unit is expected to be straight forward as the unit will arrive at the PSH lab pre-assembled. Support brackets with legs sit on the base of the test tank. The filter modules are secured onto the support brackets. The outlet module has a pipe stub that fits up to the tank outlet via standard Fernco® coupling. The test tank has an open top. The Filter Module will be submerged during testing. The unit's simple design provides ready access to all of its components and all components can be observed from above and through the viewing port during operation.

There are no electrical or mechanical control systems for the unit, no utility hook-ups, and no moving parts. The unit does not have any alarms or indicators to alert users to replace the medium that need to be maintained.

The laboratory will maintain a detailed logbook describing all observations made during the tests. Any unit cleaning, clearing of debris, unclogging of the screens or media, etc. will be recorded. Observations will also be recorded on the ease/difficulty of installation, operation, and maintenance. These observations will include a qualitative assessment of the degree of difficulty encountered during the cleaning of the unit at the end of each phase and on the ease/difficulty of replacing the Media Pack.

Flow rates, volume of water processed, amount of stock solutions pumped from the stock feed tanks, and related operational data for each test run will be recorded in the operational log. Any deviations or changes from the prescribed test plan will be thoroughly documented. The measurements of residue volumes and weights will be recorded after cleaning periods.

Any other observations on the operating condition of the unit or the test system as a whole will be recorded for future reference. Observations of changes in effluent quality based visual observations, such as color change, oil sheen, obvious sediment load, etc., will be recorded for use during the verification report preparation.

The operating and maintenance logbook(s) will be important records for use during the verification report preparation. These logs will provide the information to validate the flow and operating conditions during the test periods. Further, they will serve as the basis for making qualitative performance determinations regarding the unit’s operability and the level/degree of maintenance required.

Chapter 5
Sampling and Analysis Plan

5.1 Sampling Locations

There are two primary sampling locations in the laboratory test system. As shown in Figure 3-10, the two locations are the influent sampling location just upstream of the entrance to the unit and the treated effluent sampling location located just downstream of the test unit discharge. Each of these sampling locations is setup so that grab samples can be collected directly into sample containers. Flow weighted composites for this test plan are straight forward as all test conditions call for a steady flow rate for a set period of time. Therefore, a set sample volume can be collected on a cumulative flow basis and a flow-weighted composite will be obtained.

In addition to the influent and effluent challenge water samples being collected throughout the four phases of testing, samples will also be collected of the solids and absorbent material at the end of each test phase. These samples will be manual grab samples collected from the residue material obtained from the test unit. The solids will be removed from the sedimentation chamber by vacuuming the chamber and then collecting the residue from the vacuum reservoir. The residue will be placed in a container for weight and volume measurement.

5.2 Sampling Frequency

Sampling type, frequency and the analytical list will vary for each phase of the testing. The sampling is discussed in narrative form in the experimental design section. A summary table showing all of the sampling by Phase is given in Table 5-1.

Table 5-1. Sampling Locations, Frequency, Type, and Analysis

Phase	Sample Location	Frequency	Type	Analysis
Phase I				
Day 1-5	Influent and Effluent	1 daily sample each day	Flow-weighted composite	SSC, TSS, PSD, TP, RP, COD
Phase II				
Capacity Study	Influent and Effluent	1 sample at startup 1 sample/10,000 gal treated 1 sample at end of run	Grab	SSC, TSS, PSD, TP, RP, COD
Phase III				
Part 1	No samples			
Part 2	Influent and Effluent	1 sample per flow rate (30, 40, 50, 60 gpm, etc)	Grab	SSC, TSS, PSD, TP, RP, COD
Part 3	Influent and Effluent	1 sample per flow rate (30, 40, 50, 60 gpm, etc)	Grab	SSC, TSS, PSD, TP, RP, COD
Phase IV				
	Influent and Effluent	1 sample at startup 1 sample/10,000 gal treated 1 sample at end of run	Grab	SSC, TSS, PSD, TP, RP, COD

5.3 Sample Collection, Preservation, and Storage

There are two basic types of samples being collected for this verification test, grab samples and flow weighted composite samples from the grab samples. The flow weighted composite samples will be collected by taking manual grab samples of a set volume at predetermined cumulative flow points (i.e., 500, 1,000, 1,500, 2,000, 2,500 gallons, etc.) Flow weighted composites are only being collected during Phase I, when the flow rate to the unit is held constant for all testing. Samples will be collected only when the unit is actively being dosed with water.

The grab samples will be collected in individual 250 mL high-density polyethylene (HDPE) bottles. All of the sample from the bottle for SSC will be used to run the analysis. This is necessary to insure that the heavier sand particles are included in the sample analysis. Pre-testing in the laboratory has shown that it is difficult to sub sample from a sample bottle containing sand and obtain a representative sample that includes the heavier sand. Further, the clay present in the sample tends to blind the filter paper. Therefore, the sample size must be kept small in order to pass all of the water through the filter in a reasonable time. The procedure for suspended solids analysis will be to use the entire contents of each TSS sample bottle. The volume of the sample will be recorded and the entire contents will be filtered for TSS measurement. The bottle will be rinsed to remove any remaining solids and the rinseate added to the sample being filtered. The flow weighted composite result (either one hour or eight hour composites) will be determined one of two ways. If the sample from an individual bottle filters easily, then more than one sample bottle (individual grab) may be filtered through the same filter paper. In the case of the one (1) hour composites, two grab samples (two collected per hour) may be filtered together, yielding a single flow weighted composite result. The same approach may be used for the eight hour composite, which will consist of four sample bottles (one every two hours) instead of two bottles. In this approach, the total mass of dry solids measured on the filter(s) will be divided by the original sample volume (without rinseate volume) of the two or four bottles to determine both the TSS and SSC concentration. The alternative, if only one bottle of sample (individual grab) can be passed through a filter, will be to filter each grab sample individually. The dry weight of solids from the individual samples will be added together and the total dry solids weight divided by the total sample volume (of two or four vials) to calculate the TSS concentration. Table 5-2 shows the bottle types, sample size, and preservation required for each parameter.

The sample bottles required for the various analyses will be provided by the PSH laboratory. The bottles will come without preservative. If needed, the preservative will be added to the bottle after the sample is collected. The samples will be pre-labeled by analysis type.

The PSH physical testing laboratory is in the same building as the chemical laboratory. The chemical laboratory will perform all of the analysis. Given the proximity of the laboratories, samples will be hand delivered to the laboratory login desk with appropriate PSH project approval forms and chain of custody forms. The samples will be logged in and placed in refrigeration as needed. Because of the proximity of the labs, coolers with ice to maintain temperature will not be needed for interim storage or transport.

Table 5-2. Bottle Type, Preservation, and Sample Size by Analysis

Sample Matrix	Analyses	Bottle Type, Size	Preservation, Holding Time
Liquid	TSS, SSC, PSD	HDPE, 250 mL	Cool to 4° C, 7 days
	Total/Reactive phosphorus	Amber glass, 250 mL	Cool to 4° C, pH < 2 H_2SO_4, 28 days
	COD	Amber glass, 250 mL	Cool to 4° C, pH < 2 H_2SO_4, 28 days
Solid	TCLP	Glass 250 mL or larger, special handling for volatiles	Cool to 4° C
	Total solids	HDPE or glass, 500 mL	Cool to 4° C

5.4 Chain of Custody

Chain of Custody will be maintained for all samples collected during the verification test. The unit operators who are responsible for sample collection will fill out an NSF project approval form (See example in Appendix B) for each set of samples. The form will be signed and dated for each set of samples delivered to the PSH laboratory. The receiving technician will acknowledge receipt of the samples by signing the project approval form and providing a copy of the form to the sample delivery person. All project approval and chain of custody records will be maintained by the physical laboratory and by the chemical laboratory for all samples. Copies of the completed project approval forms will be included with all laboratory reports transmitting final analytical results.

5.5 Analytical Methods

All of the analytical methods used during the verification test will be EPA approved methods or methods from Standards Methods for the Examination of Water and Wastewater, 20th Edition. Table 5-3 shows the analytical methods that will be used for the verification test and the typical detection limits that are achieved by these methods.

Table 5-3. Analytical Methods

Constituent	Method No.	Method Detection Limit	Lab Reporting Limits	Container Type	Max. Holding Time
SSC	ASTM D-3977	5 mg/L	5 mg/L	500-mL HDPE	7 days
TSS	EPA 160.2	5 mg/L	5 mg/L	500-mL HDPE	7 days
PSD	SM 2560	N/A	1,000 particles/mL	HDPE	28 days[1]
PO_4-P	SM 4500-P	0.2 mg/L	0.2 mg/L	HDPE or Amber Glass	7 days[1]
COD	EPA 410.4	3 mg/L	3 mg/L	HDPE or Amber Glass	28 days

[1] Because of the concern of bacterial growth in the samples, analysis will be completed within 48 hours, although the method allows for a holding time of 28 days.

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 described in the Quality Assurance Project Plan (Section 6) and as outlined in the laboratory SOPs and the PSH Laboratory QA/QC Plan. Any deviations from the standard test procedures or difficulties encountered during the analyses will be documented and reported with the data.

Chapter 6
Quality Assurance and Quality Control – Project Plan

The purpose of this section is to describe the quality assurance/quality control program that will be used during the test plan to ensure that data and procedures are of measurable quality and support the quality objectives and test plan objectives for this verification test. The quality assurance activities and scope are based on the guidance provided in the protocol. The plan has been developed with guidance from the EPA's Guidance for Quality Assurance Project Plans and Guidance for the Data Quality Objectives Process. The QA/QC plan is tailored to this specific test plan and requirements for verification of the Hydro International Up-Flo™ Filter in this application. The QA/QC Plan is written as part of the test plan and should be read and used with the test plan as a reference. The test plan contains descriptions of various requirements of the QA/QC Plan, and they are incorporated by reference at several locations.

6.1 Verification Test Data – Data Quality Indicators (DQIs)

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

- 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 DQIs 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.

6.1.1 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) and/or relative percent difference (RPD) recorded from sample analyses are methods used to quantify precision. Relative percent difference is calculated by the following formula:

$$\text{RPD} = [(C_1 - C_2) / (C_1 + C_2) / 2] \times 100\% \qquad (6\text{-}1)$$

Where:

C_1 = Concentration of the compound or element in the sample
C_2 = Concentration of the compound or element in the duplicate

Field duplicates will be collected of both influent and effluent samples. The field duplicates will be collected at a frequency of one duplicate for every ten samples collected of influent and effluent. 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 6-3 shows the laboratory precision that has been established for each analytical method. The data quality objective varies from a relative percent difference of ±10% to ±30%.

6.1.2 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

The laboratory will run matrix spike samples at a frequency of one spiked sample for every 15 samples analyzed for solid and liquid samples. The laboratory will also analyze liquid and solid samples of known concentration as lab control samples. The accuracy objectives by parameter or method are shown in Table 6-3.

6.1.3 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 (Tables 5-3 and 6-1). 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.

6.1.4 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 grab samples of influent and effluent to be collected and then analyzed individually or as flow-weighted composites. The sampling locations for the grab samples are designed for easy access and for collection of a large cross section of the flow in the bottle. This design will help ensure that a representative sample of the flow is obtained in each grab sample bottle. Composite samples will be made from the grab samples. The compositing procedure includes a thorough mixing of the individual samples prior to pouring the samples in to the composite container. 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. In addition, special sample handling procedures for TSS and RP have been incorporated in the test plan to ensure composite samples for these constituents are prepared properly. These procedures include using the entire grab sample(s) for the analysis, thus having the composite made in the laboratory rather than at the time of sample collection. These special procedures are described in Section 5.3.

The laboratory setup for this test has been designed and reviewed to determine that it is representative of a typical catch basin inlet (gravity flow through a grate) and is typical of the standard application/installation for this treatment technology. The Up-Flo™ Filter unit will be operated in a manner consistent with the vendor-supplied O&M manual so that the operating conditions will be representative of 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 sampling handling and storage, review and observation of the sample collection, and review of the operating logs maintained at the test site.

6.1.5 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:

$$\text{Percent Completeness} = (V / T) \times 100\%$$

Where:

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

The goal for this data quality objective will be to achieve minimum 80% completeness for samples scheduled in the test plan.

6.2 Project Management

6.2.1 Management Team

The TO is responsible for management of the test plan including meeting the test plan objectives and the Data Quality Objectives. Section 2 of the test plan describes the key personnel involved in this ETV program and the persons responsible to implement the test plan, including a Quality Control Officer from NSF who will be responsible for audits, assessment, and review of procedures and quality data. The phone number, email address, and mailing address for each person named are given in Section 2.

6.2.2 Project Description and Objectives

A full description of the project history, the Up-Flo™ Filter technology being verified, and the objectives has been presented in Sections 1 through 3 of the test plan. A brief summary of the project is presented herein. Sections 4 and 5 describe the experimental design and the sampling and analysis plan for the verification test. The reader is referred to the test plan for more details.

The Up-Flo™ Filter is a patented treatment-train filtration device that includes screening, sediment containment and overflow protection. The catch basin configuration Up-Flo™ Filter unit is designed for use in catch basins as an in-drain treatment technology. Units can be manufactured for new or retrofit catch basin installations. Units are retrofitted into existing catch basins by removing the grate/cover, installing the components in the chamber, and replacing the cover. For new installations, a concrete catch basin with pre-assembled and installed components arrives on site and is installed in ground with a crane. Water flow enters the sump and is directed up through Angled Screens into the bottom (inlet) of the Filter Module. Floatable trash, gross debris and coarse sediment are contained in the chamber, while fine sediment and associated pollutants are captured in the Filter Module. Water then flows to the Outlet Module through the Conveyance Channel located at the top of the Filter Media. Water in the Outlet Module flows out of the chamber via a 12-inch outlet pipe.

Units are designed to trap contaminants contained in water flowing through the unit during storm events, while providing overflow protection to ensure sufficient flow can pass through the catch basin during intense storm events. Figure 3-1 shows the internal components of the catch basin configuration Up-Flo™ Filter. The treatment unit that will be tested in this verification is a full scale, commercially available, one-module catch basin unit.

The primary objective of the ETV is to measure the performance of this technology through a well-defined test plan that includes measurement of key parameters in the challenge water before and after application of the treatment technology. This objective will be accomplished by implementing the sampling and analysis program described in Section 5 and by meeting the data quality objectives described in this Quality Assurance Project Plan. The test plan includes characterizing the synthetic challenge water, installing and operating the Up-Flo™ Filter, and measuring the influent to and effluent from the unit, and all residuals removed and contained within the Up-Flo™ Filter unit. The primary parameters being measured are TSS, SSC, PSD, TP, and RP. The volume and weight of the residuals will be measured.

6.2.3 Project Schedule

The test elements for this project are divided into four (4) Phases. Phase I is a five-day test run under normal operating conditions. Phases II and IV are capacity tests that are expected to be completed in one to three days for each phase of testing. Phase III is a hydraulic capacity test and spike loading test that is expected to require one to two days of system operation. Table 5-1 shows the sampling schedule by test phase.

6.3 Measurements and Data Acquisition

6.3.1 Sample Collection and Chain of Custody

There are two basic types of samples being collected for this verification test, grab samples and flow weighted composite samples. The flow weighted composite samples will be collected by taking manual grab samples of a set volume at predetermined cumulative flow points (i.e., 10,000, 20,000, 30,000 gallons, etc.) Flow weighted composites are only being collected during Phase I, when the flow rate to the unit is held constant for all testing. Samples will be collected only when the unit is actively being dosed with water.

The grab samples for TSS and SSC will be collected in individual 250 mL HDPE bottles. All of the sample from all of the bottles will be used to run the analysis. This is necessary to insure that the heavier sand particles are included in the sample analysis. Pre-testing in the laboratory has shown that it is difficult to sub sample from a sample bottle containing sand and obtain a representative sample that includes the heavier sand. Further, the clay present in the sample tends to blind the filter paper. Therefore, the sample size must be kept small in order to pass all of the water through the filter in a reasonable time. The procedure for suspended solids analysis will be to use the entire contents of each TSS and SSC sample bottle. The volume of the sample will be recorded and the entire contents will be filtered for TSS measurement. The bottle will be rinsed to remove any remaining solids and the rinseate added to the sample being filtered. The flow weighted composite result (either one hour or eight hour composites) will be determined one of two ways. If the sample from an individual bottle filters easily, then more than one sample bottle (individual grab) may be filtered through the same filter paper. In the case of the one-hour composites, two grab samples (two collected per hour) may be filtered together, yielding a single flow weighted composite result. The same approach may be used for the eight hour composite, which will consist of four sample bottles (one every two hours) instead of two bottles. In this approach, the total mass of dry solids measured on the filter(s) will be divided by the original sample volume (without rinseate volume) of the two or four bottles to determine the TSS and SSC concentration. The alternative, if only one vial of sample (individual grab) can be passed through a filter, will be to filter each grab sample individually. The dry weight of solids from the individual samples will be added together and the total dry solids weight divided by the total sample volume (of two or four vials) to calculate the TSS concentration.

The samples for phosphorus (total and reactive) will be collected in 250-mL HDPE bottles (pre-rinsed with acid to ensure that the bottle is not a source of the phosphorus). Table 5-2 shows the bottle types, sample size, and preservation required for each parameter.

The sample bottles required for the various analyses will be provided by the PSH laboratory. The bottle will come with preservative in the bottles and labeled by analysis type. The PSH testing laboratory is in the same building as the chemical laboratory. Given the proximity of the PSH physical and chemical laboratories, samples will be hand delivered to the laboratory log in desk with appropriate chain of custody forms. The samples will be logged in and placed in refrigeration as needed. Because of the proximity of the labs, coolers with ice to maintain temperature will not be needed for interim storage or transport.

Chain of Custody will be maintained for all samples collected during the verification test. The unit operators who are responsible for sample collection will fill out a chain of custody form (See example in Appendix B) for each set of samples. The form will be signed and dated for each set of samples delivered to the PSH laboratory. The receiving technician will acknowledge receipt of the samples by signing the chain of custody and providing a copy of the form to the sample delivery person. All project approval and chain of custody records will be maintained by the physical laboratory and by the chemical laboratory for all samples. Copies of the completed project approval and chain of custody forms will be included with all laboratory reports transmitting final analytical results.

6.3.2 Analytical Methods

Analytical methods used during the verification test will be EPA approved methods or methods from Standard Methods for the Examination of Water and Wastewater, 20th Edition, while the SSC analyses will be performed in accordance with an American Society for Testing and Materials (ASTM) approved method. Table 6-1 shows the analytical methods that will be used for the verification test and the typical detection limits that are achieved by these methods.

6.3.3 Analytical Quality Control

The quality control procedures for blanks, spikes, duplicates, calibration of equipment, standards, reference check samples and other quality control measurements will follow the guidance in the EPA methods, the PSH SOP's, and the PSH Laboratory Quality Assurance Manual. Table 6-2 shows the frequency of analysis of various quality control checks. Table 6-3 shows the quality control limits that will be used by the laboratory for these analyses and to ensure compliance with the DQI for accuracy and precision. Field and laboratory duplicates will be performed at a frequency of one duplicate per ten samples collected. Samples will be spiked for accuracy determination at a frequency of one sample per fifteen samples analyzed by the laboratory. Accuracy and precision will be calculated for all data using the equations presented in Section 6.1.

Table 6-1. Analytical Methods, Reporting Limits, Container Type, and Holding Times

Constituent	Method No.	Method Detection Limit	Lab Reporting Limits	Container Type	Max. Holding Time
SSC	ASTM D-3977	5 mg/L	5 mg/L	500-mL HDPE	7 days
TSS	EPA 160.2	5 mg/L	5 mg/L	500-mL HDPE	7 days
COD	EPA 410.4	3 mg/L	3 mg/L	Amber Glass	28 days
PO_4-P	SM 4500-P	0.2 mg/L	0.2 mg/L	HDPE or Amber Glass	7 days[1]
PSD	SM 2560	N/A	1,000 particles/mL	HDPE	28 days[1]

[1] Because of the concern of bacterial growth in the samples, analysis will be completed within 48 hours, although the method allows for a holding time of 28 days.

Table 6-2. Summary of Calibration Frequency and Criteria

Analyte	Calibration	QC Frequency	Acceptable Limits
TSS and SSC	Calibrate balance daily NIST traceable weights	QC standard each run Blank	QC std within supplier specifications Blank < RDL
Particle Size Distribution	Calibrate Coulter Counter daily and with every change of aperture tube.	QC standard run (as standard addition) every 10 samples.	QC std within supplier specifications (median particle size within 0.5% of manufacturer's specification)
PO_4-P	Calibrate at start of each run Check calibration after every 10 non-calibration analyses	Initial Calibration: Check: mid-range standard from alternative source standard (CCV) blank	Continuing: CCV ±10% of Theoretical value Blank <RDL
COD	Calibrate at start of each run Check calibration after every 10 non-calibration analyses	Initial Calibration: Three point standard curve, blank Continuing Calibration Check: mid-range standard from(CCV) blank	Initial: Correl. Coeff. ≥0.995 Blank <RDL Continuing: CCV ±20% of Theo. Value Blank <RDL

Table 6-3. Summary Of Analytical Accuracy and Precision Limits

Sample Matrix	Analyte	Reference Method	Accuracy (% Recovery)	Precision RPD
Water	TSS	EPA 160.2	N/A	0-30
	SSC	ASTM D-3977	NA	0-30
	PSD	N/A	N/A	N/A
	TP, RP	SM 4500-P	80-150	0-10
	COD	EPA 410.4	80-120	0-20
Solids	TCLP	SW 846-1311	Varies by matrix	
	Total Solids		N/A	0-30

N/A - Not applicable

Laboratory blank water of known quality will be used for all laboratory analyses and water for final sample bottle rinsing for the TSS analysis. If contamination is detected in the blank water, the analysis will be stopped and the problem corrected. Laboratory blanks, method blanks and any other blank water data must be reported with all analytical results. One set of field blanks will be prepared and analyzed to verify bottle cleanliness and sample handling in the physical lab. One complete set of bottles (for all analyses) will be filled with distilled or deionized water and submitted for analyses. Travel blank samples will be collected randomly and sent with samples to be analyzed at the subcontract laboratory.

Laboratory control samples where applicable will be used to verify that the methods are performing properly. The control samples will be blank water spiked with constituents from standards obtained from certified source material. Lab control samples will be carried through the entire analysis including the digestion step in the case of the solid matrix.

Calibration for the various analyses will be based on a confirming minimum three-point calibration curve in the linear range of the method and instrument as detailed in the SOPs. The calibration sequence includes a method blank, three-five point calibration curve, and a standard check sample prepared from a secondary source, which must be within the limits shown in Table 6-2. The calibration is checked after each group of ten samples. If the calibration check results fall outside the acceptance criteria, the instrument is recalibrated and the affected samples are analyzed again. Table 6-2 provides calibration information and other run sequence information.

Balances are calibrated each day with NIST traceable weights. A calibration logbook is maintained to demonstrate the balances are accurate.

6.3.4 Data Reduction, Handling, and Reporting

All analytical results will be reported in standard units of mg/L, ug/L, mg, grams, etc. Flow rates and volumes will be reported as gallons and gallons per minute. Analysis of solids will clearly indicate if the concentration is on a dry weight or weight basis.

6.3.4.1 Documentation

All of the field and laboratory activities will be thoroughly documented by the use of field logbooks, project approval/chain of custody sheets, laboratory notebooks and bench sheets, and instrument records.

A field logbook will be maintained at the PSH laboratory. Daily activity entries will be made in the logbook documenting operating conditions, observations, and maintenance activities, if any are needed. Each sample collected will be noted in the logbook and any other pertinent information will be recorded. Completed pages in the logbook will be signed and dated.

Original project approval and chain of custody forms will accompany all sample(s) sent to the chemical laboratory and will be maintained by the TO. The laboratory will produce a final data report that includes all chemical test results, physical measurements, QA/QC data for blanks, accuracy (recovery), and precision (percent difference), and lab control or matrix check samples. Any deviations from the standard protocols will be discussed in a narrative, any data that does not meet the QA/QC requirements will be flagged, and a narrative will be prepared discussing the findings of any corrective action.

The laboratory will maintain all logbooks, bench sheets, instrument printouts, etc. in accordance with the PSH laboratory QA/QC Manual. The QA/QC or Laboratory Coordinator will make these records available for inspection upon request.

6.3.4.2 Document Handling

During the test period the original field logbook will be kept at the physical laboratory. At the end of the test period, the original logbook will be sent to the NSF VO manager for storage in a secure central project file. Original laboratory data reports with the original project approval forms and chain of custody will be placed in the central project file at PSH. Copies of these reports and any electronic data will be sent to the Project Manager (TO) and QA/QC officer for review. Other copies of the data or logbooks may be distributed to other project team members.

6.3.4.3 Data Reduction and Validation

All measurements and analytical results will be reported in units that are consistent with the methods used and as shown in Table 6-4. The laboratory analysts will record raw data in laboratory notebooks or bench sheets using standard formats. Each analytical method will contain instructions for recording and calculating the results. The laboratory analyst will have primary responsibility to verify that the results recorded are accurate. Data review and QA/QC review will be the responsibility of the PSH laboratory staff following the PSH standard data review and verification procedures for the laboratory. Data transcribed for entry to a computerized database will be checked against the lab bench sheets or instrument printouts by a second person. The same procedure will be followed for any electronic reporting of data, such as the Excel spreadsheet that is required for final data submittal. The final data report will be signed by an authorized laboratory manager/supervisor in accordance with laboratory policy.

The final data reports and electronic data received by the project team from the laboratory will be 100% checked. The Project Manager (TO) or designee will cross check 100% of the data in the final reports from the laboratory with a printout of the spreadsheet provided by the laboratory. The QA/QC officer for the VO will review the final data reports and all QA/QC information. The QA/QC officer will issue a QA/QC review report discussing the quality of the data, how it compares to the Data Quality Objectives, and any data that should be flagged as invalid or questionable. The VO Project Coordinator will back check 100% of the draft verification report data tables and calculations with the laboratory data and spreadsheets provided by the TO.

6.4 Assessments

The project QA/QC officer or a designee will be responsible for making announced and unannounced laboratory audits to observe adherence to the cleaning/operational protocols, sample collection methodology, sample handling practices, and analytical procedures detailed in the test plan. The QA/QC Officer will review logbooks and final data reports to ensure that these records meet the DQI requirements and other requirements for the test plan. The Project Manager (TO) or a designee and the QA/QC Officer (part of the TO team) will validate data, as it is received from the laboratory.

The PSH laboratory has an assessment program consisting of internal audits, while the NSF laboratory has an assessment program that includes internal and external audits, Quality reports to management, and other internal checks are part the system used to ensure the NSF QA/QC procedures are being implemented and maintained. The NSF 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.

At least one audit will be conducted by the VO 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 sampling logbook(s). A written report will be prepared by the auditor and submitted to the QA/QC Officer and the Project Coordinator. At least one lab audit will be performed during the test to observe sample receipt, handling, storage, and to confirm that the proper analytical methods, QA/QC procedures and calibrations are being used.

6.5 Corrective Action

Testing-related activities that could require corrective action include problems with sample collection, labeling, and improper entries or missed entries in logbooks or operational problems with the unit. The primary person responsible for monitoring these activities will be Brad Mikula with audits by the NSF designated staff. If a problem occurs, the problem will be noted in the sampling logbook and Mr. Mikula will notify the VO in all cases and the vendor in the case of Up-Flo™ Filter unit operating issues. The problem, once identified will be corrected. If a change in sampling protocol related to sample collection or handling is needed, the change will be approved by the VO Project Manager. All corrective action required will be thoroughly documented and discussed in the verification report.

Laboratory corrective action will be taken 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; and/or
- Data reporting or calculations are determined to be incorrect.

The PSH laboratory has a formal Corrective Action Plan as part of the QA/QC Manual. These procedures will be followed including notifying the laboratory QA/QC Manager and the TO's QA/QC Officer. All corrective action will be thoroughly documented and reported to the Test Organization. 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 testing laboratory or in the analytical 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 make a determination 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 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. The response by the VO will be in writing by email, fax, or letter.

Chapter 7
Data Management and Analysis

Several types of data will be collected or generated during the testing periods of this test plan. Quantitative data, including flow data, influent and effluent water quality data, type and amount of residuals generated, etc., will be measured and reported by the laboratory. Qualitative data describing the setup, operation, and maintenance of the Up-Flo™ Filter unit will collected in the laboratory throughout the test period. All of this information will be managed during the verification using methods outlined in this section.

7.1 Data Management

The data being collected during this verification will include both manual and electronic data collection and storage methods. Laboratory notebooks will be maintained to document all activities related to the sampling, operation, and maintenance activities at the site, and to document sample handling, equipment calibrations, and other related activities in the laboratory. Laboratory results will be reported in paper reports showing all of results and QA findings for each set of data. These results will then be entered into Excel spreadsheets for ease of analysis and storage.

All samples collected in the laboratory will be assigned a specific identification number that will be used to track and record the data throughout the collection, analysis, and data reporting steps. The numbering system will include the use of an identifier for the test phase associated with the sample (characterization or verification), an identifier of sample type (solid, liquid, residual), sample location (influent, effluent) and the date of collection. The sampling personnel will assign the sample number for all samples collected on-site. The samples collected will have a clear label with the sample number and date on the label. The project approval form and/or chain of custody sheet accompanying the sample(s) from the test lab to the analytical laboratory will also show this sample identification number. The analytical laboratory will also be generating samples and sub-samples during the test. The analytical laboratory will assign unique identification numbers to these sub-samples that will clearly identify their nature and will tie back directly to the sample identification assigned in the testing laboratory. The laboratory data reports will show the sample identification numbers and will include copies of the project approval and chain of custody forms that clearly track the sample names from their assignment in the field through the analysis in the laboratory.

7.1.1 Manual Data Collection

All data collection, observations, and sample records will be written in a logbook maintained at the site by sampling personnel. Copies of these records will then be reviewed by the Project Manager (TO) or a designee to ensure the records are being properly maintained. At the end of the verification test, the sampling log will become part of the permanent record.

The laboratory will use laboratory notebooks to record all manual data and related information in accordance with good laboratory practice and the laboratory QA/QC and SOP documents. The laboratory logbooks will be available for review by the Quality Assurance Officer or Project Coordinator at any time. The analytical laboratory will be responsible for maintaining and archiving the notebooks and manual records that support the data reported by the laboratory. The original project approval and chain of custody records and any appropriate supporting documents will be provided with the data reports. The data reports will include a discussion of any problems that occurred during the analysis, corrective action taken, and any other factors that could impact the data. The laboratory reports will include all QA/QC results, including blanks, spikes, duplicates, check samples, etc., such that the Quality Control Officer can validate the data and make an independent opinion as to the quality and acceptability of the data.

7.1.2 Electronic Data Collection

The laboratory will provide the analytical results in both hard copy reports and in electronic format. The data will be entered into an Excel spreadsheet in a format that will be finalized and provided by the laboratory coordinator. The laboratory will verify the data in the spreadsheet by comparing a print out of the spreadsheet with the hard copy results and their supporting documents prior to release of the data.

Upon receipt of the laboratory reports and spreadsheets, the Project Manager (TO), QA Officer or their designee will verify the accuracy of the data. A direct comparison of the hard copy data and the electronic spreadsheet will be made. Any corrections required will be written on the print out of the spreadsheet and the corrections made to the spreadsheet.

7.2 Data Analysis and Presentation

All results, including statistical analysis, will be provided in the verification report. Any data that was excluded in statistical analysis will be reported with an explanation as to why it was not included in the analysis. The data obtained during verification testing will be statistically analyzed, reduced, and presented in tables, graphs and charts. All raw data will be included as an appendix to the verification report. The statistical methods and any statistical programs used will be described in the verification report. A detailed discussion of the results will accompany the tables, graphs and/or charts and shall be presented in the verification report (see Section 7.3). Conclusions drawn from the analysis of the test results will be presented in the verification report.

7.2.1 Flow Data

Flow data will be collected by the physical laboratory during all four phases of verification testing. The total flows and flow rate for each Phase, day, or activity will be summarized in a spreadsheet. The results will be presented in the final report as a table showing average, maximum and minimum daily flow.

7.2.2 Treatment Performance Quality Data

Valid challenge water quality data obtained during the verification test will be analyzed and presented as follows:

- Tables showing the average, maximum and minimum influent concentration for the sampling events for the target contaminate list;
- Tables showing the average, maximum and minimum effluent concentration for the sampling events and removal efficiency for the target contaminate list;
- Table(s) showing the mass of the residual stream.

7.2.3 Operations and Maintenance Parameters

Results of monitoring operation and maintenance parameters during verification testing shall be presented in a discussion format. The verification report will include a thorough discussion of any difficulties encountered in operating or maintaining the unit during the verification test. Discussion will include observations regarding the ease/difficulty of installation, and factors, such as operator training, presentation clarity in the O&M manual, etc.

7.2.4 Equations

The data analysis will include the calculations of removal efficiency and various statistics. The equations to be used in the data analysis are provided below.

7.3 Verification Report

The verification report will be a document containing all raw and analyzed data, all QA/QC data sheets, a description of all types of data collected, a detailed description of the testing procedure and methods, results and QA/QC results. The Report will thoroughly present and discuss the findings of the verification test. Conclusions regarding the performance of the Up-Flo™ Filter will be made and compared with the performance goals for the verification test.

It is expected that the verification report will contain the following main sections. There may be some deviation from the order given below in order to present the findings in a clear and precise manner. Additional sections will added as needed to properly present all of the findings.

- Verification Statement
- Preface
- Glossary
- Acknowledgements
- Executive Summary
- Introduction and Background
- Procedures and Methods Used In Testing (summarizing essential information from the test plan)
- Results and Discussion
- Limitations
- Conclusions
- Recommendations
- References

- Appendices
    - Raw Data
    - Special Laboratory Procedures – Standard Operating Procedures
    - QA/QC Manual/Procedures
    - O&M Manual
    - Sampling logs and supporting documentation as appropriate

References

1. NSF International, *Protocol for the Verification of In-Drain Treatment Technologies*, April 2001, Ann Arbor, Michigan.

2. United States Environmental Protection Agency: *Environmental Technology Verification Program - Quality and Management Plan for the Pilot Period (1995 – 2000),* EPA/600/R-98/064, 1998. Office of Research and Development, Cincinnati, Ohio.

3. NSF International, *Environmental Technology Verification – Source Water Protection Technologies Pilot Quality Management Plan*, 2000. Ann Arbor, Michigan.

4. United States Environmental Protection Agency: *Methods and Guidance for Analysis of Water,* EPA 821-C-99-008, 1999. Office of Water, Washington, DC.

5. United States Environmental Protection Agency*: Methods for Chemical Analysis of Water and Wastes,* Revised March 1983, EPA 600/4-79-020.

6. United States Environmental Protection Agency*: Test Methods for Evaluating Solid Waste: Physical/Chemical Methods 3rd ed - 4 vols.,* November 1986, Final Update IIB and Proposed Update III, January 1995.

7. APHA, AWWA, and WEF: *Standard Methods for the Examination of Water and Wastewater, 20th Edition,* 1998. Washington, DC.

8. United States Environmental Protection Agency: *EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5*, EPA/600/R-98-018, 1998. Office of Research and Development, Washington, DC.

9. United States Environmental Protection Agency, *Guidance for the Data Quality Objectives Process, EPA QA/G-4*, EPA/600/R-96-055, 1996. Office of Research and Development, Washington, DC.

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.

Commissioning – the installation of the in-drain treatment technology and start-up of the technology using test site challenge water.

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

Completeness – a qualitative 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.

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 in drain treatment technologies.

Testing Organization – an independent organization qualified by the Verification Organization to conduct studies and testing in accordance with protocols and test plans.

Vendor – a business that assembles or sells in drain 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 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	Up-Flo™ Filter O & M Manual
B	Chain of Custody Form