APPENDIX M

Project Quality Assurance Project Plan

QUALITY ASSURANCE PROJECT PLAN

Filterra® Bioretention System Phosphorus Treatment and Supplemental Basic and Enhanced Treatment Performance Monitoring

Prepared for

Americast, Inc.

June 2012

Note:
Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

QUALITY ASSURANCE PROJECT PLAN

Filterra® Bioretention System Phosphorus Treatment and Supplemental Basic and Enhanced Treatment Performance Monitoring

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June 7, 2012

Title and Approval Sheet

Title: Quality Assurance Project Plan: Filterra Bioretention Filtration System Phosphorus Treatment Performance Monitoring

Author: Herrera Environmental Consultants, Inc., Seattle, Washington

Date: June 7, 2012

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Introduction

The Washington State Department of Ecology (Ecology) has established specific use designations for emerging stormwater treatment technologies in accordance with guidelines identified by Ecology (2011) in the Technology Assessment Protocol – Ecology (TAPE). These use designations allow limited application of emerging stormwater treatment technologies in western Washington to facilitate field testing. If testing shows that the treatment technology meets minimum treatment goals identified in the TAPE, Ecology may issue a general use level designation (GULD) for the technology that permits more widespread use in western Washington.

In December 2009, Americast, Inc. received the following use designations from Ecology for the Filterra stormwater treatment system (Ecology 2009):

- A GULD for basic, enhanced (dissolved metals), and oil treatment
- A conditional use level designation (CULD) for phosphorus treatment

As a condition of the CULD, Ecology requires preparation of a Quality Assurance Project Plan (QAPP) that describes testing procedures used to verify that the phosphorus treatment performance of the Filterra system meets requirements identified in the TAPE (Ecology 2011) for obtaining a GULD. In addition to the CULD monitoring for phosphorus, the Filterra system will also be monitored for the required parameters for basic and dissolved metals treatment in order to demonstrate pollutant removal performance at a higher infiltration rate than the current GULD approval. This QAPP was prepared in accordance with Ecology's *Guidelines for Preparing Quality Assurance Project Plans* (Ecology 2004), and documents sample collection, processing, and analysis procedures to ensure that resulting data are scientifically and legally defensible. This document is organized as follows:

- Background
- Project Description
- Organization and Schedule
- Quality Objectives
- Experimental Design
- Sampling Procedures
- Measurement Procedures
- Quality Control
- Data Management Procedures
- Audits and Reports
- Data Verification and Validation
- Data Quality Assessment
- References

Monitoring of the installed test system is expected to begin in 2012 and continue through 2013. After monitoring is complete, a Technical Evaluation Report (TER) analyzing collected data will be prepared to compare Filterra system performance to the performance goals specified in the TAPE. The TER will be submitted to Ecology by the December 1, 2013, deadline.

Background

This section provides a detailed description of the Filterra system, briefly summarizes the results of previous laboratory testing and field monitoring, and provides recommendations on operation and maintenance of the Filterra system.

Technology Description

The Filterra Bioretention System is a self-contained stormwater treatment system manufactured by Americast, Inc. The technology packages soil media, plants and drainage infrastructure found in typical bioretention best management practices (BMPs) into a prefabricated concrete housing. The Filterra system is a flow-through stormwater treatment device intended to remove suspended sediments, nutrients, heavy metals, and oil and grease from stormwater flows within small-scale catchments like parking lots and streetscapes (Figure 1).

Figure 1. Typical Filterra stormwater treatment applications.

The Filterra unit is available in a range of sizes (see design drawings in Appendix A). The standard configuration has a 6 x 6 foot surface area, but actual dimensions of the performance monitoring unit will be determined based upon site and installation requirements. The filter media for the standard unit consists of a 3-inch mulch layer, 21 inches of specially engineered soil media, and 6 inches of gravel, which provides a bed for the perforated underdrain. The shredded wooden mulch and engineered soil media composition are consistent with the standard Filterra design specifications tested at the Port of Tacoma for GULD approval. The Filterra unit also includes specified vegetation that may include flowers, grasses, a shrub or tree. Vegetation will be selected based on treatment needs, aesthetics, and local climatic conditions.

The Filterra system provides water quality treatment of captured flows through a broad assortment of physical, chemical, and biological unit processes including sedimentation, filtration, adsorption, volatilization, evapotranspiration and biological measures supported by the high organic content of the soil media and the vegetative substrate (Figure 2). The overall stormwater treatment performance of the Filterra system depends on a balance between flow-through capacity (the percentage of total runoff volume captured) and the ability of the plant/soil/microbial complex to remove target pollutants from the captured runoff.

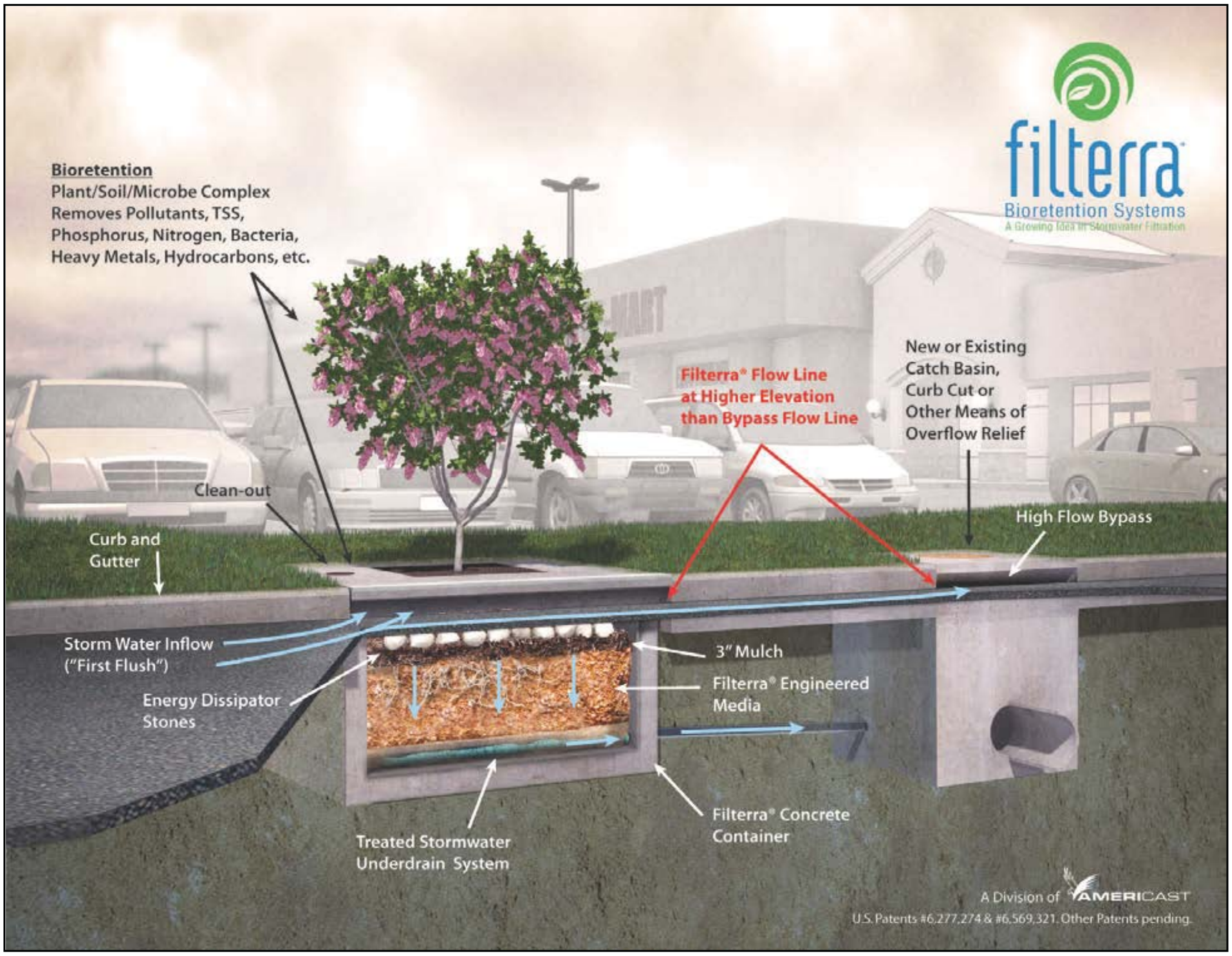

Figure 2. Typical Filterra system design.

A comprehensive technical summary of the unit processes (hydraulic and treatment) in the Filterra system, and previously reported performance data and a summary of operation and maintenance (O&M) procedures, are provided in the State of Washington Department of Ecology Application for Conditional Use Designation (Americast, Inc. 2006).

Results of Previous Studies

Field testing and laboratory testing show that the Filterra system is promising as a stormwater treatment BMP and can meet Ecology's performance goals for phosphorus treatment. The following are the Findings of Fact as reported in the original use level designation letter that are specifically related to phosphorus (Ecology 2006):

- The field data showed an average removal of 52 percent for total phosphorus with an average influent of 0.11 ± 0.05 milligrams per liter (mg/L).
- Laboratory testing was performed on a scaled down version of the Filterra unit. The lab data showed an average removal from 50 to 61 percent for soluble reactive phosphorus with influents ranging from 2.46 to 14.37 mg/L.

Findings of Fact reported in the revised use level designation letter that are specifically related to phosphorus include the following (Ecology 2009):

- The field data showed low percentage removals of total phosphorus at all storm flows at an average influent concentration of 0.189 mg/L (average effluent concentration of 0.171 mg/L). The relatively poor treatment performance of the Filterra system at this location may be related to influent characteristics for total phosphorus that are unique to the Port of Tacoma site. It appears that the Filterra system will not meet the 50 percent removal performance goal when the majority of phosphorus in the runoff is expected to be in the dissolved form.
- Laboratory testing was performed on a scaled down version of the Filterra unit. The lab data showed an average removal from 50 to 61 percent for orthophosphate with influents ranging from 2.46 to 14.37 mg/L.

Operation and Maintenance

Routine, semi-annual maintenance for the Filterra system is recommended. Maintenance procedures should follow those in the most recent version of the Filterra Installation, Operation, and Maintenance Manual. The only tools required to perform maintenance activities are typical landscaping tools, including a rake, shovel, and pruning tools. One person can typically perform required maintenance in 30 to 45 minutes.

The following are specific maintenance procedures to be completed:

1. Open tree grate and inspect. The tree or shrub may need to be trimmed back to allow for easy access through the tree grate opening.
2. Remove accumulated trash and degraded 3-inch mulch layer using a rake and shovel.

3. Add fresh 3-inch mulch layer, consisting of shredded wooden mulch purchased from local gardening and home improvement stores.

4. Replace tree grate, sweep, and record maintenance details.

Each Filterra system must receive adequate irrigation to ensure survival of the living system during periods of drier weather. This may be achieved through a piped system, gutter flow, or through the tree grate. In general, irrigation needs should be the same as that of the surrounding landscaping (i.e., if the landscaping is being watered, the Filterra system should also be watered).

Americast, Inc. provides Filterra customers with a complete installation, operation and maintenance manual and 1-year maintenance plan. Americast also offers an extended maintenance service contract and maintenance training based on the Installation, Operation, and Maintenance Manual for those who wish to perform their own maintenance.

Project Description

The purpose of this monitoring program is to verify the phosphorus treatment performance of the Filterra system pursuant to requirements identified in the TAPE (Ecology 2011) for obtaining a GULD. The Filterra system has already been issued the following designations (Ecology 2009):

- **GULD for basic (total suspended solids [TSS]), enhanced, and oil treatment**. May be used anywhere in Washington, subject to Ecology's conditions. The current GULD applies to the infiltration rates summarized in Table 1.

- **CULD for phosphorus treatment**. May be issued for emerging technologies that have a considerable amount of performance data, but does not necessary fully meet the TAPE protocol. A CULD allows for continued use of the technology for a specified time period during which field testing must be completed.

Table 1. Approved hydraulic conductivity and infiltration rates for approved Filterra system installations and the proposed monitoring.

Treatment Category	Hydraulic Conductivity (inches/hour)	Infiltration Rate (inches/hour)
Current GULD approval for Basic and Oil Treatment	35.46	50
Current GULD approval for Enhanced Treatment	24.82	35
Proposed monitoring for Basic, Enhanced, and Phosphorus Treatment	**70.9**	**100**

The TAPE program establishes a testing protocol and process for evaluating new and emerging stormwater treatment technologies. A CULD certification approves qualifying technologies for use (within the state of Washington) in a performance monitoring study, in accordance with the TAPE protocol. A monitoring site in Bellingham, Washington has been selected for evaluating the phosphorus treatment performance of the Filterra system. Supplemental data will also be obtained from monitoring at this site to evaluate basic and enhanced treatment performance at higher flow rates than were observed during the previous monitoring study (Herrera 2009) for the TAPE program (Table 1).

The minimum water quality parameters required by the TAPE (2011) guidelines will be monitored at this site and include:

- TSS
- Total phosphorus
- Soluble reactive phosphorus (SRP)
- Hardness

- Total and dissolved copper and zinc
- Screening parameters (particle size distribution [PSD] and pH)

The pollutant removal effectiveness of the Filterra system will be demonstrated through field testing of the system. The objectives of the field study include:

- Characterizing the pollutant removal effectiveness and effluent quality of the system at a range of flow rates (50 to 125 percent of the design infiltration rate of 100 inches/hour: 50 to 125 inches/hour) for TSS, dissolved metals (copper and zinc), total phosphorus, and SRP

- Provide data that demonstrates the phosphorus removal effectiveness of the system based on event mean concentrations (EMCs)

To yield a representative performance assessment of the Filterra system, the ideal test drainage area will generate sufficient concentrations of the pollutants being assessed. Previous monitoring at the Bellingham, Washington site has shown that total phosphorus concentrations typically fall within the 0.1 to 0.5 milligram per liter (mg/L) range required by TAPE. Total suspended solids concentrations are usually in the 20 to 100 mg/L range, but sometimes fall below the minimum TAPE concentration of 20 mg/L. Limited dissolved metals data has been collected at this location; thus, this is a potential constraint of the selected monitoring site. Out of the two samples that have been collected for dissolved metals, the detection limit for dissolved copper was at the upper end of the acceptable influent range (0.02 mg/L) and the influent dissolved zinc data was lower than the required 0.02 mg/L concentration; therefore, it is difficult to tell if there are sufficient dissolved metals concentrations in this basin for evaluating the enhanced treatment performance goal. Other constraints such as seasonal or meteorological conditions, site access, safety, and availability of personnel or equipment are not expected to be an issue for this monitoring program.

Organization and Schedule

Americast, Inc. has asked Herrera Environmental Consultants, Inc. (Herrera) to serve as an independent technical professional to assist with evaluation and field sampling for the Filterra system. Aquatic Research, Inc. will provide analytical laboratory services for the majority of the water quality analysis, and Analytical Resources, Inc. will perform the particle size distribution (PSD) analysis. Project organization and personnel for this study are identified in Table 2.

Table 2. Project organization and key personnel.

Title	Name	Affiliation
Client Project Manager	Mindy Ruby	Americast, Inc.
Client Supervisor	Will Harris	Americast, Inc.
Test Site Contact	Bill Reilly	City of Bellingham
Herrera Principal-in-Charge	John Lenth	Herrera
Herrera Project Manager	Rebecca Dugopolski	Herrera
Herrera Monitoring Lead	Dan Bennett	Herrera
Herrera Water Quality Data Quality Assurance Lead	Gina Catarra	Herrera
Herrera Flow Data Quality Assurance Lead	Dylan Ahearn	Herrera
Herrera Data Management Lead	David Yu	Herrera
Herrera Field Sampling Support	Alex Svendsen	Herrera
Analytical Laboratory Quality Assurance Officer	Damien Gadomski	Aquatic Research, Inc.
Analytical Laboratory Quality Assurance Officer	Mark Harris	Analytical Resources, Inc.

Responsibilities

Client Project Manager – Mindy Ruby

Mindy Ruby will oversee project progress and lead agency project personnel, and review and comment on the technical work and deliverables. She will be the primary point of contact for Americast, Inc.

Client Supervisor – Will Harris

Will Harris will provide a senior review of technical work and deliverables throughout all phases of the project and will assistant in the project management coordination for Americast, Inc.

Test Site Contact – Bill Reilly

Bill Reilly will provide information on the current Filterra installation and contributing drainage area. He will review the site modifications necessary to facilitate monitoring at the site to ensure that it is consistent with City of Bellingham requirements.

Herrera Principal-in-Charge – John Lenth

John Lenth will provide senior quality assurance review of technical work and deliverables throughout all phases of the project.

Herrera Project Manager – Rebecca Dugopolski

Rebecca Dugopolski will direct all technical work related to the project and will be the primary point of contact for Americast, Inc. for issues related to project management.

Herrera Monitoring Lead – Dan Bennett

Dan Bennett will coordinate all field work related to this project including site visits for routine equipment maintenance, storm sampling, and equipment troubleshooting.

Herrera Water Quality Data Quality Assurance Lead – Gina Catarra

Gina Catarra will independently review water quality data entry (laboratory reports compared to electronic files) and will review quality assurance worksheets to determine appropriate response actions to any quality assurance issues.

Herrera Flow Data Quality Assurance Lead – Dylan Ahearn

Dylan Ahearn will perform routine audits on flow data compiled throughout the project to ensure all monitoring equipment is functioning as designed. He will also perform a final quality assurance review on these data to assess their accuracy and determine their usability for subsequent analysis related to system performance evaluations.

Herrera Data Management Lead – David Yu

David Yu will coordinate data management and assist with statistical analysis as needed.

Herrera Field Sampling Support – Alex Svendsen

Alex Svendsen will:

- Assist with setup of monitoring sites
- Assist with equipment maintenance
- Collect flow and water quality data
- Track quality assurance, including preliminary review of field and laboratory data, document sample collection procedures and quality assurance/quality control measures
- Maintain field records

Analytical Laboratory Quality Assurance Officer – Damien Gadomski and Mark Harris

Damien Gadomski and Mark Harris will:

- Track samples and results in the laboratory
- Provide properly cleaned sample bottles with appropriate preservatives
- Evaluate laboratory compliance with this QAPP and laboratory quality assurance plan
- Report discrepancies to the Herrera Project Manager
- Transmit laboratory results to the Herrera Project Manager

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Schedule

The estimated project schedule for the Filterra monitoring program is outlined in Table 3.

Table 3. Project milestones.

Project Milestone	Date Completed
Submit draft QAPP to Ecology	November 15, 2011
Finalize QAPP based on comments from Ecology	June 2012
Conduct performance monitoring	August 2012 – September 2013
Monitoring equipment installation and test system modification	July– August 2012
Expected sampling start date	August 10, 2012
Projected sampling end date	September 30, 2013
Complete analysis of monitoring data and performance evaluation	November 15, 2013
Submit draft TER to Ecology	December 1, 2013
Phosphorus CULD expires	December 1, 2014

Quality Objectives

The goal of this QAPP is to ensure that data collected through this study are scientifically accurate and legally defensible. To meet this goal, the collected data will be evaluated using the following quality assurance objectives:

- **Precision**: A measure of the variability in the results of replicate measurements due to random error.
- **Bias**: The systematic or persistent distortion of a measurement process which causes errors in one direction (i.e., the expected measurement is different from the true value).
- **Representativeness**: The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency, and sampling methods.
- **Completeness**: The amount of data obtained from the measurement system.
- **Comparability**: The ability to compare data from the current project to data from other similar projects, regulatory requirements, and historical data.

Method Quality Objectives (MQOs) are performance or acceptance criteria that are established for each of these quality assurance objectives. The specific MQOs that have been identified for this project are described below and summarized in Table 4.

Precision

Precision will be assessed using laboratory and field duplicates. Precision for laboratory duplicates will be ± 25 percent relative percent difference (RPD) for TSS, ± 10 percent for pH, and ± 20 percent for all other water quality parameters. Precision for field duplicates will be ± 15 percent RPD for pH and ± 25 percent for all other water quality parameters. In all cases, the RPD of duplicate samples will be calculated using the following equation:

$$RPD = \frac{(C_1 - C_2) \text{ x } 100\%}{(C_1 + C_2)/2}$$

where: RPD = relative percent difference

C_1 = larger of two values

C_2 = smaller of two values

Table 4. Method quality objectives for water quality data.

Parameter	Detection Limit	Units	Method Blank	Rinsate Blank	Control Standard Recovery	Matrix Spike/ Duplicate Matrix Spike Recovery	Laboratory Duplicate RPD [a]	Field Duplicate RPD [a]
Total suspended solids	0.5	mg/L	<RL	<2 x RL	90 - 110%	NA	≤25% or ± 2 x RL	≤25% or ± 2 x RL
Total phosphorus	0.002	mg/L	<RL	<2 x RL	90 - 110%	75 - 125%	≤20% or ± 2 x RL	≤25% or ± 2 x RL
Soluble reactive phosphorus	0.001	mg/L	<RL	<2 x RL	90 - 110%	75 - 125%	≤20% or ± 2 x RL	≤25% or ± 2 x RL
Hardness	2	mg/L	<RL	NA	90 - 110%	75 - 125%	≤20% or ± 2 x RL	≤25% or ± 2 x RL
Copper, dissolved Copper, total	0.001	mg/L	<RL	<2 x RL	90 - 110%	75 - 125%	≤20% or ± 2 x RL	≤25% or ± 2 x RL
Zinc, dissolved Zinc, total	0.005	mg/L	<RL	<2 x RL	90 - 110%	75 - 125%	≤20% or ± 2 x RL	≤25% or ± 2 x RL
pH	NA	std. units	<RL	NA	NA	NA	≤10% or ± 2 x RL	≤15% or ± 2 x RL
Particle size distribution	0.5	microns	NA	NA	NA	NA	NA	NA

[a] The relative percent difference will be less than or equal to the indicated percentage for values greater than 5 times the reporting limit, and ± 2 time the reporting limit for values less than or equal to 5 times the reporting limit.

mg/L = milligrams per liter

std. units = standard units

RL = reporting limit

RPD = relative percent difference

NA = not applicable

Bias

Bias will be assessed based on analyses of method blanks, matrix spikes, and control standards. Method blank values will not exceed the reporting limit. The percent recovery of matrix spikes will be ± 25 percent for total phosphorus, SRP, hardness, and total and dissolved metals. Duplicate matrix spikes will also be run on a portion of the samples. The laboratory control sample recovery will be ± 10 percent for TSS, total phosphorus, SRP, hardness, and total and dissolved metals. Percent recovery for matrix spikes will be calculated using the following equation:

$$\%R = \frac{(S - U) \times 100\%}{C_{sa}}$$

where:

where:	%R	=	percent recovery
	S	=	measured concentration in spike sample
	U	=	measured concentration in unspiked sample
	C_{sa}	=	actual concentration of spike added

If the analyte is not detected in the unspiked sample, then a value of zero will be used in the equation.

Percent recovery for control standards will be calculated using the following equation:

$$\%R = \frac{(M) \times 100\%}{T}$$

where:	%R	=	percent recovery
	M	=	measured value
	T	=	true value

Representativeness

Sampling events will be selected to represent a range of rainfall volume and intensity conditions to ensure representative data and to meet or exceed TAPE guidelines. The following guidelines will be used for defining the acceptability of specific storm events for sampling and are identical to those identified in the TAPE guidelines (Ecology 2011):

- **Target storm depth**: A minimum of 0.15 inches of precipitation.
- **Storm start (antecedent conditions)**: A period of at least 6 hours preceding the storm event with less than 0.04 inches of precipitation.

- **Storm end (post storm dry period)**: A period of at least 6 hours at the end of the storm event with less than 0.04 inches of precipitation.
- **Minimum duration**: Target storms must have a duration of at least 1 hour.

The following sample collection requirements for automated sampling will also be used to ensure the representativeness of flow-proportional composite samples and are identical to those identified in TAPE guidelines (Ecology 2011):

- **Minimum aliquot number**: 10 aliquots.
- **Storm event coverage**: For storm events lasting less than 24 hours, samples shall be collected for at least 75 percent of the storm event hydrograph (by volume). For storm events lasting longer than 24 hours, samples shall be collected for at least 75 percent of the hydrograph (by volume) of the first 24 hours of the storm.
- **Maximum sampling duration**: 36 hours.
- **Minimum number of samples**: 12 samples.

Sample collection requirements for discrete flow sampling include the following:

- **Design hydraulic loading rate**: 50 to 125 percent.
- **Minimum number of samples**: None; however, a sufficient number of samples must be collected to develop regression equations to evaluate pollutant removal as a function of flow rate.
- **Influent concentrations**: Similar to influent concentrations measured during flow-proportional composite sampling. Concentrations must also meet the influent concentration ranges specified in TAPE (2011).

Data from a minimum of 12 storms is considered adequate to meet sampling program objectives, if the samples meet the specified influent concentration ranges and the storm event guidelines provided above.

Completeness

A minimum of 95 percent of the samples submitted to the laboratory will be judged valid. An equipment checklist will be used to prevent loss of data resulting from missing containers or inoperable instruments prior to embarking on field sampling trips. Automatic recording equipment will be checked regularly to ensure that it is in good working order.

Comparability

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate analysis and comparison with water quality threshold limits (e.g., WAC 173-201A).

Experimental Design

This section of the QAPP provides background information on the selected monitoring site and discusses the equipment that will be used to facilitate precipitation monitoring, flow monitoring, and water sampling. Accumulated sediment sampling is not included in the experimental design since it is not feasible based on the design of the Filterra system.

Monitoring Site

Americast, Inc. intends to monitor their Filterra system installation located on Hayward Drive in Bellingham, Washington to obtain data on phosphorus treatment performance and supplemental data for basic and enhanced treatment. This section provides background information on the location and drainage basin, baseline stormwater data, and treatment system sizing.

Location and Drainage Basin Characteristics

As shown in Figure 3, the Filterra test system is located on the northwest end of Lake Whatcom near the intersection of Hayward Drive and Northshore Drive in Bellingham, Washington (latitude = 48°46’6.70” N, longitude = 122°24’16.16” W). Figure 4 shows a photograph of the 4-foot by 6.5-foot Filterra unit that was installed at this location in 2007. The drainage plan and details for the Hayward Drive installation are included in Appendix B.

The drainage basin contributing to the Filterra system includes stormwater runoff from Hayward Drive and Hayward Court. The land use in the drainage basin (located in the Silver Beach neighborhood) is primarily medium density single-family residential, but includes a few undeveloped parcels. This site was selected for monitoring for this study because previous monitoring conducted at the site indicated the majority of the influent total phosphorus concentrations fell within the range specified in the TAPE guidelines. Lake Whatcom is also on Ecology’s 303(d) list for phosphorus and development of a total maximum daily load (TMDL) for phosphorus is underway. Approval of treatment technologies for phosphorus treatment would be beneficial for future drainage basin retrofits.

The City of Bellingham has provided the drainage basin delineation for this system which includes 0.4 acres of impervious area (streets and driveways) with minimal contribution from lawns and landscaping and no contribution from rooftops. The drainage area will be verified through field reconnaissance during the course of monitoring for this project.

Slopes in the drainage basin are moderate (5 to 15 percent). The soils in the drainage basin are classified as Squalicum-gravely loam (hydrologic soil group B). Treated runoff from the Filterra system is routed into the existing stormwater drainage system and discharges to Lake Whatcom west of Hayward Drive. Bypass flow exceeding the infiltration capacity of the filter media enters the catch basin located directly south of the Filterra system and also discharges to Lake Whatcom. Pretreatment is not required in combination with the Filterra system.

Legend

- Drainage area
- Catch Basin
- Stormwater main
- Culvert
- Ditch
- 25-foot contour
- 5-foot contour

Figure 3. Vicinity map for the Filterra® System at Hayward Drive, Bellingham, Washington.

N

0 100 200 400 Feet

HERRERA

Aerial: City of Bellingham, 2008

K:\Projects\10-04715-000\Project\vicinity.mxd (11/14/2011)

Figure 4. Photograph of the Hayward Drive Filterra system.

Potential pollutant sources in the drainage basin consist of residential sources: vehicle use (resulting in TSS, dissolved metals, and oil), fertilizer use and yard waste (resulting in phosphorus runoff), pet waste and leaky septic systems (resulting in fecal coliform bacteria loading), and car washing (resulting in phosphorus runoff). No adverse site conditions in the drainage basin (i.e., high groundwater, steep slopes, erosion, high spill potential, or illicit connections) that could impact monitoring have been identified.

Baseline Stormwater Data

The City of Bellingham monitored the Filterra system at Hayward Drive from February 2009 through April 2010. A majority of the samples collected did not meet the TAPE goals for percent coverage and storm end (post storm dry period). Monitoring data from all 26 storm events monitored is summarized in Table 5 and the monitoring data from 6 storm events that met the TAPE criteria are summarized in Table 6. In addition to the basic and phosphorus treatment monitoring, two samples were also analyzed for dissolved metals. The detection limit for dissolved copper (0.02 mg/L) was at the upper end of the acceptable range of influent dissolved copper concentrations required by the TAPE guidelines, so it is unclear whether the influent concentrations at this site are sufficient for dissolved copper monitoring. Out of the two samples collected for dissolved zinc, concentrations for both were below the lower end (0.02 mg/L) of the required influent concentration range required by the TAPE guidelines.

Table 5. All storm events from City of Bellingham monitoring conducted at the Hayward Drive Filterra installation.

	All Storm Events [a]					
	n	Average Influent Concentration	Average Effluent Concentration	Influent Std. Deviation	Effluent Std. Deviation	Percent Removal [b]
Total suspended solids	26	52 mg/L	6.1 mg/L	66 mg/L	5.3 mg/L	81%
Total phosphorus	26	0.126 mg/L	0.058 mg/L	0.084 mg/L	0.027 mg/L	49%
SRP	26	0.027 mg/L	0.026 mg/L	0.017 mg/L	0.010 mg/L	-38%
pH	26	6.7	6.8	0.3	0.4	NA

[a] A new inlet weir was installed in March 2009, thus sampling conducted from 2-9-09 to 3-14-09 is not presented in this table. This summary includes all storm events (both TAPE-qualifying and non TAPE-qualifying) that were monitored from 3-17-09 through 4-28-10.

[b] Percent removal values were calculated using paired influent and effluent concentration data from all 26 storm events.

SRP = soluble reactive phosphorus

Table 6. TAPE-qualifying storm events from City of Bellingham monitoring conducted at the Hayward Drive Filterra installation.

	TAPE-Qualifying Storm Events [a]					
	n	Average Influent Concentration	Average Effluent Concentration	Influent Std. Deviation	Effluent Std. Deviation	Percent Removal [b]
Total suspended solids	2	59 mg/L	4.2 mg/L	24 mg/L	2.5 mg/L	93%
Total phosphorus	2	0.116 mg/L	0.051 mg/L	0.015 mg/L	0.013 mg/L	56%
SRP	3	0.020 mg/L	0.023 mg/L	0.009 mg/L	0.003 mg/L	-48%
pH	3	6.6	6.7	0.3	0.1	NA

[a] TAPE-qualifying storm events based on storm event guidelines and percent coverage include the following sample dates: 3-29-10, 4-8-10, and 4-28-10. The influent concentrations from the 3-29-10 sampling event were lower than the required influent concentration range for TSS and TP, thus only data collected on 4-8-10 and 4-28-10 are presented in this table for those two parameters.

[b] Percent removal values were calculated using paired influent and effluent concentration data from the 2 to 3 qualifying storm events.

SRP = soluble reactive phosphorus

Treatment System Sizing

Pursuant to the TAPE guidelines, drainage area flow rates (i.e., water quality design flow, 2-year, 10-year, and 100-year recurrence interval peak flow rates) at 15-minute and 1-hour time steps must be derived using an approved continuous runoff model.

In accordance with Ecology requirements (Ecology 2005), the Filterra test system was sized to provide treatment for 91 percent of the annual runoff volume. To confirm that the test system sizing was correct, modeling was performed using the Western Washington Hydrology Model, Version 3 (WWHM3). WWHM3 is a continuous hydrologic model that simulates rainfall runoff based on topography, soils, and vegetation. For this evaluation, the sand filter module in WWHM3 was run at a 15-minute timestep for a 51-year simulation period (October 1948 to September 1999) using the Whatcom County precipitation series from the Blaine rain gauge. Model parameters were selected based on the Western Washington Engineering Design Assistance Kit (Appendix A) produced in 2010 and may be slightly different from the model parameters recommended when the Filterra system was installed in 2007. The following parameters were specifically used as inputs to the sand filter module:

- Bottom length: 6.5 feet
- Bottom width: 4 feet
- Filter material depth: 1.8 feet
- Effective ponding depth: 0.75 feet
- Slope on the filter box: 0
- Infiltration: yes
- Filter hydraulic conductivity: 35.46 inches/hour
- Riser height: 0.7 feet
- Riser diameter: 100 inches
- Riser type: flat

Screen shots from model showing these inputs and the associated results are provided in Appendix C. These results indicate the Filterra test system will treat approximately 88.5 percent of the annual runoff volume with the 4-foot by 6.5-foot box. Based on these results, the Filterra test system is slightly undersized. The design flow rates obtained from the model for the associated drainage basin are listed below in Table 7.

Table 7. Flow rates obtained from WWHM3 for predeveloped conditions and the developed, mitigated condition for the Hayward Drive Filterra installation.

Flow (cubic feet per second)	Predeveloped	Developed, Mitigated
Water quality design flow	NA	0.0615
2-year peak flow	0.0069	0.1026
10-year peak flow	0.0130	0.1843
100-year peak flow	0.0206	0.3028

These results were modeled at a 15-minute timestep. Hourly timestep results include the following for predeveloped conditions: 2-year = 0.0069; 10-year = 0.0146; 100-year = 0.0263. Hourly timestep results include the following for developed, mitigated conditions: WQ design flow = 0.0651; 2-year = 0.0821; 10-year = 0.1476; 100-year = 0.2425.

A model check was also performed with the 100 inch/hour design infiltration rate (hydraulic conductivity of 70.9 inches/hour) that will be tested as part of this monitoring study. Based on the 100 inch/hour infiltration rate, the modeling results indicate that the Filterra test system will treat approximately 97.6 percent of the annual runoff volume. Based on these results, the Filterra test system is slightly oversized.

Sampling Process Design

In general, this project will require the collection of hydrologic and water quality monitoring data in association with the Filterra test system to meet the overall objectives of this study. Separate sections below describe the sampling process design that will be used in conjunction with each of these monitoring elements.

Hydrologic Monitoring

Effluent and bypassed flows from the Filterra test system will be monitored continuously over an approximately 1.5-year period beginning in April 2012. In addition, precipitation depths at the monitoring site will be monitored continuously over this same period. Due to the residential setting of the Hayward Drive Filterra installation, limited site modifications were recommended by the City of Bellingham Public Works due to public safety issues in the existing right-of-way. Consequently, influent flow measurement is not feasible at this monitoring location and effluent flow monitoring data will be used to represent both influent and effluent flow. In previous monitoring of Filterra systems of similar design, it has been shown that influent and effluent flows track very closely with each other (Figure 5). Consequently, pacing the influent sampler based on effluent flow rates should not introduce measurable error.

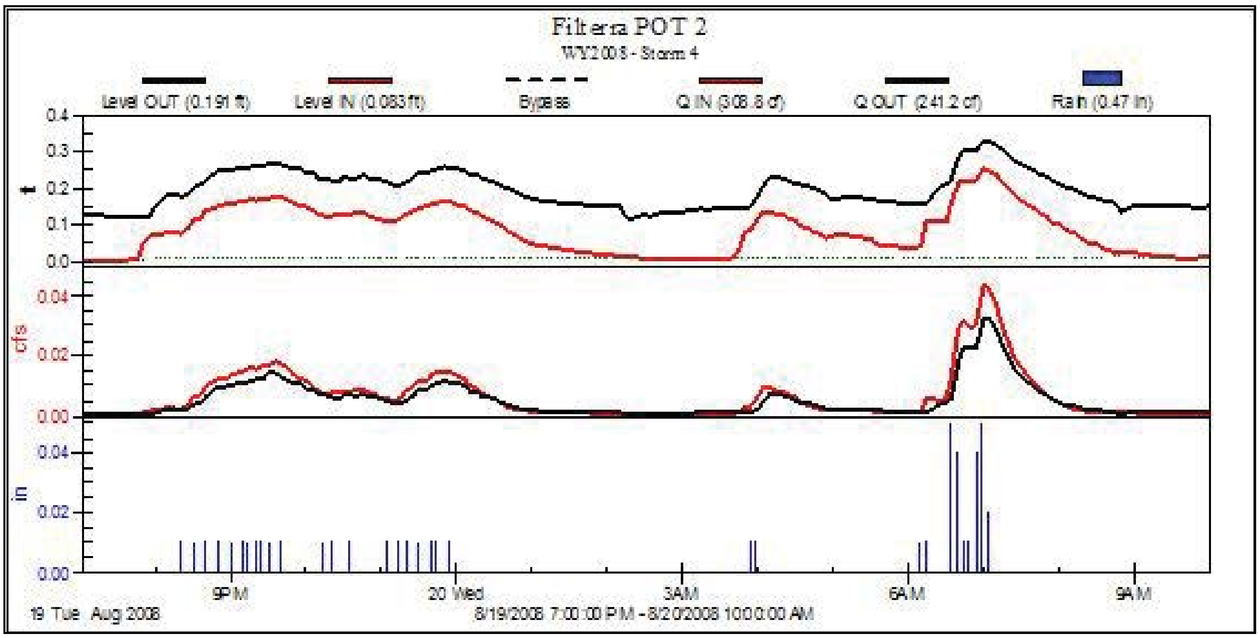

Figure 5. Example inlet and outlet hydrograph from Filterra monitoring at the Port of Tacoma in 2008.

Effluent Flow Monitoring

To facilitate continuous monitoring of effluent flow rates, a monitoring station, designated FB-OUT, will be established in the 6-inch underdrain at the downstream end of the Filterra system. The underdrain will be accessed through a 12-inch monitoring port that narrows to

6 inches as it interfaces with the 6-inch underdrain pipe at the south end of the system (Figure 6). Downstream of the monitoring port, the underdrain pipe intersects with a pipe that drains the hillside to the east of the system. Water from the hillside produces a “base flow” that backs water up into the underdrain pipe (approximately 0.5 inches of standing water in the pipe at the monitoring well between storm events). Due to these backwater conditions, an area-velocity meter (Marsh McBirney Flo-Tote 3, Appendix D) will be used for measuring flow in the underdrain. The velocity sensor will be placed directly in the bottom of the monitoring well access so that depth calibration measurements can be collected from the surface. The velocity meter will be interfaced with a FL900 logger housed in the equipment enclosure. The FL900 will be interfaced via a Modbus RS-232 connection to a Campbell Scientific CR800 datalogger (Appendix D). The datalogger will be programmed to continuously record hydrological measurements (effluent and bypass discharge and precipitation depth).

The datalogger will be interfaced with a Raven XTV digital cellular modem (Appendix D). This communication system will be configured to automatically download data on an hourly basis and send text message alarms to field technicians based on programmable sampling criteria. The downloaded data will then be processed and validated in accordance with procedures described later in this QAPP. All flow data will be stored on a SQL server.

Power to the data logger will be supplied using a 12-volt sealed, rechargeable battery that is charged using a 60-watt solar panel installed at the site. The data logger, battery, and digital cell phone links will be housed in a Knaack box model 3068 enclosure (Appendix D). Conduit will be installed to convey cabling for the FL900 logger from the base of the enclosure to the area-velocity meter.

Bypass Flow Monitoring

Monitoring the bypass flow will require the installation of an H-flume along the curb between the Filterra unit and the bypass inlet located south (downslope) of the Filterra system (Figure 6). This flow monitoring station will be designated FB-BP. The flume will be installed flush with the asphalt of the street and a temporary asphalt curb will be poured to direct flow into the flume and prevent damage from passing automobiles. An OTT CBS bubble level gauge (Appendix D) will be installed in conjunction with the flume to measure the water level. The OTT bubbler will be interfaced with the datalogger described above using SDI-12 communication protocol. Water level measurements will be recorded on a 5-minute logging interval. When bypass occurs, the data logger will convert these water level readings to estimates of discharge based on standard hydraulic equations (Walkowiak 2006).

Precipitation Monitoring

In addition to the two flow monitoring stations, a third station, designated FB-RG, will be installed in order to monitor precipitation. A Texas Electronics (TR-525) rain gauge will be installed on an 8-foot pole adjacent to the equipment enclosure (Figures 6 and 7). The pole will be bolted to the equipment enclosure for added security. The rain gauge will be capable of measuring rainfall to the nearest 0.01 inch.

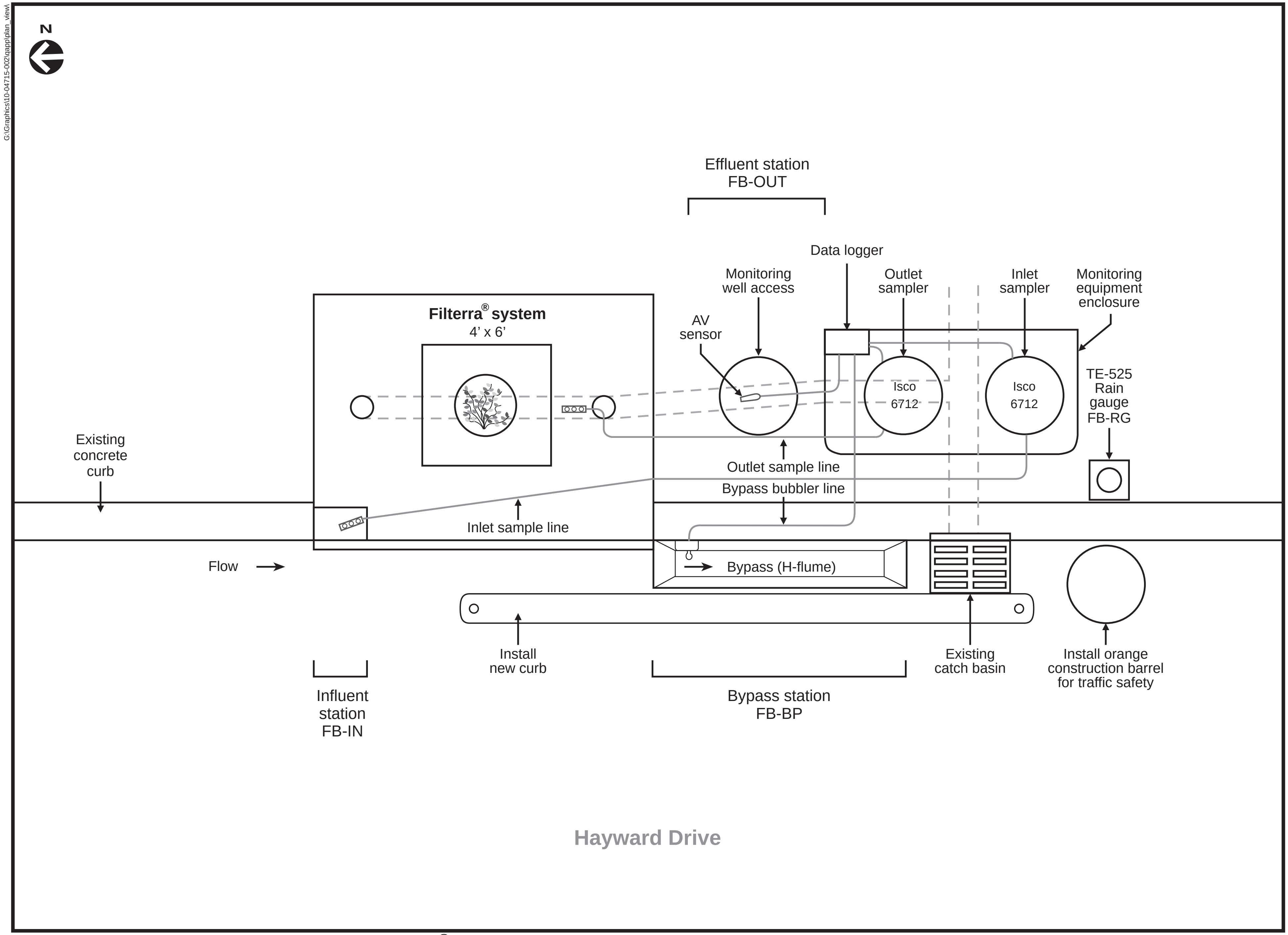

Figure 6. Site schematic (plan view) for Filterra® system performance monitoring at Hayward Drive, Bellingham, Washington.

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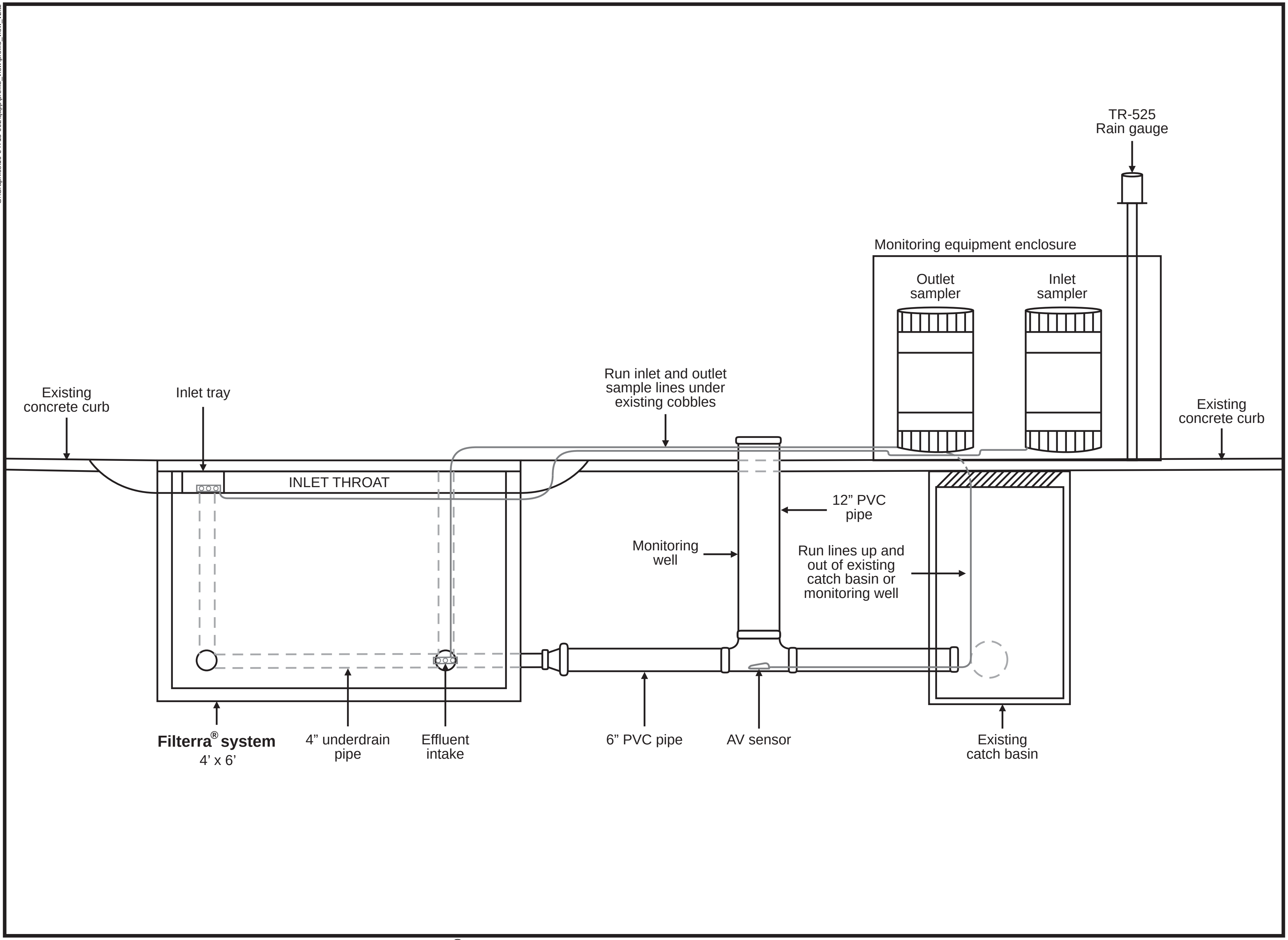

Figure 7. Site schematic (profile view) for Filterra® system performance monitoring at Hayward Drive, Bellingham, Washington.

The gage will be interfaced with the datalogger mentioned above and set to record rainfall in 5-minute intervals. All precipitation data will be downloaded via cellular telemetry on an hourly basis and stored locally on a SQL server. The rainfall data will be used to determine whether sufficient rainfall (> 0.15 inches) occurred for the storm to qualify as a viable sampling event. Rainfall data will also be useful to verify the measured treated and bypassed flow volumes and characterizing the size, duration, and temporal patterns of the monitored storm events.

Water Quality Monitoring

This section describes monitoring equipment and locations for influent and effluent water quality monitoring, sampling methodology, monitoring parameters, and monitoring duration.

Influent Water Quality Monitoring

Influent samples will be collected by installing a tray (FB-IN) in the upstream edge of the Filterra system on top of the mulch layer. Water will pass through this tray during a storm event. The influent sample intake will be placed in the tray to collect representative influent samples (Figure 7). The tubing will be run through the unit and out a roto-hammered hole on the southern top edge of the Filterra system. The tubing will then be routed to an ISCO 6712 automated sampler that will be housed within the equipment enclosure that is described above in connection with hydrologic monitoring (Figures 6 and 7). Care will be taken to ensure the tubing is installed with a constant linear grade so that water completely drains through the sample tube during rinse, purge, and sampling cycles. The sampler intakes will be carefully positioned to ensure the homogeneity and representativeness of the samples. Specifically, the sampler intake will be installed to ensure that an adequate depth will be available for sampling and to avoid the capture of litter, debris, and bed load that may be present.

The automated sampler will be powered by a 12-volt sealed, rechargeable battery that will also be housed in the enclosure. The datalogger will be programmed to use hydrological measurements at the FB-OUT station to trigger the FB-IN automated sampler at pre-defined flow pacing intervals. Once triggered, the automated sampler will collect a 220 milliliter (mL) sub-sample for compositing into a 20 liter high density polyethylene (HDPE) bottle. The FB-IN sampler will be programmed to collect a sample at initiation to account for the volume of water that passed the FB-IN station before initiation can occur based on flow measurements at the FB-OUT station.

Effluent Water Quality Monitoring

Effluent samples will be collected downstream of the two Filterra cleanout access points (Figures 6 and 7). Care will be taken to insert the effluent sample intake immediately next to the Filterra underdrain to reduce the likelihood that backed up water from the hillside flow will be collected in the intake. The tubing will be run through the top of the cleanout and routed to an ISCO 6712 sampler in the equipment enclosure described above in connection with hydrologic monitoring. The effluent sample intake will be placed in the outlet pipe and the tubing affixed the wall of the cleanout for ease of removal (Figure 7). The FB-OUT sampler will be configured similarly to the FB-IN sampler except that a sample will not be collected at initiation.

Sampling Methodology

Three out of the five sampling methods listed in the TAPE guidelines (Ecology 2011) will be used for this monitoring program:

- **Method 1 – Automated flow-proportional composite sampling**: This sampling method will be used for a majority of the sampling to generate EMCs that will be used to determine whether the treatment system meets Ecology's performance goals.
- **Method 2 – Discrete flow sampling**: If the data collected using Method 1 does not include the full range of required flow rates (50 to 125 inches per hour), Method 2 will be used to collect additional monitoring data using an automated sampler and a multi-bottle rack to collect discrete time composite samples. Due to the minimal lag time within the treatment system and the restrictions on influent flow monitoring (see Figure 5), the influent and effluent samples will be collected simultaneously.
- **Method 5 – *In situ* sampling**: pH measurements will be collected *in situ* using a hand held field meter.

The automated flow-proportional composite sampling (Method 1) will be used to average system performance across the entire storm event based on the EMCs. Discrete flow sampling (Method 2) will target higher flow rates than those calculated for the automated flow-proportional composite sampling to evaluate pollutant removal as a function of flow rate. The goal of the discrete flow sampling approach is to determine if the applicable performance goal for a given parameter is being met at the design hydraulic loading rate (Ecology 2011).

Monitoring Parameters

This monitoring program will include the following parameters:

- TSS (basic treatment)
- Total phosphorus and SRP (phosphorus treatment)
- Hardness, total and dissolved copper and zinc (enhanced [dissolved metals] treatment)
- PSD and pH (screening parameters)

The parameters monitored for basic (total suspended solids), phosphorus, and enhanced (dissolved metals) treatment will be collected from both the influent and effluent stations. PSD will be analyzed on three of the composite samples collected during the monitoring period. These samples will be spread throughout the monitoring period, with one sample collected towards the beginning, one in the middle, and one towards the end. pH will be monitored *in situ* during three storm events. If a substantial change in pH is measured (> 1 standard unit difference between influent and effluent measurements) or an abnormal pH value is measured (< 4 or > 9 standard units), additional storm events will be monitored.

Monitoring Duration

A minimum of 12 flow-proportional composite samples will be collected to ensure representative concentrations are available for assessing system performance across a variety of storm event conditions; however, additional sampling may be required to demonstrate performance of the system at the required level of statistical confidence for obtaining a GULD. Herrera is expecting to conduct sampling for 24 storm events (16 composite and 8 discrete) to achieve the target influent concentrations and range of design flow rates.

Sampling Procedures

This section of the QAPP describes field sampling procedures necessary to ensure the quality and representativeness of the collected samples. This section includes information on field safety, flow monitoring, precipitation monitoring, and water sampling.

Field Safety Procedures

Field personnel will possess the following equipment while performing field work related to this project:

- Protective footwear
- Safety vest
- Roof-mounted flasher for vehicles

At a minimum, field personnel will follow the general requirements for personal protective equipment (PPE) by dressing appropriately for close proximity to vehicular traffic (WAC 296-155-200).

Flow Monitoring

The flow monitoring equipment will be installed and calibrated in accordance with the manufacturer's instructions. Flow monitoring equipment will be inspected after each sampled storm event (at a minimum) and maintenance will be performed if necessary. The calibration of water level sensors at each flow monitoring station will be checked upon installation and at least monthly throughout the monitoring period. Control charts and other quality assurance measures will be used to track instrument drift. Control limits (statistical warning and action limits calculated based on control charts) will be established to track instrument drift. Warning limits will be set at ±2 standard deviations from the mean and action limits will be set at ±3 standard deviations from the mean.

pH Monitoring

To measure pH at FB-IN the pH electrode will be submerged in the collection tray during a storm event. To measure pH at FB-OUT, the outlet sampler will be used to collect a grab sample into a 500 mL container. The pH electrode will be immersed in the container to measure the effluent pH.

Precipitation Monitoring

The Texas Electronics rain gauge will be calibrated (if necessary) and installed in accordance with the manufacturer's instructions. Once installed, the rain gauge will be inspected monthly (at a minimum) and maintenance will be performed if necessary. Rain gauge calibration will be checked upon installation and at the end of the monitoring period.

Water Sampling

This section discusses station set-up, field forms, sample containers and preservation, sample identification and labeling, and chain of custody forms.

Automated Sampling Procedures

As described above, this project involves the collection of flow-weighted composite samples during discrete storm events. Antecedent conditions and storm predictions will be monitored via the Internet, and a determination will be made as to whether to target an approaching storm. Before each targeted storm event, field staff will conduct site visits to set up the automated samplers at both the FB-IN and FB-OUT monitoring stations. During these pre-storm site visits, field staff will perform the following activities:

- Remove any blockages in the rain gage and flow monitoring stations
- Check calibration of the flow measurement devices
- Backflush the sample lines with deionized water
- Check the state of the desiccant associated with the equipment
- Place clean samples bottle in the samplers
- Pack ice around the sample bottles within each sampler

(Ice is estimated to keep the interior of the samplers cool for 48 hours; therefore, ice will be added to the samplers not more than 24 hours before a targeted storm event.)

For composite sampling, the automated samplers will be programmed to collect a minimum of 10 aliquots of equal volume at equal increments of flow. For discrete sampling, the automated samplers will be programmed to fill 24 bottles (2 bottles per sample time) on a time-paced schedule. Volumetric sample pacing for the automated samplers will be determined based on rainfall versus runoff relationships that are developed using linear regressions of data that were collected during previous storm events. These regressions will be continually updated throughout the year to reflect changing hydrologic conditions. The rainfall versus runoff regressions are used to convert forecast rainfall totals into runoff volumes. The resultant runoff volume (cubic feet) is then divided by 44 (the median number of 220 mL aliquots that a 20-liter bottle will hold) to estimate the sample pacing (cubic feet) volume necessary to collect an adequate number (greater than 10) of aliquots across at least 75 percent of the storm. A minimum of 2.65 liters (approximately 12 aliquots) is required to analyze all of the targeted water quality parameters (including PSD). Without PSD, a minimum of 1.65 liters (approximately 8 aliquots) is required to analyze the targeted water quality parameters. Due to the minimum volume requirements, two 1-liter bottles will be filled for each discrete sample to ensure sufficient volume for the laboratory analyses.

Flow-weighted composite sampling criteria will be assessed before post-storm sample retrieval by accessing sampling data with a remote cellular link (Raven 100 XTV). If sampling criteria are not met, the samples will be retrieved before the next storm event. If sampling criteria are met, field personnel will return to the site and make visual and operational checks of the system and collect detailed field notes using standardized field forms (see *Field Quality Control Procedures*). Field personnel will then remove the 20-liter or 1-liter HDPE bottles from each automated sampler and transport them on ice to the laboratory within the allowable limits for sample holding times (see Table 8). Additional samples will also be collected through the course of the performance verification for quality assurance purposes (see Table 9).

In general, the laboratory will be given prior notice of a pending sampling event to ensure that adequate laboratory staff will be available to process the incoming samples. Once in the laboratory, water from the 20-liter HDPE bottles (composite samples collected using Method 1) will be split using a 22-liter churn splitter and divided into decontaminated, preserved (where appropriate) sample bottles for the required analyses. Since the churn splitter is the most effective for samples that are 5 liters or more, the smaller 1-liter bottles collected using a multi-bottle rack for the discrete sampling approach (Method 2) will be composited in a pre-cleaned carboy, vigorously shaken, and subdivided into decontaminated, preserved (where appropriate) sample bottles for the required analyses. The samples will be analyzed for the suite of parameters that is identified in the *Sampling Process Design* section. Samples for PSD analysis will be shipped to Analytical Resources, Inc. in Tukwila, Washington from Aquatic Research, Inc. in Seattle, Washington.

Field Forms

At each monitoring station, personnel will record the following information on a standardized field form (see Appendix E) before and after storm sampling events:

- Date
- Time of sample collection, measurement, or observation
- Name(s) of field personnel present
- Station location
- Weather and flow conditions
- Sample volume collected in sample bottles
- Battery voltage

- Desiccant condition
- Presence of obstructions in primary measurement device or sample bottles
- Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
- Modifications of, or unusual, sampling procedures
- Any miscellaneous factors that might influence samples

Sample Containers and Preservation

The analytical laboratory will provide clean sample bottles with the appropriate preservatives already added in advance of each storm event. Spare sample bottles will be carried by field personnel in case of breakage or possible contamination. Sample containers and preservation techniques will follow Code of Federal Regulations [40 CFR 136] guidelines. Refer to Table 8 in the *Measurement Procedures* section for information on recommended sample containers and preservation.

Sample Identification and Labeling

All sample containers will be labeled with the following information, using indelible ink and placed on dry sample container lids with labeling tape:

- Station ID
- Date of sample collection (month/day/year)
- Time of sample collection (military format)
- Sample type (composite/discrete)

Chain-of-Custody

After samples have been obtained and the collection procedures properly documented, a written record of the chain-of-custody of each sample should be made. This is recommended to ensure that samples have not been tampered with or compromised in any way and to track the requested analysis for the analytical laboratory. Information necessary in the chain-of-custody includes:

- Name(s) of field personnel
- Date and time of sample collection
- Location of sample collection
- Names and signatures of field personnel and laboratory personnel handling the samples

- Laboratory analysis requested and control information (e.g., duplicate or spiked samples) and any special instructions (e.g., time sensitive analyses)

Sample custody will be tracked in the laboratory through the entire analytical process, and the signed chain-of-custody forms and analytical results returned to the Herrera project manager. The Herrera monitoring lead will record the date and time of sample deliveries for the project file.

Sample Packing, Shipping, and Delivery

Samples for the PSD analysis will be shipped to Analytical Resources, Inc. in Tukwila, Washington, from Aquatic Research, Inc. in Seattle, Washington. Samples may also be shipped from Bellingham to Analytical Resources, Inc. if local monitoring support is obtained for this project. Recommended steps for packing and shipping samples include:

1. Fold the field-sampling sheets and chain of custody record form and place them in plastic bags to protect the sheets during transport.

2. Clearly mark the analyses to be performed for each sample.

3. Pack samples to prevent breakage or leakage (samples should already be labeled).

4. Securely seal shipping containers and affix identification labels to each shipping container.

5. Mark containers THIS END UP and number containers in a shipment.

Aquatic Research, Inc. is the analytical laboratory for a majority of the parameters that will be analyzed for this study. Field personnel will deliver or ship the samples to the analytical laboratory directly following each sampling event. If field personnel are unable to deliver the samples to the laboratory within 12 hours (e.g., samples are collected over the weekend or at night), samples will be field filtered using a 0.45 μm filter for parameters requiring filtration (i.e., soluble reactive phosphorus, dissolved copper, and dissolved zinc), placed in a storage container (e.g., cooler), packed on ice or an ice substitute, and delivered to the laboratory as soon as possible.

Measurement Procedures

Laboratory analytical procedures will follow methods approved by the U.S. Environmental Protection Agency (EPA) (APHA et al. 1992, 1998; U.S. EPA 1983, 1984). These methods provide reporting limits that are below the state and federal regulatory criteria or guidelines and will allow direct comparison of the analytical results with these criteria. Preservation methods, analytical methods, reporting limits, and sample holding times are presented in Table 8.

Samples for parameters requiring filtration (i.e., soluble reactive phosphorus, dissolved copper, and dissolved zinc) will be delivered to the laboratory within 12 hours of their collection. Upon their receipt, laboratory personnel will immediately filter and preserve these samples.

Aquatic Research, Inc., the laboratory identified for this project, is certified by Ecology and participates in audits and interlaboratory studies by Ecology and EPA. These performance and system audits have verified the adequacy of the laboratory's standard operating procedures, which include preventive maintenance and data reduction procedures. Analytical Resources, Inc. will be used for the PSD analysis.

The laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide sample and quality control data in standardized reports suitable for evaluating the project data. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Table 8. Methods and detection limits for water quality analyses.

Analyte	Analytical Method	Method Number [a]	Holding Time [b]	Sample Container	Preservation	Reporting Limit/ Resolution	Units
Total suspended solids	Gravimetric, 103°C	SM 2540D	7 days	P, FP, G	Cool, ≤6°C	0.50	mg/L
Total phosphorus	Automated ascorbic acid	EPA 365.3or 365.4	28 days	P, FP, G	Cool, ≤6°C; H_2SO_4 to pH<2	0.01	mg/L
Soluble reactive phosphorus	Automated ascorbic acid	EPA 365.1	Filter - 12 hours Analyze - 48 hours	P, FP, G	Cool, ≤6°C; filtration, 0.45 µm	0.01	mg/L
Hardness	Persulfate	SM 2340B or C	6 months	P, FP, G	HNO_3 or H_2SO_4 to pH < 2	0.1	mg/L
Copper, dissolved	GFAA	EPA 200.8	Filter - 12 hours Analyze - 6 months	P, FP, G	Cool, ≤6°C; filtration, 0.45 µm; HNO_3 to pH <2	0.1	µg/L
Copper, total			6 months	P, FP, G	Cool, ≤6°C; HNO_3 to pH <2		
Zinc, dissolved	ICP	EPA 200.8	Filter - 12 hours Analyze - 6 months	P, FP, G	Cool, ≤6°C; filtration, 0.45 µm; HNO_3 to pH <2	1.0	µg/L
Zinc, total			6 months	P, FP, G	Cool, ≤6°C; HNO_3 to pH <2	5.0	µg/L
pH	Field meter	NA	NA	NA	NA	0.01	std. units
Particle size distribution	TAPE method	ASTM 3977 (modified)	7 days	P	Cool, ≤6°C	1	micron

[a] SM method numbers are from APHA et al. 1998; EPA method numbers are from U.S. EPA 1983, 1984. The 18th edition of Standard Methods for the Examination of Water and Wastewater (APHA et al. 1992) is the current legally adopted version in the Code of Federal Regulations (CFR). However, the 20th edition provides additional guidance on certain key items. For this reason, the 20th edition is referenced in this table as the best available guidance. An equivalent standard method can be substituted.

[b] Holding time specified in EPA guidance or referenced in Standard Methods for equivalent method.

[c] Follows laboratory procedure specified in the TAPE guidelines (Ecology 2011).

GFAA = graphite furnace atomic absorption.
ICP = inductively coupled plasma
NA = not applicable
mg/L = milligrams per liter
std. units = standard units

µm = micron
C = Celsius
FP – fluoropolymer (polytetrafluoroethylene [PTFE, Teflon] or other fluoropolymer)
G – glass
P – polyethylene

Quality Control

This section includes information on field quality assurance/quality control (QA/QC) and laboratory quality control.

Field Quality Control

This section summarizes the QA/QC procedures that field personnel will implement to evaluate sample contamination and sampling precision and to maintain and calibrate monitoring equipment.

Rinsate Blanks

Automated samplers will be cleaned using the rinse and purge-pump-purge cycle. Rinsate blanks will be collected at the beginning of the monitoring program after decontaminating the equipment, after the first or second storm event following the initial equipment startup, and toward the end of the monitoring program. The rinsate blank will be collected by pumping reagent-grade water through the intake tubing into a pre-cleaned sample container. The volume of reagent-grade water pumped through the sampler for the rinsate blank will be similar to the volume of water collected during a storm event. To prevent the buildup of contaminants on the tubing, intake tubing will be replaced annually. After replacing the tubing, the rinsate blank procedure described above will be repeated.

Field Duplicate Samples

For composite sampling, field duplicates will be collected by placing a 4-bottle rack in the automated sampler and compositing two sub-samples at the end of the sampled storm event. For discrete sampling, a 24-bottle rack will be installed in the automated sampler and two sample bottles will be filled each time the sampler is triggered. The sample bottles will be composited for routine analysis, but will be analyzed separately for the field duplicates. The number of field duplicates to be collected during the sampling season is listed in Table 9. The station where the field duplicates are to be collected will be chosen at random in advance of the storm event. All duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples. The resultant data from these samples will then be used to assess variation in the analytical results that is attributable to environmental (natural), sub-sampling, and analytical variability.

Equipment Maintenance and Calibration

Maintenance procedures and frequencies are summarized in Table 10. Instrument maintenance and calibration activities will be documented on standardized field forms (see Appendix E).

Table 9. Anticipated number of samples and associated quality assurance requirements.

Parameter	Sample Type	Storm Events [a]	Number of Monitoring Locations	Total Number of Samples	Field Blanks	Method Blanks	Control Standard	Matrix Spike	Lab Duplicates	Field Duplicates
Total suspended solids	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	NA	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	NA	1/storm event	5% of samples
Total phosphorus	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Soluble reactive phosphorus	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Hardness	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Copper, dissolved	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Copper, total	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Zinc, dissolved	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
Zinc, total	Flow-weighted composite	16	2	32	3	1/storm event	1/storm event	1/storm event	1/storm event	10% of samples
	Discrete	8	2	16	NA	1/storm event	1/storm event	1/storm event	1/storm event	5% of samples
pH	*In situ*	3	2	6	NA	NA	NA	NA	NA	10% of samples
Particle size distribution	Flow-weighted composite	3	2	6	NA	NA	NA	NA	NA	10% of samples

NA = not applicable.

[a] Sixteen storm events will be monitored during the sampling season using the flow-weighted composite method and eight storm events using the discrete sampling method at a total of two monitoring locations (inlet and outlet). Additional storm events may be required if statistical significance is not demonstrated by the sampled storm events.

Table 10. Equipment maintenance schedule.

Equipment	Item	Procedure	Minimum Frequency
Rain Gauge	Funnel and screen	Check for debris	Monthly
	Level check	Verify level with bubble indicator	Monthly
	Calibration	Calibrate in accordance with manufacturer's instructions	At installation and once annually
Flow Monitoring	Desiccant	Check color – when pink, exchange for new desiccant	Every visit
	Vent tubing	Check for obstructions	Every visit
	Calibration	Calibrate in accordance with manufacturer's instructions	At installation and monthly
Automated Sampler	Pump tubing	Check integrity	Every visit
	Sample tubing and intake	Check integrity; verify no obstructions at intake	Every visit
	Humidity indicator	Check surface indicator	Every visit
pH field meter	Calibration	Calibrate in accordance with manufacturer's instructions	Before and after each use

Laboratory Quality Control

This section summarizes the quality control procedures the laboratory will perform and report with the analytical results. Accuracy of the laboratory analyses will be verified using blank analyses, duplicate analyses, laboratory control spikes and matrix spikes in accordance with the EPA methods employed. Aquatic Research, Inc. and Analytical Resources, Inc. will be responsible for conducting internal quality control and quality assurance measures in accordance with their own quality assurance plans. The required frequency for quality control procedures and evaluation criteria are summarized in Table 9.

Water quality results will first be reviewed at the laboratory for errors or omissions. Laboratory quality control results will be reviewed by the laboratory to verify compliance with acceptance criteria. The laboratory will also validate the results by examining the completeness of the data package to determine whether method procedures and laboratory quality assurance procedures were followed. The review, verification, and validation by the laboratory will be documented in a case narrative that accompanies the analytical results.

Data will be reviewed and validated within 7 days of receiving the results from the laboratory. This review will be performed to ensure that all data are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Table 4) will also be examined to determine if MQOs for the project have been met.

Results from these data validation reviews will be summarized in quality assurance worksheets (see example in Appendix E) that are prepared for each sample batch. The Herrera project manager and Herrera quality assurance lead for water quality data will be jointly responsible for identifying and initiating corrective action. Values associated with minor quality control problems will be considered estimates and assigned *J* qualifiers. Values associated with major quality control problems will be rejected and qualified with an *R*. Estimated values may be used for evaluation purposes, but rejected values will not be used. The following sections describe in detail the data validation procedures for quality control.

Data Management Procedures

All hydrologic data (discharge and precipitation depth) will be downloaded via cellular telemetry on an hourly basis and imported directly into the Aquarius data management software for subsequent analysis and archiving purposes. To the extent possible, gaps in flow data will be interpolated and the data will be stored and presented in a manner that that identifies the data that are from direct equipment measurements, and the data that are interpolated.

Aquatic Research, Inc. and Analytical Resources, Inc. will report the analytical results within 30 days of receipt of the samples. The laboratories will provide sample and quality control data in standardized reports that are suitable for evaluating the project data. These reports will include all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifies.

Laboratory data will subsequently be entered into a database for all subsequent data management and archiving tasks. Herrera's quality assurance lead for water quality data will perform an independent review to ensure that the data were entered without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and crosschecking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found in the data.

Audits and Reports

This section provides information on audits and reports that will be part of this monitoring program.

Audits

Audits will be performed to detect potential deficiencies in the hydrologic and water quality data collected for this project. Audits of the hydrologic data will occur on a weekly basis. In connection with these audits, data collected from each monitoring station will be compared to data from prior storms and data from the rain gauge station to identify potential data quality issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies between the discharge and water level data from previous monitoring events. Any data generated from calibration checks that were performed at a particular monitoring station will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. In addition, sample collection and hydrologic data will be reviewed to assess whether MQOs have been met.

In the event that QA issues are identified on the basis of these audits, measures will be taken to troubleshoot the problem(s) and to implement corrective actions if needed. Further, if bias in the hydrologic record is detected and can be corrected by calibration, corrective actions will be documented in the database. All QA issues identified in the hydrologic data and the associated corrective actions will be documented using data flagging features that are a component of the Aquarius data management software (see *Data Management Procedures* section).

Audits performed for water quality data will occur within 7 business days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Table 4) and raw data will also be examined to determine if the MQOs for the project have been met. Results from these audits will be documented in QA worksheets (see Appendix E) that will be prepared for each batch of samples.

In the event that a potential QA issue is identified through these audits, Herrera’s data quality assurance lead will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples, reanalysis of existing samples if not yet past holding time, or advising the laboratory that methodologies or QA/QC procedures need to be improved.

Reports

Herrera will prepare a TER pursuant to the TAPE guidelines to document the performance characteristics of the test system and compare those results to identified phosphorus treatment and performance as a function of flow rate goals. The TER will include:

- A cover letter
- An executive summary
- A description of any deviations from the sampling procedures identified in the QAPP
- The approved QAPP and any subsequent addenda (in an appendix)
- A thorough description of the technology including sizing methodology, flow diagrams, and appropriate illustrations.
- All relevant performance test results, statistical analyses, factors other than performance, and O&M activities.
- An Individual Storm Report (ISR) for each sampled storm event summarizing storm, hydrologic, and pollutant data (in an appendix)
- Any available non-standard data (data not collected per the TAPE, such as laboratory testing)
- Conclusions and recommendations including recommended O&M procedures and frequency, use limitations, sizing criteria, recommended information to be posted on Ecology's website, and additional testing recommendations (if needed)

A third-party review memorandum is not required since the field monitoring will be conducted by an independent professional third party, and the TER will also be prepared by an independent professional third party.

Data Verification and Validation

Data verification and validation will be performed on both the hydrologic and water quality data that are collected through the duration of this project. The specific procedures that will be used to verify and validate each type of data are described in the following sections.

Verification and Validation Methods for Hydrologic Data

The verification and validation process for hydrologic data will involve the following steps:

1. Precipitation data from the study will be reviewed to identify any significant gaps. If possible, these gaps will be filled using data obtained from a nearby rain gauge.

2. The available discharge and water level data from FB-OUT and FB-BP will be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events. Gross anomalies (such as data spikes), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are quality assurance issues associated with the data that limit their usability.

3. If minor quality assurance issues are identified in any portion of the discharge record or in the water level data from a particular station and storm event, the data from that station and event will be considered an estimate and assigned a *J* qualifier. If major quality assurance issues are identified in any portion of the data from a particular station and/or storm event, the data from that station and event will be rejected and assigned an *R* qualifier. Estimated values will be used for evaluation purposes while rejected values will not.

Verification and Validation Methods for Water Quality Data

Data will be reviewed and audited within 7 business days of receiving the results from the field or laboratory. This review will be performed to ensure that all data are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Table 4) will also be examined to determine if the MQOs for the project have been met. Results from these data validation reviews will be summarized in quality assurance worksheets that are prepared for each sample batch (see Appendix E). Values associated with minor quality control problems will be considered estimates and assigned *J* qualifiers. Values associated with major quality control problems will be rejected and qualified *R*. Estimated values may be used for evaluation purposes, while rejected values will not be used. The following sections describe in detail the data validation procedures for these quality control elements:

- Completeness
- Methodology
- Holding times
- Method and rinsate blanks
- Reporting limits
- Duplicates
- Matrix spikes
- Control standards
- Sample representativeness

Completeness

Completeness will be assessed by comparing valid sample data with this quality assurance project plan and the chain-of-custody records. Completeness will be calculated by dividing the number of valid values by the total number of values. If less than 95 percent of the samples submitted to the laboratory are judged to be valid, then more samples will be collected until at least 95 percent are judged to be valid. If less than 95 percent of the collected flow data is complete, additional monitoring will be implemented until 95 percent of the flow record has been collected.

Methodology

Methodologies for analytical procedures will follow U.S. EPA approved methods (APHA et al. 1992, 1998; U.S. EPA 1983, 1984) specified in Table 8. Field procedures will follow the methodologies described in this QAPP. Any deviations from these methodologies must be approved by Ecology and documented in an addendum to this QAPP. Deviations that are deemed unacceptable will result in rejected values (*R*) and will be corrected for future analyses.

Holding Times

Holding times for each analytical parameter in this study are summarized in Table 8. Holding time compliance will be assessed by comparing sample collection dates and times to filtration (pre-filtration) and analytical (post-filtration or total) dates and times. Sample collection times will be based on the date and time that the last aliquot was collected, but start of sampling date and time will be recorded as well.

Pre-Filtration Holding Times

Samples requiring filtration should be filtered within 12 hours of collection of the last aliquot. U.S. EPA requires that dissolved metals and SRP should be filtered within 15 minutes of the collection of the last aliquot. Meeting this holding time goal would be exceedingly difficult for this project given that the time of last aliquot collection is unknown when samples are collected on a flow-weighted basis. Consequently, dissolved metals and soluble reactive phosphorus samples that are filtered within 12 hours will be flagged as estimated values (*J*). Dissolved metals and soluble reactive phosphorus samples that are filtered after this 12-hour limit will be considered rejected (*R*).

Post-Filtration or Total Holding Times

- **For analytes with holding times in excess of 7 days**:

  Data from samples that exceed the specified maximum post-filtration holding times by less than 48 hours will be considered estimates (*J*). Data from samples that exceed the maximum post-filtration holding times by more than 48 hours will be rejected values (*R*).

- **For analytes with holding equal to or less than 7 days**:

  Data from samples that exceed the specified maximum post-filtration holding times by less than 24 hours will be considered estimates (*J*). Data from samples that exceed the maximum post-filtration holding times by more than 24 hours will be rejected values (*R*).

Method Blanks

Method blank values will be compared to the MQOs that have been identified for this project (see Table 4). If an analyte is detected in a method blank at or below the reporting limit, no action will be taken. If blank concentrations are greater than the reporting limit, the associated data will be labeled with a *U* (in essence increasing the reporting limit for the affected samples), and associated project samples within 5 times the de facto reporting limit will be flagged with a *J* (G. Grepogrove, Manchester Laboratory, personal communication, September 4, 2007). In each of these cases, the de facto reporting limit for that analyte will be recorded along with the raw data, equipment will be decontaminated, and samples will be rerun if possible.

Rinsate Blanks

Rinsate blank concentrations will be compared to the MQOs that have been identified for this project (see Table 4). If concentrations are detected in the rinsate blanks that exceed 2 times the reporting limit, then associated sample tubing will be cleaned or replaced and associated samples collected since the previous rinsate blank that are within 5 times the new reporting limit will be flagged with a *J*.

Reporting Limits

Both raw values and reporting limits will be presented in each laboratory report. If the proposed reporting limits are not met by the laboratory, the laboratory will be requested to reanalyze the samples or revise the method, if time permits. Proposed reporting limits for this project are summarized in Table 8.

Duplicates

Duplicate results exceeding the MQOs for this project (see Table 4) will be recorded in the raw data tables, and noted in the quality assurance worksheets; and associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (such as more than twice the objective), then associated values will be rejected (*R*).

Matrix Spikes

Matrix spike results exceeding the MQOs for this project (see Table 4) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (*J*). However, if the percent recovery exceeds the MQOs and a value is less than the reporting limit, the result will not be flagged as an estimate. Nondetected values will be rejected (*R*) if the percent recovery is less than 30 percent.

Control Standards

Control standard results exceeding the MQOs for this project (see Table 4) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (such as more than twice the objective), then associated values will be rejected (*R*).

Sample Representativeness

Each flow-weighted composite sample is interpreted to represent the mean concentration for the sampled storm event. However, flow gage or laboratory error can lead to compromised data. The data collected for this study will be labeled with unique quality assurance flags for both laboratory and field data quality issues. Table 11 presents the flagging scheme that will be used in the reports produced for this project.

Table 11. Data qualifier definitions and usage criteria.

Data Qualifier	Definition	Criteria for Use
J	Value is an estimate based on analytical results	MQOs for field duplicates, laboratory duplicates, matrix spikes, laboratory control samples, holding times, or blanks have not been met
R	Value is rejected based on analytical results	Major quality control problems with the analytical results
j	Value is an estimate based on storm sampling criteria	Hydrograph is compromised from gage error, but is still deemed an adequate estimate
r	Value is rejected based on storm sampling criteria	Hydrograph is compromised from gage error, and has rendered the EMC non-representative
Jj	Value is an estimate based on analytical results and storm sampling criteria	Analytical and storm sampling criteria have not been met, but data is still usable
Jr	Value is an estimate based on analytical results and rejected based on storm sampling criteria	Analytical criteria have not been met but data still usable; Hydrograph is compromised from gage error, and has rendered the EMC non-representative.
U	Value is below the reporting limit	Based on laboratory method reporting limit
UJ	Value is below the reporting limit and is an estimate based on analytical results	Based on laboratory method reporting limit; MQOs for analytical results have not been met.
Ur	Value is below the reporting limit and is rejected based on storm sampling criteria	Based on laboratory method reporting limit; hydrograph is compromised from gage error, and has rendered the EMC non-representative.
Uj	Value is below the reporting limit and is an estimate based on storm sampling criteria	Based on laboratory method reporting limit; analytical and storm sampling criteria have not been met, but data is still usable.

Data Quality Assessment

Separate subsections herein describe the procedures that will be used to assess the usability of the data, and analyze the data.

Data Usability Assessment

The Herrera quality assurance officer will provide an independent review of the water quality QC data from each sampling event using the MQOs that have been identified in this QAPP. The results will be presented in a water quality data quality assessment report that will be prepared prior to the TER for the project (see *Audits and Reports* section). The data quality assessment report will summarize quality control results, identify when data quality objectives were not met, and discuss the resulting limitations (if any) on the use or interpretation of the data. Specific quality assurance information that will be noted in the data quality assessment report includes the following:

- Changes in and deviations from the QAPP
- Results of performance or system audits
- Significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data

To assess the quality of the flow data, the Herrera quality assurance officer will review results from the verification and validation process that was applied to the hydrologic data (see *Data Verification and Validation* section). Based on this review, specific data points or periods in the continuous time series data that are considered estimated or rejected values will be summarized in a tabular format. These results will then be presented in hydrologic data quality assessment report that will include a discussion of the resulting limitations, if any, on the use or interpretation of the data. The hydrologic data quality assessment report will also be prepared prior to the TER for the project (see *Audits and Reports* section).

Data Analysis Procedures

Data analysis will be performed to document the performance of the Filterra test system relative to treatment goals that are specified in the TAPE guidelines (Ecology 2011) for basic, enhanced, phosphorus, and oil control treatment. Separate subsections below describe the specific data analysis procedures that will be applied to meet these objectives.

Evaluation of Treatment Performance

To evaluate the treatment performance of the Filterra test system, the following data compilations and analyses will be generated from the monitoring results:

- Storm event data will be reviewed to determine if goals for representativeness that are specified in the *Quality Objectives* section of this QAPP were met.
- ISRs will be prepared for each storm event to summarize storm event characteristics, hydrologic, and pollutant data.
- Statistical comparisons of influent and effluent concentrations will be performed.
- Pollutant removal efficiency will be calculated for each parameter during each storm event.
- Statistical analyses of the compiled data will be performed to determine if specific treatment goals specified in the TAPE guidelines (Ecology 2011) were met.

Each of these activities is described in more detail below.

Storm Event Data

Using the compiled storm and sampling data, a summary table will be prepared with the following data from sampled storm events:

- Storm ID or number
- Location
- Storm depth
- Antecedent dry period
- Storm duration
- Influent and effluent volume of water
- Presence/absence of bypass
- Peak and average flow rates through the treatment system
- Number of influent aliquots
- Number of effluent aliquots
- Percentage of influent and effluent storm volume sampled

This information will be compared to storm event and sample collection guidelines that are specified in the *Quality Objectives* section of this QAPP to evaluate the overall representativeness of the compiled data.

Individual Storm Reports

ISRs will be prepared to provide a detailed description of each storm event monitored in an easy to read format. The ISRs will include the following general, storm, hydrologic, and pollutant information:

General Information

- Monitoring site name
- Site location (UTM or latitude/longitude)
- Drainage area

Storm Information

- Storm name or number
- Storm event date
- Antecedent dry period conditions
- Total precipitation depth (inches)
- Precipitation duration (hours)
- Mean precipitation intensity (inches per hour)
- Maximum precipitation intensity (inches per hour)

Hydrologic Information

- Influent/effluent/bypass peak flow rate (gallons per minute [gpm] or cubic feet per second [cfs])
- Average influent/effluent/bypass flow rate (gpm or cfs)
- Total influent/effluent/bypass runoff volume (gallons or cubic feet [cf])
- Event hydrograph (with time on x-axis, flow and precipitation on y-axes) that includes precipitation, influent flow, effluent flow, influent aliquots, and effluent aliquots
- Data flags for identified QA issues

Pollutant Information

- Number of influent aliquots
- Number of effluent aliquots
- Percent of storm sampled
- Parameters monitored
- Influent EMCs
- Effluent EMCs
- Removal efficiency
- Laboratory detection limits
- Data flags for identified QA issues

Statistical Comparisons of Influent and Effluent Pollutant Concentrations

Statistical analyses will be performed to determine whether there are significant differences in pollutant concentrations between the influent (FB-IN) and effluent (FB-OUT) stations across individual storm events. The specific null hypothesis (H_o) and alternative hypothesis (H_a) for these analyses are as follows:

> H_o: Effluent pollutant concentrations are equal to or greater than influent concentrations.
>
> H_a: Effluent concentrations are less than influent concentrations.

To evaluate these hypotheses, a 1-tailed Wilcoxon signed-rank test (Helsel and Hirsch 2002) will be used to compare the influent and effluent performance data. (The Wilcoxon signed-rank test is a nonparametric analogue to the paired t-test.) Statistical significance will be assessed based on an alpha (α) level of 0.05.

Pollutant Removal Efficiency Calculations

The removal efficiencies for each monitoring parameter during each storm event will be calculated using the following formula:

$$\frac{100[A-B]}{A}$$

where: A = (Storm 1 influent concentration) x (Storm 1 volume)

B = (Storm 1 effluent concentration) x (Storm 1 volume)

Pollutant Removal as a Function of Flow Rate

For flow-proportional composite sampling, an aliquot-weighted flow rate will be calculated based on the time that each aliquot was collected. Specifically, the influent flow rate at the time each aliquot was collected will be determined for each storm event based on the continuous flow measurements from the influent monitoring station; these values will then be averaged to obtain an aliquot-weighted flow rate for the sampled storm event. For discrete sampling, the flow rate at the time each sample was collected will be assigned to the sample based on comparisons of sample collection times to the continuous measurements from the influent monitoring station. A linear regression model will be developed using the influent flow rates as the independent variable and pollutant removal performance data (from the composite samples or discrete samples) as the dependent variable. The suitability of the regression equation should be evaluated using the diagnostics described in Helsel and Hirsch (2002).

Statistical Evaluation of Performance Goals

Statistical analyses will be performed to determine whether the collected data demonstrate the Filterra test system met applicable performance goals specified in the TAPE guidelines (Ecology

2011) for basic, enhanced, and phosphorus treatment (see Table 12). The statistical analysis will involve the computation of bootstrapped confidence intervals around the mean effluent concentration or pollutant removal efficiency. Bootstrapping offers a distribution-free method for computing confidence intervals around a measure of central tendency (Efron and Tibshirani 1993). The generality of bootstrapped confidence intervals means they are well-suited to non-normally distributed data or datasets not numerous enough for a powerful test of normality (Porter et al. 1997).

Table 12. Basic, enhanced, and phosphorus performance goals for TAPE monitoring.

Performance Goal	Influent Range	Criteria
Basic Treatment	20-100 mg/L TSS	Effluent goal ≤20 mg/L TSS [a]
	100-200 mg/L TSS	≥80% TSS removal [b]
	>200 mg/L TSS	>80% TSS removal [b]
Enhanced (Dissolved Metals) Treatment	Dissolved copper 0.003 – 0.2 mg/L	Must meet basic treatment goal and exhibit >30% dissolved copper removal [b,]
	Dissolved zinc 0.02 – 0.3 mg/L	Must meet basic treatment goal and exhibit >60% dissolved zinc removal [b,]
Phosphorus Treatment	Total phosphorus (TP) 0.1 to 0.5 mg/L	Must meet basic treatment goal and exhibit ≥50% TP removal [b]

Source: Ecology (2011).

[a] The upper 95 percent confidence interval around the mean effluent concentration for the treatment system being evaluated must be lower than this performance goal to meet the performance goal with the required 95 percent confidence.

[b] The lower 95 percent confidence interval around the mean removal efficiency for the treatment system being evaluated must be higher than this performance goal to meet the performance goal with the required 95 percent confidence.

mg/L – milligrams per liter

Cu – copper

TP – total phosphorus

TSS – total suspended solids

Zn – zinc

In its simplest form, bootstrapping a summary statistic of a dataset of sample size *n* consists of drawing *n* elements from the dataset randomly with replacement and equal probabilities of drawing any element. The statistic of interest is then calculated on this synthetic dataset, and the process is repeated for many repetitions. Repetition generates a distribution of possible values for the statistic of interest. Percentiles of this distribution are confidence intervals of the statistic. For example, if the mean is calculated for 1,000 synthetic datasets, after sorting the replications, the result for ranks 25 and 975 are the lower and upper 95 percent confidence intervals, respectively, around the mean.

For basic, enhanced, and phosphorus treatment with goals that are expressed as a minimum removal efficiency (i.e., 80 percent TSS removal, 30 percent dissolved copper removal, 60 percent dissolved zinc removal, and 50 percent TP removal), bootstrapping will be used to compute the 95 percent confidence interval around the mean removal efficiency for each parameter. The lower 95 percent confidence limit will then be compared to the applicable performance goal. If the lower confidence limit is higher than the treatment goal, it can be concluded that the Filterra test system met the performance goal with the required 95 percent confidence.

For the basic treatment with goal that is expressed as a maximum effluent concentration (i.e., 20 mg/L TSS), bootstrapping will be used to compute the 95 percent confidence interval around the mean effluent concentration. The upper 95 percent confident limit will then be compared to the applicable performance goal. If the upper confidence limit is lower than the treatment goal, it can be concluded that the Filterra test system met the performance goal with the required 95 percent confidence.

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APPENDIX A

Western Washington Engineering Design Assistance Kit

WA DOE GULD TAPE/TARP
APPROVED

WESTERN WASHINGTON

Engineering Design Assistance Kit (DAKit) v01 - WA

filterra®
Bioretention Systems
A Growing Idea in Stormwater Filtration

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Filterra® Stormwater Bioretention Filtration System

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Introduction and Scope of this Document

At federal, state and local levels, stormwater management is increasingly important. Americast's Filterra® units can help developers comply with NPDES legislation by removing pollutants, using a small efficient natural system that is both cost-effective and reliable.

This document is compiled to assist engineers in the proper design for the best results where Filterra® is used for stormwater quality management. We want your project to be successful and it is important to this success that you follow guidelines contained herein. Please review the essential reading section (p. 7).

The Filterra® Bioretention Filtration System has received General Use Level Designation by the Washington State Department of Ecology for BASIC, ENHANCED AND OIL/GREASE TREATMENT as well as Conditional Use Level Designation for PHOSPHORUS treatment.

It is essential to (as per WA DOE approval conditions):

- Adhere to the Design Guidelines, p.7
- Size the Filterra® unit correctly, using the regional Sizing Table, p.11-12
- Complete the Project Information Form (p.9) and submit with plans to Americast for review before permitting. THIS REVIEW IS MANDATORY as a DOE condition and for warranty to apply and helps ensure that each Filterra® system operates efficiently to maximize performance and minimize maintenance.

Other documents available on request include:

Technical Whitepaper	Scientific paper more fully explaining processes occurring within the system
Filterra Product Performance Data Summary	Data sheet providing the latest facts available
Third Party Data	Data presented by independent parties
Operation & Maintenance Manual	Owner's manual presenting technical and operational details.
Installation Manual	Instruction manual for proper installation.

Table of Contents

Section A

Essential Reading - Filterra Overview

Important!

Please remember to complete and send the Project Information Form (p.9) to Filterra® with plans for evaluation. This review is mandatory as proper placement ensures optimum performance and validates the product warranty.

Toll Free: (866) 349-3458
Fax: (804) 798-8400
design@filterra.com

Filterra® Overview
Stormwater Bioretention Filtration System

Save valuable space with small footprint for urban sites

Improve BMP aesthetics with attractive trees or shrubs

Reduce lifetime cost with safer and less expensive maintenance

Remove Pollutants and Comply with NPDES

Filterra® is well-suited for the ultra-urban environment with high removal efficiencies for many pollutants such as petroleum, heavy metals, phosphorus, nitrogen, TSS and bacteria. Filterra® is similar in concept to bioretention in its function and applications, with the major distinction that Filterra® has been optimized for high volume/flow treatment and high pollutant removal. It takes up little space (often only a 4'x4' unit for each mandatory catch basin) and may be used on highly developed sites such as landscaped areas, green space, parking lots and streetscapes. Filterra® is exceedingly adaptable and is the urban solution for Low Impact Development.

Stormwater flows through a specially designed filter media mixture contained in a landscaped concrete container. The filter media captures and immobilizes pollutants; those pollutants are then decomposed, volatilized and incorporated into the biomass of the Filterra® system's micro/macro fauna and flora. Stormwater runoff flows through the media and into an underdrain system at the bottom of the container, where the treated water is discharged. Higher flows bypass the Filterra® via a downstream inlet structure, curb cut or other appropriate relief.

Expected Average Pollutant Removal Rates
(Ranges Varying with Particle Size, Pollutant Loading and Site Conditions)

TSS Removal	85%
Phosphorous Removal	60% - 70%
Nitrogen Removal	43%
Total Copper Removal	> 58%
Dissolved Copper Removal	46%
Total Zinc Removal	> 66%
Dissolved Zinc Removal	58%
Oil & Grease	> 93%

Design Guidelines for Using Filterra®

1. Do not place in a sump condition. The Standard Filterra® cannot be used as a stand alone inlet – it will need effective bypass during higher intensity rainfall events.

   Plans MUST show Filterra® Top Curb (TC) and Flow Line (FL) spot elevations and also bypass TC (where applicable) and bypass FL spot elevations.

   The Filterra® TC and FL elevations MUST be higher than the bypass TC and FL elevations for effective bypass. Use Drawing FLP-2 (p.24) as a detail on the project plans.

2. For proper trash collection ensure a minimum 4” and maximum 6” Filterra® throat opening depth and use Drawing CGT-5 (p.25) as a detail on the project plans.

3. Do not direct surface flow to the standard Filterra® in a “head-on” configuration. Refer to Guidelines GU1-A (p.12) and GU2 (p.13) for grading design that encourages flow to enter a Filterra® in a cross linear flow – left-to-right or right to-left in the gutter in front of the throat, as per a wet curb which prevents system damage. During extreme storm events the excess flow should continue past the Filterra® to a bypass inlet or other means of relief. Guideline GU3, Parking Lot Corners, shows common situations (p.14).

4. To calculate which size Filterra® is required, use Table 1, Filterra® Quick Sizing Table, appropriate to the project’s geographical region and then follow the WWHM instructions on (p.13) to ensure the 91% threshold is met. The maximum contributing drainage area will vary with site conditions and project locations. For further information relating to sizing, please contact Filterra.

5. To ensure correct installation, include the Standard Filterra® Plan Notes (p.29-30) on your Filterra® detail project sheet, as well as detailed drawings FLP-2 and CGT-5 (p.27,28).

6. Positive drainage of each Filterra® unit’s effluent treatment pipe is required to prevent free standing water from accumulating in the system or underdrain. This could occur due to tidal influences or improper connection of Filterra’s effluent pipe to a bypass structure or other outfall.

7. **Send plans and the completed Filterra® Project Information Form** (p.9) to Americast for Filterra® placement review. Plan sheets should include grading, drainage areas, stormwater schedules or profiles, landscape sheets and Filterra® detail sheets. THIS REVIEW IS MANDATORY for warranty to apply and helps ensure that each Filterra® system operates efficiently to maximize performance and minimize maintenance. Our staff also looks for value engineering opportunities.

Methods of sending information for review are as follows:
E-mail: design@filterra.com

AutoCAD or PDF files
Fax: (804) 798-8400
FTP Site: contact Filterra for details

Mail or other:
Filterra Review
11352 Virginia Precast Road
Ashland, VA 23005

Items Considered in Americast's Filterra® Plan Reviews

Following is a summary list of the items Americast considers during plan review. Plan sheets should include grading, drainage areas, stormwater schedules or profiles, landscape sheets and Filterra® details.

Notes

- Filterra® Structure Label or Identification Number
- Planned Filterra® Box Size
- Filterra® Contributing Drainage Area (not the bypass inlet Drainage Area)
- The C Factor for each individual Filterra® drainage area

Checks

- The planned Filterra® box size meets project's regional sizing specification
- Spot elevations (Top Curb & Flow Line) for Filterra® and bypass (TC & FL)
- The Filterra® spot elevations (TC & FL) are higher than bypass spot elevations
- The grading design encourages cross linear flow and not head-on flow
- Filterra® invert elevations are shown (3.5' below TC)
- Filterra® effluent treatment pipe invert elevations are higher than bypass structure or other out fall invert elevations
- The Filterra® outlet drain pipe is sized correctly
- The outlet drain pipe exits perpendicular to the Filterra® wall
- For any conflicting structures such as storm drain pipes below Filterra®
- For most efficient placement of Filterra® units
- Plans include Filterra® details listed below:

  FLP-2: Filterra® Typical Flow Line and Outlet Pipe Relationship

  CGT-5: Filterra® Throat Opening and Gutter or Flume Detail

  Filterra® Standard Plan Notes (2 pages)

Filterra® Project Information Form

PLEASE PRINT AND FAX OR EMAIL THIS FORM

12/09-v01- Western WA

Complete & send to Americast by email, fax or mail.

Project Information

Address: 11352 Virginia Precast Road
Ashland, VA 23005

Toll Free: **(866) 349-3458**
Fax: (804) 798-8400
Email: design@filterra.com

filterra Bioretention Systems

Project Name/Number:
Regulatory Municipality and State (City, County, etc.):
Target Treatment Rate:
WWHM Gage:
WWHM Precipitation Factor:

Engineering Contact Information	
Engineering Firm:	Current Date:
Contact:	Phone:
Email:	Fax:

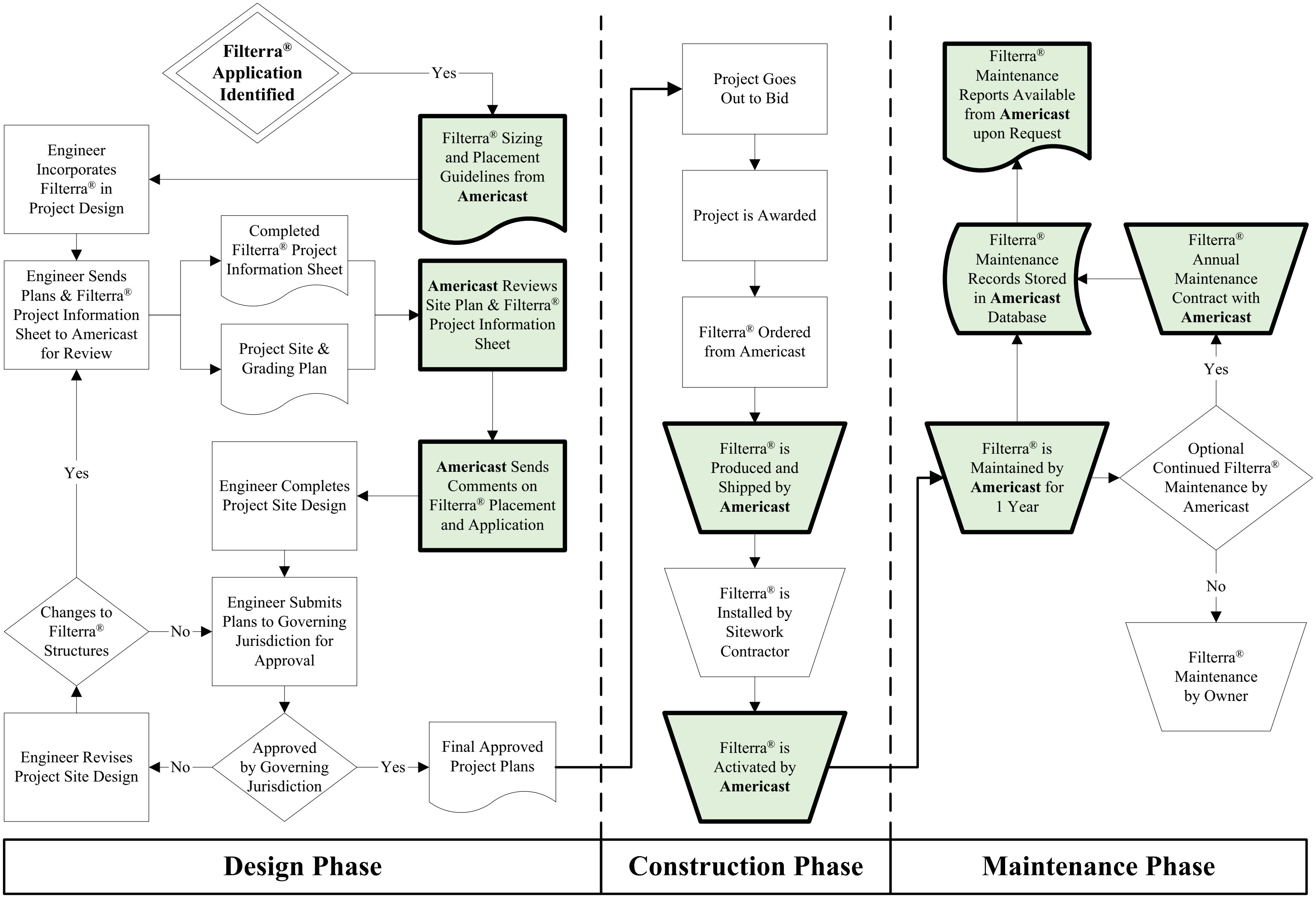
Filterra® Details (Email, mail or fax plans to Americast - Acceptable formats are AutoCAD or pdf)
Plans sheets should include (1) cover, (2) grading, (3) drainage areas, (4) stormwater schedules or profile, (5) landscaping & (6) Filterra® details.

Filterra Structure #												
Filterra Size (ID ft)	Throat L x W											
Impervious Drainage Area	Acres											
Pervious Drainage Area	Acres											
Percent Filtered												
Filterra Spot Elevation	TC											
	FL											
	INV OUT											
Bypass Spot Elevation	TC											
	FL											
Bypass or Effluent	INV IN											
Modified Structure	Y/N?											
Grate or Top Options	Y/N?											

TC = Top Curb , FL = Flow Line

FLP Detail on plans (Y/N) ____ CGT Detail on plans (Y/N) ____ FT Plan Notes shown (Y/N) ____

Filterra® Project Process Flowchart - Design to Maintenance



Bold items indicate services provided by Americast.

01/04/05

Bioretention Systems

Table 1: WWHM Sizing for Basic, Oil/Grease and Phosphorous Treatment
Western Washington Region - v01

Available Filterra® Box Sizes (feet)	**Approximate Contributing Drainage Area (acres)**
4 x 4	0.195
4 x 6 or 6 x 4	0.285
4 x 8 or 8 x 4	0.375
6 x 6	0.430
6 x 8 or 8 x 6	0.575
6 x 10 or 10 x 6	0.720
6 x 12 or 12 x 6	0.865

Notes:

1. Sizing table intended for planning level use. The design engineer must use the latest version of WWHM to calculate the appropriately sized facility.
2. Sizing table meets WA DOE 2005 Stormwater Manual's 91% annual stormwater volume filtered.
3. Sizing table based on WWHM3 parking/flat and the SeaTac rain gage with a precipitation factor of 1.0. Other precipitation factors, geographic locations and site conditions will affect Filterra sizing.
4. Sand Filter (Filterra) parameters:
   - Filter material depth = 1.8 feet
   - Effective ponding depth = 0.75 feet
   - Zero slope on the filter box
   - Riser height = 0.7 feet
   - Riser diameter = 100 inches
   - Filter Hydraulic Conductivity = 35.46 inches per hour
5. All boxes are a standard 3.5 feet depth (INV to TC).
6. A standard SDR-35 PVC pipe coupling is cast into the wall for easy connection to discharge drain.
7. Dimensions shown are internal. Please add 1' to each external (using 6" walls)
8. Valid for Basic (TSS), Oil/Grease and Total Phosporous Treatment regiments.

Bioretention Systems

Table 1: WWHM Sizing for Enhanced Treatment ONLY
Western Washington Region - v01

Available Filterra® Box Sizes (feet)	Approximate Contributing Drainage Area (acres)
4 x 4	0.140
4 x 6 or 6 x 4	0.210
4 x 8 or 8 x 4	0.275
6 x 6	0.310
6 x 8 or 8 x 6	0.415
6 x 10 or 10 x 6	0.520
6 x 12 or 12 x 6	0.630

Notes:

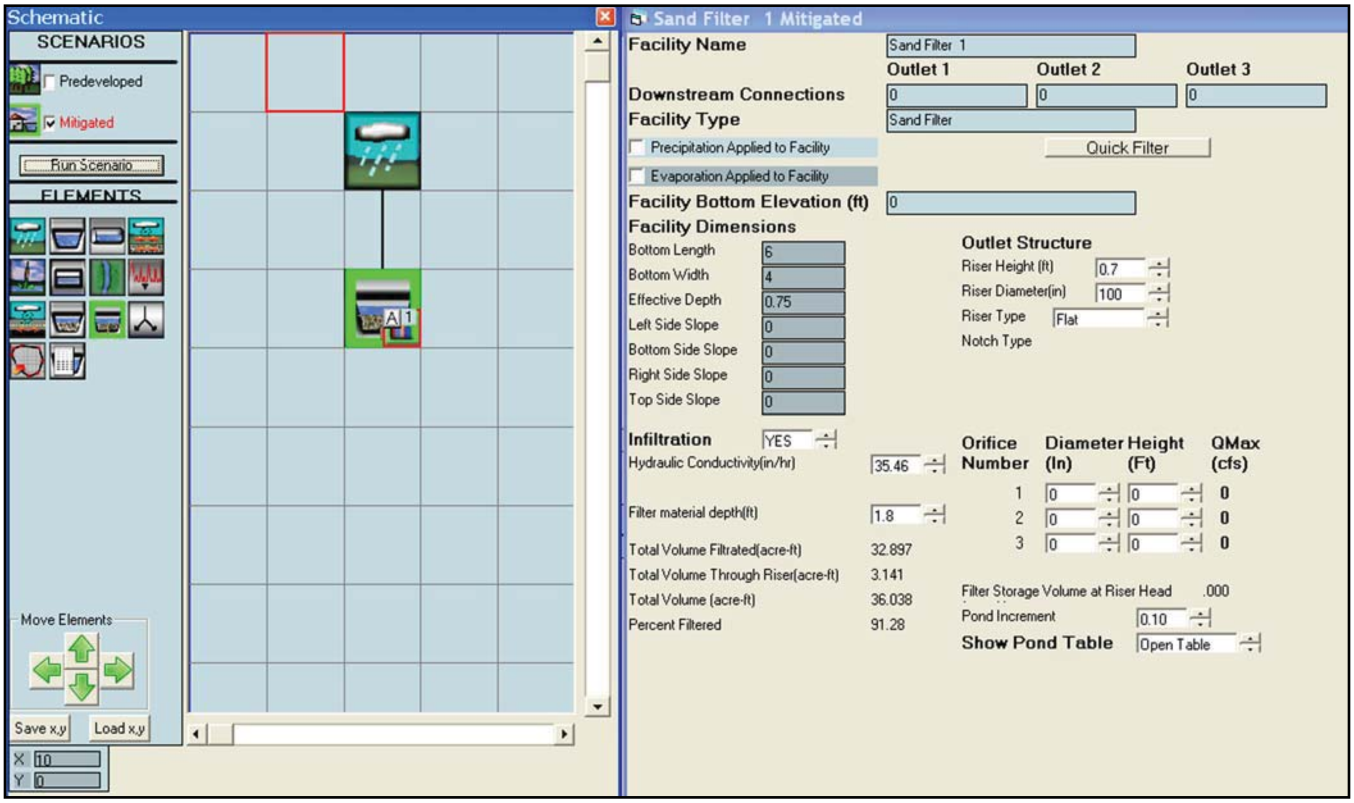
1. Sizing table intended for planning level use. The design engineer must use the latest version of WWHM to calculate the appropriately sized facility.
2. Sizing table meets WA DOE 2005 Stormwater Manual's 91% annual stormwater volume filtered.
3. Sizing table based on WWHM3 parking/flat and the SeaTac rain gage with a precipitation factor of 1.0. Other precipitation factors, geographic locations and site conditions will affect Filterra sizing.
4. Sand Filter (Filterra) parameters:
   - Filter material depth = 1.8 feet
   - Effective ponding depth = 0.75 feet
   - Zero slope on the filter box
   - Riser height = 0.7 feet
   - Riser diameter = 100 inches
   - Filter Hydraulic Conductivity = 24.82 inches per hour
5. All boxes are a standard 3.5 feet depth (INV to TC).
6. A standard SDR-35 PVC pipe coupling is cast into the wall for easy connection to discharge drain.
7. Dimensions shown are internal. Please add 1' to each external (using 6" walls)
8. Valid for Enhanced Treatment regiments (Dissolved Zinc and Copper).

Steps To Sizing A Filterra® Bioretention System

1. Use the Filterra Design Assistance (DA) Kit
2. Follow Filterra Guidelines on page 7 and page 8 in DA Kit.
3. Open and run WWHM – In the "Site Information" window, select the appropriate county from the pull down menu in the top left corner and then click on the project location on the map. Next, click the "General Project Information" button and build your drainage basin (usually <1 acre of impervious) with the "Mitigated" Scenario checkbox selected. Enter all pervious and impervious areas that direct runoff into the basin.
4. Connect your "basin" to the Sand Filter Element (Filterra)
5. Connect both interflow and surface flow to the Filterra element.
6. Build Filterra using the Sand Filter module and enter the WWHM inputs as described on the following page.
7. Right click sand filter module to ensure the Filterra becomes the POC, Point of Compliance.
8. Ensure both OUTLET 1 and OUTLET 2 checkboxes are selected when the POC screen appears.
9. Click on the "Run Scenario" button and verify that the Percent Filtered is equal or greater than DOE's 91% threshold for treated runoff (% of stormwater filtered through the Filterra).
10. Click the "Analysis" button and select the "Water Quality" tab.
11. Select the "701 IN Flow to POC 1 Mitigated" dataset and click the "Run Analysis" button.

Send to design@filterra.com your project information sheet, grading plan, drainage divides, profiles and cover sheet.

WWHM – Sand Filter/Filterra Inputs



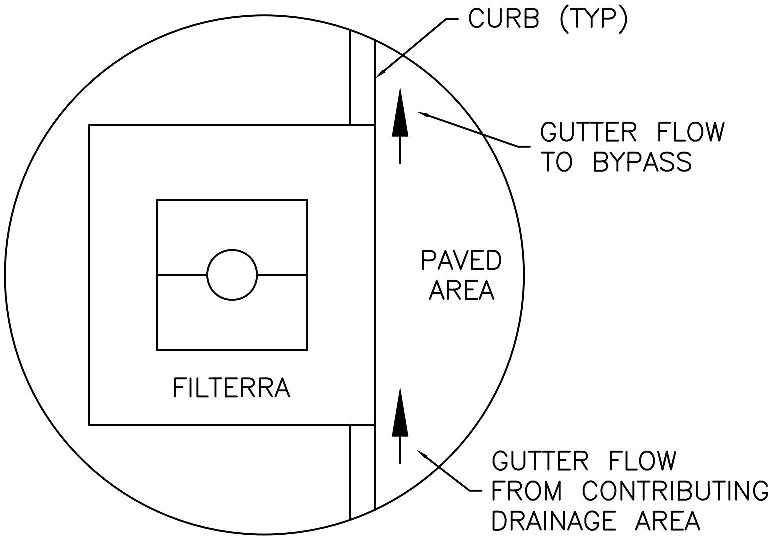
A. **BMP Facility**

- Bottom Length /Width = Filterra box size (choose from Filterra sizing table)
- Effective Depth (freeboard) = 0.75 feet (9 inches of freeboard)
- There is no slope to a square vault or box
- Hydraulic Conductivity = 35.46"/hr (Basic) or 24.82"/hour (Enhanced)
- Filter Material Depth = 1.80 feet

B. **Outlet Structure (mimics the bypass CB)**

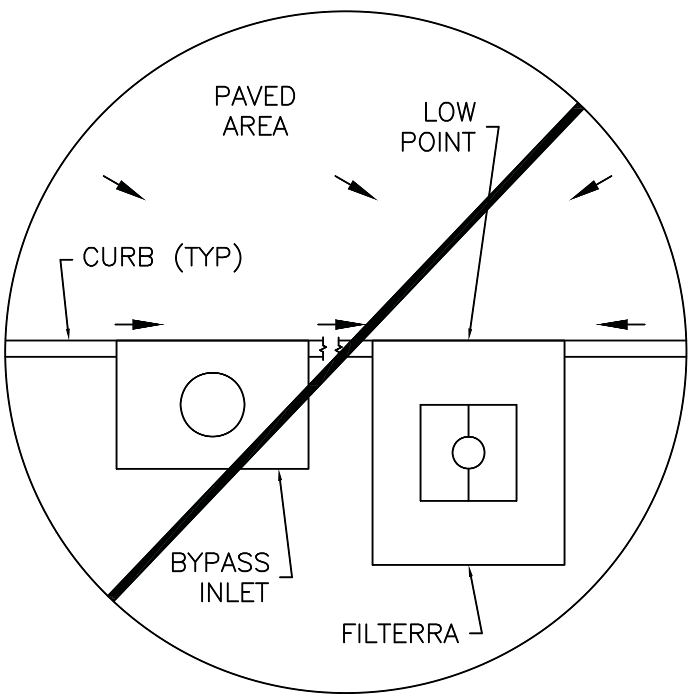
- Riser Height (lower than max. freeboard) = 0.7 feet
- Riser Diameter = 100 inches (no restriction in flow)

GRADING AND GUTTER FLOW

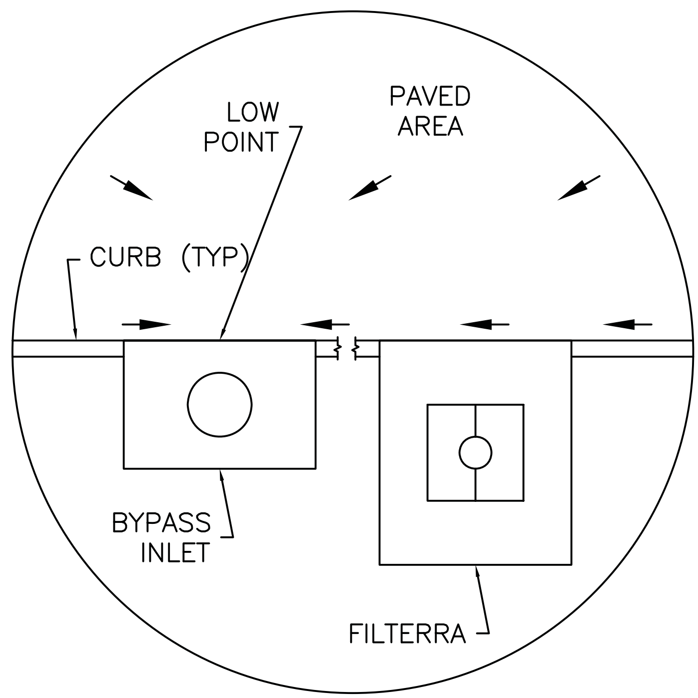


GUTTER FLOW

GRADING AND CURB AND GUTTER SHOULD BE SUCH THAT GUTTER FLOW APPROACHES THE FILTERRA FROM ONE SIDE OF THE THROAT AND FLOWS AWAY FROM THE FILTERRA ON THE OPPOSITE SIDE DURING EXTREME STORM EVENTS. DESIGN OR INSTALLATION SUCH THAT FLOW APPROACHES FROM BOTH SIDES WILL RESULT IN SITE MAINTENANCE ISSUES AND VOID MANUFACTURER'S MAINTENANCE PROGRAM AND WARRANTY.



INCORRECT



CORRECT

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DATE: 03-03-05 DWG: GU1-A

FILTERRA® GUIDELINES
GRADING AND GUTTER FLOW

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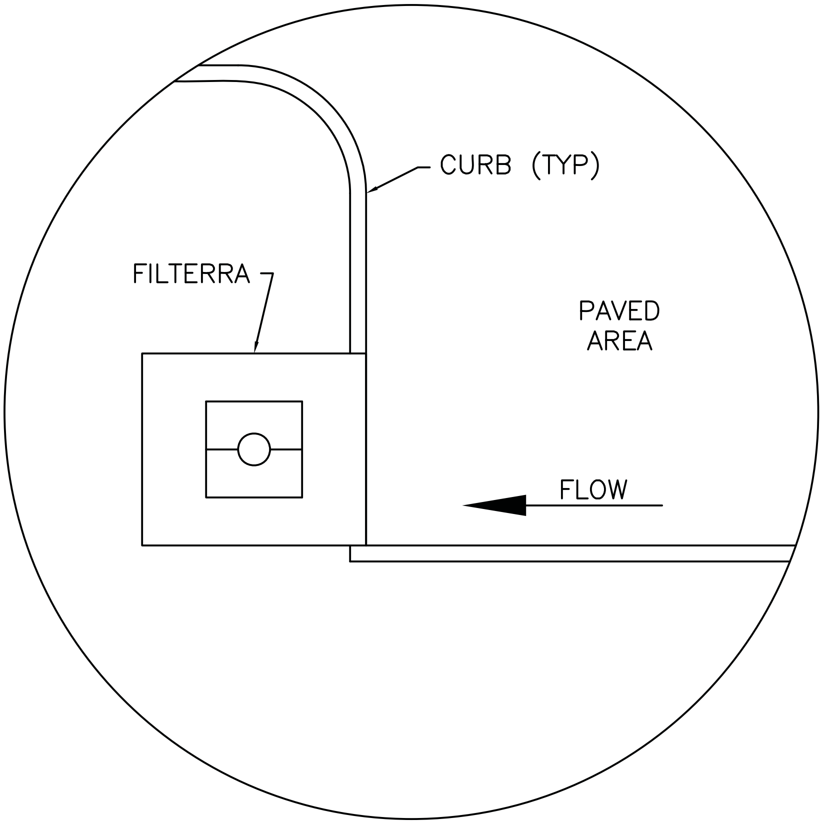
US PAT 6,277,274 AND 6,569,321

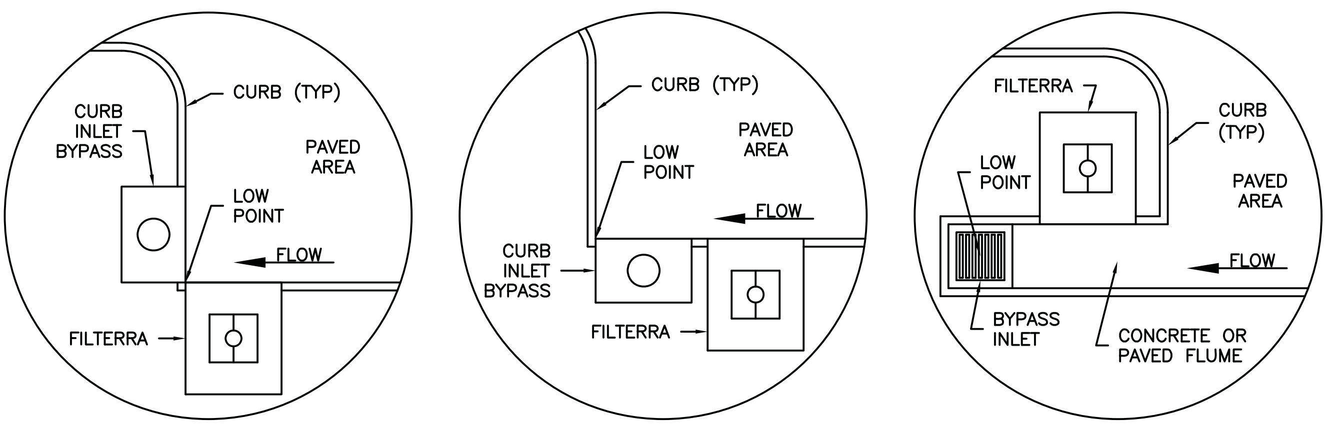
AVOID "HEAD-ON" GUTTER FLOW



PROBLEM

FLOW FROM THE ADJACENT GUTTER HITS THE FILTERRA "HEAD–ON". THIS CAN CAUSE SYSTEM DAMAGE (MEDIA EROSION OR SUSPENSION). REGARDLESS OF WHETHER BYPASS IS PROVIDED THIS IS A PROBLEM SCENARIO.

GUTTER FLOW SHOULD APPROACH THE FILTERRA PARALLEL TO THE THROAT SO THAT WATER FLOWS IN A LINEAR PATTERN IN FRONT OF THE THROAT. DURING EXTREME STORM EVENTS, EXCESS WATER SHOULD CONTINUE TO FLOW IN FRONT OF THE FILTERRA TO A BYPASS INLET OR OTHER RELIEF.



POSSIBLE SOLUTIONS

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DATE: 12–22–04	DWG: GU2

FILTERRA® GUIDELINES
AVOID "HEAD-ON" GUTTTER FLOW

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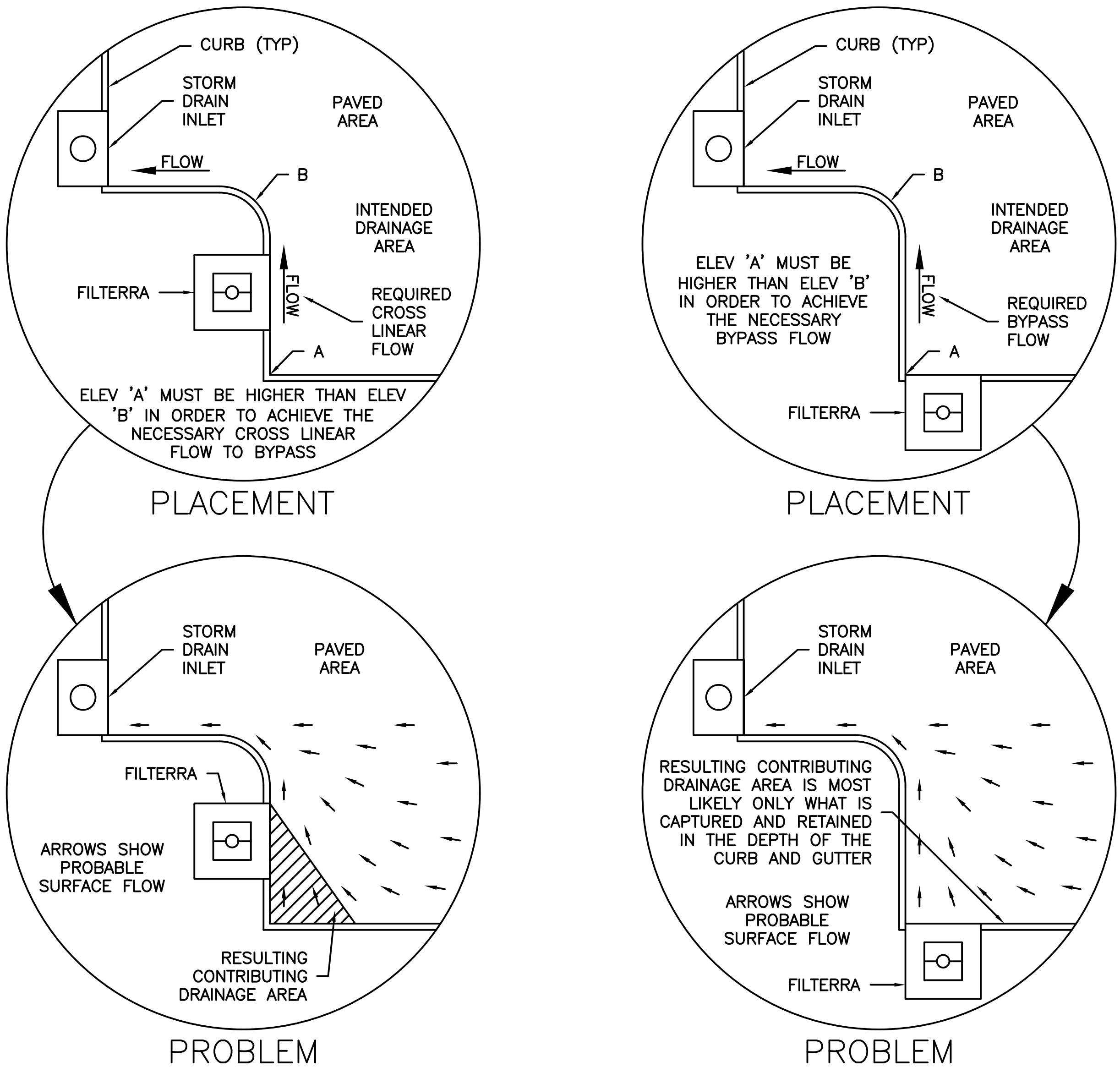
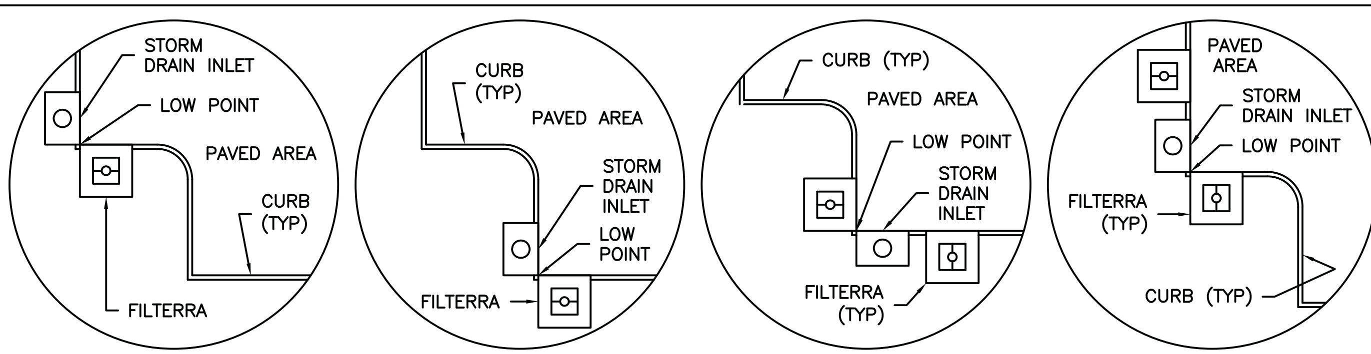
PARKING LOT CORNERS





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POSSIBLE PLACEMENT SOLUTIONS

DATE:	12–14–04	DWG:	GU3

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FILTERRA® GUIDELINES
PARKING LOT CORNERS

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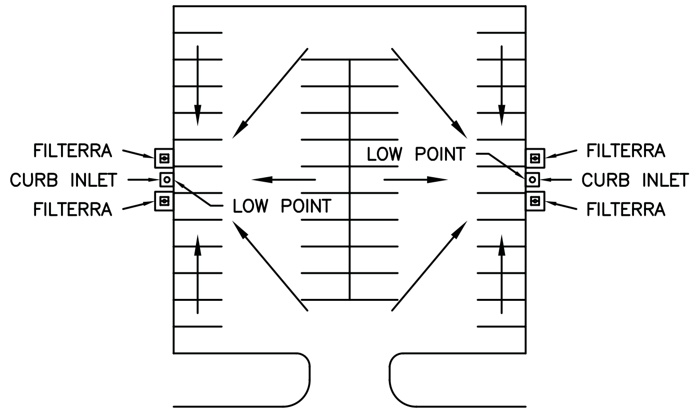
Section B

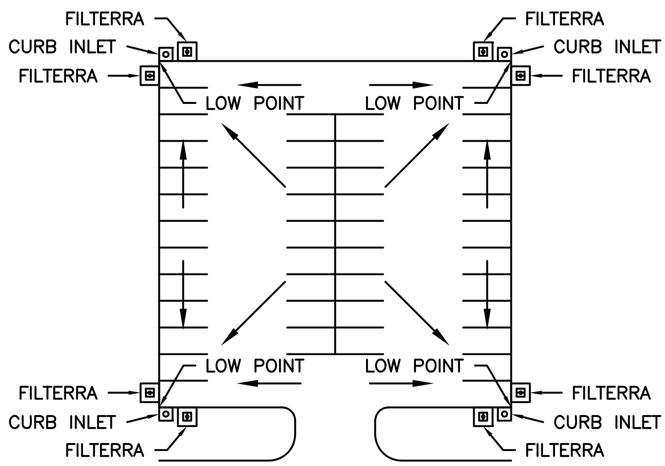
Filterra® Plans, Placement & Grading

Scenario Ideas to Ensure
Maximum Efficiency &
Minimum Space Used

Toll Free: (866) 349-3458
Fax: (804) 798-8400
design@filterra.com

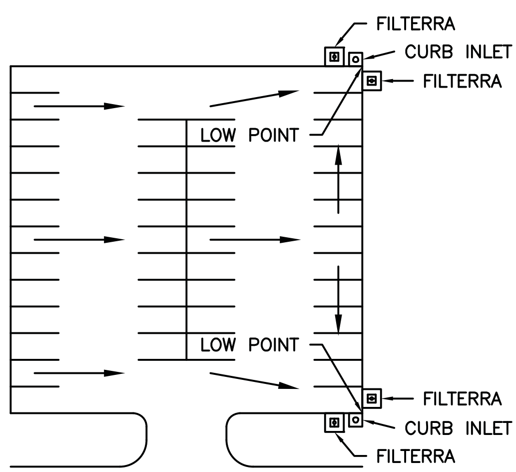


LOW POINTS AT 2 SIDES



LOW POINTS AT 4 CORNERS

ARROWS INDICATE
DIRECTION OF SURFACE
DRAINAGE FLOW



LOW POINTS AT 2 CORNERS

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FROM FILTERRA

DATE:	01–03–05	DWG:	PLG1

FILTERRA® EXAMPLE SCENARIOS
TYPICAL PARKING
LOT APPLICATIONS

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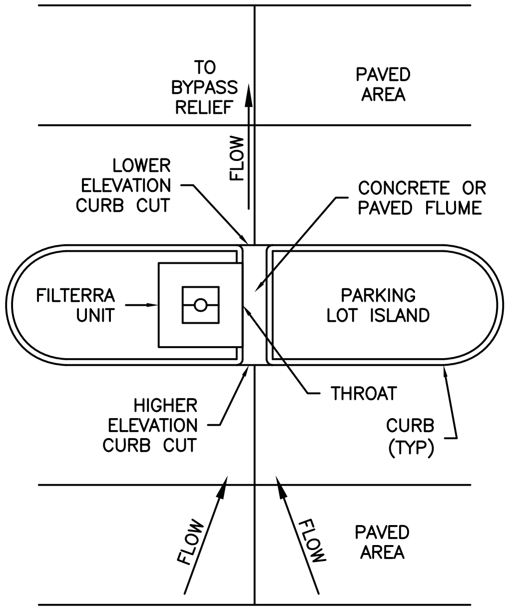
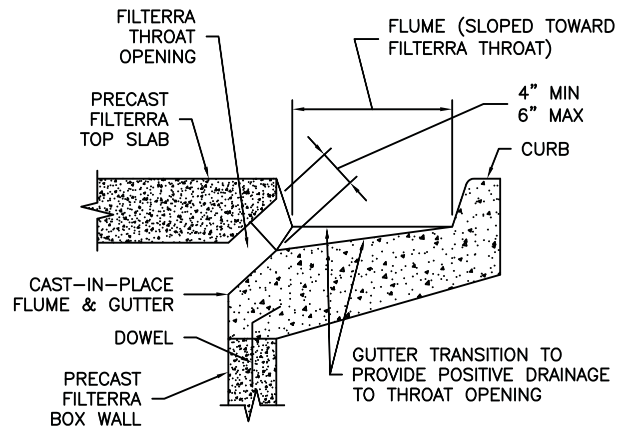
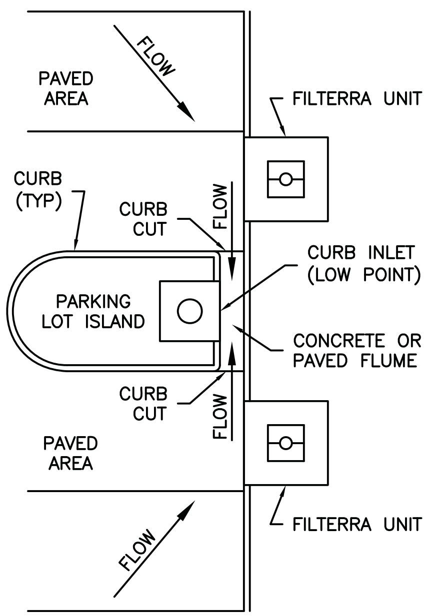


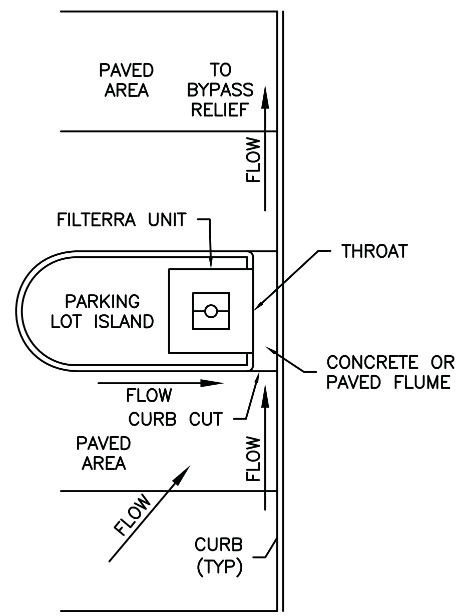
ON–GRADE ISLAND
IN OPEN PARKING LOT



SECTION VIEW OF FILTERRA
THROAT AND FLUME



LOW POINT ISLAND
AT SIDE OF PARKING LOT



ON–GRADE ISLAND
AT SIDE OF PARKING LOT

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DATE: 01–03–05	DWG: PLG2

FILTERRA® EXAMPLE SCENARIOS
PARKING LOT ISLAND APPLICATIONS

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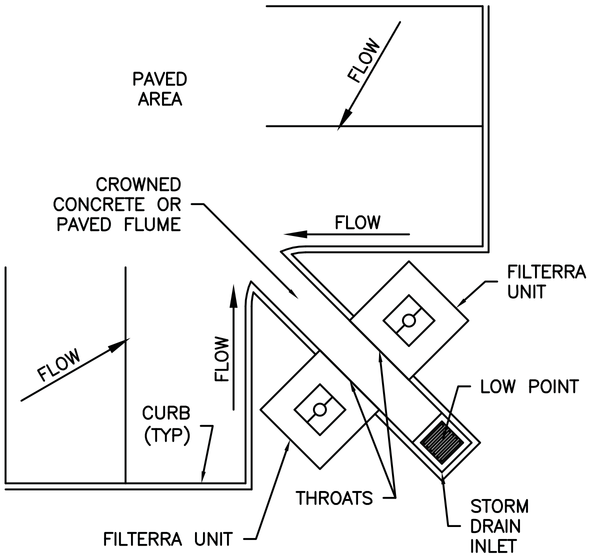
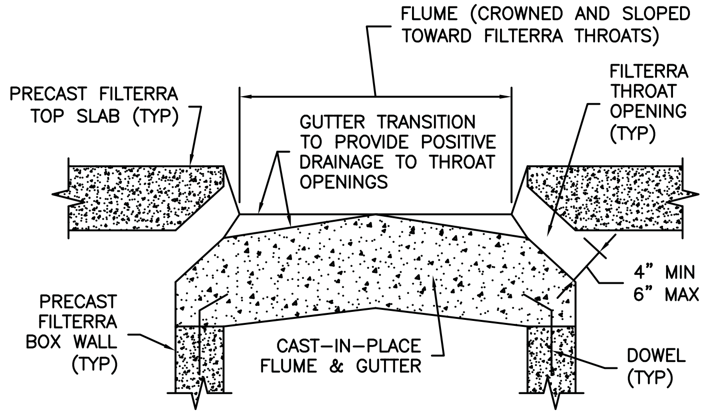
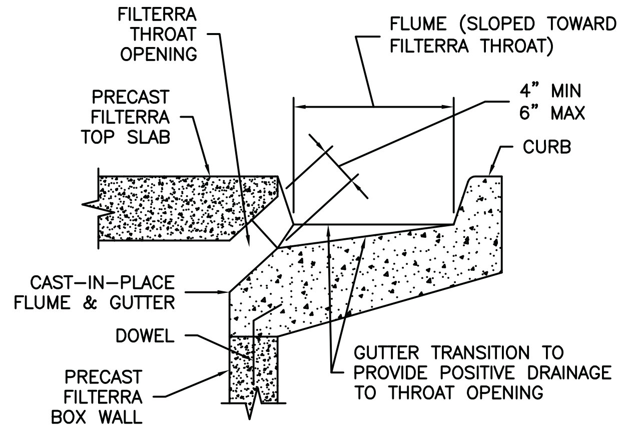


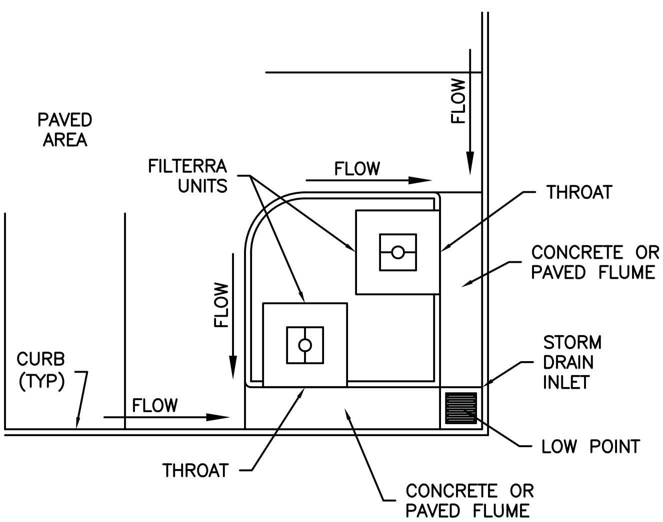
CROWNED FLUME CORNER



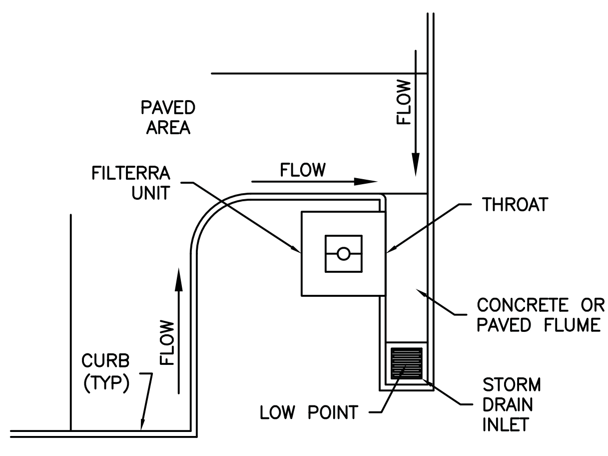
SECTION VIEW OF CROWNED FLUME



SECTION VIEW OF FILTERRA THROAT AND FLUME



TWO FLUME CORNER



ONE FLUME CORNER

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FILTERRA® EXAMPLE SCENARIOS
PARKING LOT CORNER APPLICATIONS

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Example A

INFILTRATION AND STORAGE CONFIGURATION

The Filterra System is well suited for pretreating runoff for underground infiltration and storage applications.

The use of the Filterra System significantly lowers the maintenance and cost of such underground systems.

Example B

INFILTRATION AND STORAGE CONFIGURATION

The compact design of the Filterra System allows it to be easily combined with numerous infiltration and storage application to meet your site's specific requirements.

Examples of possible management practices include but are not limited to the pretreatment of stormwater for gravel infiltration galleries and storage applications in reinforced concrete pipe.

Example C

INFILTRATION, STORAGE AND RE-USE CONFIGURATION

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DATE: 12-12-09 DWG: FTHYD -1a

TYPICAL FILTERRA® CONFIGURATIONS

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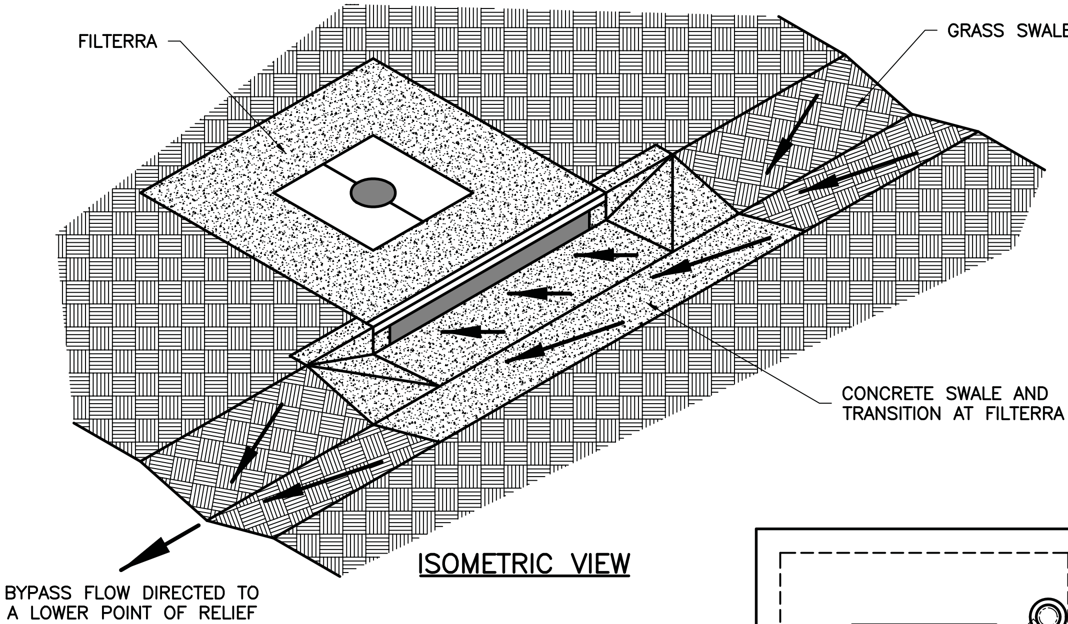
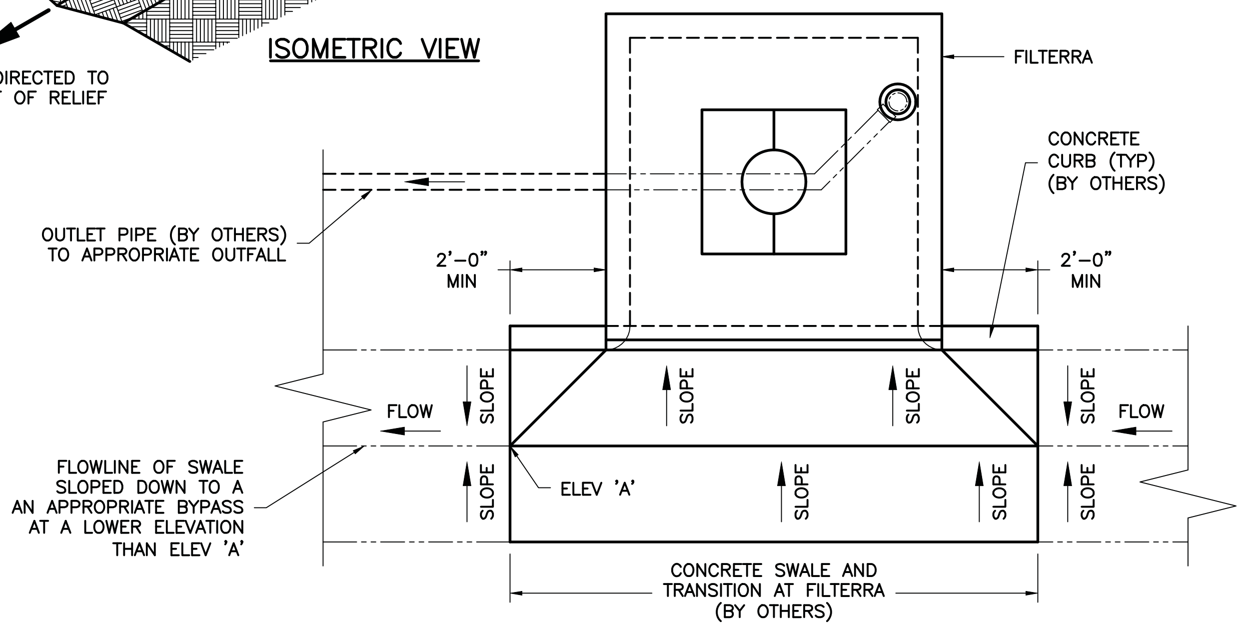
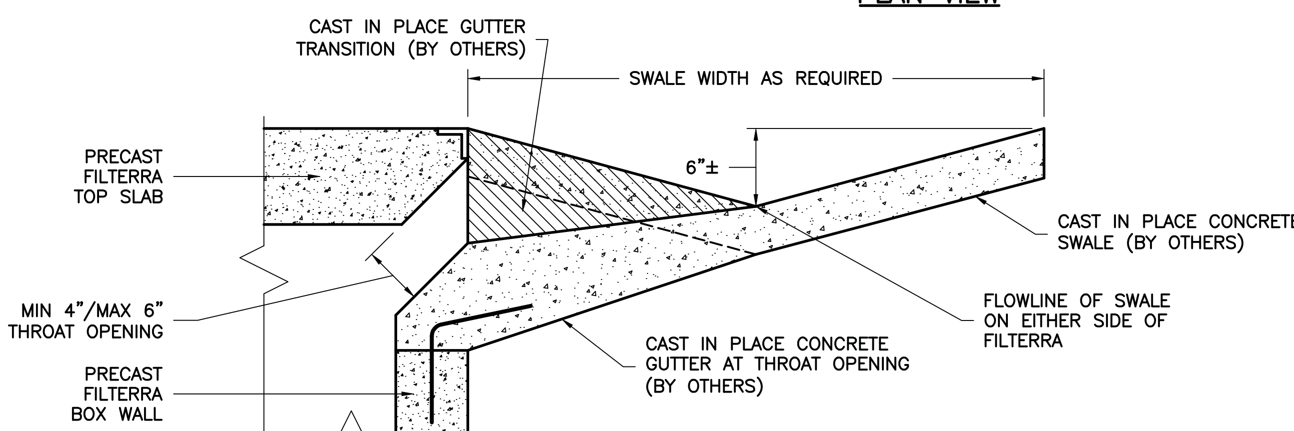


ISOMETRIC VIEW



PLAN VIEW



SECTION VIEW AT FILTERRA

DRAWING AVAILABLE IN TIF FILE FORMAT.

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DATE: 03–10–05 DWG: FTSWL–1

PRECAST FILTERRA® UNIT
TYPICAL SWALE
CONFIGURATION

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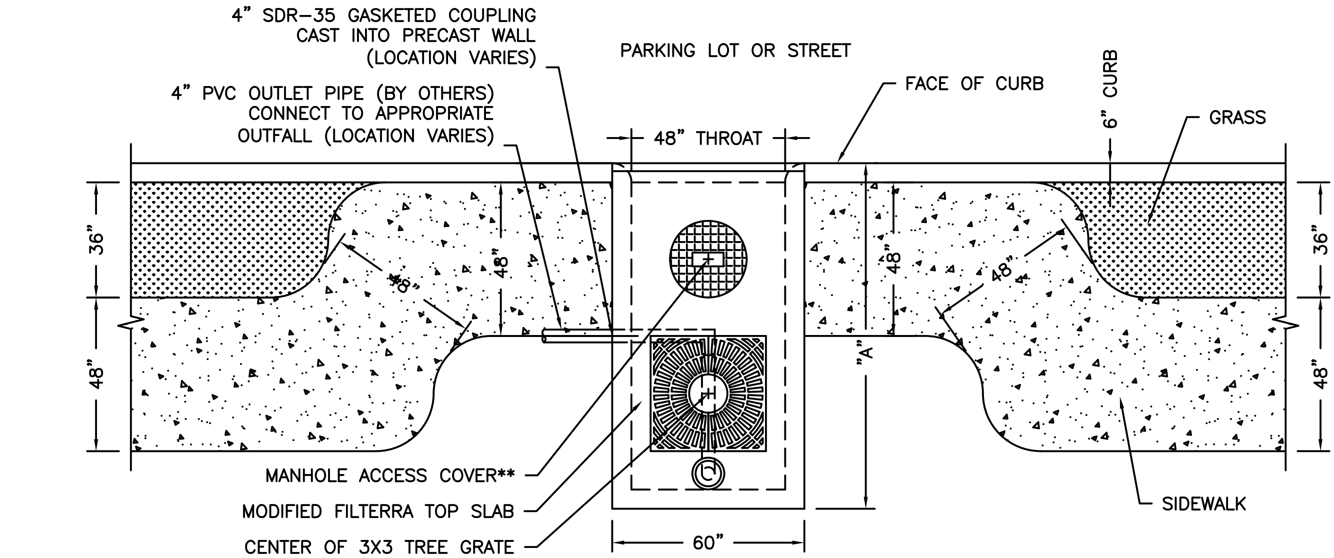


BOX SIZE	DIM. "A"	TREE GRATE	MANHOLE
4x8	9'–0"	3'x3'	YES
6x8	9'–0"	4'x4'*	YES
6x10	11'–0"	(1) 4'x4'	YES
6x12	13'–0"	(1) 4'x4'	YES

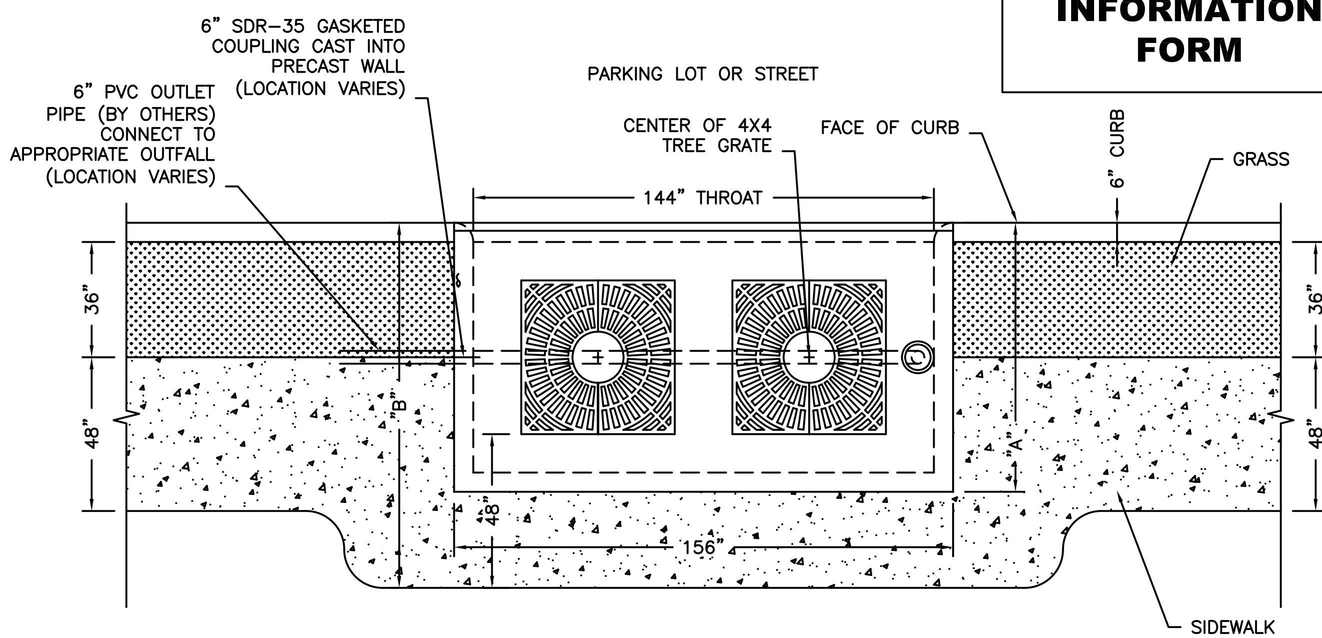
*3'x3' TREE GRATE IS OPTIONAL

**THE MANHOLE COVER IS REQUIRED ON SOME MODIFIED TOP SLABS FOR ACCESS DURING MAINTENANCE VISITS

MODIFIED NARROW LENGTH
FILTERRA UNIT

ONLY FOR 4x8 (SHOWN)
6x8 AND 6x10 BOXES

PLEASE NOTE MODIFICATION ON PROJECT INFORMATION FORM



BOX SIZE	DIM. "A"	DIM. "B"	TREE GRATE
8x4	5'–0"	9'–0"	3'x3'
8x6	7'–0"	9'–0"	4'x4'
10x6	7'–0"	11'–0"	4'x4'*
12x6	7'–0"	13'–0"	4'x4'*

*3'x3' TREE GRATE IS OPTIONAL

STANDARD NARROW WIDTH
FILTERRA UNIT

SUITABLE FOR ALL
STANDARD BOXES

MODIFICATIONS OF DRAWINGS ARE ONLY PERMITTED BY WRITTEN AUTHORIZATION FROM FILTERRA

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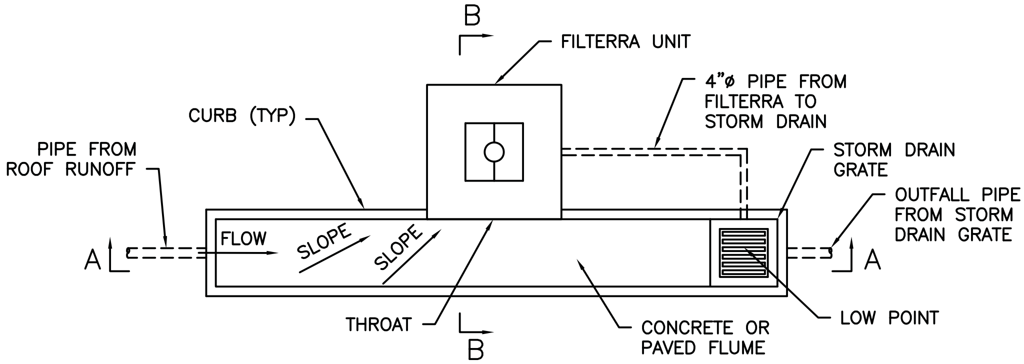
DATE: 12–09–09 DWG: WWA FTSC–4

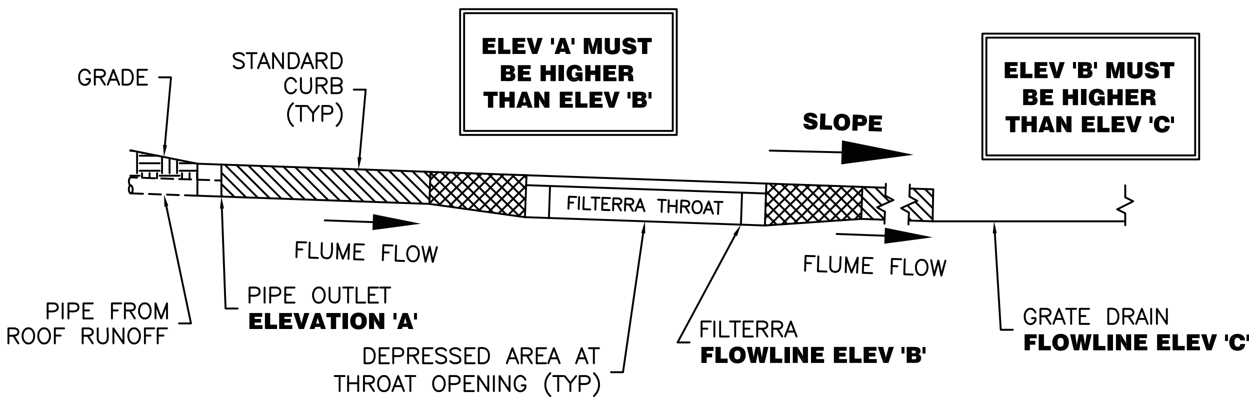
TYPICAL FILTERRA® SIDEWALK CONFIGURATIONS WESTERN WASHINGTON

filterra®

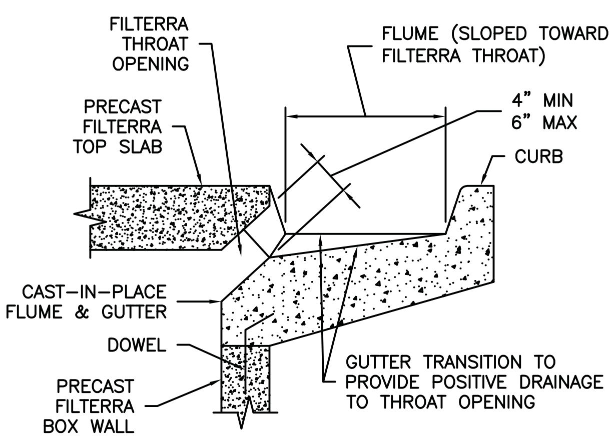
US PAT 6,277,274 AND 6,569,321



FLUME PLAN



FLUME CROSS SECTION A–A



FLUME SECTION B–B

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DATE: 03–17–05	DWG: FTRDF–1

FILTERRA® EXAMPLE SCENARIOS
ROOF DRAIN FLUME APPLICATION

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Section C

Standard Filterra® Detail Drawings & Filterra® Plan Notes

For TIF, PDF or CADD versions of these detail drawings, please contact Americast.
Toll Free: (866) 349-3458
E-mail: design@filterra.com

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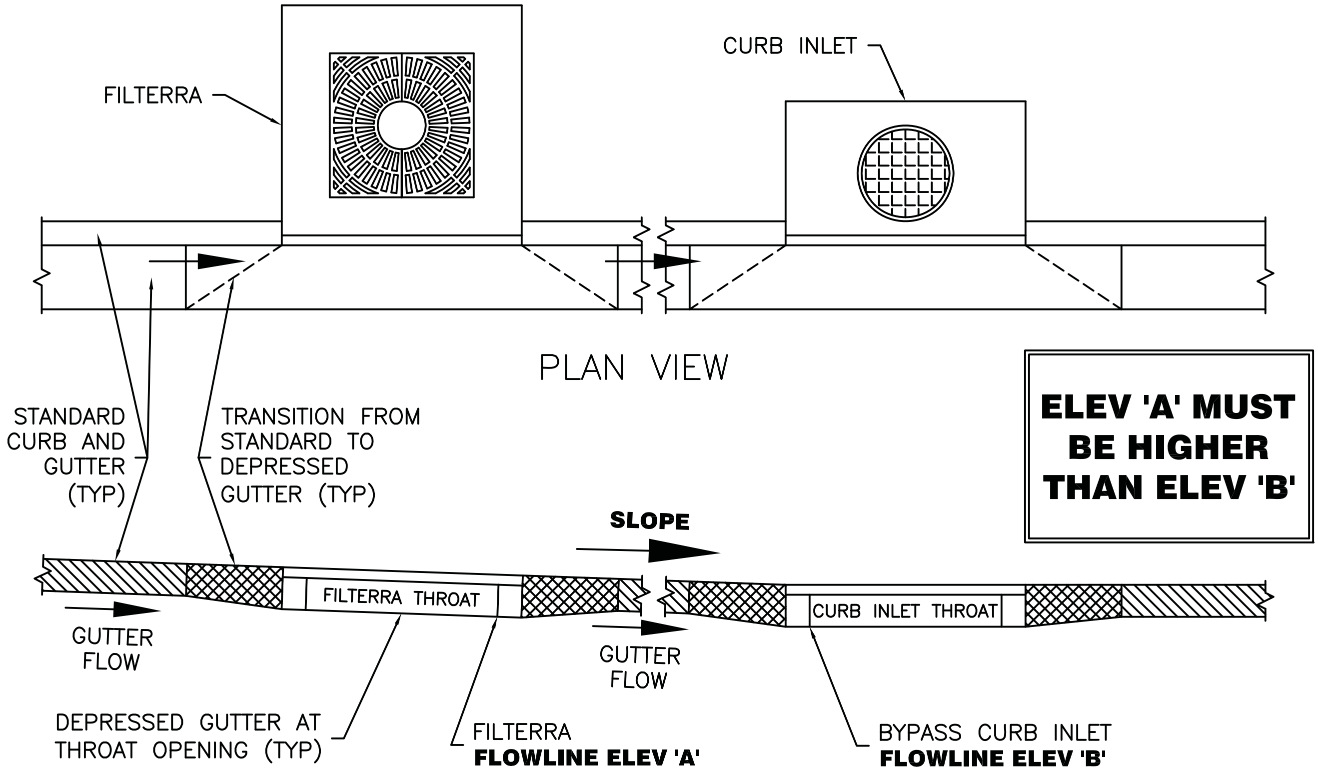
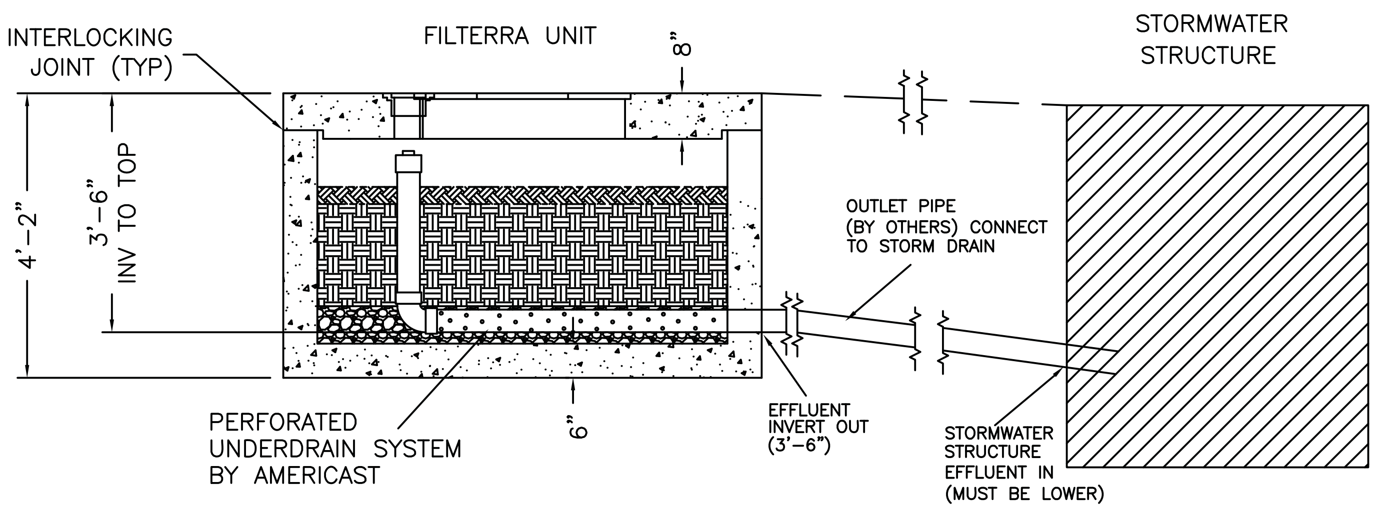
Filterra and Americast reserve the right to alter specifications without notice. Please make certain the Filterra Project Information Form is completed to ensure the verification of the latest specifications for your project.



ELEVATION VIEW



CROSS SECTION

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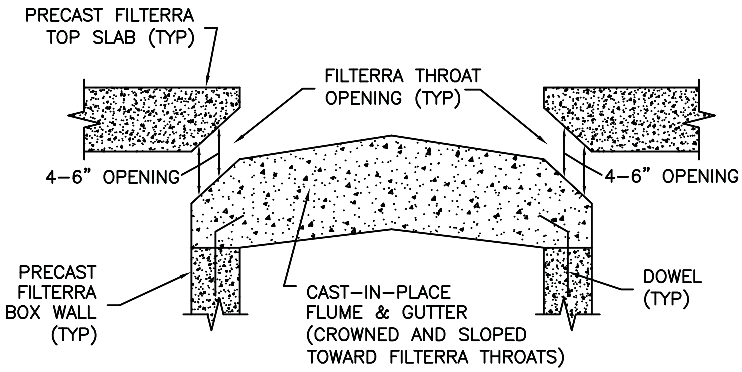
DATE:	07-07-06	DWG:	FLP-2

FILTERRA® TYPICAL FLOWLINE AND OULET PIPE RELATIONSHIP

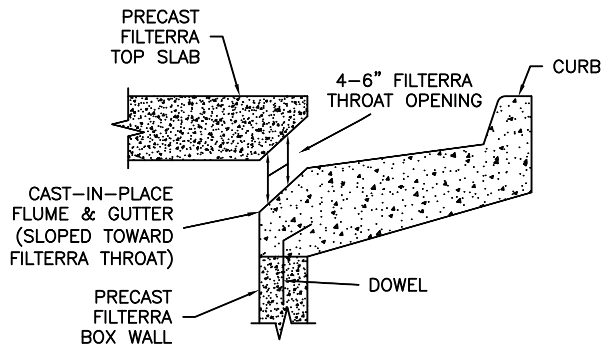
filterra®

US PAT 6,277,274 AND 6,569,321

CROWNED FLUME

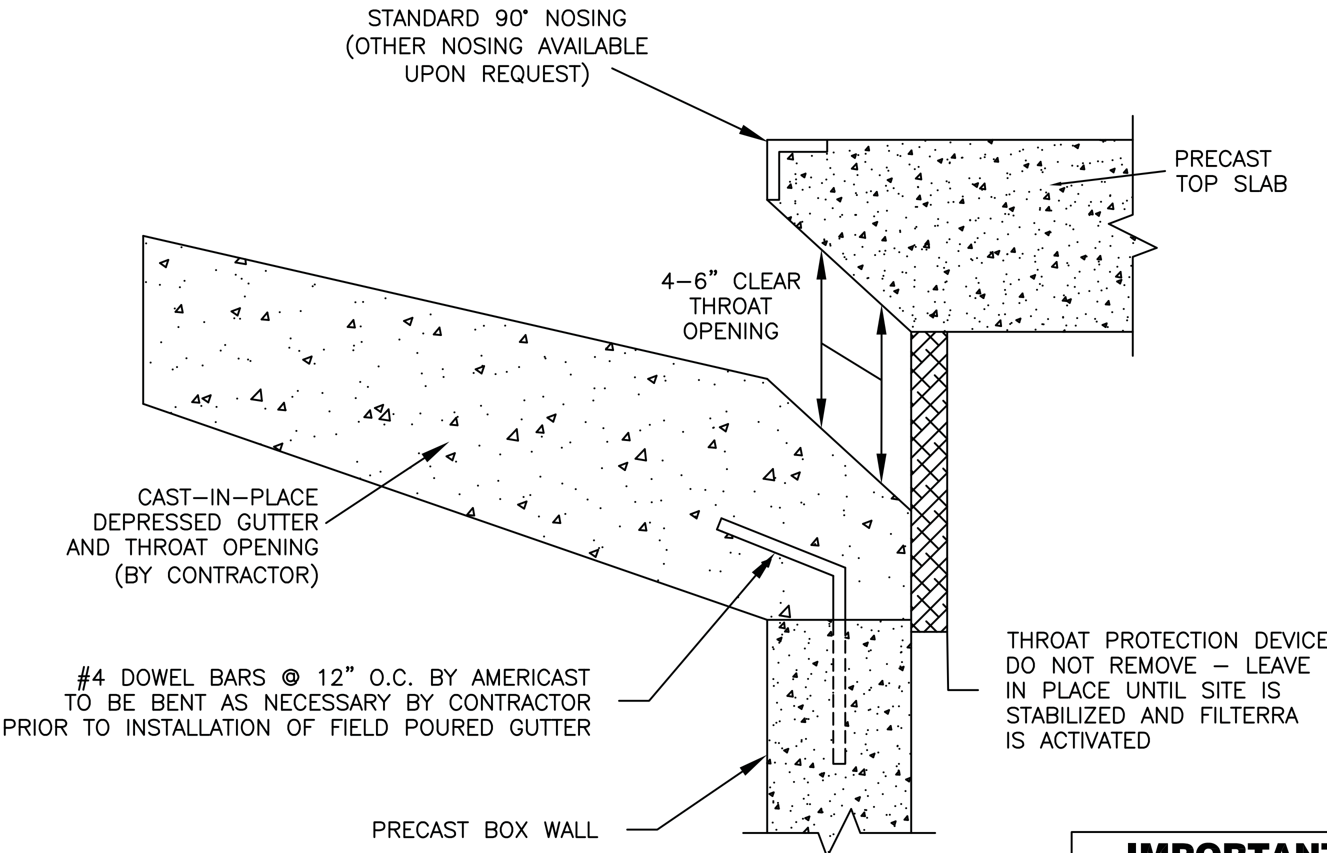


FLUME – SLOPED TOWARDS FILTERRA THROAT



SECTIONS VIEWS OF FILTERRA IN TYPICAL FLUME APPLICATIONS

SEE BELOW FOR DETAILS NOT SHOWN



IMPORTANT

FILTERRA FLOWLINE MUST BE AT A HIGHER ELEVATION THAN BYPASS FLOWLINE (DROP INLET OR OTHER)

SECTION VIEW
STANDARD FILTERRA THROAT OPENING

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DATE: 02–26–09 DWG: CGT–5

FILTERRA® THROAT OPENING AND GUTTER OR FLUME DETAIL

filterra®

US PAT 6,277,274 AND 6,569,321

Filterra® Standard Plan Notes

Construction & Installation

A. Each unit shall be constructed at the locations and elevations according to the sizes shown on the approved drawings. Any modifications to the elevation or location shall be at the direction of and approved by the Engineer.

B. If the Filterra® is stored before installation, the top slab must be placed on the box using the 2x4 wood provided, to prevent any contamination from the site. All internal fittings supplied (if any), must be left in place as per the delivery.

C. The unit shall be placed on a compacted sub-grade with a minimum 6-inch gravel base matching the final grade of the curb line in the area of the unit. The unit is to be placed such that the unit and top slab match the grade of the curb in the area of the unit. Compact undisturbed sub-grade materials to 95% of maximum density at +1- 2% of optimum moisture. Unsuitable material below sub-grade shall be replaced to the site engineer's approval.

D. Outlet connections shall be aligned and sealed to meet the approved drawings with modifications necessary to meet site conditions and local regulations.

E. Once the unit is set, the internal wooden forms and protective mesh cover must be left intact. Remove only the temporary wooden shipping blocks between the box and top slab. The top lid should be sealed onto the box section before backfilling, using a non-shrink grout, butyl rubber or similar waterproof seal. The boards on top of the lid and boards sealed in the unit's throat must **NOT** be removed. The Supplier (Americast or its authorized dealer) will remove these sections at the time of activation. Backfilling should be performed in a careful manner, bringing the appropriate fill material up in 6" lifts on all sides. Precast sections shall be set in a manner that will result in a watertight joint. In all instances, installation of Filterra® unit shall conform to ASTM specification C891 "Standard Practice for Installation of Underground Precast Utility Structures", unless directed otherwise in contract documents.

F. The contractor is responsible for inlet protection/sediment control and cleaning around each Filterra unit.

G. Curb and gutter construction (where present) shall ensure that the flow-line of the Filterra® units is at a greater elevation than the flow-line of the bypass structure or relief (drop inlet, curb cut or similar). Failure to comply with this guideline may cause failure and/or damage to the Filterra® environmental device.

H. Each Filterra® unit must receive adequate irrigation to ensure survival of the living system during periods of drier weather. This may be achieved through a piped system, gutter flow or through the tree grate.

Activation

A. Activation of the Filterra® unit is performed ONLY by the Supplier. Purchaser is responsible for Filterra® inlet protection and subsequent clean out cost. This process cannot commence until the project site is fully stabilized and cleaned (full landscaping, grass cover, final paving and street sweeping completed), negating the chance of construction materials contaminating the Filterra® system. Care shall be taken during construction not to damage the protective throat and top plates.

B. Activation includes installation of plant(s) and mulch layers as necessary.

Included Maintenance

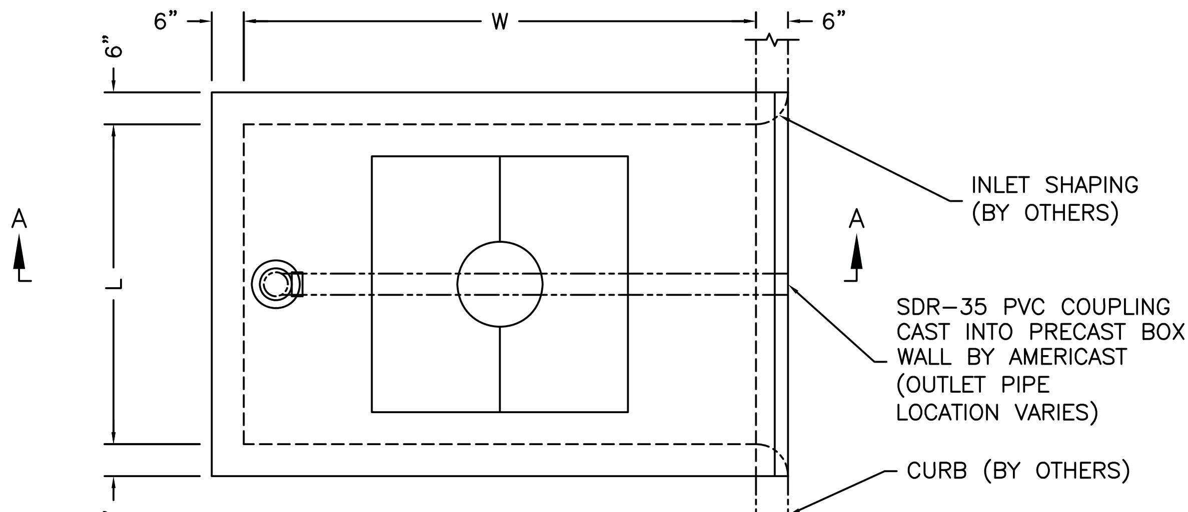
A. Each correctly installed Filterra® unit is to be maintained by the Supplier, or a Supplier approved contractor for a minimum period of 1 year. The cost of this service is to be included in the price of each Filterra® unit. Extended maintenance contracts are available at extra cost upon request.

B. Annual included maintenance consists of a maximum of (2) scheduled visits. The visits are scheduled seasonally; the spring visit aims to clean up after winter loads that may include salts and sands. The fall visit helps the system by removing excessive leaf litter.

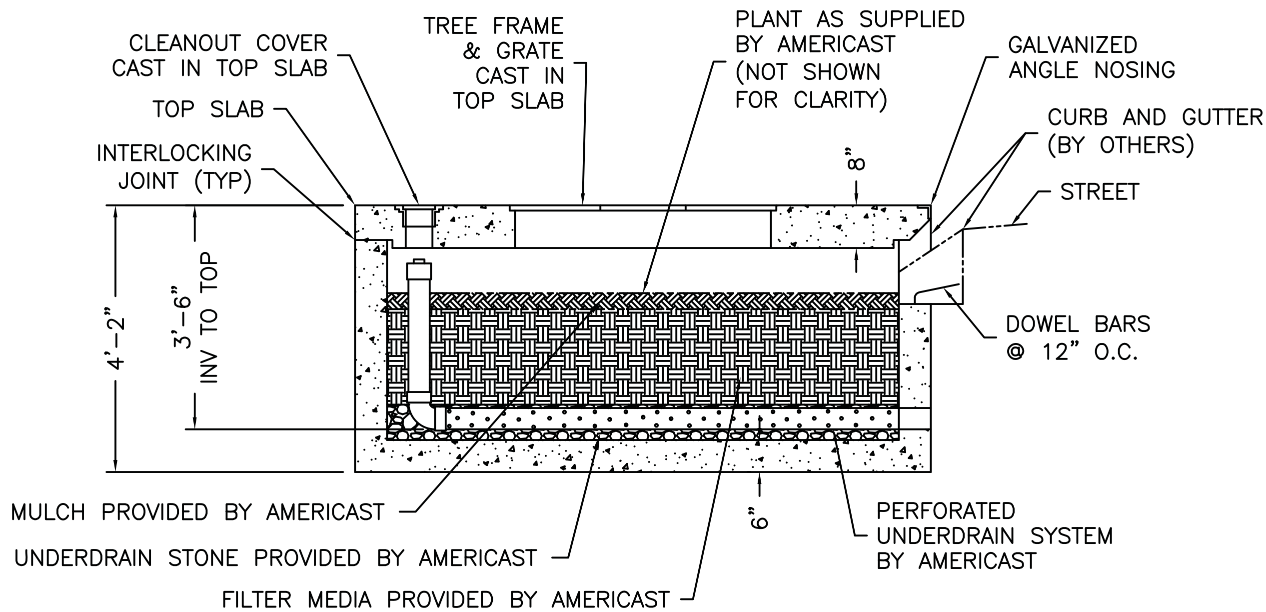
C. Each Included Maintenance visit consists of the following tasks.

1. Filterra® unit inspection
2. Foreign debris, silt, mulch & trash removal
3. Filter media evaluation and recharge as necessary
4. Plant health evaluation and pruning or replacement as necessary
5. Replacement of mulch
6. Disposal of all maintenance refuse items
7. Maintenance records updated and stored (reports available upon request)

D. The beginning and ending date of Supplier's obligation to maintain the installed system shall be determined by the Supplier at the time the system is activated. Owners must promptly notify the Supplier of any damage to the plant(s), which constitute(s) an integral part of the bioretention technology.



PLAN VIEW



SECTION A-A

DESIGNATION	L	W	TREE GRATE QTY & SIZE	OUTLET PIPE
4 x 6	4'-0"	6'-0"	(1) 3x3	4" SDR-35 PVC
4 x 8	4'-0"	8'-0"	(1) 3x3	4" SDR-35 PVC
6 x 8	6'-0"	8'-0"	(1) 4x4	4" SDR-35 PVC
6 x 10	6'-0"	10'-0"	(1) 4x4	6" SDR-35 PVC
6 x 12	6'-0"	12'-0"	(2) 4x4	6" SDR-35 PVC

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PRECAST FILTERRA® UNIT NARROW LENGTH CONFIGURATION WESTERN WASHINGTON

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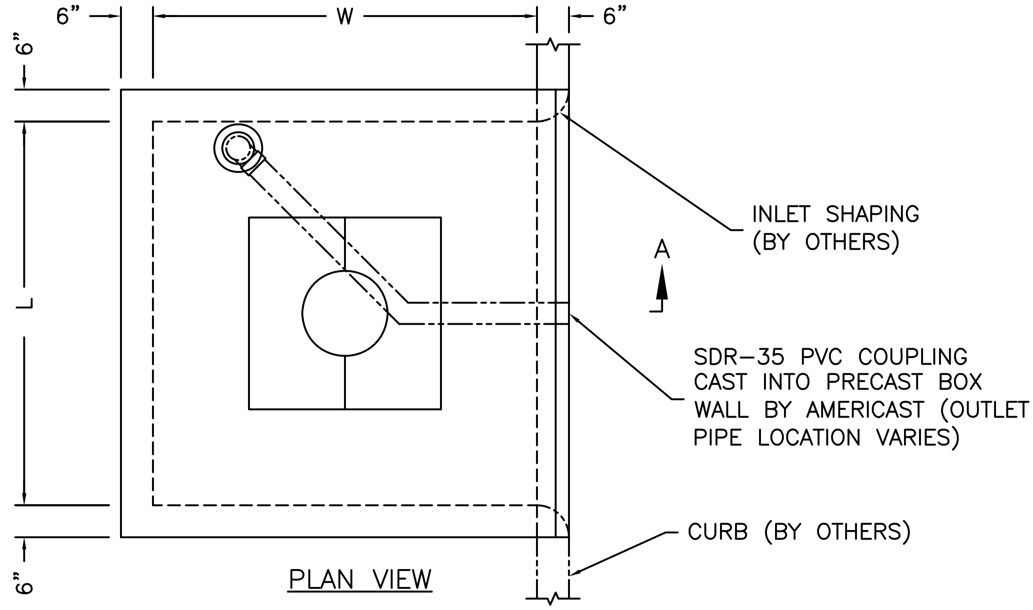
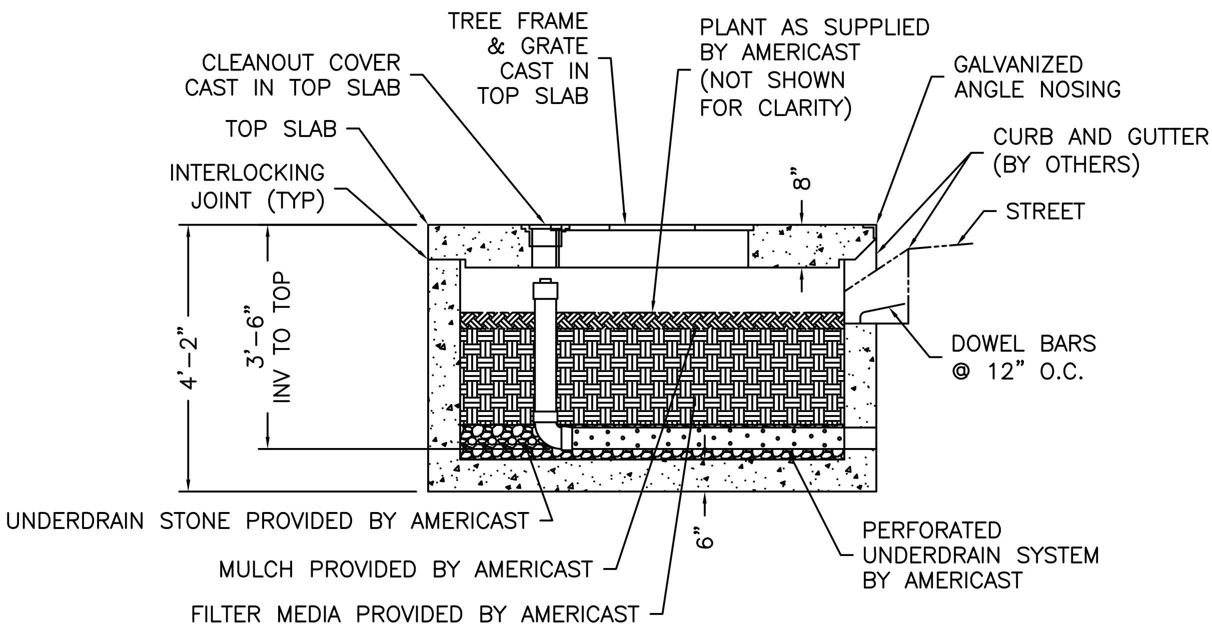
US PAT 6,277,274 AND 6,569,321



PLAN VIEW



SECTION A–A

DESIGNATION	L	W	TREE GRATE QTY & SIZE	OUTLET PIPE
4 x 4	4'–0"	4'–0"	(1) 3x3	4" SDR–35 PVC
6 x 6	6'–0"	6'–0"	(1) 3x3	4" SDR–35 PVC

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PRECAST FILTERRA® UNIT STANDARD CONFIGURATION WESTERN WASHINGTON

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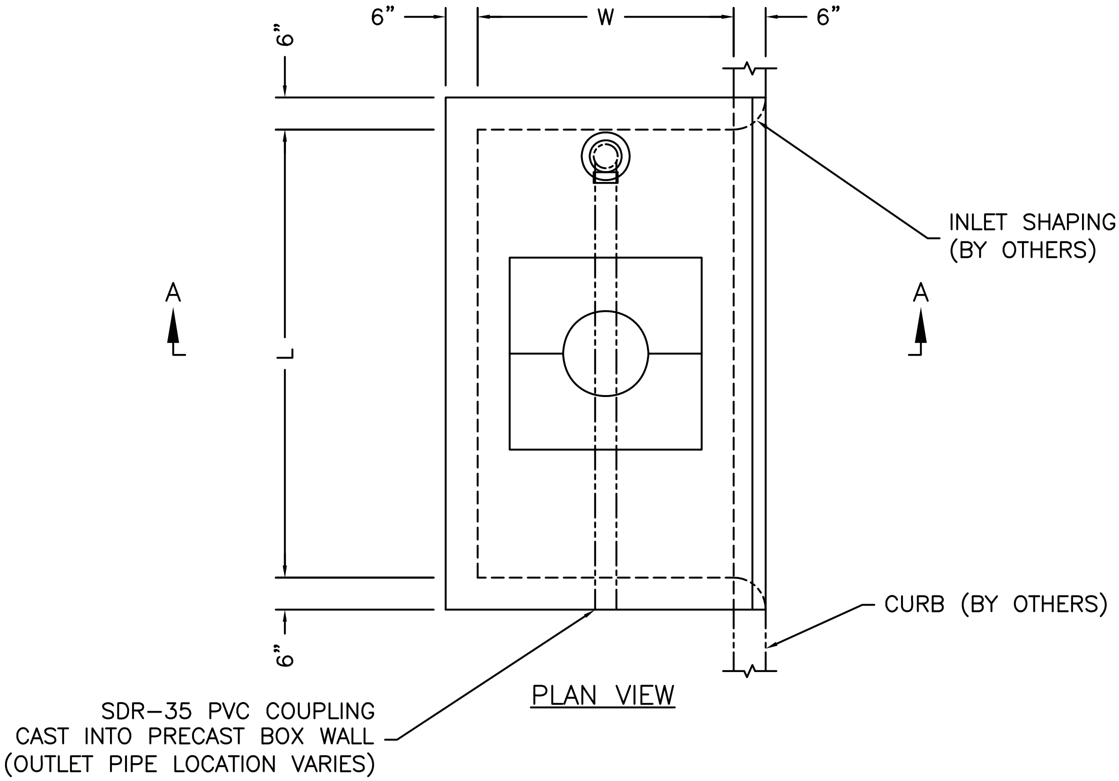
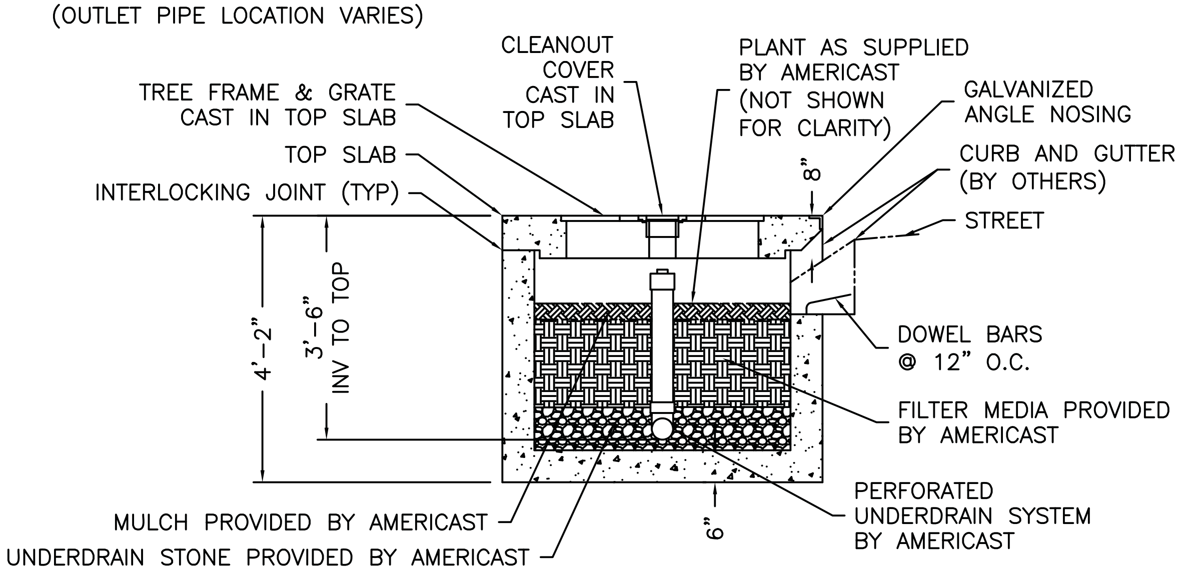


PLAN VIEW



SECTION A-A

DESIGNATION	L	W	TREE GRATE QTY & SIZE	OUTLET PIPE
6 x 4	6'-0"	4'-0"	(1) 3x3	4" SDR-35 PVC
8 x 4	8'-0"	4'-0"	(1) 3x3	4" SDR-35 PVC
8 x 6	8'-0"	6'-0"	(1) 4x4	4" SDR-35 PVC
10 x 6	10'-0"	6'-0"	(1) 4x4	6" SDR-35 PVC
12 x 6	12'-0"	6'-0"	(2) 4x4	6" SDR-35 PVC

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DWG: WWA FTNW-4

PRECAST FILTERRA® UNIT
NARROW WIDTH CONFIGURATION
WESTERN WASHINGTON

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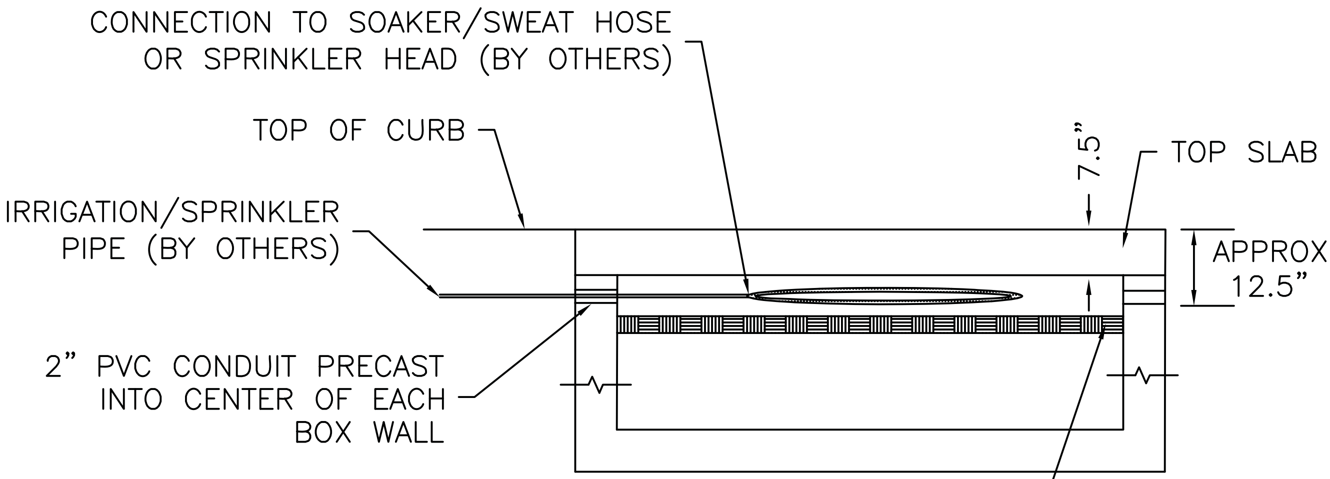
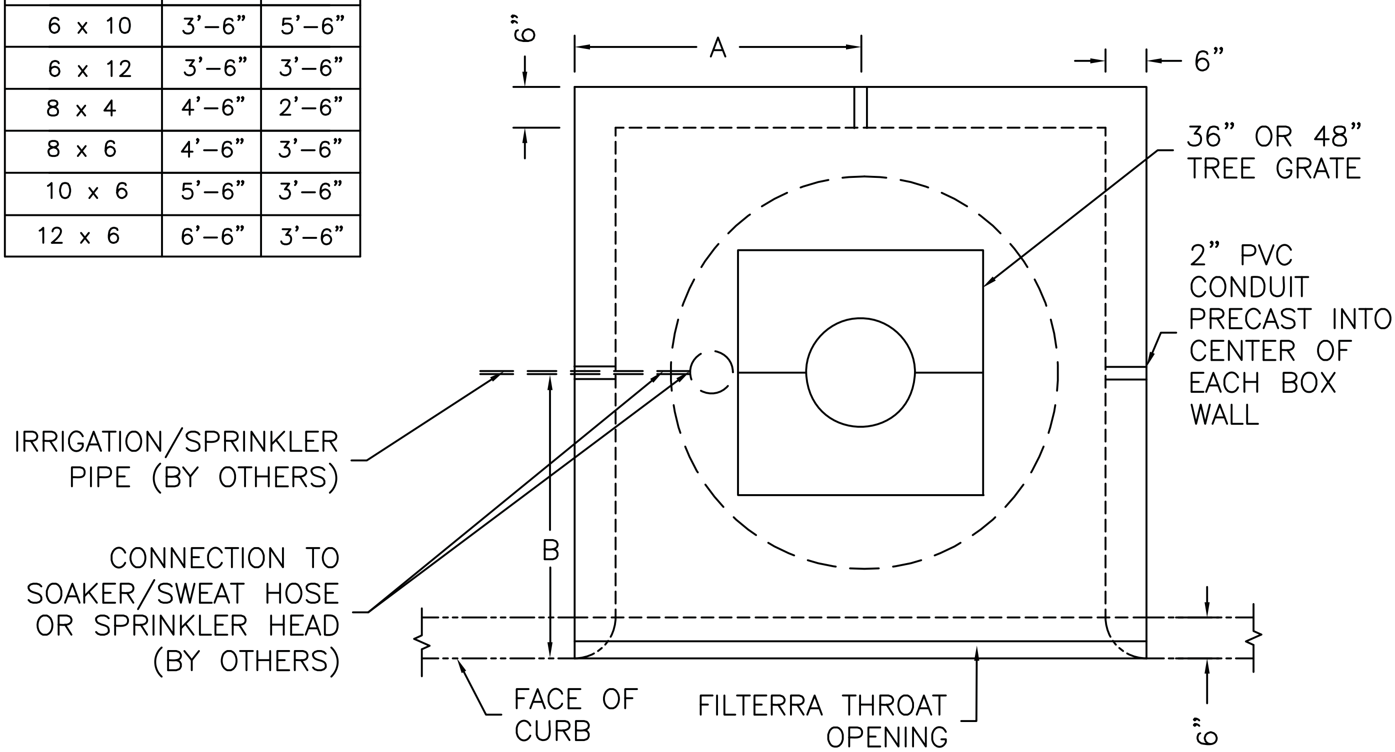
US PAT 6,277,274
AND 6,569,321



ELEVATION VIEW

UNIT SIZE	A	B
4 x 4	2'–6"	2'–6"
4 x 6	2'–6"	3'–6"
4 x 8	2'–6"	4'–6"
6 x 6	3'–6"	3'–6"
6 x 8	3'–6"	4'–6"
6 x 10	3'–6"	5'–6"
6 x 12	3'–6"	3'–6"
8 x 4	4'–6"	2'–6"
8 x 6	4'–6"	3'–6"
10 x 6	5'–6"	3'–6"
12 x 6	6'–6"	3'–6"



PLAN VIEW

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FILTERRA® IRRIGATION PLANNING LAYOUT WESTERN WASHINGTON

filterra®

US PAT 6,277,274 AND 6,569,321

Section D

Filterra® Technical Section

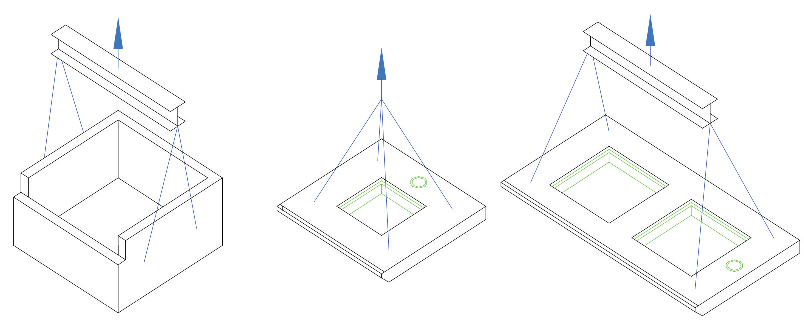
Toll Free: (866) 349-3458
Fax: (804) 798-8400
design@filterra.com

Americast Filterra Weights and Lifting Details

Western Washington

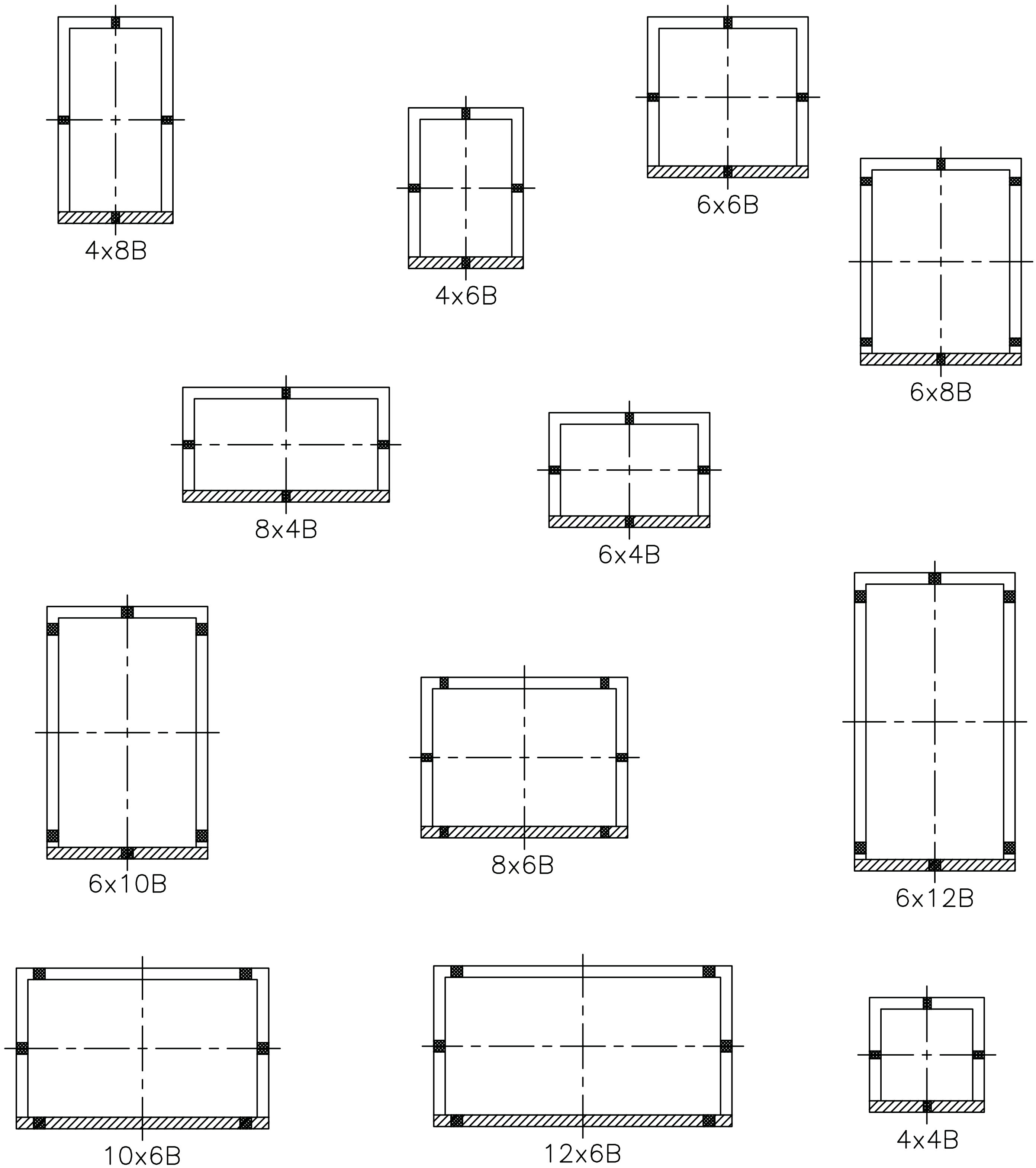
Throat	Size	Top Only Pounds	Top Only Tons	Box + Media Pounds	Box + Media Tons	*Spreader Bar Min	*Spreader Bar Max
4'-0" Throat	4x4	1,482	0.74	7,570	3.78	4.67 ft	7.17 ft
	4x6	2,618	1.31	11,613	5.81	4.83 ft	7.33 ft
	4x8	3,829	1.91	15,996	8.00	5.00 ft	7.50 ft
6'-0" Throat	6x4	2,385	1.19	11,483	5.74	5.33 ft	7.33 ft
	6x6	**3,758**	**1.88**	**14,186**	**7.09**	**6.67 ft**	**8.67 ft**
	6x8	4,589	2.29	19,014	9.51	6.67 ft	8.67 ft
	6x10	6,242	3.12	24,801	12.40	6.83 ft	8.83 ft
	6x12	6,825	3.41	30,847	15.42	7.00 ft	9.00 ft
8'-0" Throat	8x4	3,787	1.89	15,686	7.84	5.50 ft	7.50 ft
	8x6	4,568	2.28	18,911	9.46	7.17 ft	9.17 ft
10'-0" Throat	10x6	6,199	3.10	24,446	12.22	7.33 ft	9.33 ft
12'-0" Throat	12x6	6,762	3.38	30,382	15.19	7.50 ft	9.50 ft

*** BOX AND TOP MUST BE LIFTED SEPARATELY**



* A 7.50 ft spreader bar is suitable for all sizes shown.

12/23/2009



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DWG: WWA FTOPC-3

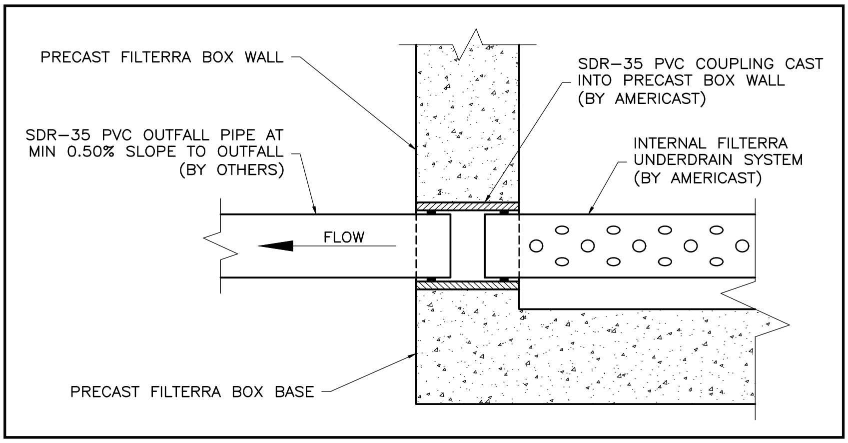
FILTERRA® PVC OUTLET PIPE COUPLING LOCATIONS WESTERN WASHINGTON

filterra®

US PAT 6,277,274 AND 6,569,321

Filterra® Piping Technical Details

Filterra® is supplied with an internal underdrain system that exits a wall in a perpendicular direction. Most efficient drainage is accomplished when the drain exits on the lower side of the Filterra®, i.e. nearest the overflow bypass. This is more important when using the larger sized Filterras®.



Drawing DP1: Section View through Filterra Precast Box Wall at Outfall Pipe Connection.

All units are supplied with the drainage pipe coupling precast into the wall, at a depth of 3.50 feet (INV to TC). Drawing DP1 is a detail of the coupling. The coupling used is SDR-35 PVC

Typically, a minimum slope of 0.50% is adequate to accommodate the flow of treated water from the Filterra®, but each site may present unique conditions based on routing of the outfall pipe (elbows). The pipe must not be a restricting point for the successful operation of Filterra®. All connecting pipes must accommodate freefall flow. Table 3 lists WA DOE approved treatment sizing flow rates of the various size Filterra® units. A safety factor of at least two should be used to size piping from the Filterra based on these conservative approved treatment flow rates.

Table 3: Filterra WA DOE Approved Treatment Flow Rates for WA Sizing & Pipe Details

Important Note: Actual flow rates may be more than double rates below.

Filterra® Size (feet)	Expected Flow Rate (cubic feet/second)	Connecting Drainage Pipe
4 x 4	0.019	4" SDR-35 PVC
4 x 6 or 6 x 4	0.028	4" SDR-35 PVC
4 x 8 or 8 x 4	0.037	4" SDR-35 PVC
6 x 6	0.042	4" SDR-35 PVC
6 x 8 or 8 x 6	0.056	4" SDR-35 PVC
6 x 10 or 10 x 6	0.069	6" SDR-35 PVC
6 x 12 or 12 x 6	0.083	6" SDR-35 PVC

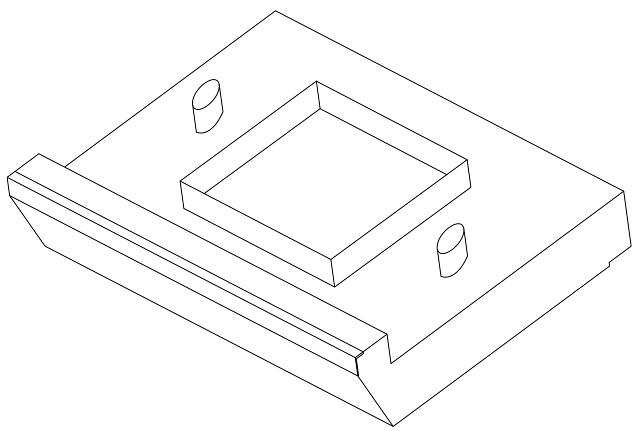
Filterra® Modified Options: Recessed Tops

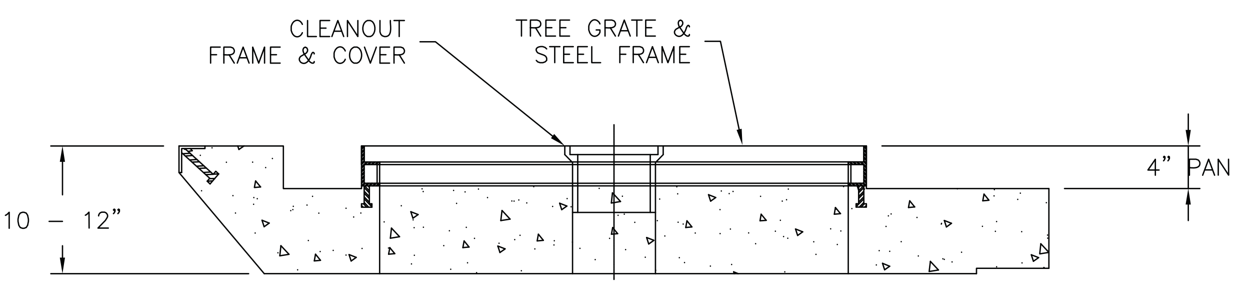
Modified recessed top with mulch

Filterra® modified recessed tops allow a seamless integration using pavers, mulch or sod.

NOTE: Modified recessed tops increase the depth of the Filterra® invert out.

Modified recessed top prior to shipping





Filterra® Modified Options: Ornamental Grates

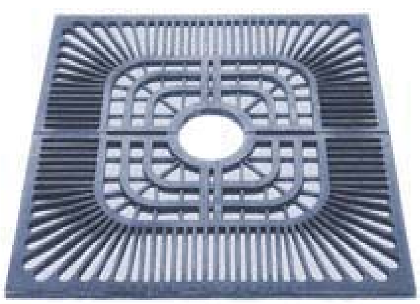
Modified colored grates are plastic coated to reduce corrosion. All grates are available in 36” and 48”. Some modified grates may not be ADA compliant. For additional options please call (866) 349-3458.

FT Radial

Color Choices: ■ Black ■ Green

FT New Orleans

Color Choices: ■ Black ■ Green



UA Standard Flat

UA Title-24

UA OT Title- 24

UA Chinook

Common Filterra® Placements

Providing aesthetics and treatment in a residential area.

Typical Filterra placement at a fast food chain.

Even the largest Filterra unit blends in with landscaping.

Filterra used with a flumed bypass in a commercial parking lot.

Ideal for stormwater treatment where space is tight.

High flows bypass Filterra into a grass swale.

Filterra® Plant Selections

The Filterra® Stormwater Bioretention Filtration System harnesses the power of nature to capture, immobilize and cycle pollutants to treat stormwater runoff. Trees, grasses and shrubs do more than make it attractive; they also enhance pollutant removal.

Above ground, the system's shrubs, grasses or trees add beauty and value to the urban landscape. Underground, nature's complex physical, chemical and biological processes are hard at work removing a wide range of non-point source pollutants from treated stormwater. Pollutants are decomposed, volatilized and incorporated into the biomass of Filterra's micro/macro fauna and flora.

A wide range of plants are suitable for use in bioretention systems, and a list is available indicating those suitable for use with Filterra.

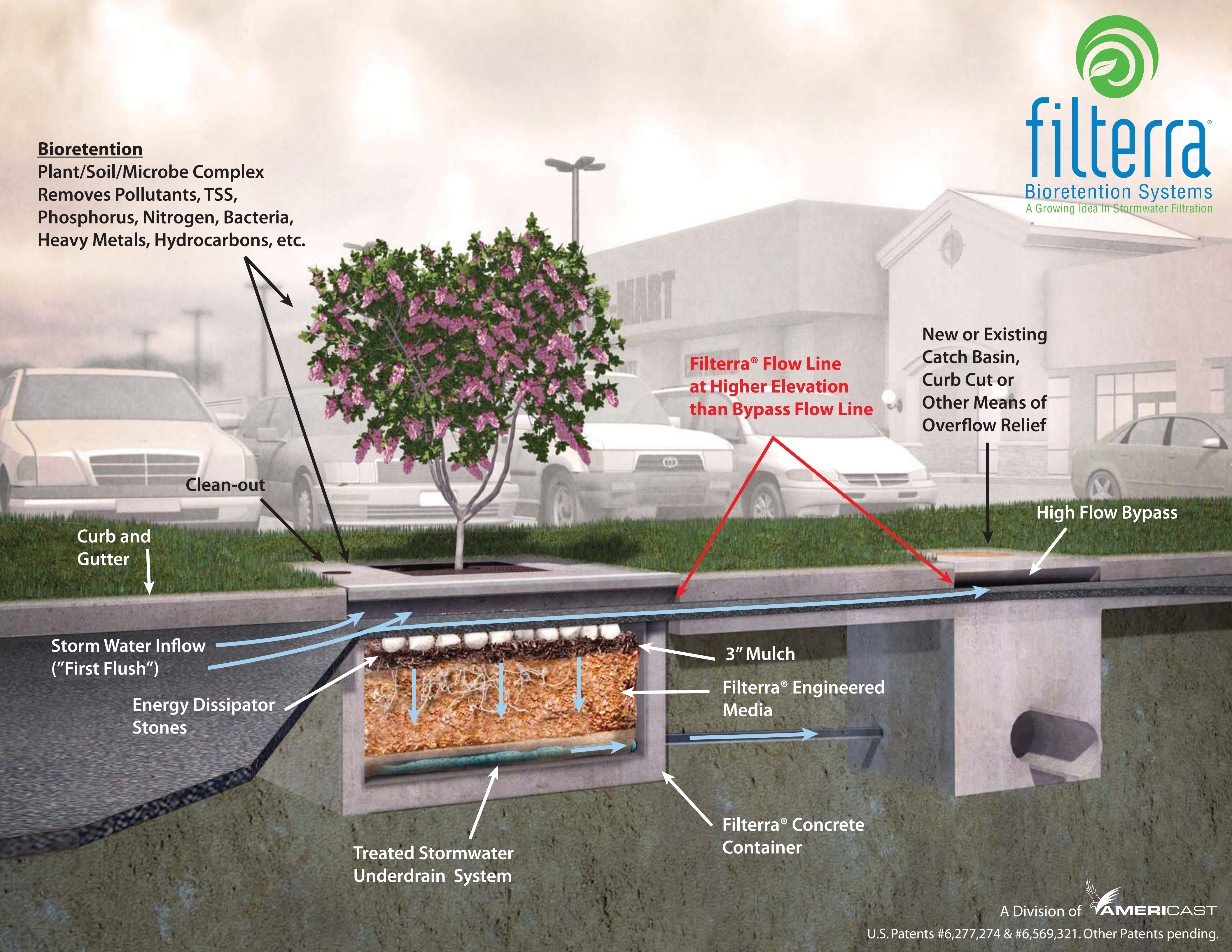
The selection varies by location according to climate. Additional photos are available at www.filterra.com. Some of the most popular selections to date are shown below:

Filterra® with Heavenly Bamboo

Filterra® with Galaxy Magnolia

Filterra® with Western Rebud

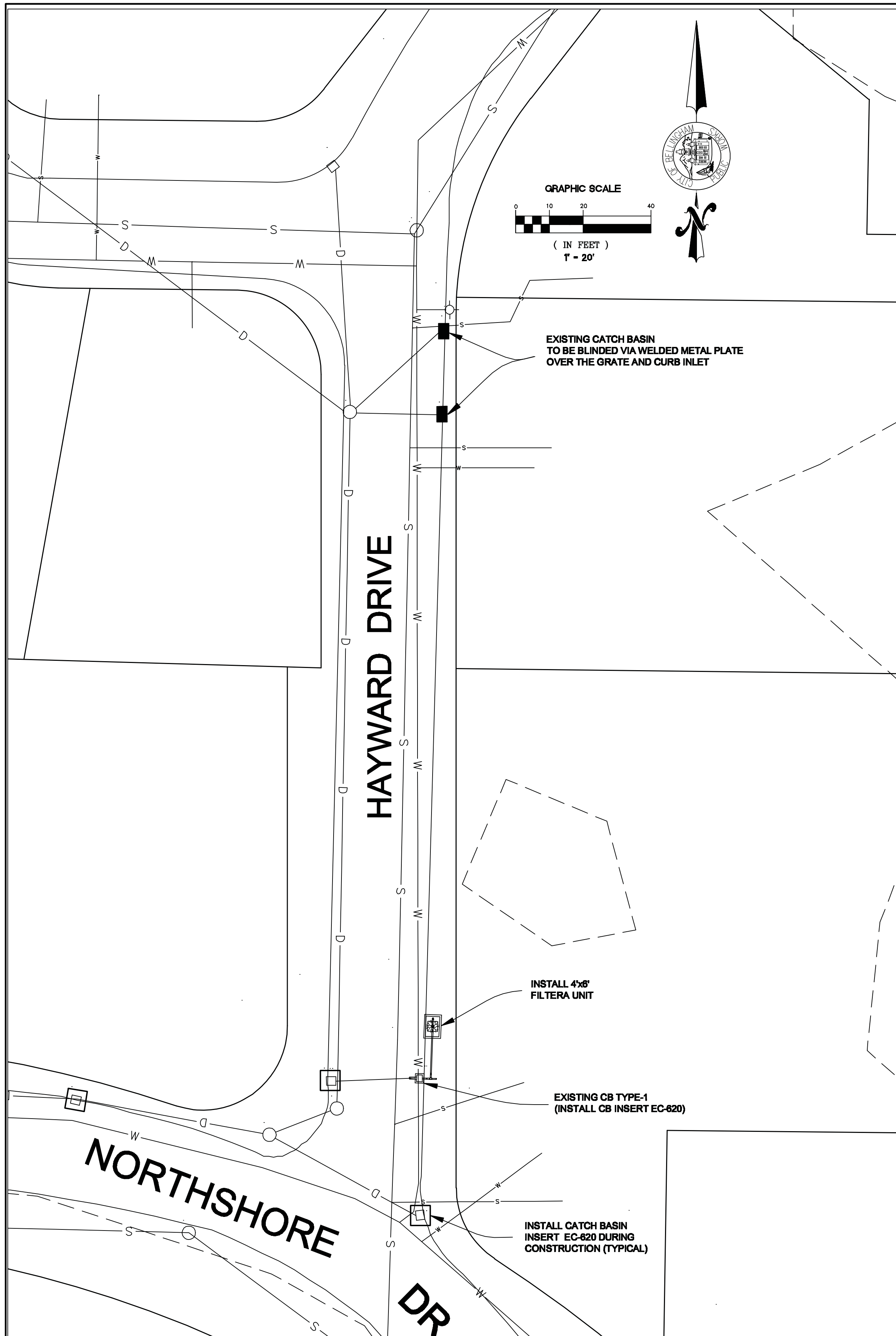
Filterra® with Purple Leaf Plum

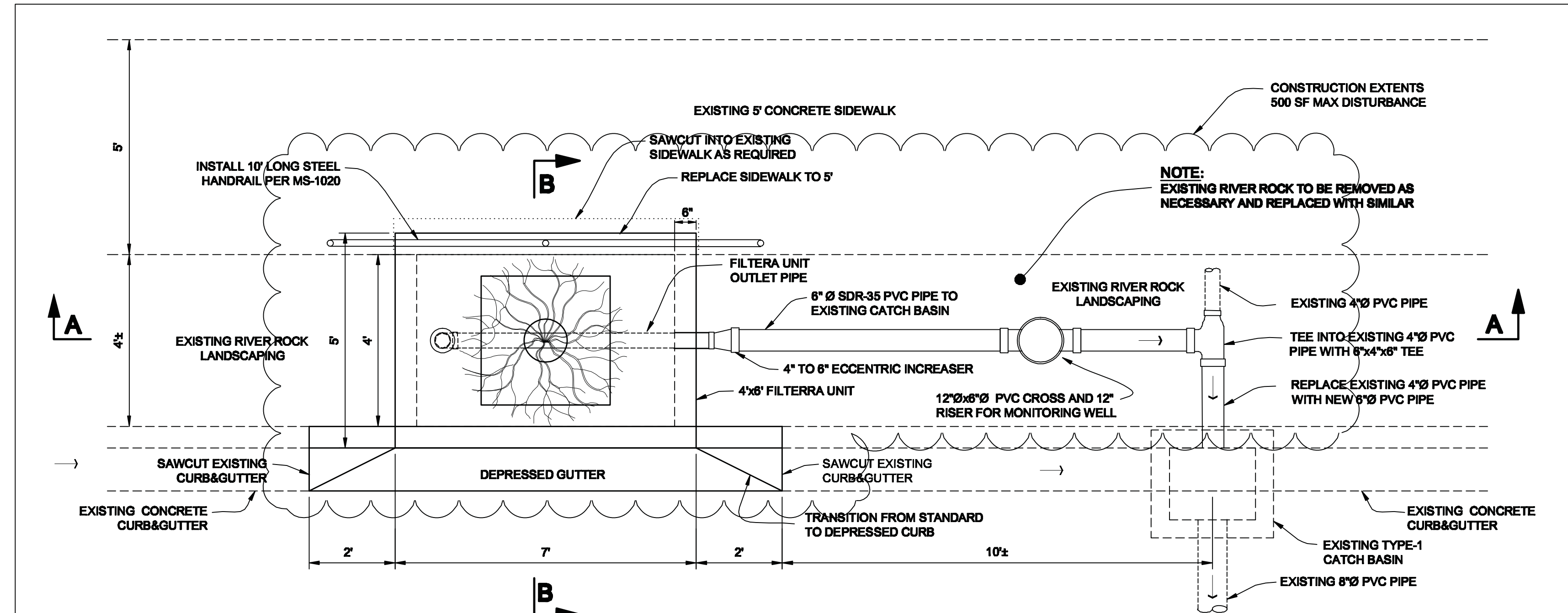


filterra®
Bioretention Systems
A Growing Idea in Stormwater Filtration
Bioretention
Plant/Soil/Microbe Complex
Removes Pollutants, TSS,
Phosphorus, Nitrogen, Bacteria,
Heavy Metals, Hydrocarbons, etc.
Clean-out
Curb and
Gutter
Filterra® Flow Line
at Higher Elevation
than Bypass Flow Line
New or Existing
Catch Basin,
Curb Cut or
Other Means of
Overflow Relief
High Flow Bypass
Storm Water Inflow
("First Flush")
Energy Dissipator
Stones
3" Mulch
Filterra® Engineered
Media
Filterra® Concrete
Container
Treated Stormwater
Underdrain System
A Division of AMERICAST
U.S. Patents #6,277,274 & #6,569,321. Other Patents pending.

APPENDIX B

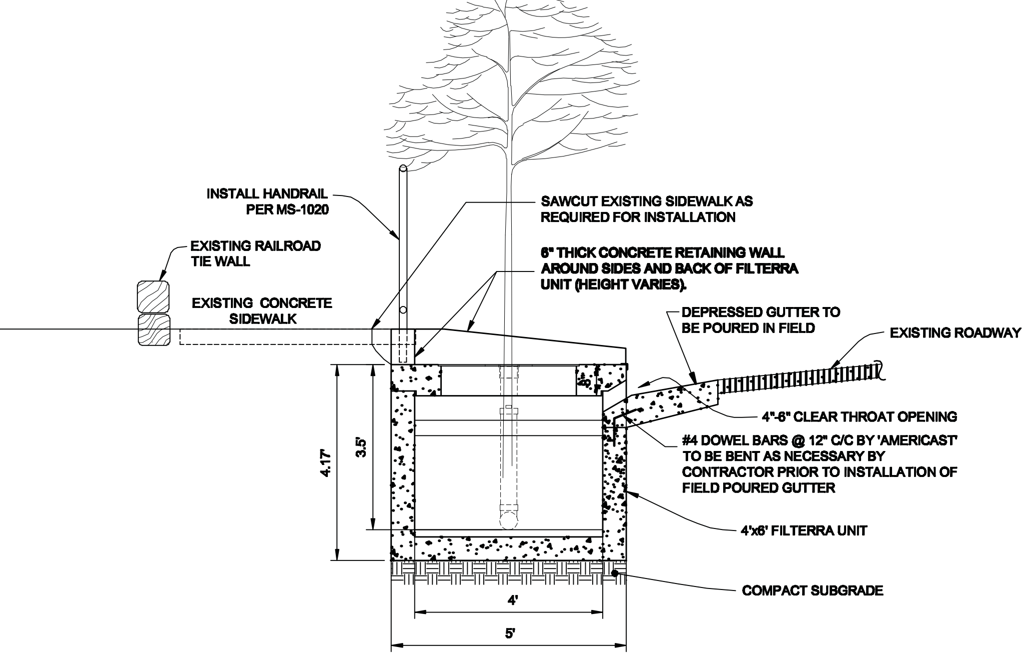
Hayward Drive Installation Drainage Plan and Details





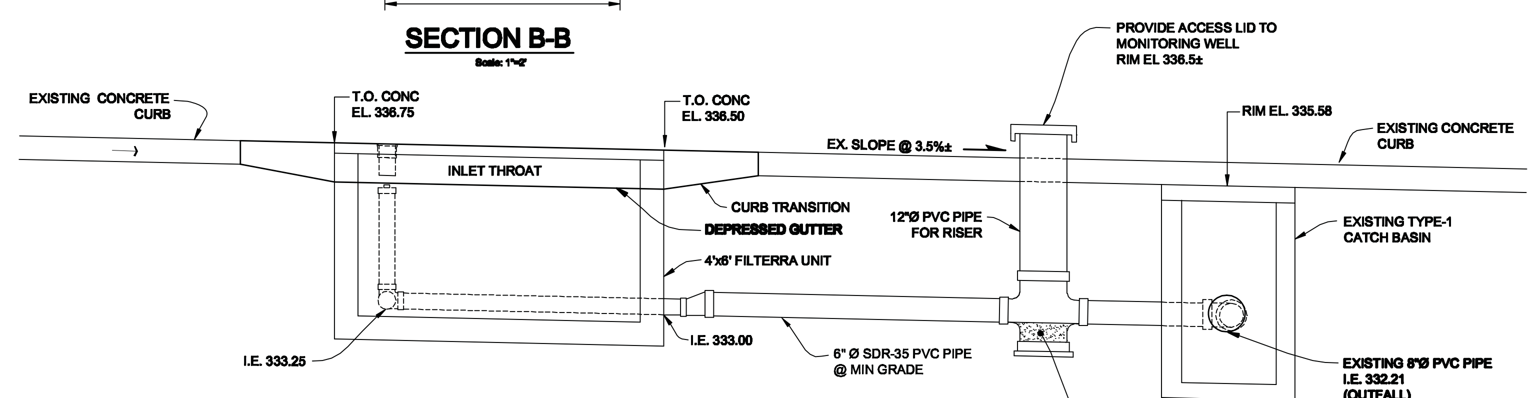
PLAN

Scale: 1"=5'



SECTION B-B

Scale: 1"=2'



SECTION A-A

Scale: 1"=2'

STORMWATER MAINTENANCE NOTES:

1. SAW CUTTING:
   - SLURRY AND CUTTINGS SHALL BE VACUUMED DURING CUTTING AND SURFACING OPERATIONS.
   - SLURRY AND CUTTINGS SHALL NOT REMAIN ON PERMANENT CONCRETE OR ASPHALT PAVEMENT OVERNIGHT.
   - SLURRY AND CUTTINGS SHALL NOT DRAIN TO ANY NATURAL OR CONSTRUCTED DRAINAGE CONVEYANCE.
   - COLLECTED SLURRY AND CUTTINGS SHALL BE DISPOSED OF IN A MANNER THAT DOES NOT VIOLATE GROUNDWATER OR SURFACE WATER QUALITY STANDARDS
2. THE ENTIRE CONSTRUCTION AREA SHALL BE COVERED WITH TARPS OR WATERPROOF MEMBRANES AT THE END OF EACH DAY.
3. NO WORK SHALL BE CARRIED OUT DURING RAIN EVENTS.
4. ALL SPOILS TO BE REMOVED FROM SITE IMMEDIATELY.
5. IF DEWATERING IS REQUIRED, CONTRACTOR MAY PUMP TO ADJACENT SANITARY SEWER WITH CITY APPROVAL.

Date	No	Revision	By
	4		
	3		
	2		
	1		

PROJECT ENGINEER FA
DESIGNED/DRAWN DFO
INSPECTOR INSP

DIR. PUBLIC WORKS R.E.M.
CITY ENGINEER R.A.R.
OPER. ENGINEER T.L.R.

CITY OF BELLINGHAM, WASHINGTON
PUBLIC WORKS DEPARTMENT
ENGINEERING DIVISION

SCALE
Horiz. .
Vert. .

DATUM
CITY

Job. No. EV-0062
Date 03-30-07
Field Bk.

HAYWARD DRIVE DRAINAGE IMPROVEMENTS
PLAN and DETAILS

SHEET 1 OF 1

CONTACT PERSON: FRITZ ANTHONY PROJECT ENGINEER AT 676-6961

V0062-02

APPENDIX C

Screen Shots and Model Output Report from WWHM3

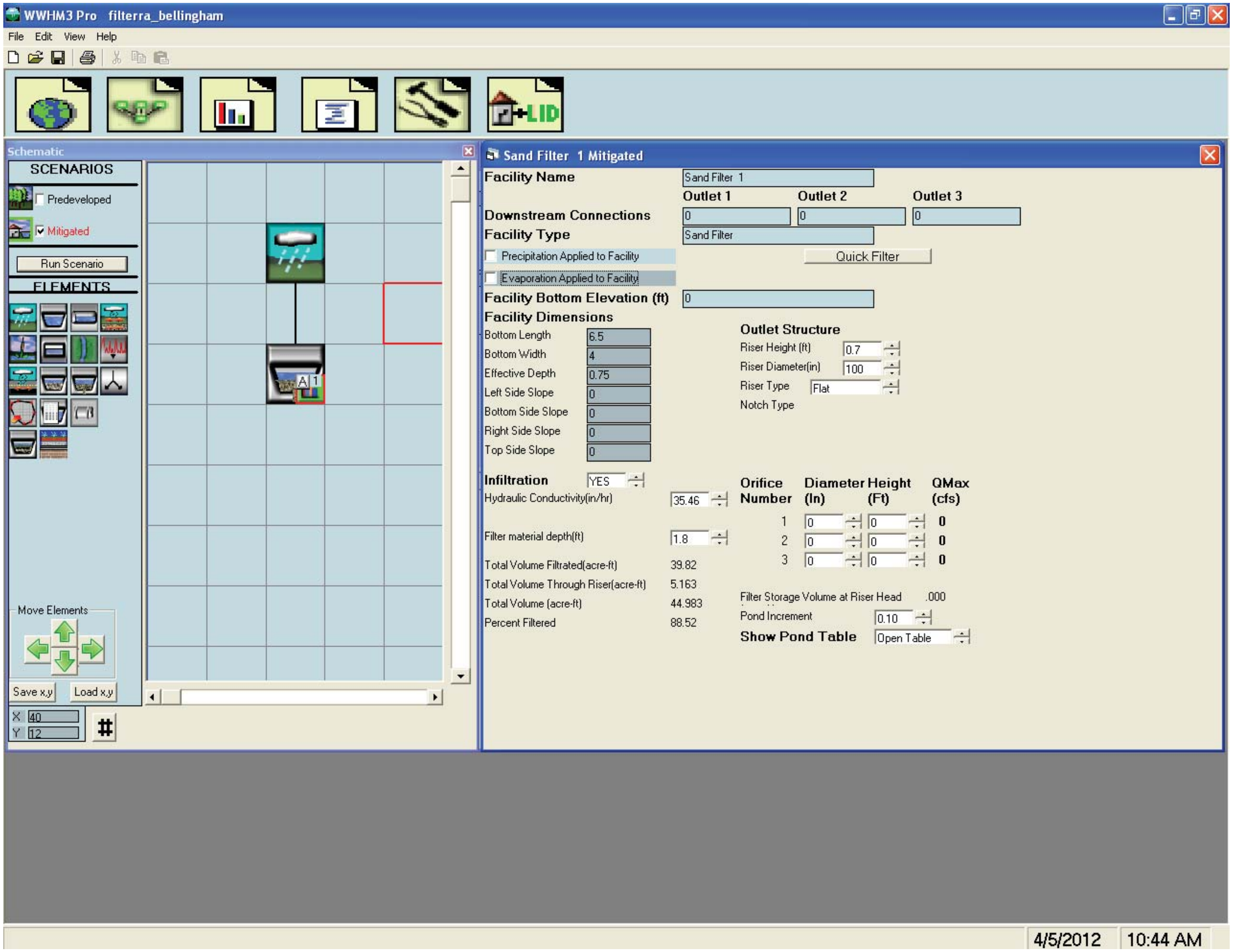


Figure C-1. Screen shot from WWHM3 run of the Hayward Drive Filterra installation in Bellingham, Washington.

Western Washington Hydrology Model
PROJECT REPORT

Project Name: filterra_bellingham_15min_timestep
Site Address: Hayward Dr.
City : Bellingham
Report Date : 4/5/2012
Gage : Blaine
Data Start : 1948/10/01
Data End : 1999/09/30
Precip Scale: 0.86
WWHM3 Pro Version:

PREDEVELOPED LAND USE

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
C, Forest, Mod	.4

Impervious Land Use	Acres

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres

Impervious Land Use	Acres
ROADS MOD	0.4

Element Flows To:

Surface	Interflow	Groundwater
Sand Filter 1,	Sand Filter 1,	

Name : Sand Filter 1
Bottom Length: 6.5ft.
Bottom Width : 4ft.

Depth : 0.75ft.
Side slope 1: 0 To 1
Side slope 2: 0 To 1
Side slope 3: 0 To 1
Side slope 4: 0 To 1
Filtration On
Hydraulic conductivity : 35.46
Depth of filter medium : 1.8
Discharge Structure
Riser Height: 0.7 ft.
Riser Diameter: 100 in.

Element Flows To:
Outlet 1 **Outlet 2**

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	0.006894
5 year	0.010576
10 year	0.013036
25 year	0.016118
50 year	0.018379
100 year	0.020603

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	0.102558
5 year	0.1503
10 year	0.18432
25 year	0.229865
50 year	0.265582
100 year	0.302792

POC #1
The Facility PASSED

The Facility PASSED.

Flow(CFS)	Predev	Dev	Percentage	Pass/Fail
0.0034	0	0	0	Pass
0.0036	0	0	0	Pass
0.0037	0	0	0	Pass
0.0039	0	0	0	Pass
0.0041	0	0	0	Pass
0.0042	0	0	0	Pass
0.0044	0	0	0	Pass
0.0045	0	0	0	Pass
0.0047	0	0	0	Pass
0.0048	0	0	0	Pass
0.0050	0	0	0	Pass
0.0051	0	0	0	Pass
0.0053	0	0	0	Pass
0.0054	0	0	0	Pass

0.0056	0	0	0	Pass
0.0057	0	0	0	Pass
0.0059	0	0	0	Pass
0.0060	0	0	0	Pass
0.0062	0	0	0	Pass
0.0063	0	0	0	Pass
0.0065	0	0	0	Pass
0.0066	0	0	0	Pass
0.0068	0	0	0	Pass
0.0069	0	0	0	Pass
0.0071	0	0	0	Pass
0.0072	0	0	0	Pass
0.0074	0	0	0	Pass
0.0075	0	0	0	Pass
0.0077	0	0	0	Pass
0.0078	0	0	0	Pass
0.0080	0	0	0	Pass
0.0081	0	0	0	Pass
0.0083	0	0	0	Pass
0.0084	0	0	0	Pass
0.0086	0	0	0	Pass
0.0087	0	0	0	Pass
0.0089	0	0	0	Pass
0.0090	0	0	0	Pass
0.0092	0	0	0	Pass
0.0093	0	0	0	Pass
0.0095	0	0	0	Pass
0.0096	0	0	0	Pass
0.0098	0	0	0	Pass
0.0099	0	0	0	Pass
0.0101	0	0	0	Pass
0.0102	0	0	0	Pass
0.0104	0	0	0	Pass
0.0105	0	0	0	Pass
0.0107	0	0	0	Pass
0.0108	0	0	0	Pass
0.0110	0	0	0	Pass
0.0111	0	0	0	Pass
0.0113	0	0	0	Pass
0.0114	0	0	0	Pass
0.0116	0	0	0	Pass
0.0117	0	0	0	Pass
0.0119	0	0	0	Pass
0.0120	0	0	0	Pass
0.0122	0	0	0	Pass
0.0123	0	0	0	Pass
0.0125	0	0	0	Pass
0.0126	0	0	0	Pass
0.0128	0	0	0	Pass
0.0129	0	0	0	Pass
0.0131	0	0	0	Pass
0.0133	0	0	0	Pass
0.0134	0	0	0	Pass
0.0136	0	0	0	Pass
0.0137	0	0	0	Pass
0.0139	0	0	0	Pass
0.0140	0	0	0	Pass

0.0142	0	0	0	Pass
0.0143	0	0	0	Pass
0.0145	0	0	0	Pass
0.0146	0	0	0	Pass
0.0148	0	0	0	Pass
0.0149	0	0	0	Pass
0.0151	0	0	0	Pass
0.0152	0	0	0	Pass
0.0154	0	0	0	Pass
0.0155	0	0	0	Pass
0.0157	0	0	0	Pass
0.0158	0	0	0	Pass
0.0160	0	0	0	Pass
0.0161	0	0	0	Pass
0.0163	0	0	0	Pass
0.0164	0	0	0	Pass
0.0166	0	0	0	Pass
0.0167	0	0	0	Pass
0.0169	0	0	0	Pass
0.0170	0	0	0	Pass
0.0172	0	0	0	Pass
0.0173	0	0	0	Pass
0.0175	0	0	0	Pass
0.0176	0	0	0	Pass
0.0178	0	0	0	Pass
0.0179	0	0	0	Pass
0.0181	0	0	0	Pass
0.0182	0	0	0	Pass
0.0184	0	0	0	Pass

Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 0.0417 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 0.0615 **cfs.**
Off-line facility target flow: 0.0331 **cfs.**
Adjusted for 15 min: 0.0331 **cfs.**

Perlnd and Implnd Changes

No changes have been made.

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Western Washington Hydrology Model
PROJECT REPORT

Project Name: filterra_bellingham_1hour_timestep
Site Address: Hayward Dr.
City : Bellingham
Report Date : 4/5/2012
Gage : Blaine
Data Start : 1948/10/01
Data End : 1999/09/30
Precip Scale: 0.86
WWHM3 Pro Version:

PREDEVELOPED LAND USE

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres
C, Forest, Mod	.4

Impervious Land Use	Acres

Element Flows To:

Surface	Interflow	Groundwater

Name : Basin 1
Bypass: No

GroundWater: No

Pervious Land Use	Acres

Impervious Land Use	Acres
ROADS MOD	0.4

Element Flows To:

Surface	Interflow	Groundwater
Sand Filter 1,	Sand Filter 1,	

Name : Sand Filter 1
Bottom Length: 6.5ft.
Bottom Width : 4ft.

Depth : 0.75ft.
Side slope 1: 0 To 1
Side slope 2: 0 To 1
Side slope 3: 0 To 1
Side slope 4: 0 To 1
Filtration On
Hydraulic conductivity : 35.46
Depth of filter medium : 1.8
Discharge Structure
Riser Height: 0.7 ft.
Riser Diameter: 100 in.

Element Flows To:
Outlet 1 **Outlet 2**

ANALYSIS RESULTS

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	Flow(cfs)
2 year	0.006874
5 year	0.011301
10 year	0.014574
25 year	0.019033
50 year	0.022564
100 year	0.026257

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	Flow(cfs)
2 year	0.082121
5 year	0.120365
10 year	0.14762
25 year	0.184111
50 year	0.21273
100 year	0.242546

POC #1
The Facility PASSED

The Facility PASSED.

Flow(CFS)	Predev	Dev	Percentage	Pass/Fail
0.0034	0	0	0	Pass
0.0036	0	0	0	Pass
0.0038	0	0	0	Pass
0.0040	0	0	0	Pass
0.0042	0	0	0	Pass
0.0044	0	0	0	Pass
0.0046	0	0	0	Pass
0.0048	0	0	0	Pass
0.0050	0	0	0	Pass
0.0052	0	0	0	Pass
0.0054	0	0	0	Pass
0.0056	0	0	0	Pass
0.0058	0	0	0	Pass
0.0059	0	0	0	Pass

0.0061	0	0	0	Pass
0.0063	0	0	0	Pass
0.0065	0	0	0	Pass
0.0067	0	0	0	Pass
0.0069	0	0	0	Pass
0.0071	0	0	0	Pass
0.0073	0	0	0	Pass
0.0075	0	0	0	Pass
0.0077	0	0	0	Pass
0.0079	0	0	0	Pass
0.0081	0	0	0	Pass
0.0083	0	0	0	Pass
0.0085	0	0	0	Pass
0.0087	0	0	0	Pass
0.0088	0	0	0	Pass
0.0090	0	0	0	Pass
0.0092	0	0	0	Pass
0.0094	0	0	0	Pass
0.0096	0	0	0	Pass
0.0098	0	0	0	Pass
0.0100	0	0	0	Pass
0.0102	0	0	0	Pass
0.0104	0	0	0	Pass
0.0106	0	0	0	Pass
0.0108	0	0	0	Pass
0.0110	0	0	0	Pass
0.0112	0	0	0	Pass
0.0114	0	0	0	Pass
0.0116	0	0	0	Pass
0.0117	0	0	0	Pass
0.0119	0	0	0	Pass
0.0121	0	0	0	Pass
0.0123	0	0	0	Pass
0.0125	0	0	0	Pass
0.0127	0	0	0	Pass
0.0129	0	0	0	Pass
0.0131	0	0	0	Pass
0.0133	0	0	0	Pass
0.0135	0	0	0	Pass
0.0137	0	0	0	Pass
0.0139	0	0	0	Pass
0.0141	0	0	0	Pass
0.0143	0	0	0	Pass
0.0144	0	0	0	Pass
0.0146	0	0	0	Pass
0.0148	0	0	0	Pass
0.0150	0	0	0	Pass
0.0152	0	0	0	Pass
0.0154	0	0	0	Pass
0.0156	0	0	0	Pass
0.0158	0	0	0	Pass
0.0160	0	0	0	Pass
0.0162	0	0	0	Pass
0.0164	0	0	0	Pass
0.0166	0	0	0	Pass
0.0168	0	0	0	Pass
0.0170	0	0	0	Pass

0.0172	0	0	0	Pass
0.0173	0	0	0	Pass
0.0175	0	0	0	Pass
0.0177	0	0	0	Pass
0.0179	0	0	0	Pass
0.0181	0	0	0	Pass
0.0183	0	0	0	Pass
0.0185	0	0	0	Pass
0.0187	0	0	0	Pass
0.0189	0	0	0	Pass
0.0191	0	0	0	Pass
0.0193	0	0	0	Pass
0.0195	0	0	0	Pass
0.0197	0	0	0	Pass
0.0199	0	0	0	Pass
0.0201	0	0	0	Pass
0.0202	0	0	0	Pass
0.0204	0	0	0	Pass
0.0206	0	0	0	Pass
0.0208	0	0	0	Pass
0.0210	0	0	0	Pass
0.0212	0	0	0	Pass
0.0214	0	0	0	Pass
0.0216	0	0	0	Pass
0.0218	0	0	0	Pass
0.0220	0	0	0	Pass
0.0222	0	0	0	Pass
0.0224	0	0	0	Pass
0.0226	0	0	0	Pass

Water Quality BMP Flow and Volume for POC 1.
On-line facility volume: 0.0414 acre-feet
On-line facility target flow: 0.01 **cfs.**
Adjusted for 15 min: 0.0651 **cfs.**
Off-line facility target flow: 0.0317 **cfs.**
Adjusted for 15 min: 0.0358 **cfs.**

Perlnd and Implnd Changes

No changes have been made.

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APPENDIX D

Equipment Specification Sheets

CR800-series Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE

10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS

3 differential (DF) or 6 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

	Input Referred Noise Voltage	
Input Range (mV)[1]	*DF Res (μV)*[2]	*Basic Res (μV)*
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 μs Integration: 0.34 μV RMS
50/60 Hz Integration: 0.19 μV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR800-series integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 μs Analog Integration: ~1 ms SE
1/60 Hz Analog Integration: ~20 ms SE
1/50 Hz Analog Integration: ~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS

2 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR800-series provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_x

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 6 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	*Signal (peak to peak)*[4] *Min*	*Max*	*Min. Pulse W.*	*Max*[5] *Freq.*
±2500 mV	500 mV	10 V	2.5 μs	200 kHz
±250 mV	10 mV	2 V	10 μs	50 kHz
±25 mV	5 mV	2 V	62 μs	8 kHz
±2.5 mV	2 mV	2 V	100 μs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS

Two 24-bit inputs selectable for switch closure, high frequency pulse, or low-level ac.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 μs time constant.

LOW LEVEL AC MODE: Internal ac coupling removes dc offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	*Range (Hz)*
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS

4 ports software selectable, as binary inputs or control outputs. They also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH FREQUENCY MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V

One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT

Control ports 1 and 3 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE

STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE

PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (60 Hz rejection)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (250 μs integration)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (250 μs integration)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD OR CR850'S ON-BOARD KEYBOARD DISPLAY CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal; reverse polarity protected.

PHYSICAL SPECIFICATIONS

DIMENSIONS: 9.5" x 4.1" x 2" (24.1 x 10.4 x 5.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 1.5 lbs (0.7 kg)

WARRANTY

Three years against defects in materials and workmanship.

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Printed September 2007

Hach FL900 Standard (Non-Wireless) Flow Logger

NEW!

When combined with the Flo-Dar®, Flo-Tote® 3, or Submerged Area Velocity Sensor, the Hach FL900 Series Flow Logger takes flow monitoring to a whole new level. With features that reduce site time and increase crew safety, the flow monitoring system allows you to easily manage your flow data, as well as your budget.*

Features and Benefits

The FL900 Flow Logger provides users with a reliable, budget saving solution for open channel portable flow monitoring applications. The robust logger's time-saving features will drastically decrease site time and increase safety for monitoring crews. The Logger LED provides instant communication verification of correct site set-up and flow meter communication prior to leaving the site.

Increase Monitoring Crew Safety

With the time saving features designed into the FL900 Flow Loggers, crews spend less time in the manhole and less time on site to decrease monitoring costs while increasing the safety of flow monitoring crews.

Plug and Play Sensor Ports

The FL900 Series Flow Logger is available with 1 sensor port. The logger auto-detects the type of sensor connected to allow customers maximum flexibility for their Hach flow sensor inventories.

Easy Installation/Versatile Mounting Options

The logger can be quickly attached to a wall, pole or manhole ladder in minutes. Users can choose to hang logger from standard carabiner or optional 4-bolt wall mount for pole, horizontal or vertical wall mount or ladder rung mount.

Applications

Municipal

- *Sanitary Sewer Evaluation Studies*
- *Collection Systems*
- *Capacity Studies*
- *Combined Sewer Overflows*
- *Inflow and Infiltration (I&I) Studies*
- *Billing / Custody Transfer*
- *Plant Influent and Effluent*

Industrial

- *Process Waste*
- *Plant Influent*
- *Plant Effluent*
- *Non-contact Cooling Water*
- *Stormwater Monitoring and Compliance*

**Requires AV9000 Analyzer module.*

Specifications*

Dimensions (W x D x H)
25.4 x 22 x 40 cm (10.0 x 8.7 x 16.0 in.)

Enclosure
PC/ABS structural foam

Environmental Rating
NEMA 6P (IP68)

Weight (Using Model FL900)
4.5 kg (10 lb)—no batteries; 6.3 kg (14 lb)—2 batteries;
8.2 kg (18 lb)—4 batteries

Operating Temperature
-18 to 60ºC (0 to 140ºF) at 95% RH

Storage Temperature
-40 to 60ºC (-40 to 140ºF)

Power Requirements
8 to18 Vdc from batteries

Battery Life at 15 minute logging intervals (at room temperature)
185 days with 4 lantern batteries and a Flo-Dar sensor
306 days with 4 lantern batteries and a Flo-Tote sensor
296 days with 4 lantern batteries and a Sub AV sensor with AV9000 analyzer module
(4 lantern batteries shall be included with each logger)

Sensor Ports
1

Connectors
Stainless steel connectors

LED Status Indicator
– Green Flashes every 3 seconds during normal operation. Flashes every 15 seconds during sleep mode.
– Red Flashes when an attached sensor does not agree with the logger program, when an expected sensor is not found or the sensor is not working properly.

Datalog Channels
16 maximum

Logging Intervals
1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 or 60 minutes
Primary and secondary intervals for dynamic logging.

Data Storage
Event Log: 1,000 events maximum in non-volatile flash memory
Sample History: 2,000 sample events maximum in non-volatile flash memory
Datalog: 325,000 data points; 1128 days for 3 channels at 15-minute log intervals

Local Communication
USB
RS232 (Baud rates: 9600, 19200, 38400, 57600, 115200)

Timebase Accuracy
±0.002%

Supported Sensors
Flo-Dar, Flo-Dar with SVS, Flo-Tote 3, Submerged Area Velocity Sensor†, and Sigma 950†

Certifications
Logger: CE; optional AC power supply: UL/CSA/CE

Warranty
1 year

Set-up/Data Retrieval
Flo-Ware for Windows software is required for programming the logger, data management, and report generation. It is compatible with desktop/laptop computers utilizing Windows operating system. Minimum resolution needed is 1024x768.

CE FL900 Flow Logger meets CE requirements.

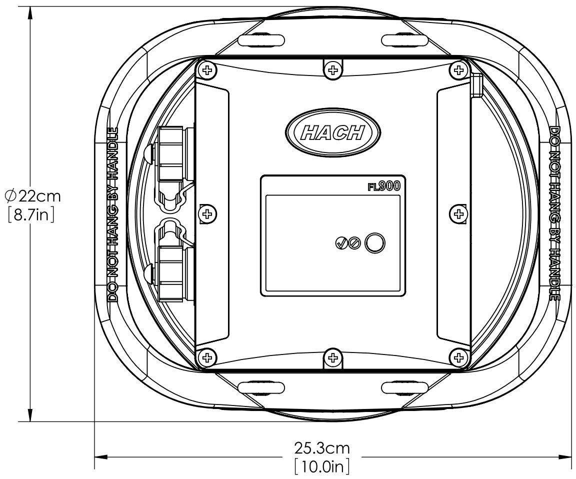
†Requires external module.

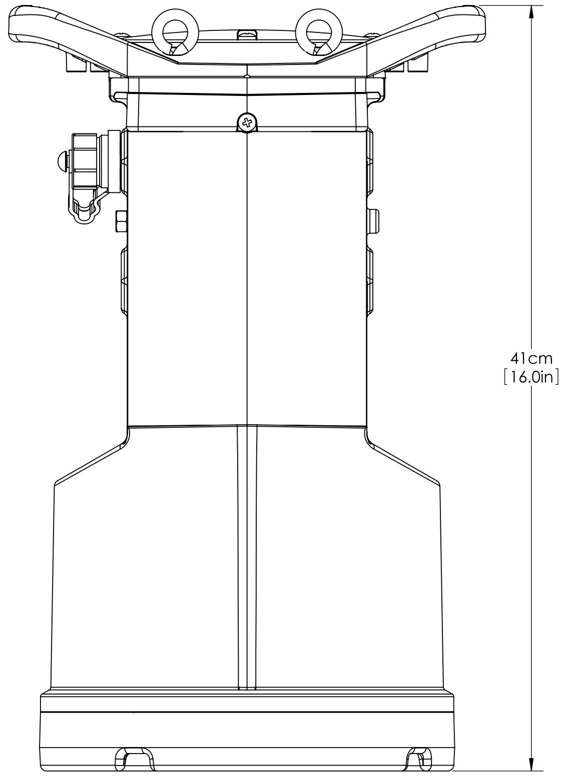
**Specifications subject to change without notice.*

Engineering Specifications

1. Exterior dimensions of the Flow Logger shall be:
   25.4 W x 22 D x 40 cm H
   (10.0 W x 8.7 D x 16.0 in. H)
2. The Flow Logger enclosure material shall be PC/ABS structural foam with NEMA 6P (IP68) rating.
3. The Operating temperature for the Flow Logger shall be -18 to 60ºC (0 to 140ºF) at 95% relative humidity and storage temperature of -40 to 60ºC (-40 to 140ºF).
4. Power requirements of the Flow Logger shall be 8 to18 Vdc from batteries.
5. The Flow Logger shall have a battery life of 185 days, when using a Flo-Dar sensor, 306 days when using a Flo-Tote sensor, and 360 days when using a Sub AV with AV9000 analyzer module, utilizing 4 batteries at a 15 minute logging interval at room temperature)
6. The Flow Logger shall have one sensor port and one communications port with stainless steel connector.
7. The Flow Logger shall have primary logging intervals of 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 or 60 minutes.
8. The Flow Logger shall have secondary logging intervals available to modify the logging rate based on a defined channel alarm condition or trigger for dynamic logging.
9. The Flow Logger data storage event log shall be 1,000 events maximum in non-volatile flash memory.
10. Timebase Accuracy of the Flow Logger shall be 0.002%.
11. The Flow Logger shall support the Flo-Dar, Flo-Dar with SVS, Flo-Tote 3, Submerged Area Velocity Sensor and Sigma 950.
12. The Flow Logger shall be able to connect to a lap top or desk top PC using either USB or RS232 serial connection.
13. The Flow Logger shall have an LED indicator for operating /programming status visible on the topmost horizontal surface of the logger.
14. The Flow Logger shall be a Hach FL900 Flow Logger.

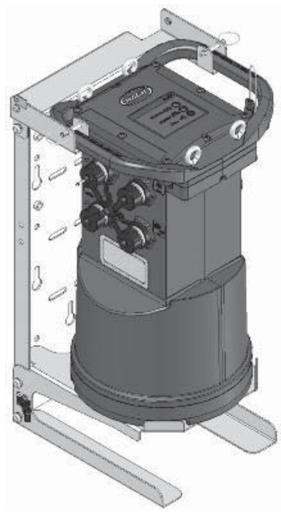
Dimensions



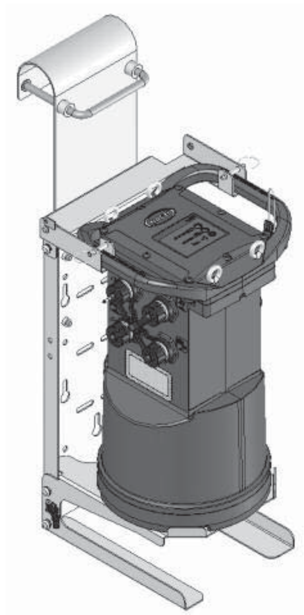


Installation/Mounting Options

Flow Logger
Suspension Cable with Carabiner
(Standard)



Flow Logger Wall Mount
Prod. No. 8542700
(Optional)



Flow Logger Ladder Rung Mount
Prod. No. 854450
(Optional)

Ordering Information

Flow Logger

FL900.97	FL900 Flow Logger, 1 sensor port, English
FL900AV.97	FL900 Flow Logger with AV9000 analyzer module, 1 sensor port, English

Analyzer Modules

8531300	AV9000 Digital Analyzer module (required to attach a Sigma Sub AV sensor)
8549800	IM9001 Interface module (required to attach a Sigma 950 flow meter)

Cables

8528200	Cable, Communication, RS232
8528300	Cable, Communication, USB
8528400	Cable, Aux, 7pin MIL 5015 (Connect to Sigma Sampler), 9 ft.
8528401	Cable, Aux, 7pin MIL 5015 (Connect to Sigma Sampler), 25 ft.

Software

Model T200-200	Flo-Ware Desktop PC/Laptop Software

Mounting Hardware

9542	Manhole Support Bracket/Spanner; 18-28"
9557	Manhole Support Bracket/Spanner; 28-48"
5713000	Manhole Support Bracket; 18-27"
8544300	Suspension cable, 16 in.
8543800	Wall mount bracket (304 Stainless)
8545600	Wall mount bracket with ladder hanger (304 Stainless)
8542700	Wall mount bracket with AC Power Supply shelf (304 Stainless)
8544500	Wall mount bracket with AC Power Supply Shelf with ladder hanger (304 Stainless)

Replacement Parts

8755500	Desiccant refill beads, Bulk 1.5 lb
11013M	Battery, 6V lantern
8524400	Battery compartment cover
8533400	O-ring for battery cover

At Hach, it's about learning from our customers and providing the right answers. It's more than ensuring the quality of water—it's about ensuring the quality of life. When it comes to the things that touch our lives...

Keep it pure.

Make it simple.

Be right.

For current price information, technical support, and ordering assistance, contact the Hach office or distributor serving your area.

In the United States and all other countries except Europe, contact:

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4539 Metropolitan Court
Frederick, MD 21704-9452, U.S.A.
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www.flow-tronic.com

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Be Right™

Marsh-McBirney FLO-TOTE® 3 Electromagnetic Area/Velocity Flow Meter Sensor

The Marsh-McBirney Flo-Tote 3 Flow Meter Sensor, when combined with a Hach FL900 Series Flow Logger, provides an ideal solution for cost-effective portable flow monitoring. (For permanent flow monitoring applications, use with Flo-Station.) Electromagnetic sensor technology provides highly accurate flow measurements.

Features and Benefits

The Marsh-McBirney Flo-Tote 3 Electromagnetic Flow Meter Sensor measures both velocity and depth in the same cross-section providing accurate measurements based on the Continuity Equation. Combined with the portable FL900 Flow Logger or permanent Flo-Station, users have an ideal solution for their flow measurement needs.

Accurate Flow Measurement

Flo-Tote 3 provides the user with highly accurate flow measurements under a wide range of flows and site conditions. The flow accuracy of the Flo-Tote is based upon the accurate measures of both velocity and depth in hydraulic flow labs, as well as under actual sewer conditions. Verification of our specifications by an independent flow laboratory assures you of our commitment to accuracy.

Disconnectable, Interchangeable and Field Replaceable Sensor

Provides easy maintenance and eliminates meter down time.

Grease Tolerant Sensor

Grease shedding electrodes allow for reliable data collection even in these difficult environments.

Q-Stick Band/Sensor Install Tool

Sensor and band can be safely and easily installed from street level with the Q-Stick tool eliminating confined space entry.

Ideal for a Variety of Open Channel Sizes & Shapes

- *Wastewater Sewers-*
  Round, Rectangular, and Odd Shaped
- *Storm Sewers*
- *Creeks, Rivers, and Streams*

Applications

- *Inflow/Infiltration Studies*
- *Modeling/Sewer System Evaluation*
- *EPA Permitting Requirements*
- *Combined Sewer Overflow (CSO Monitoring)*
- *Sewer System Evaluation*
- *Wastewater Treatment Plant Balancing*

HACH®
Be Right™

Specifications*

FLO-TOTE 3 FLOW METER SENSOR

Material
Polyurethane

Dimensions
13.6 L x 4.4 W x 2.8 H cm (5.37 L x 1.73 W x 1.10 H in.)

Weight
1.1 kg (2.4 lb) with 30 ft cable

Operating Temperature
0 to 45°C (32 to 113°F)

Storage Temperature
–20 to 52°C (–4 to 125°F)

Power Requirements
Supplied by FL900 Logger, Flo-Logger/Logger XT, or Flo-Station

VELOCITY MEASUREMENT

Method
Electromagnetic (Faraday's law)

Range
-1.5 to 6.1 m/s (-5 to +20 ft/s)

Accuracy
±2% of reading

Zero Stability
±0.015 m/s (±0.05 ft/s) at 0 to 3 m/s (0 to 10 ft/s)

Resolution
±0.0003 m/s (0.01 ft/s)

DEPTH MEASUREMENT

Method
Submerged pressure transducer

Standard Operating Range
10 mm to 3.5 cm (0.4 to 138 in.)
Contact the factory for extended ranges.

Accuracy
±1% of reading

Zero Stability
±0.009 m (±0.03 ft.), for 0 to 3 m (0 to 10 ft.)
Includes non-linearity, hysteresis and velocity effects.

Resolution
2.5 mm (0.1 in.)

Over Range Protection
2X range

FLOW MEASUREMENT

Method
Conversion of water depth and pipe size to fluid area.
Conversion of local velocity reading to mean velocity.
Multiplication of fluid area by mean velocity to equal flow rate.

Conversion Accuracy
±5.0% of reading. Assumes appropriate site calibration coefficient, pipe flowing 10% to 90% full with a level greater than 5.08 cm (2 in.).

TEMPERATURE MEASUREMENT

Method
1 wire digital thermometer

Range
–10 to 85°C (14 to 185°F)

Accuracy
±2°C (±3.5°F)

SENSOR CABLE

Material
Polyurethane jacketed

Length
Available in specified lengths from 30 to 1000 ft.

Connectors
To use with portable FL900 Series Logger or Flo-Logger:
Sensor with connector end (30 to 1000 ft. lengths)

Sensor with junction box, desiccant hub, sealant/potting kit and connector; allows for usage with conduit (30 to 1000 ft. lengths)

Important Note: The sensor cable assembly with desiccant hub is compatible with either the Marsh McBirney Flo-Logger/Logger XT or the Hach FL900 Series Flow Loggers. When using this cable assembly with the Marsh McBirney Flo-Logger, do not disconnect the desiccant cartridge that is attached to the Flo-Logger itself.

If using Tote 3 cable with Flo-Station, sensor will have bare leads on cable end (30 to 1000 ft. lengths), and there will be no desiccant hub, as the air tube terminates inside of the Flo-Station housing.

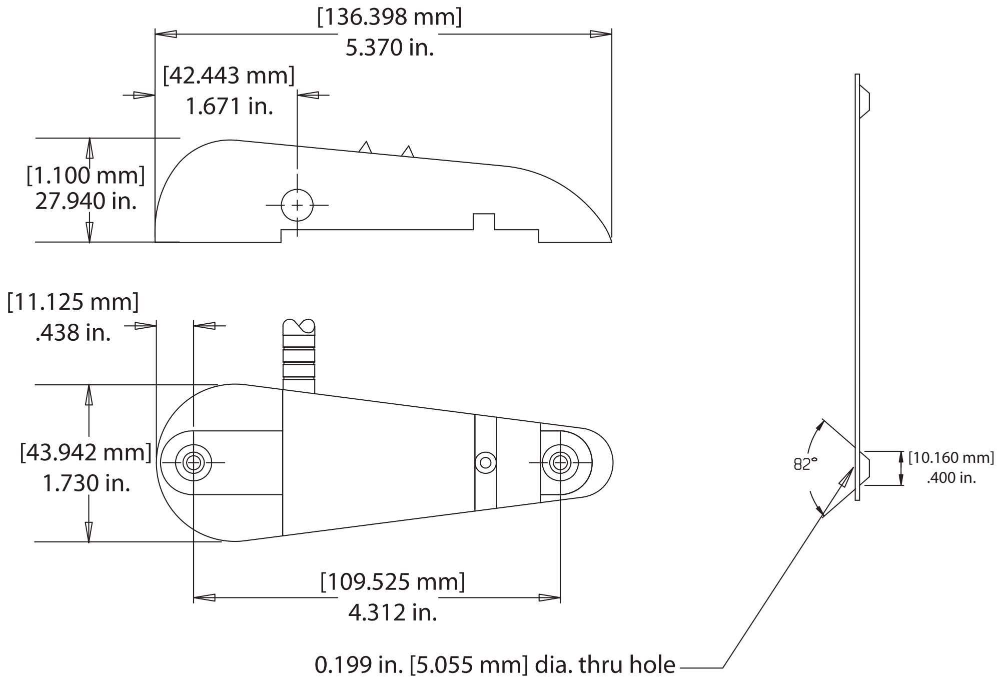
Flo-Tote 3 Electromagnetic Flow Meter Sensor meets CE requirements.

**Specifications subject to change without notice.*

Engineering Specifications

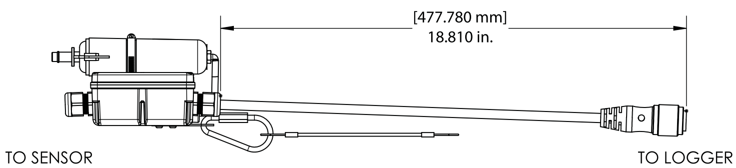
1. The flow meter shall be capable of directly measuring both velocity and depth in the same cross section.
2. The method of measurement shall be electromagnetic.
3. The range of velocity measurement shall be -1.5 to +6.1 m/s (-5 to +20 ft/s)
4. The accuracy of the velocity measurement shall be ±2% of reading.
5. Zero stability of the velocity measurement shall be ±0.015 m/s (±0.05 ft/s) at 0 to 3 m/s (0 to 10 ft/s).
6. The range for depth measurement shall be 10 mm to 3.5 m (0.4 to 138 in.). (Contact the factory for extended ranges.)
7. The accuracy of the depth measurement shall be ±1% of reading.
8. Zero stability of the depth measurement shall be ±0.009 m (±0.03 ft), for 0 to 3 m (0 to 10 ft). Includes non-linearity, hysteresis and velocity effects.
9. The flow sensor shall be the Marsh-McBirney Flo-Tote 3 Open Channel Flow Meter Sensor.

Dimensions

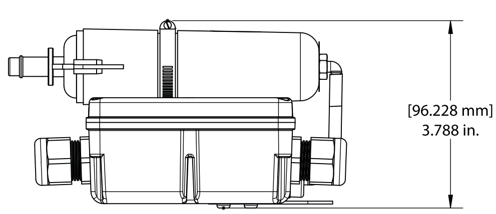


Flo-Tote 3 Electromagnetic Flow Meter Sensor

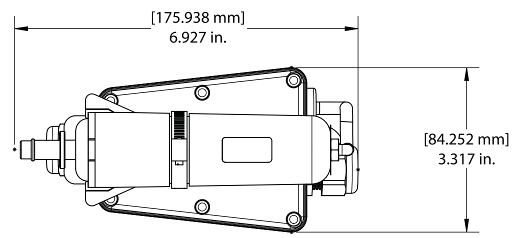
The desiccant hub assembly includes a junction box to connect sensor cable to the desiccant and subsequently to the FL900 Logger. The desiccant can easily be replaced without need to purchase a separate desiccant module.



Side View



Top View



Desiccant Hub Assemblies for use with portable FL900 Series loggers and Flo-Logger.
(Sensor cable for use with Flo-Station will not contain a desiccant hub and will have bare wires on cable end.)

Ordering Information

Flo-Tote 3 Sensor with Cable

EM9000-XXX* FL900 Logger, Flo-Logger/Logger XT
Includes sensor with cable, sealed desiccant hub and connector to logger.

EMJCTBOXCBL-XXX* FL900 Logger, Flo-Logger/Logger XT (For use with conduit)
Includes sensor with cable, unsealed desiccant hub, potting kit and connector to logger.

Model 3000-9 Flo-Station
(Specify cable length of Hach Prod. No. 360001901 using table below) Includes sensor and cable with bare leads.

**XXX—specify length from table below.*

Available Cable Lengths (in feet)

30	125	225	400	700
60	150	250	450	800
75	175	300	500	900
100	200	350	600	1000

See Lit. No. 2709 (standard models) and Lit. No. 2711 (wireless models) for FL900 Series Flow Logger ordering information.
See Lit. No. 2616 for Flo-Station ordering information.

Mounting Hardware

Mounting Bands - Several configurations available. Consult factory.

Accessories & Spares

55031-SS Profiling Adapter - allows sensor to be mounted on pole for profiling flow channel

750000201 Q-Stick Insertion Tool

245000501 Q-Stick Replacement Pole Only

8755500 Bulk desiccant beads (1.5 pounds)

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Keep it pure.

Make it simple.

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For current price information, technical support, and ordering assistance, contact the Hach office or distributor serving your area.

In the United States and all other countries except Europe, contact:

HACH COMPANY
4539 Metropolitan Court
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Fax: 301-874-8459
E-mail: hachflowsales@hach.com
www.hachflow.com

In Europe contact:

Flow-Tronic
Rue J.H. Cool 19a
B-4840 Welkenraedt Belgium
Telephone: +32-87-899799
Fax: +32-87-899790
E-mail: site@flow-tronic.com
www.flow-tronic.com

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Be Right™

Isco Product Data

Isco 6712 Full-size Portable Sampler

Isco's 6700 Series Portable Samplers have set the industry standard, providing the most comprehensive and durable performance available. With the introduction of our new 6712, Isco takes another step toward the ultimate by including SDI-12 interface capabilities.

This full-size portable lets you take full advantage of the advanced 6712 Controller, with its powerful pump, versatile programming, and optional plug-in modules for integrated flow measurement. Setup is fast and simple, with online help just a key stroke away.

The environmentally-sealed 6712 controller delivers maximum accuracy and easily handles all of your sampling applications, including:

- Flow-paced sampling with or without wastewater effluent
- stormwater monitoring
- CSO monitoring
- permit compliance
- pretreatment compliance

In the Standard Programming Mode, the controller walks you through the sampling sequence step-by-step, allowing you to choose all parameters specific to your application. Selecting the Extended Programming Mode lets you enter more complex programs.

Optional land-line and GSM and CDMA cellular telephone modems allow programming changes and data collection to be performed remotely, from a touch-tone phone. They also provide dial-out alarm.

Bottle options are available for practically any sequential or composite application.

Versatile and Convenient

With eleven bottle choices, Isco's 6712 Sampler lets you quickly adapt for simple or intricate sampling routines. Up to 30 pounds (13.5 kg) of ice fits in the insulated base, preserving samples for extended periods, even in extreme conditions. The 6712 with the “Jumbo Base” option holds bottles up to 5.5 gallon (21 liter).

Tough and Reliable

The 6712 Portable Sampler features a vacuum-formed ABS plastic shell to withstand exposure and abuse. Its tapered design and trim 20-inch (50.8 cm) diameter result in easy manhole installation and removal. Large, comfortable handles make transporting safe and convenient—even when wearing gloves.

Isco's 6712 Portable Sampler carries a NEMA 4X, 6 (IP67) enclosure rating.

Superior capability, rugged construction, and unmatched reliability make the 6712 the ideal choice for portable sampling in just about any application.

Specifications

Isco 6712 Full-size Portable Sampler

Size (Height x Diameter):	27 x 20 inches (50.7 x 68.6 cm)
Weight:	Dry, less battery - 32 lbs (15 kg)
Bottle configurations:	24 - 1 Liter PP or 350 ml Glass 24 - 1 Liter ProPak Disposable Sample Bags 12 - 1 Liter PE or 950 ml Glass 8 - 2 Liter PE or 1.8 Liter Glass 4 - 3,8 Liter PE or Glass 1 - 9,5 Liter PE or Glass 1 - 5.5 gallon (21 Liter)PE or 5 gallon (19 Liter) Glass, (with optional Jumbo Base)
Power Requirements:	12 V DC (Supplied by battery or AC power converter.)

Pump

Intake suction tubing: Length Material Inside dimension	 3 to 99 feet (1 to 30 m) Vinyl or Teflon 3/8 inch (1 cm)
Pump tubing life:	Typically 1,000,000 pump counts
Maximum lift:	28 feet (8.5 m)
Typical Repeatability	±5 ml or ±5% of the average volume in a set
Typical line velocity at Head height: of 3 ft. (0.9 m) 10 ft. (3.1 m) 15 ft. (4.6 m)	 3.0 ft./s (0.91 m/s) 2.9 ft./s (0.87 m/s) 2.7 ft./s (0.83 m/s)
Liquid presence detector:	Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.

Controller

Weight:	13 lbs. (5.9 kg)
Size (HxWxD)	10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)
Operational temperature:	32° to 120°F (0° to 49°C)
Enclosure rating:	NEMA 4X, 6 (IP67)
Program memory:	Non-volatile ROM
Flow meter signal input:	5 to 15 volt DC pulse or 25 millisecond isolated contact closure.
Number of composite samples:	Programmable from 1 to 999 samples.
Clock Accuracy:	1 minute per month, typical, for real time clock

Software

Sample frequency:	1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses
Sampling modes:	Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)
Programmable sample volumes:	10 to 9,990 ml in 1 ml increments
Sample retries:	If no sample is detected, up to 3 attempts; user selectable
Rinse cycles:	Automatic rinsing of suction line up to 3 rinses for each sample collection
Program storage:	5 sampling programs
Sampling Stop/Resume:	Up to 24 real time/date sample stop/resume commands
Controller diagnostics:	Tests for RAM, ROM, pump, display, and distributor

Ordering Information

***Note**: Power source, bottle configuration, suction line, and strainer must be ordered separately. Many options and accessories are available for 6712 Samplers; see separate literature for 700 Series Modules and other components to expand your monitoring capabilities. Contact Isco, or your Isco representative for pricing and additional information.*

Description	Part Number
6712 Portable Sampler, Full-size Includes controller with 512kB RAM, top cover, center section, base, distributor arm, instruction manual, pocket guide.	68-6710-070
6712 Portable Sampler, with Jumbo Base As described above	68-6710-082

The 6712 Controller is also an SDI-12 data logger, and has many optional capabilities. Please contact Isco or your Isco distributor for more information.

Water is life. Protect it.

Teledyne Isco, Inc.
4700 Superior Street
Lincoln NE 68504 USA
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USA and Canada: (800) 228-4373
Fax: (402) 465-3022
E-Mail: iscoinfo@teledyne.com
Internet: www.isco.com

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Knaack Classic Slanted Storage Chest Model 3068

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Knaack Classic Chest Model 3068

~~$606.40~~$568.50

Catalog Number: KN3068

The Knaack Model 3068 Classic Storage Chest with slanted top allows easy access to storage chest contents.

Features include:

• One Time Lock Install
• Recessed Lock Housing protects padlock from bolt cutters
• Recessed Handles protect from damage during transport
• Permanently Welded built-in shelf measures D: 2 1/2 W: 11 L: 60
• 16 Gauge Steel construction is fully arc welded
• 12 Gauge Steel Caster ready skides
• Durable baked enamel finish

Weight: 225 lbs

Select Qty. 1 Check Stock

Ship to Myself

ADD TO CART

Specifications | **Accessories**

Dimensions: H: 37 W: 30 L: 60
Storage Capacity: 31 Cu Ft.
Weight: 225 lbs

Recently Viewed

Knaack Classic Chest Model 2060

SSL Certificates

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CS470 and CS471

OTT CBS Compact Bubbler Sensors

The CS470 and CS471 use the air bubble principle for measuring liquid level. Generally, they measure ground or surface water level, but any liquid level can be measured.

The CS470 and CS471 differ in their accuracy. The CS470 is the standard accuracy version, providing an accuracy of ±0.02 ft. The CS471 is the high-accuracy version, providing an accuracy of ±0.01 ft (0 to 15 ft), ±0.065% of reading (15 to 35 ft), or ±0.02 ft (35 to 50 ft).

Features/Benefits

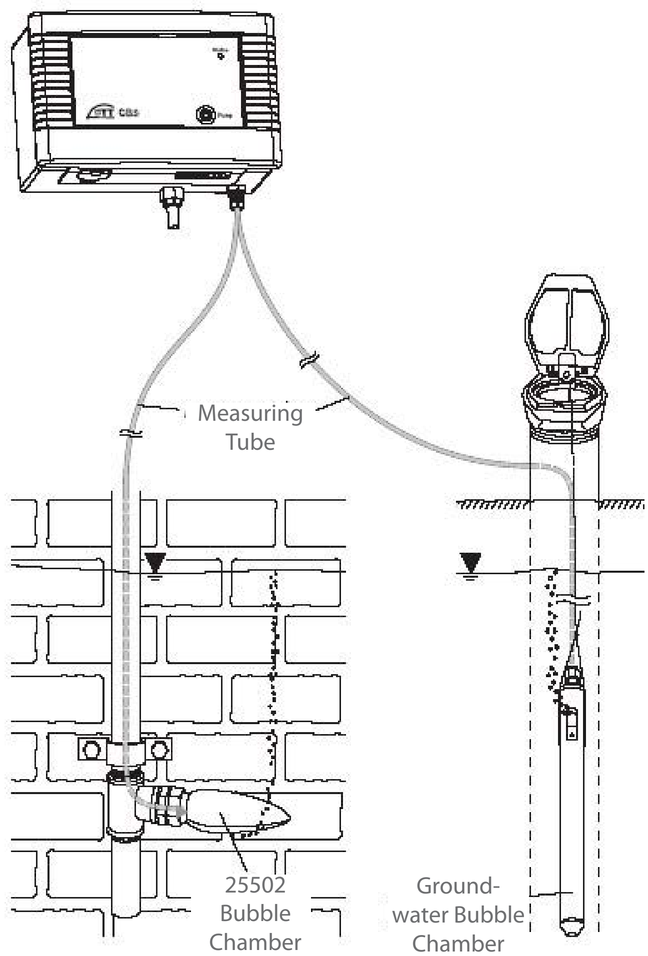
- Gives drift-free measurement and offset compensation using relative measurement
- Contains a purge function that clears the measuring tube and the bubble chamber of minor contamination
- Supports three communication options: SDI-12, 4 to 20 mA, or RS-485 (SDI-12 protocol via a physical RS-485 interface)

Air Bubble Principle

Compressed air produced by a piston pump flows via a measuring tube into the water to be measured. The pressure created in the measuring tube is directly proportional to the water column above the bubble chamber. The sensor determines the barometric air and bubble pressure one after the other. By taking the difference between the two signals, the sensors calculates the height of the water level above the bubble chamber.

System Components

Besides the bubble sensor, the system should contain the measuring tube, a bubble chamber, power supply, and datalogger. Campbell Scientific offers the measuring tube and a bubble chamber for these sensors (see Ordering Information on page 2). Compatible dataloggers include our CR200(X)-series, CR510, CR10X, CR800-series, CR1000, CR3000, and CR5000. The sensor, datalogger, and power supply need to be housed in an environmental enclosure. Hardware for mounting the sensor to an enclosure backplate is shipped with the sensor.



Above is the main layout of a level station with a CS470 or CS471 bubble sensor. Environmental enclosure not shown.

Ordering Information

Compact Bubbler Sensors

CS470	OTT CBS Compact Bubbler Sensor, Standard Accuracy
CS471	OTT CBS Compact Bubbler Sensor, High Accuracy

Common Accessories

CABLE4CBL-L	4-conductor, 24-AWG cable that connects the CS470 or CS471 with a datalogger. Enter the lead length, in feet, after the -L.
25503	Measuring Tube; specify length, in feet, when ordering. Maximum tubing length is 330 feet.
25502	OTT EPS-50 Bubble Chamber (required)

Specifications

Power Requirements: 10 to 30 Vdc

Typical Measurement/Communication Current
- **1-min. Query Interval:** 320 mAhr/day
- **15-min. Query Interval:** 25 mAhr/day

Measurement Time: 1 minute

Outputs: SDI-12 (version 1.3) 1200 Baud, 4-20 mA, RS-484 (SDI-12 Protocol via RS-485 interface)

Measurement Range: 0 to 50 ft

Accuracy
- **CS470:** ±0.02 ft
- **CS471:** ±0.01 ft (0 to 15 ft)
  ±0.065% of reading (15 to 35 ft)
  ±0.02 ft (35 to 50 ft)

Resolution: 0.003 ft /0.014 psi

Temperature Range
- **Operating:** -20° to 60°C
- **Storage:** -40° to 85°C

Relative Humidity Range: 10% to 95% RH, non-condensing

25503 Measuring Tube Description
- **Material:** Polyethylene
- **Inner Diameter:** 1/8 in. (3.175 mm)
- **Outer Diameter:** 3/8 in, (9.525 mm)
- **Maximum Length:** 330 ft (100.6 m)

Electronics Box Dimensions: 6.5 in x 8.1 in x 4.5 in. (16.5 cm x 20.5 cm x 11.5 cm)

Weight: 3.3 lbs (1500 g)

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Printed May 2010

Plasti-Fab®, Inc.

PRODUCTS FOR THE WATER AND WASTEWATER INDUSTRY

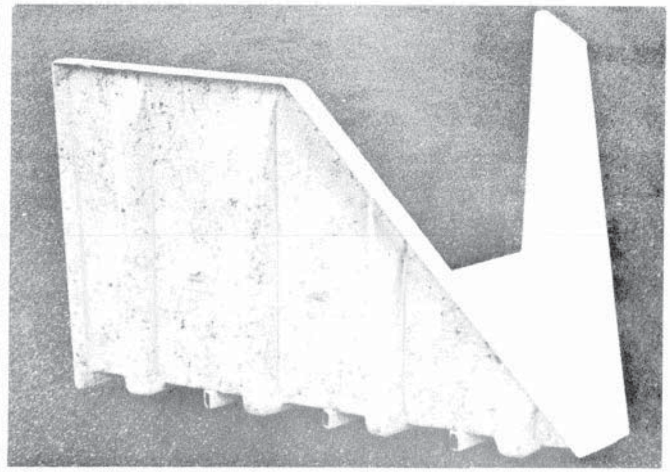
H FLUMES
HS & HL FLUMES

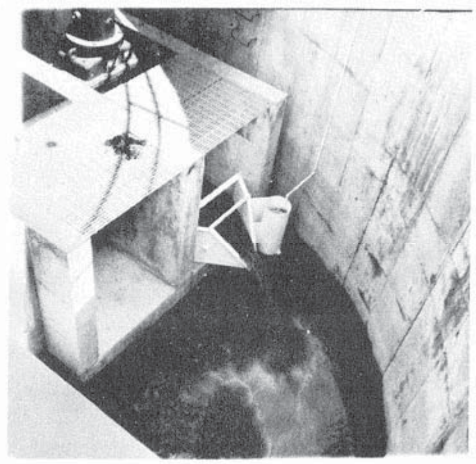
PRODUCT BULLETIN
HF-2, REV. 1

H FLUMES
HS FLUMES
HL FLUMES

FOR METERING WIDE RANGES OF FLOW

SIZES:
H Flumes from .5′ to 4.5′
HS Flumes from .4′ to 1.0′
HL Flumes, 4.0′





H Flumes are capable of monitoring flows that vary over wide ranges with a high degree of accuracy. Unlike the Parshall, Palmer-Bowlus or others which have a useable range of approximately 10:1, the H Flume is capable of providing accurate measurement for applications with flow ranges of 100:1 or more. This wide range gives excellent resolution at low flows and the capacity to handle higher flows. Because of this, the H Flume and two variations, the HS and HL flumes, have been used effectively for some time by the Soil and Agricultural Branches of the Federal and various State Governments for stream, drainage basin, and storm water runoff studies.

Plasti-Fab fiberglass H Flumes are available in a variety of sizes and can be used to measure flows ranging from zero to 80 cfs. HS Flumes are typically recommended for lower flows, not exceeding 0.8 cfs. The 4.0′ HL Flume may be recommended for larger flows up to 111 cfs.

APPROACH CHANNEL

The channel carrying water to the H Flume should be rectangular, having the same depth and width as the H Flume and a length of 3 to 5 times the depth of the flume. Entrance channels are available from Plasti-Fab.

EXIT CHANNEL

The H Flume is generally installed with a free spill off of the downstream end. It was not originally intended to be used with pipe at either the inlet or outlet end, but with the present day need to measure industrial and municipal waste water, which is usually in a pipeline, the H Flume can often be installed quite satisfactorily.

As for the exit channel, if water is permitted to flow or spill away from the H Flume in such a way that it does not slow down the flow through the flume notch, the H Flume may then be used in conjunction with an outlet pipe.

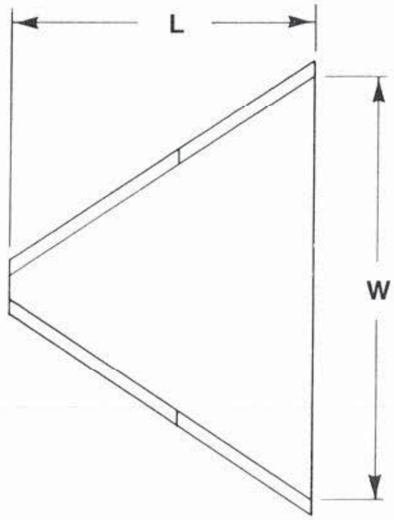
INSTALLATION

The H Flume must be installed level, with the floor of the flume at the same elevation as the inlet channel. The velocity of the water entering the flume must be subcritical and not turbulent. The water must spill from the flume or flow unimpeded in a manner comparable to spilling off of the end.

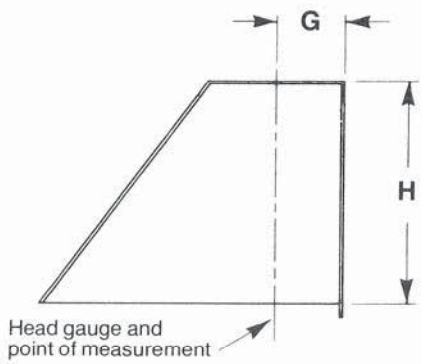
EXAMPLES OF INSTALLATIONS

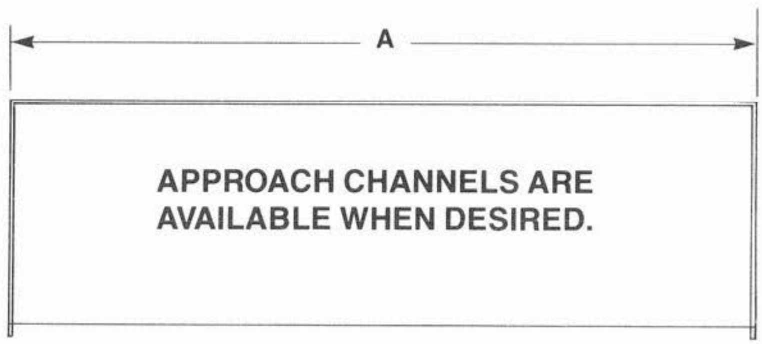
- A large industrial plant with a process or cooling water effluent of X gpm with roof drains and parking lot drains tied to the same effluent line that produce a flow of 50 X gpm during a rainstorm.
- Industrial plants, particularly food processors, where they have a periodic washdown of 50 to 100 times normal flow.
- Municipal sewage systems where present day flow may be very small, but future growth is expected to produce much higher flows. Note, often a double Parshall is used for this, and correctly so, but due to particular circumstances the H flume has been used to good advantage.
- Municipal sewage treatment plants that have very wide swings in flow rate, such as in resort areas.
- Portable — Plasti-Fab has supplied several special H Flumes to government agencies for temporary installation in the field.

STANDARD H, HS AND HL FLUME DIMENSIONS



FLUME SIZE	H	W	L	G	A
0.4 HS	0'-4 13/16"	0'-5"	0'-7 3/16"	2 3/8"	2'-0"
1.0 HS	1'-0"	1'-0 5/8"	1'-6"	6"	5'-0"
0.5 H	0'-6"	0'-11 3/8"	0'-8 1/8"	1 7/8"	2'-6"
0.75	0'-9"	1'-5 1/8"	1'-0 1/8"	2 11/16"	3'-9"
1.0	1'-0"	1'-10 13/16"	1'-4 3/16"	3 5/8"	5'-0"
1.5	1'-6"	2'-10 3/16"	2'-0 5/16"	5 3/8"	4'-6"
2.0	2'-0"	3'-9 5/8"	2'-8 3/8"	7 3/16"	6'-0"
2.5	2'-6"	4'-9"	3'-4 1/2"	9"	7'-6"
3.0	3'-0"	5'-8 3/8"	4'-0 5/8"	10 7/8"	9'-0"
4.0 HL	4'-0"	12'-9 5/8"	6'-0"	1'-0"	12'-0"
4.5 H	4'-6"	8'-6 5/8"	6'-0 15/16"	1'-4 3/16"	13'-6"





CAPACITIES OF VARIOUS H, HS AND HL FLUMES

H = Head in feet Q = Capacity in cubic feet per second

FLUME SIZE	.4 HS	1.0 HS	.5	.75	1.0	1.5	2.0	2.5	3.0	4.0 HL	4.5
H	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
0.02	0.0002	0.0004	0.0004	0.0006	0.0007	0.0011	0.0014	0.0018	0.0021	0.005	0.0031
0.1	0.0042	0.0074	0.0101	0.0126	0.015	0.020	0.025	0.030	0.035	0.089	0.050
0.3	0.044	0.060	0.105	0.119	0.132	0.157	0.183	0.209	0.234	0.565	0.311
0.5		0.176		0.370	0.398	0.454	0.509	0.564	0.620	1.42	0.785
0.7		0.367		0.813	0.851	0.942	1.03	1.13	1.22	2.71	1.49
0.9		0.646			1.53	1.65	1.78	1.92	2.05	4.48	2.45
1.0						2.09	2.25	2.41	2.57	5.56	3.04
1.4						4.60	4.82	5.06	5.33	11.2	6.11
1.9							9.85	10.2	10.5	21.7	11.8
2.0								11.5	11.9	24.3	13.2
2.4								17.6	18.1	36.5	19.7
2.5									19.9	39.9	21.6
2.9									28.3	55.9	30.2
3.0										60.3	32.7
3.9										111.0	60.2
4.4											80.0

SOURCE: USDA Agricultural Handbook No. 224.

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RavenXT-Series

Sierra Wireless Airlink Digital Cellular Modems

CAMPBELL® SCIENTIFIC
WHEN MEASUREMENTS MATTER

The RavenXT-series modems are full-duplex devices that transmit data to the local cellular tower. A PC retrieves the data from the cellular tower via the Internet*. Internet communications provide faster communication rates and eliminate dialing delays and long distance fees.

The following modems are offered:

- **RavenXTV**—Code Division Multiple Access (CDMA) modem configured for Verizon networks
- **RavenXTG**—General Packet Radio Service (GPRS) modem configured for AT&T networks

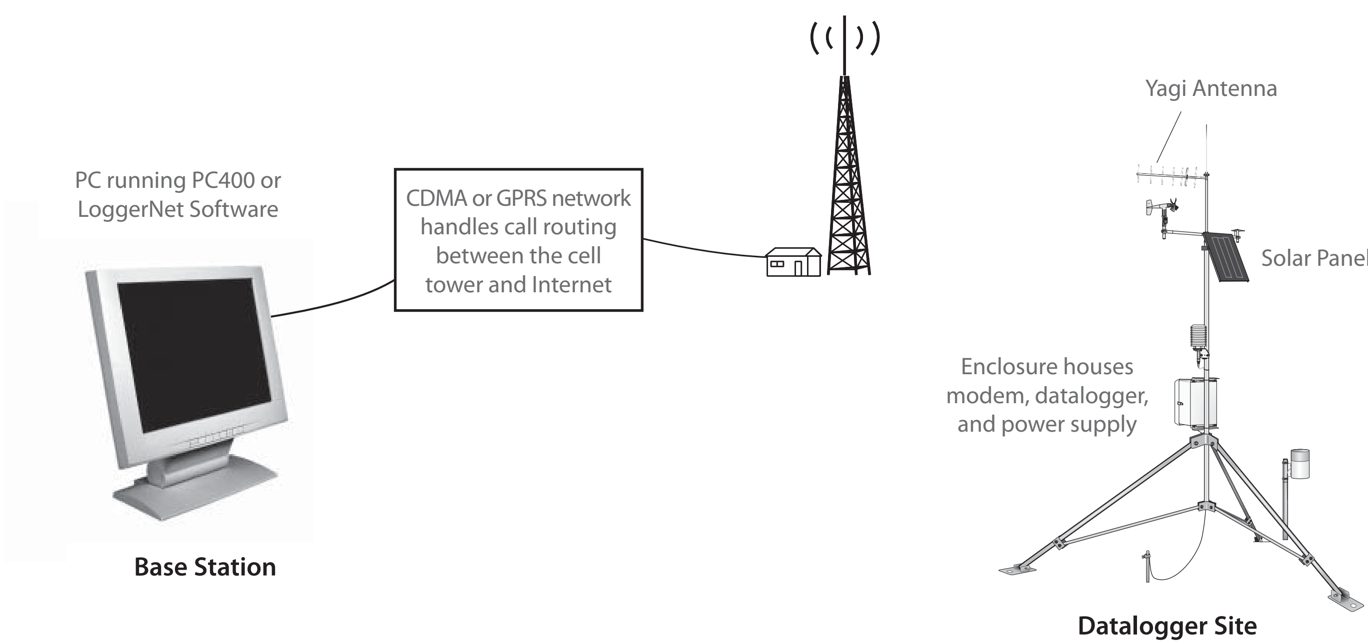
Features

- Eliminates the dialing delays and long distance fees that land-line phone modems experience
- Allows simultaneous communications with multiple dataloggers in the network
- Housed in a rugged aluminum case
- Operates over a wide operating temperature range (see specifications)

Cellular Coverage

Before purchasing a digital cellular modem, ensure that there is a CDMA or GPRS network with coverage at the datalogger site. For the RavenXTV, you'll need to contact Verizon and ask them about coverage. For the RavenXTG, a coverage map is available at: www.wireless.att.com/coverageviewer/

Typical System*



The RavenXTV uses 1xRTT/EVDO to communicate over the Internet. It can also use IS-95 to communicate over standard telephone lines. Contact Campbell Scientific for system requirements if using IS-95.

Establishing Cellular Service

RavenXTV

Call Verizon at 1-888-384-1775 and set up either a static or dynamic IP account[1]. When setting up the account, you will need the ESN number, which is listed on the modem's label. You will also need to request the *unrestricted IP*. Verizon's *Broadband Plan* is recommended.

RavenXTG

Call AT&T at 1-800-331-0500 and ask for an *unrestricted data account* for a GPRS modem. Either a static IP account or a dynamic IP account needs to be established. After the account has been set up, mobile termination needs to be configured onto the account to make the modem accessible through the Internet. This is done by adding an *I2gold APN*[2] or *custom APN*[3] to the account. A data account with an *I2gold APN* will have a Static IP address.

After establishing service, AT&T will provide a SIMM card for each modem. In some cases, the SIMM card can be picked up at the local AT&T store.

Datalogger Site Equipment

Digital Cellular Modem

The RavenXTV and RavenXTG are shipped with a power cable, our Resource CD, and a CD containing the Airlink software and the Airlink manual. The modems are configured using the following software:

- **Airlink AceManager software**—activates the modem and configures the generic parameters of the modem.
- **Campbell Scientific's Raven CDMA Template (RavenXTV) or Raven GPRS Template (RavenXTG)**—used with Airlink AceManager software to configure the modem. The template sets up the Raven serial interface, which is specific to Campbell Scientific systems. The Raven CDMA Template and Raven GPRS Template are available, at no charge, from: www.campbellsci.com/downloads

Network connection information can be viewed using the Airlink AceManger or Airlink AceView software.

Datalogger Connections

All of our contemporary and many of our retired dataloggers are compatible. The datalogger connects with the modem using one of the following devices:

- **18663 Null Modem Cable**—connects the modem directly to the datalogger's RS-232 port. This cable is the only option available for connecting the modem to a CR200(X)-series datalogger.
- **SC105 DCE Interface**—connects the modem to the datalogger's CS I/O port via an SC12 cable. The SC105 is recommended for PakBus® dataloggers when the RS-232 port is unavailable.
- **SC932A DCE Interface**—connects the modem to the datalogger's CS I/O port via an SC12 cable. The SC932A is recommended for mixed-array dataloggers when the RS-232 port is unavailable.

18663

SC932A

SC105

One of the above is required to connect the datalogger to the modem. The best choice for your application depends on the datalogger you are using.

Power Considerations

A power cable included with the modem connects to the datalogger's 12 V or switched 12 V terminal. Connection to the switched 12 V terminal allows the datalogger to switch power to the modem during scheduled transmission intervals, thereby conserving power. When using the switched 12 V terminal, the modem can be powered with a BP12 battery, CH100 regulator, and SP10 solar panel. For help on analyzing your system's power requirements, refer to our Power Supply product brochure or application note.

---

[1]*A static IP account eliminates the need for a third party Dynamic Domain Name System (DDNS) such as IP manager. The DDNS translates the domain name to a dynamic IP address so that the modem can be contacted as if it had a static IP address.*

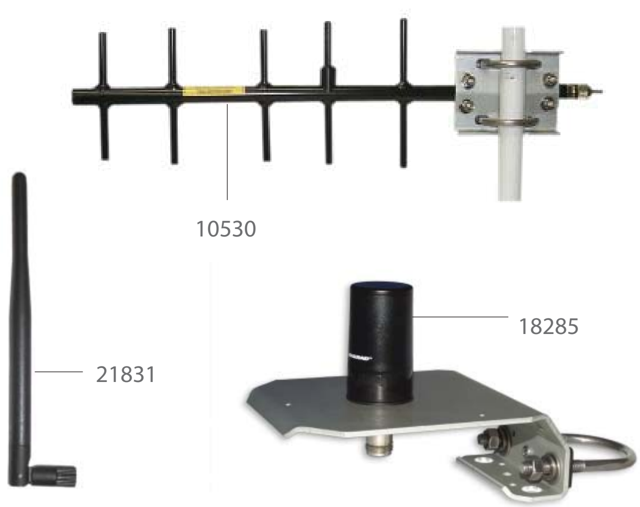
[2]*At one time, feature code G821 was used instead of the I2gold APN. Feature code G821 has been discontinued, and all RavenXTGs need either an I2gold APN or custom APN.*

[3]*A custom APN may offer more efficient routing and better security for large cellular phone networks. It will take four to six weeks for AT&T to develop a custom APN and cost about $250.00.*

Antennas

A choice of four antennas is offered for the modems. Contact an Applications Engineer for help in determining the best antenna for your application.

- **21831 0 dBd, ½ Wave Dipole Whip Antenna**—supports the 800 MHz band. It is intended for locations that have strong cellular coverage. This antenna attaches directly to the modem's SMA connector and must reside in an environmental enclosure or building. It has an articulating knuckle joint that can be oriented vertically or at right angles.
- **18285 1 dBd, Omnidirectional Antenna**—covers both the 800 MHz and 1.9 GHz bands. It includes a mounting bracket for attaching the antenna to a crossarm, tripod, tower, or pole. Connection to the modem requires an antenna cable (*see right column*).
- **20679 800 MHz/0 dBd and 1.9 GHz/3 dBd Omnidirectional Antenna**—includes a mounting bracket for attaching the antenna to a crossarm, tripod, tower, or pole. Connection to the modem requires an antenna cable (*see right column*).
- **10530 9 dBd, Yagi Antenna**—supports the 800 MHz band and is intended for sites near the edge of the cellular coverage. It includes a bracket for attachment to a mast or pole (outer diameter of up to 1.5" (3.8 cm)). Some sites may require the CM230 mount (see *Adjustable Angle Mounting Kit*). Connection to the modem requires an antenna cable (*see right column*).



Above are antennas used with the RavenXT-series digital cellular modems. The 20679 antenna is not shown.

Antenna Cables/Surge Suppressor

Installations that are susceptible to lightning should use the COAXNTN cable and 19533 surge protector kit.

Typically, a 21847 or COAXSMA-L cable is used with a 18285, 20679, or 10530 antenna. Both of these cables have a type N male connector on the antenna end and an SMA connector on the transceiver end. They differ in their length:

- **21847 Antenna Cable with 12-ft Length**
- **COAXSMA-L Antenna Cable with User-specified Length**—enter cable length, in feet, after the L. Length should not exceed 20 ft (6 m).

Use the following when the modem is in an environment susceptible to lightning or electrostatic buildup:

- **COAXNTN-L** antenna cable with type N male to type N male connectors (requires 19533)—specify length, in feet, after the L. Cable lengths longer than 20 ft will weaken the signal strength.
- **19533 Antenna Surge Protector Kit—**includes one COAXSMA-L1.5 cable. A COAXNTN-L cable is required (see above).

Adjustable Angle Mounting Kit

The CM230 Adjustable Angle Mounting Kit allows the 10530 Yagi antenna to be aimed at the service provider's antenna.

Enclosures and Mounting Bracket

An ENC12/14, ENC14/16, or ENC16/18 environmental enclosure can house the modem, datalogger, and power supply. The modem is secured to the enclosure's backplate via the 14394 Mounting Bracket.

Base Station Requirements

- PC running PC400 or LoggerNet Datalogger Support Software.
- Access to the Internet.

Specifications

	RavenXTV	RavenXTG
Technology	CDMA 1xRTT, EVDO Rev. A, CDMA IS-95, dual band	GPRS (MS-12), quad band
Bands	**Dual band:** 800 MHz Cellular, 1900 MHz PCS	**Quad band:** 850/1900 MHz; 900/1800 MHz
Transmit Frequency	1850 to 1910 MHz and 824 to 849 MHz	**850/1900 MHz:** 824 to 849 MHz; 1850 to 1910 MHz **900/1800 MHz:** 890 to 915 MHz; 1710 to 1785 MHz
Transmit Power	1.0 W for 1900 MHz; 0.8 W for 850 MHz	1.0 W for 1900 MHz; 0.8 W for 850 MHz
Receiver Frequency	1930 to 1990 MHz and 869 to 894 MHz	**850/1900 MHz:** 869 to 894 MHz; 1930 to 1990 MHz **900/1800 MHz:** 935 to 960 MHz; 1805 to 1880 MHz
CDMA or GPRS Throughput	up to 80 kbps (CDMA)	up to 70 kbps (GPRS)
RS-232 Data Rates	1200 bps to 115.2 kbps	1200 bps to 115.2 kbps
Serial Interface	RS-232, DB9-F	RS-232, DB9-F
Serial Protocols	AT Commands, PPP, SLIP, UDP/IP, TCP/IP	AT Commands, PPP, SLIP, UDP, TCP
RF Antenna Connector	50 Ohm SMA	50 Ohm SMA
Input Current Range	50 to 250 mA	40 to 250 mA
Typical Current Drain (at 12 Vdc)	50 mA dormant (idle for 10 to 20 seconds), 120 mA transmit/receive	50 mA dormant (idle for 10 to 20 seconds), 120 mA transmit/receive
Input Voltage Range	6 to 28 Vdc	6 to 28 Vdc
Operating Temperature Range	-30° to +70°C	-30° to +65°C
Operating Humidity Range	5% to 95% RH non-condensing	5% to 95% RH non-condensing
Status LEDs	Power, Network, Signal, Activity	Power, Network, Signal, Activity
Dimensions	3”W x 1”D x 4”L (7.6 x 2.5 x 10 cm)	3”W x 1”D x 4”L (7.6 x 2.5 x 10 cm)
Weight	<1 lbs (<0.5 kg)	<1 lbs (<0.5 kg)

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TE525-Series

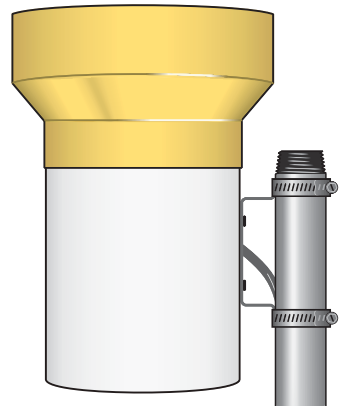
Texas Electronics Tipping Bucket Rain Gages

CAMPBELL® SCIENTIFIC
WHEN MEASUREMENTS MATTER

The TE525-series tipping bucket rain gages are manufactured by Texas Electronics. They funnel precipitation into a bucket mechanism that tips when filled to a calibrated level. A magnet attached to the tipping mechanism actuates a switch as the bucket tips. The momentary switch closure is counted by the pulse-counting circuitry of Campbell Scientific dataloggers.

Three models are available:

- **TE525WS**—provides an 8-inch diameter orifice, and measures in 0.01-inch increments
- **TE525**—provides a 6-inch diameter orifice, and measures in 0.01-inch increments
- **TE525MM**—provides a 9.6-inch orifice, and measures in 0.1-mm increments



The TE525WS conforms to the National Weather Service recommendation for an 8-inch funnel orifice.

Mounting

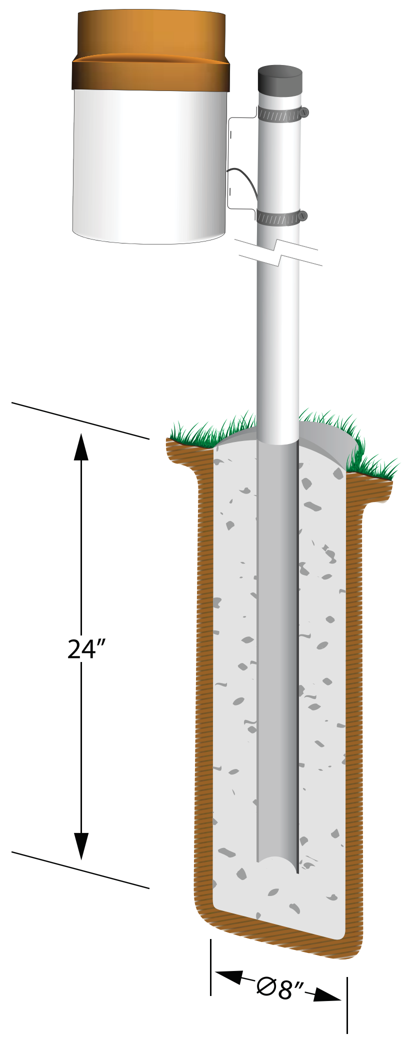
The TE525-series rain gages mount to a CM300-series Mounting Pole or a user-supplied 1.5-in. IPS pole. Several pedestal options are available to secure a CM300-series pole to the ground (see Ordering Information on page 2). Accurate measurements require the gage to be level.

Snowfall Adapter

Campbell Scientific's CS705 Snowfall Conversion Adapter uses antifreeze to melt snow, allowing the TE525WS to measure the water content of snow. The CS705 cannot be directly used with either the TE525 or TE525MM. However, both the TE525 and TE525MM can be converted to a TE525WS by returning them to Campbell Scientific. For more information about the CS705, refer to the CS705 brochure.

Wind Screen

Campbell Scientific offers the 260-953 Wind Screen to help minimize the affect of wind on the rain measurements. This wind screen consists of 32 leaves that hang freely and swing as the wind moves past them.



A TE525 mounted onto a CM310 pole is embedded directly in a concrete pad (-NP no pedestal base option).

Ordering Information

Tipping Bucket Raingages

Recommended cable length is 25 feet, but many customers will order a 50-ft cable to place the gage away from the tower or tripod.

TE525WS-L Tipping bucket with 8-inch diameter orifice and 0.01-inch tips. Enter cable length (in feet) after the -L. Must choose a cable termination option (see below).

TE525-L Tipping bucket with 6-inch diameter orifice and 0.01-inch tips. Enter cable length (in feet) after the -L. Must choose a cable termination option (see below).

TE525MM-L Tipping bucket with 24.5 cm diameter orifice and 0.1-mm tips. Enter cable length (in feet) after the -L. Must choose a cable termination option (see below).

Cable Termination Options (choose one)

-PT Cable terminates in stripped and tinned leads for direct connection to a datalogger's terminals.

-PW Cable terminates in connector for attachment to a prewired enclosure.

Mounting Poles

CM300 23-inch Mounting Pole with Cap

CM305 47-inch Mounting Pole with Cap

CM310 56-inch Mounting Pole with Cap

Pedestal Options for Mounting Poles (choose one)

-NP No Pedestal Base

-PJ CM340 Pedestal J-Bolt Kit

-PS CM350 Pedestal Short Legs (23-in. legs)

-PL CM355 Pedestal Long Legs (39-in. legs)

Common Accessories

CS705 Snowfall adapter for the TE525WS

10869 Four one-gallon containers of 50:50 PG:E Antifreeze; only US ground shipments

260-953 Novalynx Alter-type Rain Gage Wind Screen

Specifications

Sensor Type: Tipping bucket/magnetic reed switch

Material: Anodized aluminum

Temperature: 0° to +50°C

Resolution: 1 tip

Volume per Tip
- **TE525WS:** 0.28 fl. oz./tip (8.24 ml/tip)
- **TE525, TE525MM:** 0.16 fl. oz./tip (4.73 ml/tip)

Rainfall per Tip
- **TE525WS, TE525:** 0.01 in. (0.254 mm)
- **TE525MM:** 0.004 in. (0.1 mm)

Accuracy
- **TE525WS:** ±1% (up to 1 in./hr); +0, -2.5% (1 to 2 in./hr); +0, -3.5% (2 to 3 in./hr)
- **TE525:** ±1% (up to 1 in./hr); +0, -3% (1 to 2 in./hr); +0, -5% (2 to 3 in./hr)
- **TE525MM:** ±1% (up to 10 mm/hr); +0, -3% (10 to 20 mm/hr); +0, -5% (20 to 30 mm/hr)

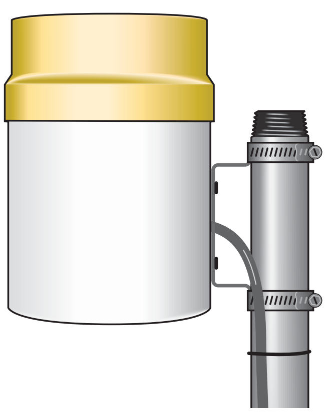
Funnel Collector Diameter
- **TE525WS:** 8 in. (20.3 cm)
- **TE525:** 6.06 in. (15.4 cm)
- **TE525MM:** 9.66 in. (24.5 cm)

Height
- **TE525WS:** 10.5 inches (26.7 cm)
- **TE525:** 9.5 inches (24.1 cm)
- **TE525MM:** 11.5 inches (29.21 cm)

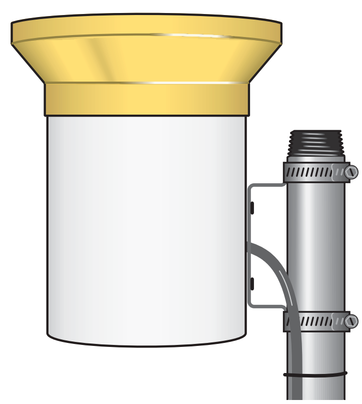
Tipping Bucket Weight
- **TE525WS:** 2.2 lb. (1.0 kg)
- **TE525:** 2.0 lb. (0.9 kg)
- **TE525MM:** 2.4 lb. (1.1 kg)

Cable: 2-conductor shielded cable

Cable Weight: 0.2 lb. (0.1 kg) per 10-ft length



The TE525 is widely used in environmental monitoring applications.



The TE525MM measures rainfall in metric rather than US units.

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APPENDIX E

Example Field and Quality Assurance Forms

FIELD LOG SHEET and FLOW DATA VALIDATION

Site:____________________________

Maintenance and Pre-Storm Checklist			
Time:	Date:	Field Staff:	Weather:

Station Name: Inlet

Time Correct? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Flume Level Checked? ________
Manual Level: ________
Data Downloaded? ________
Volume Calibrated? ________
Desiccant: ________
Notes: ________

Station Name: Outlet

Time Correct? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Manual Level: ________
Data Downloaded? ________
Volume Calibrated? ________
Desiccant: ________
Notes: ________

Station Name: Bypass

Time Correct? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Flume Level Checked? ________
Manual Level: ________
Data Downloaded? ________
Volume Calibrated? ________
Desiccant: ________
Notes: ________

Pre-Storm Visit		
Date/Time:	Field Staff:	Weather:

Sample Box Cleaned? ________
Sample Line Checked? ________
Clean Bottle? ________
Pacing Adjusted? ________
Composite/Discrete Setup? ________
Ice Added? ________
Program Started? ________
Delay to Start? ________
Notes: ________

Sample Line Checked? ________
Clean Bottle? ________
Pacing Adjusted? ________
Composite/Discrete Setup? ________
Ice Added? ________
Program Started? ________
Delay to Start? ________
Notes: ________

Notes: ________

Storm Visit		
Date:	Field Staff:	Weather:

Time: ________
Notes: ________

Time: ________
Notes: ________

Manual Measurement (mL/s)

1	
2	
3	
4	
5	

Post-Storm Visit		
Date/Time:	Field Staff:	Weather:

Date/Time End: ________
# of Samples: ________
Errors? ________
Est. Sample Vol: ________
Bottles Replaced? ________
Data Downloaded? ________
# of Samples Sent to Lab: ________
Duplicate Sample? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Notes:

Date/Time End: ________
# of Samples: ________
Errors? ________
Est. Sample Vol: ________
Bottles Replaced? ________
Data Downloaded? ________
# of Samples Sent to Lab: ________
Duplicate Sample? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Notes:

Data Downloaded? ________
Instrument Reading Before Calib. Leveling: ________
Instrument Reading After Calib. Leveling: ________
Instrument Reading After Calib. Adjust ________
Flow Present: Yes No
Notes:

Flow Data Validation

Storm Depth:	______	Storm Depth:	______
Storm Duration:	______	Storm Duration:	______
Ant. Dry Time:	______	Ant. Dry Time:	______
Storm End:	______	Storm End:	______
Av. Intensity:	______	Av. Intensity:	______

QAPP targets: Storm Depth = 0.15 in; Storm Duration = 1 hr; Antecedent Dry Time = 6 hr with <0.04 in, Storm End = 6 hr with no precip, Storm Intensity: >0.03 in/hr

Additional Notes:

Automated Data Collection
Quality Assurance Worksheet

By ____________________

Date __________ Page _____ of _____

Project Name/No./Client: Filterra Monitoring/ 10-04715-002/ Americast, Inc.

Site Name: ____________________

Sensors: Influent, Effluent, Bypass, and Rain

initials ____________________

date ____________________

____

Location and Type of Sensor	Data Upload Time Span	Data Gaps		Data Anomalies	
		Description/Time Span	Corrective Action	Description/Time Span	Corrective Action
Influent	Start: Stop:				
Effluent	Start: Stop:				
Bypass	Start: Stop:				
Rain	Start: Stop:				

NOTES:

Data Quality Assurance Worksheet

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ENVIRONMENTAL
CONSULTANTS

By ______________________

Project Name/No./Client: Filterra Monitoring/ 10-04715-002/ Americast, Inc. Date __________ Page ____ of ____

Laboratory/Parameters: Aquatic Research Inc./TSS, TP, SRP, hardness, total and dissolved Cu and Zn, pH Checked: initials __________

Sample Date/Sample ID: ______________________ date __________

Parameter	Completeness/ Methodology	Pre-preservation Holding Times (days)		Holding Times (days)		Blanks/ Detection Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
		Reported	Goal	Reported	Goal		Reported	Goal	Reported	Goal	Reported	Goal[1]	Reported	Goal[1]		
TSS	OK		**NA**		**≤7**	0.5		**NA**		**±10**		**≤ 25**		**≤ 25**		
TP	OK		**NA**		**≤28**	0.002		**±25**		**±10**		**≤ 20**		**≤ 25**		
SRP	OK		**≤1**		**≤2**	0.001		**±25**		**±10**		**≤ 20**		**≤ 25**		
Hardness	OK		**NA**		**≤28**	2.00		**±25**		**±10**		**≤ 20**		**≤ 25**		
Dissolved Copper	OK		**≤1**		**≤180**	0.001		**±25**		**±10**		**≤ 20**		**≤ 25**		
Dissolved Zinc	OK		**≤1**		**≤180**	0.005		**±25**		**±10**		**≤ 20**		**≤ 25**		
Total Copper	OK		**NA**		**≤180**	0.001		**±25**		**±10**		**≤ 20**		**≤ 25**		
Total Zinc	OK		**NA**		**≤180**	0.005		**±25**		**±10**		**≤ 20**		**≤ 25**		
pH	OK		**NA**		**≤1**	NA		**NA**		**NA**		**≤ 10**		**≤ 15**		

[1] If the sample or duplicate value is less than five times the reporting limit, the difference is calculated rather than the relative percent difference (RPD). The QA goal is a difference <2 times the detection limit instead of the number indicated in the goal column.

NA – not applicable or not available, NC – not calculable due to one or more values below the detection limit, NS – field duplicate not sampled.