ATTACHMENT 2

INTERIM TECHNICAL EVALUATION REPORT (TER)
FIELD EVALUATION OF THE
FOCALPOINT HIGH PERFORMANCE MODULAR
BIOFILTRATION SYSTEM

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EXECUTIVE SUMMARY

Summary

On October 28, 2014, ACF Environmental of Richmond, Virginia authorized Civil & Environmental Consultants, Inc. (CEC) to perform a full-scale field test to assess the water quality performance of the FocalPoint High Performance Modular Biofiltration System (HPMBS). This study was conducted at the warehouse facility owned by Civil & Environmental Consultants, Inc. (CEC) on Campbells Run Road in Pittsburgh, Pennsylvania.

CEC provides consulting services specializing in Best Management Practices (BMP) evaluation and product research and development. CEC was contracted by ACF Environmental to assist with the Quality Assurance Project Plan (QAPP) development, based on Technology Assessment Protocol - Ecology (TAPE), and execution of this study. The project focuses on the design, execution, and review of the field study to assess the hydraulic and pollutant-removal performance of the FocalPoint system.

Technology

The FocalPoint HPMBS is a specialized system utilizing biofiltration media for the treatment of stormwater runoff from impervious surfaces. The FocalPoint system was developed by Convergent Water Technologies of Houston, Texas. The modular treatment system, containing biologically active biofiltration media, is used as a complete, integrated system with a demanding specification that insures functionality, performance, and maintainability. With rigorous quality assurance standards and post construction in-situ infiltration verification, FocalPoint HPMBS guarantees performance.

The installation of the FocalPoint system and initiation of data collection was completed in July 2015. The construction and installation of the FocalPoint was performed by a third party contractor, Exact Storm of Richmond, VA. The data collection goal for the project is to retrieve water quality samples for a minimum of 20 qualifying storm events, with completion of the data collection phase by the spring of 2016.

Rainfall

For the study period to date (164 Julian Days) there were 57 of days with measurable precipitation and a total rainfall depth of 18.24 inches observed at the site.

Water Quality Performance

The FocalPoint system in this TAPE level field study was sized to treat a 1 inch runoff volume (WQv) prior to bypass from 0.25-acre impervious parking lot. The resulting filter bed area to drainage area ratio is 0.40% and the ponding volume above the system is approximately 20% of the WQv.

Of the 57 rainfall events, twelve (12) events had samples collected and were classified as qualifying storm events, as defined by the QAPP (i.e., minimum storm depth during the event of 0.15 inch). From these 12 storm events, there has been an average 31% reduction in runoff volume through the FocalPoint system for the given storms monitored to date.

Stormwater runoff bypassed during 1 of event, consequently the system treated > 95% of the total runoff generated at the site.

Water quality performance is summarized in the table below (Table 1ES). A narrative description of the pollutant removal efficiencies is included herein:

TABLE 1ES.
SUMMARY OF REMOVAL EFFICIENCIES
FOR PRIMARY CONSTITUENTS OF CONCERN –
SUSPENDED SEDIMENT (TSS), TOTAL PHOSPHORUS (TP),
TOTAL NITROGEN (TN)

Study Protocol	Constituents	% Removal Concentration Based, for the event mean [A]	% Removal Mass Based, for the event mean	% Removal, Lab Based Column Study [B]
TAPE	Suspended Sediment (TSS)	86 (n=12)	88 (n=11)	91.2
TAPE	Total Phosphorus (TP)	52 (n=7)	59 (n=7)	66
TAPE	Total Nitrogen (TN) [C]	95 (n=6)	97 (n=6)	48.5

[A] Flow-weighted composite samples were collected and the composite sample concentration is defined as a volume-weighted average of the individual samples. Therefore the Event Mean Concentration (EMC) flow-weighted composite sample is the concentration of a composite sample and is consistent with the Virginia DEQ Guidance Memo 14-2009.

[B] CEC Assessment of suspended solids and nutrient attenuation by the Virginia mixture of FocalPoint Biofiltration System via column testing, October 2014

[C] For this study period there was no measureable removal of nitrates. The reduction in TN is derived from the attenuation of the Kjeldahl Nitrogen portion of the influent concentrations

Of the 12 qualifying storm events, 12 events qualified for assessing suspended solids removal efficiencies. Relative to TSS, the influent concentrations measured from the test site range from 4.9 to 238 mg/L. The removal in average event mean concentration (EMC) of TSS was 86% on a concentration basis and 88% on a mass basis. While not required under Part IIB of the Virginia Stormwater Management Program, the TAPE upper and lower one-sided 95% confidence interval around the mean is included for TSS as follows:

- For the 20-100 mg/L influent range, the measured effluent TSS does meet the TAPE-required upper 95% confidence limit about the mean effluent concentration of less than or equal to 20 mg/L (data calculations from the study produced a 16.8 mg/L upper confidence limit concentration via bootstrapping; 14.5 mg/L upper confidence limit for the median from Q-Q plots).

- For influent TSS in the range of 100-200 mg/L, three events to date, the TAPE minimum 80% removal efficiency requirement is met with a mass loading-based 95% lower confidence limit of 90.5%, as calculated via bootstrapping.

For nitrogen-based compounds, removal efficiencies for TKN and nitrate are given. Of the 12 qualifying storm events, 6 events qualified for assessing TKN removal efficiencies and 8 events for nitrate removal efficiencies. The average event mean concentration and mass load reductions were 95% and 97% respectively.

Of the 12 qualifying storm events, seven events qualified for assessing TP. Influent TP concentration ranged from 0.121 mg/L to 0.424 mg/L and fell within the TAPE criteria for TP. The average event mean concentration and mass load reductions were 52% and 59%, respectively, with one (concentration based) and two (mass based) events producing greater than 60% removal.

The calculated p-values derived from the paired group comparison tests for the influent versus effluent concentrations are the same as the p-values derived for the influent versus effluent mass loadings, except for suspended solids, nitrate and total copper. The constituents with statistically significant decreases from influent to effluent, based on both concentrations and mass loadings, include suspended solids (TSS), TP, TN as represented by TKN, total Zn and total Pb.

1.0 INTRODUCTION

On October 28, 2014, ACF Environmental of Richmond, Virginia authorized Civil & Environmental Consultants, Inc. (CEC) to perform a full-scale field test to assess the hydraulic and water quality performance of the FocalPoint High Performance Modular Biofiltration System (HPMBS).

CEC provides consulting services specializing in Best Management Practices (BMP) evaluation and product research and development. CEC was contracted by ACF Environmental to assist with the Quality Assurance Project Plan (QAPP) development and execution of this study. The project focuses on the design, execution, and technical review of the field study to assess the hydraulic and pollutant-removal performance of the FocalPoint. The purpose of the QAPP is to document the type and quality of data needed for the project and to characterize the systems effectiveness with a given level of statistical confidence in removing pollutants from stormwater runoff and to compare test results with various regulatory goals, such as TAPE performance goals. This test protocol also assesses the systems maintainability, reliability, and longevity.

The FocalPoint HPMBS is a specialized system utilizing biofiltration media for the treatment of stormwater runoff from impervious surfaces. The FocalPoint system was developed by Convergent Water Technologies of Houston, Texas. The modular treatment system, containing biologically active biofiltration media, is used as a complete, integrated system with a demanding specification that insures functionality, performance, and maintainability. With rigorous quality assurance standards and post construction in-situ infiltration verification, FocalPoint HPMBS guarantees performance.

FocalPoint is a scalable biofiltration system which combines the efficiency of high flow rate engineered media with the durability and modularity of a highly pervious, open cell underdrain/storage/infiltration system. The system employs a 3 feet cross-section that includes a 3 inch layer of mulch, 18 inch biofiltration media, 6 inches of washed bridging stone, and 9 inch underdrain wrapped in an open-mesh microgrid (See Figure 1 below).

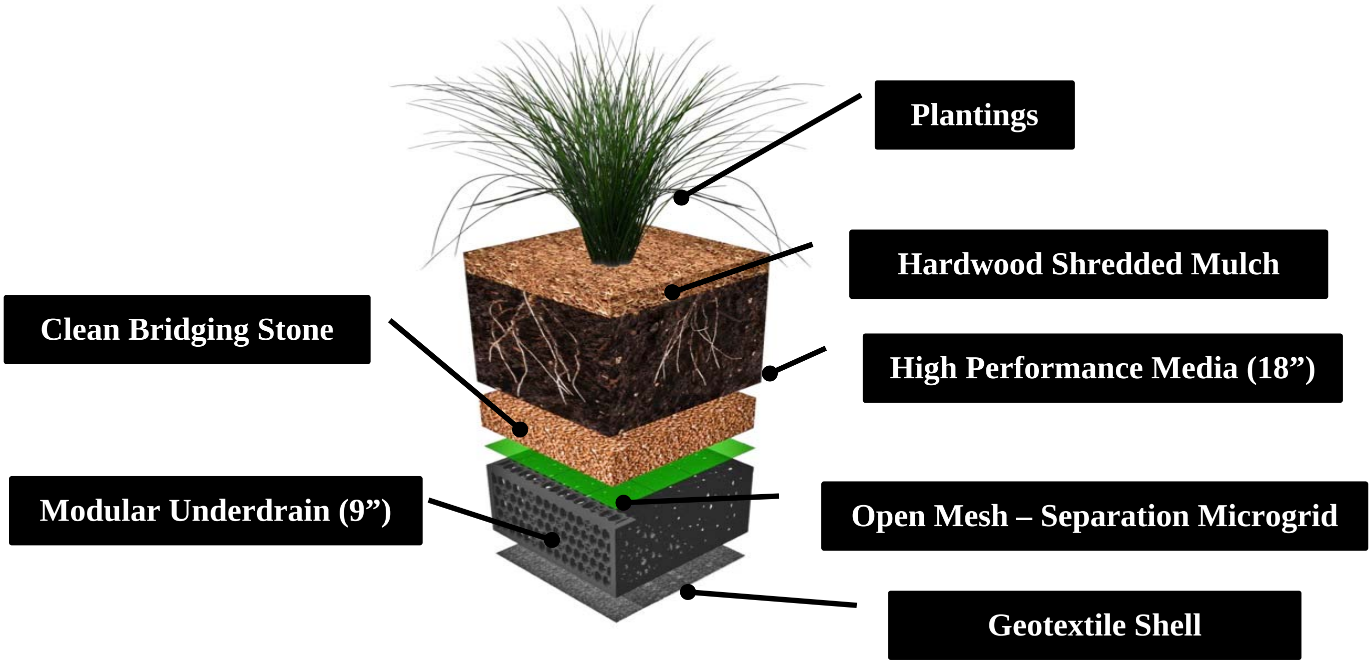

Figure 1 FocalPoint HPMBS System Components

Analytical services for all pollutants were provided by ESC Lab Sciences (ESC) located in Mt. Juliet, Tennessee. ESC is accredited under the National Environmental Laboratory Accreditation Program (NELAP). For this project, specific parameters of interest for evaluation include Total Phosphorous (TP), Total Kjeldahl Nitrogen (TKN-N), Nitrate-Nitrogen (NO3-N), Total Suspended Solids (TSS), Total Copper (Cu), Total Lead (Pb), and Total Zinc (Zn).

This study was conducted at the warehouse facility owned by Civil & Environmental Consultants, Inc. on Campbells Run Road in Pittsburgh, Pennsylvania. The construction of the FocalPoint system and installation of the data collection and monitoring equipment was completed in July 2015. The construction and installation of the FocalPoint was performed by Exact Stormwater Management, LLC.. The goal of the project is to retrieve water quality samples for a minimum of 20 qualifying storm events.

This Technical Evaluation Report (TER) summarizes the interim results of this study.

2.0 TECHNOLOGY DESCRIPTION

2.1 PHYSICAL DESCRIPTION

FocalPoint is a modular, high performance biofiltration system that often works in tandem with other integrated management practices (IMP). Contaminated stormwater runoff enters the biofiltration bed through energy dissipation/pretreatment device such as a conveyance swale, rock/stone surround, level spreader, or Rain Guardian Turret before it reaches the 3 inch layer of aged, double-shredded hardwood mulch on the surface of the biofiltration media.

As the water passes through the mulch layer, most of the larger sediment particles and heavy metals are removed through sedimentation and chemical reactions with the organic material in the mulch. Water passes through the biofiltration media where the finer particles are removed and numerous chemical reactions take place to immobilize and capture pollutants in the media.

The cleansed water passes into the underdrain/storage system and remaining flows are directed to a storm sewer system or other appropriate discharge point. Once the pollutants are in the media, bacteria begin to break down and metabolize the materials and the plants begin to uptake and metabolize the pollutants. Some pollutants such as heavy metals, which are chemically bound to organic particles in the mulch, are released over time as the organic matter decomposes to release the metals to the feeder roots of the plants and the cells of the bacteria in the media where they remain and are recycled. Other pollutants such as phosphorus are chemically bound to the media particles and released slowly back to the plants and bacteria and used in their metabolic processes. Nitrogen goes through a variety of very complex biochemical processes where it can ultimately end up in the plant/bacteria biomass, turned to nitrogen gas or dissolves back into the water column as nitrates depending on soil temperature, pH and the availability of oxygen. The pollutants ultimately are retained in the mulch, media and biomass.

The System is comprised of the following elements:

Open Cell Underdrain: A modular, high infiltration rate ‘flat pipe’ underdrain/storage system which is designed to directly infiltrate or exfiltrate water through its surface. The modular underdrain overcomes the limited collection capacity of traditional stone and pipe underdrains. A 90% open surface area collects water significantly faster and can be extended below for additional volume.

Separation Layer: A wide aperture mesh layer is utilized to prevent bridging stone from entering the underdrain system. The separation layer utilizes the concept of 'bridging' to separate the biofiltration media from the underdrain without the use of geotextile fabrics. The use of geotextile fabrics within an infiltration device can lead to clogging; by eliminating the need for a geotextile fabric, the potential for clogging is greatly reduced.

High Flow Media: The advanced high flow rate engineered soils utilize physical, chemical and biological mechanisms of the soil, plant and microbe complex, to remove pollutants found in stormwater runoff. Infiltration rates at 100 inches per hour overcome the challenges of clogging and flooding and minimize space requirements.

Mulch: Shredded, hardwood mulch acts as a pre-treatment mechanism by preventing trash, sediments and particles from entering the system. Removal and replacement of mulch is necessary only every 6-12 months and is the only maintenance requirement for the entire system. Maintenance cycles may be extended with the implementation of upstream pretreatment.

Plants: Native Plants are best suited as they adjust well to periodic droughts and temperature extremes. The media contains 10% by volume peat moss. Over the years the decaying mulch, roots, fungi, bacteria and organic inputs from stormwater runoff add to the organic mix as it evolves as more natural soil strata. Soil moisture is maintained through the use of peat moss and mulch.

The hydraulic capacity of the system is limited by the biofiltration media which is designed to operate at 100 in/hr. All other components have greater hydraulic capacity.

2.2 SITE REQUIREMENTS

The following sections provides a list of common site requirements

Necessary soil characteristics: There are typically no requirements for the native soils surrounding the system and a non-woven geotextile separation layer and underdrain are used. If the system is designed to exfiltrate\infiltrate into native soils, appropriate design considerations are given with respect to infiltration bed sizing.

Pretreatment: Pretreatment of runoff entering a FocalPoint HPMBS is necessary to trap coarse sediment particles before they reach and shear stress. Pretreatment measures must be designed to dissipate velocities and spread water out over a 2 to 4 ft. width. Many pretreatment options are available and include manufactured systems like the RainGuardian or non-propriety systems like stone aprons\diaphragms, grass filter stripes and level lip spreaders.

Hydraulic grade line requirements: All low impact development or environmental site design practices such as FocalPoint HPMBS are constrained by the invert elevation of the existing conveyance system to which the system discharges (i.e., the bottom elevation needed to tie the underdrain from the FocalPoint HPMBS into the storm drain system). In general, 3.5 ft. of elevation above this invert is needed to accommodate the required ponding and filter system depths. If the system does not include an underdrain or if an inverted or elevated underdrain design is used, less hydraulic head may be required.

Ponding depth: The recommended surface ponding depth is 6 to 12 inches and is ideal for streetscape, most permeable tree boxes and stormwater planters. Minimum and maximum surface ponding depths are 3 inches and 18 inches, respectively. When greater ponding depths are utilized the design must consider safety issues; for example, fencing requirements, aesthetics, viability and survival of plants and erosion and scour of side slopes. It should be noted these same considerations are typical of traditional low flow bioretention practices.

Side Slopes: Typically 3:1 or flatter. In highly urbanized or space constrained areas, a drop curb design or precast panel wall structure can be used to create a stable, vertical side wall.

These drop curb designs should not exceed a vertical drop of more than 12 inches, unless safety precautions such as railing, walls, grating, etc. are included.

Depth to groundwater: The system should be separated from the water table to ensure that groundwater does not inundate the filter bed. A separation distance of 2 feet is recommended between bottom of excavated FocalPoint HPMBS area and the seasonally high ground water table.

Utility requirements: The system is typically drained to a conventional closed pipe drainage system or can be piped directly to a conveyance channel or drainage course.

Applications: The manufacturer of FocalPoint HPMBS recommends the technology for the following land uses: Roadways, high-use sites, commercial, industrial, residential runoff areas. Greater than 600 FocalPoint HPMBS have been successfully installed across the United States with a high density in the Mid-Atlantic, Northeast and Southwest regions. Included below is a list of references with names and telephone numbers who have successfully implemented FocalPoint HPMBS into their projects.

Town of Falmouth
Department of Public Works
271 Falmouth Rd
Falmouth, ME 04105
Mr. Jay Reynolds
207-699-5374

Harris County Government
Engineering Department
1001 Preston, 7th Floor
Houston, TX 77002
Mr. John Blount, P.E.
713-755-6888

City of Houston
Engineering Services Section
611 Walker St
Houston, TX 77002
Ms. Kathlie Jeng-Bullock, P.E.
832-395-2511

Sebago Technics
City of South Portland Consulting Engineer
75 John Roberts Rd, Suite 1A
South Portland, ME 04106
Mr. Dan Riley, P.E.
207-200-2100

Ransom Environmental
City of Portland Consulting Engineer
400 Commercial St, Suite 404
Portland, ME 04101
Mr. John Mahoney, P.E.
207-772-2891

Highpoint Engineering
Canton Corporate Place
45 Dan Road, Suite 140
Canton, MA 02021
Mr. Michael Fabbiano, P.E.
781.770.0970

2.3 SIZING METHODOLOGY

The FocalPoint HPMBS is a low impact development or environmental site design practice that uses a higher hydraulic conductivity factor than traditional low flow bioretention practices. Its modular, flexible and scalable "outside the box" design provides civil site designers virtually an endless supply of solutions.

The FocalPoint HPMBS is sized to treat the water quality volume (WQv) as determined by a qualified project engineer per the local, state or federal regulations. The system dynamically stores, treats and discharges (either pipe conveyance or infiltrate) the WQv prior to bypass.

ACF Environmental has technical engineering staff to provide sizing assistance to engineers\designers and has developed a sizing calculator/tool (*ACF FP and RT Calculator version 1.8*). The calculator distributes the WQv using a Type I, Type II or III TR-55 storm distribution to produce an inflow hydrograph (expressed in volumetric terms). The output from the calculator is a filter bed area (measured in square feet) and storage volume above media bed that ensures the WQv passes through the system prior to overflow. The system in this TAPE level field study was sized using this calculator and results in a ratio of 0.40% (44 sq. ft. of filter bed area to 10,890 sq. ft. of impervious area) and ponding volume of 20% of the WQv.

High flow media systems such as FocalPoint HPMBS have an estimated drawdown time between 0.25 and 0.30 hrs. This is significantly less than that required for WQv requirements; therefore, it should be used as part of a system of practices that capture, store and slowly release the required volume of runoff at rates meeting channel protection flow criteria.

Where the system includes an infiltration component, Recharge Volume (REv) may be addressed as well. Because FocalPoint HPMBS are often distributed about a site, it allows for REv to be distributed across a site as much as practical to mimic natural conditions.

The minimum size FocalPoint HPMBS from a constructability and practical limit standpoint is 20 sq. ft. The smallest constructible width or length dimension is 2 ft. There are no limits on the width to length ratio.

The system has a design life equal to or great than traditional low flow bioretention facilities and is estimated to be 20-25 years.

The specific media flow rate (i.e., design velocity) of the FocalPoint HPMBS is 1 gpm/SF.

Media specifications ensure adequate media quality all the time. The physical and chemical properties are included below:

Composition and Characteristics	
Sand – Fine	< 5%
Sand – Medium	10% - 15%
Sand – Coarse	15% - 25%
Sand – Very Coarse	40% - 45%
Gravel	10% - 20%
Infiltration Rate	>100 inches per hour
Peat Moss*	5% - 15%
*** Peat Moss Specification**	
Listed by Organic Materials Review Institute 100% natural peat (no composted, sludge, yard or leaf waste) Total Carbon >85% Carbon to Nitrogen Ratio 15:1 to 23:1 Lignin Content 49% to 52% Humic Acid >18% pH 6.0 to 7.0 Moisture Content 30% to 50% 95% to 100% passing 2.0mm sieve > 80% passing 1.0mm sieve	

2.4 INSTALLATION

Installation of FocalPoint HPMBS requires conventional labor and equipment associated with site earthwork and drainage utility activities. The base of excavation shall be smooth, level and free of lumps or debris, and compacted unless infiltration of storm water into subgrade is desired. A thin layer (3”) of compacted base material is recommended to establish a level working platform (may not be needed in sandy soils). If the base of the excavation is pumping or appears excessively soft, a geotechnical engineer should be consulted for advice. In many cases, a stabilization geotextile and 6” of compactable material that drains well will be sufficient to amend the bearing capacity of the soil.

Most applications require 8 oz. Non-Woven Geotextile or equivalent nonwoven geotextile with a nominal weight of 8 oz. per square yard to line the excavation to separate in situ soils and the FocalPoint HPMBS (note: applications requiring water to infiltrate the in situ sub-soils should use a bridging stone rather than geotextile to provide a separation layer between the FocalPoint HPMBS and the in situ soils). Geotextile, when utilized, should be placed on the bottom and up the sides of the excavation. Absolutely no geotextiles should be used in the water column. If an impermeable liner is specified, it shall be installed according to supplier’s instructions and recommendations.

Specified backfill material must be free from lumps, debris and any sharp objects that could penetrate the geotextile. Material is used for backfill along the sides of the system as indicated in engineering detail drawings.

Cleanup and Protection during Ongoing Construction Activity

A. Perform cleaning during the installation and upon completion of the work.

B. Remove from site all excess materials, debris, and equipment. Repair any damage to adjacent materials and surfaces resulting from installation.

C. If surrounding drainage area is not fully stabilized, a protective covering of geotextile fabric should be securely placed to protect the Biofiltration Media.

D. Construction phase erosion and sedimentation controls shall be placed to protect the inlet(s) to the Biofiltration System. Excessive sedimentation, particularly prior to establishment of plants may damage the HPMBS.

E. Strictly follow supplier's guidelines with respect to protection of the HPMBS between Installation and Commissioning phases.

Commissioning

F. Commissioning should only be carried out once the contributing drainage area is fully stabilized. If Commissioning must be carried out sooner, it is imperative that appropriate erosion and sediment controls be placed to prevent the entry of excessive sediment/pollutant loads into the system.

G. Commissioning entails removing the protective covering from the Biofiltration Media, planting the plant material in accordance with the approved drawings, and placing mulch if specified.

1. Dig planting holes the depth of the root ball and two to three times as wide as the root ball. Wide holes encourage horizontal root growth that plants naturally produce.

2. With trees, you must ensure you are not planting too deep. Don't dig holes deeper than root balls. The media should be placed at the root collar, not above the root collar. Otherwise the stem will be vulnerable to disease.

3. Strictly follow supplier's planting guidance.

H. Cover the exposed root ball top with mulch. Mulch should not touch the plant base because it can hold too much moisture and invite disease and insects. Evenly place 3 inches of double-shredded hardwood mulch (if specified) on the surface of the media.

I. Plantings shall be watered-in at installation and temporary irrigations shall be provided, if specified.

2.5 OPERATION AND MAINTENANCE REQUIREMENTS

All stormwater treatment systems require maintenance for effective operation. This necessity is often incorporated in your property's permitting process as a legally binding operation and maintenance agreement. Other reasons for maintenance include:

- Avoid legal challenges from your jurisdiction's maintenance enforcement program.
- Prolong the lifespan of your FocalPoint HPMBS.
- Avoid costly repairs.
- Help reduce pollutant loads leaving your property.

Simple maintenance of the FocalPoint HPMBS is required to continue effective pollutant removal from stormwater runoff before any discharge into downstream waters. This procedure will also extend the longevity of the living biofiltration system. The unit will recycle and accumulate pollutants within the biomass, but may also be subjected to other materials entering the surface of the system. This may include trash, silt and leaves etc. which will be contained above the mulch and/or biofiltration media layer. Too much silt may inhibit the FocalPoint's HPMBS flowrate, which is a primary reason for system maintenance. Removal of accumulated silt/sediment and/or replacement of the mulch layer (when specified), is an important activity that prevents over accumulation of such silt/sediment.

Convergent Water Technologies and/or its Value-Added Reseller (VAR) include a 1-year maintenance plan with each system purchased. Annual included maintenance consists of two (2) scheduled maintenance visits. Additional maintenance may be necessary depending on sediment and trash loading (by Owner or at additional cost). The start of the maintenance plan begins when the system is activated for full operation. Full operation is defined as when the site is appropriately stabilized, the unit is installed and activated (by VAR), i.e., when mulch (if specified) and plantings are added.

Activation should be avoided until the site is fully stabilized (full landscaping, grass cover, final paving and street sweeping completed). Maintenance visits are scheduled seasonally; the spring visit aims to clean up after winter loads including salts and sands. The fall visit helps the system by removing excessive leaf litter. A first inspection to determine if maintenance is necessary should be performed at least twice annually after storm events of greater than (1) one inch total depth (subject to regional climate). Refer to Appendix J for the maintenance checklist for specific conditions that indicate if maintenance is necessary.

It has been found that in regions which receive between 30-50 inches of annual rainfall, (2) two visits are generally required. Regions with less rainfall often only require (1) one visit per annum. Varying land uses can affect maintenance frequency.

Some sites may be subjected to extreme sediment or trash loads, requiring more frequent maintenance visits. This is the reason for detailed notes of maintenance actions per unit, helping the VAR/Maintenance contractor and Owner predict future maintenance frequencies, reflecting individual site conditions. Owners must promptly notify the VAR/Maintenance contractor of any damage to the plant(s), which constitute(s) an integral part of the biofiltration technology. Owners should also advise other landscape or maintenance contractors to leave all maintenance of the FocalPoint HPMBS to the VAR/Maintenance contractor (i.e. no pruning or fertilizing).

Each maintenance visit consists of the following simple tasks (detailed instructions below).

1. Inspection of FocalPoint HPMBS and surrounding area
2. Removal of debris, trash and mulch
3. Mulch replacement
4. Plant health evaluation (including measurements) and pruning or replacement as necessary
5. Clean area around FocalPoint HPMBS
6. Complete paperwork, including date stamped photos of the tasks listed above.

Ideal tools include: camera, bucket, shovel, broom, pruners, hoe/rake, and tape measure. Appropriate Personal Protective Equipment (PPE) should be used in accordance with local or company procedures. This may include impervious gloves where the type of trash is unknown, high visibility clothing and barricades when working in close proximity to traffic and also safety hats and shoes.

2.6 RELIABILITY

This section of the TER describes the following, if applicable.

- When designed and installed correctly, the FocalPoint HPMBS can be impacted by sedimentation and lack of maintenance.

- As evident in this study, there are no readily observed circumstances where the system can add, transform or release accumulated pollutants.

- The media is comprised of inert sand and peat. Peat is an accumulation of naturally decomposed organic matter. Based on this information the filter medium is not expected to decompose. The potential for slime/bacteria growth is very low and has not been observed in the system.

- Pretreatment is suggested and will increase reliability and reduce the impact of heavy or fine sediment loadings.

- Underperformance is diagnosed with visual inspection and hydraulic conductivity testing. Visual inspection of the vegetation, high water marks and drain down time after storm subsidence will expose underperformance. These items are treated with routine maintenance of the mulch layer. The top 6 inches of media can be removed if significant clogging or underperformance is observed, and lastly full media depth restoration if the system has outlasted its functional design life.

- The system is commissioned with a one year warranty.

- Initial and on-going user support is provided as follows:

Vendor does not charge for the following

- Upfront design/specification and technical support
- Education and training to specifier's, installers, owners and regulators
- First year of maintenance
- Hydraulic conductivity warranty in the first year

Vendor does charge for the following

- Extended maintenance and warranty plans

3.0 SAMPLING PROCEDURES

3.1 SITE INFORMATION

Data for this study was collected over the course of multiple storm events between July 2015 and December 2015 from an urban site incorporating a full-scale FocalPoint HPMBS located in Pittsburgh, Pennsylvania. The system was installed within the 15 ft. x 70 ft. grassed segment located at the entrance to the CEC warehouse along the north portion of the property facing Campbells Run Road (4315 Campbells Run Road, Pittsburgh, PA 15205). Runoff from the crown of Campbells Run Road also flows back towards the south into the grassed area. The total watershed to the test area is approximately 10,890 ft^2.

The FocalPoint system was constructed by excavating the grassed portion of the CEC lot to accommodate approximately an 11 ft. x 4 ft. (44 ft^2) filter bed with a ponding volume of 220 ft^3. A bottom layer of crushed stone was placed initially to provide a level base for the high-performance modular underdrain/storage system. An 8 inch diameter Schedule 40 PVC pipe was installed at the bottom, extending from the modular underdrain to the effluent collection manhole. A 2 ft. x 2 ft. plastic or gum rubber anti-seep collar was installed around the non-perforated pipe immediately downstream of the modular underdrain with soil compacted around the full extent of the collar and pipe. A layer of open-mesh microgrid was installed over the modular underdrain followed by a 6 inch layer of washed, bridging stone over the microgrid. Next, an 18 inch layer of high-performance biofiltration media was placed over the bridging stone. A 3 inch layer of clean, double shredded hardwood mulch was placed over the biofiltration media to complete the system. A mixture of grass plugs and shrubs were planted in the bioretention prior to the initiation of testing.

3.2 MONITORING EQUIPMENT

Stormwater flow measurements along with influent and effluent stormwater sampling were carried out using Teledyne ISCO portable automatic samplers equipped with Teledyne ISCO acoustic (Doppler) flow meters positioned at both the influent and effluent manholes. The acoustic flow meters' area-velocity sensors trigger sampling based on the head variations detected behind the weir and corresponding flow rates.

A collection trough at the interface of the asphalt pavement and the grassed area adjacent to the road was constructed to convey the influent from the parking lot to the v-notch weir (inside the influent manhole). Water then passes into the top surface zone of the bioretention area. The Teledyne ISCO flow meter sensor and low-flow strainer of the sampler was positioned within the weir trough. A Solinst Levelogger 3100 transducer with barometric compensation and datalogging capabilities was anchored over the mulch surface to measure head fluctuations and infiltration rates of the media. Sharp crested trapezoidal weir was constructed with the invert positioned several inches above (minimum of 6 inches) the FocalPoint surface for passing flows above the design runoff/rainfall event. A second transducer was installed at the overflow weir to measure when overflows occur.

The 8 inch PVC effluent pipe from the FocalPoint was sloped to a collection manhole where the flow-meter sensor and low-flow strainer were positioned behind a v-notch weir. The effluent pipe from the sampling manhole was directed to the north to discharge via gravity into the storm sewer.

The equipment used in this study was pre-calibrated by the manufacturer or supplier. All monitoring equipment is re-calibrated when necessary and as recommended by the manufacturer. The stormwater collection trough, weirs and overflow channel/pipe were inspected at least weekly for obstructions prior to the next sampling event. Automatic samplers, flow meters transducers, and pumps were inspected at least monthly to ensure the equipment was effectively operating. All routine maintenance for the automatic samplers and flow meters strictly adhered to the Teledyne ISCO maintenance manual provided with the equipment.

3.3 STORMWATER SAMPLES COLLECTION AND HANDLING

Flow-proportional composite sampling was used for this study for both influent and effluent flows. Flow-proportional composite sampling is the extraction of sample aliquots on a fixed-volume interval (sampling trigger volumes) and immediately mixing the sample aliquot within a single 4-gallon composite container located within the ISCO automatic sampler unit. The samplers and flow meters were equipped with data logging capabilities in order to record flows and trigger volume-paced sampling. The flow volume increments chosen for programming the samplers were by determined using hydrologic modeling of the test watershed. Flow-composited sampling was programmed to cover at least 70% of the storm volume during each event. Transducer logging was programmed to take readings every 1 minute.

The time and date stamps for all data-loggers associated with the automatic samplers, flow meters, and transducers were synchronized prior to initiating sampling activities. Periodic field checks were carried out to ensure time and date stamps for all monitoring equipment was synchronized. Sandbags, Erosion Eels, or other portable diversion devices were used to divert runoff that is extraneous to the test watershed away from the testing area. The data-logging rain gage was installed during construction of the bioretention area to record site specific rainfall information. An as-built survey of the testing area was performed prior to initiating the sampling operations and is provided in Appendix E.

After each storm event, the samplers were inspected to determine how much, if any, sample volume was taken in the influent and effluent composite containers. If there was less than the required sample size for the analysis of the targeted constituents plus a single duplicate of each constituent, the sample was discarded. After removal of the sample contents, the containers were flushed with distilled water and allowed to dry before being reinstalled in the sampler.

3.4 QUALITY CRITERIA FOR FIELD SAMPLING

This section addresses quality objectives for precision, bias, sample representativeness, data completeness, and data comparability. Additional information regarding quality control criteria is available in the QAPP in Appendix D

<u>Precision</u> -To assess precision in the field, stormwater field duplicates were collected every qualifying storm event for influent and effluent composite samples submitted to the laboratory for analysis.

Bias - Defining and following standardized sampling methods such as those set forth in this QAPP minimizes error due to bias. Bias in field procedures was measured by collecting one field blank for each qualifying storm sample collection event. Additionally, bias was reduced by regularly calibrating field equipment per the recommendation schedule set forth by each manufacturer and consistently following field procedures described in this QAPP. Equipment was calibrated by the manufacturers prior to installation in the field study.

Representative Sampling and Data Comparability - To ensure representativeness of the data, composite stormwater samples were collected at inlet and outlet sample points that best represent pollutant constituents in the influent stormwater and treated effluent. Consistent and standard sampling procedures as set forth in this QAPP were followed. The inlet and outlet sample points were selected to ensure well-mixed samples that are representative of the storm conditions are collected.

Data Completeness – The required amount of valid data obtained from this project shall include representative influent and effluent composite samples from at least 20 qualifying storms. The length of the study period will be extended until the minimum number of acceptable qualifying storms is achieved.

4.0 DATA SUMMARIES AND ANALYSIS

This section includes a summary of the storm event data and an Individual Storm Report (ISR) for each sampled storm event summarizing storm, hydrologic and pollutant data.

TABLE 2

STORM EVENT SUMMARY

Storm ID	Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8	Event 9	Event 10	Event 11	Event 12
Location	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run	Campbells Run
Storm Depth (inches)	0.66	0.57	4.03	0.41	0.46	1.95	0.3	0.89	0.21	0.56	0.34	0.36
Antecedent dry period (days)	1.60	7.97	0.77	5.99	1.96	2.77	4.86	3.49	4.71	2.19	0.22	0.67
Storm duration (hours)	20.22	19.15	19.35	1.78	11.08	21.75	8.08	14.33	9.63	11.23	7.88	16.82
Influent volume of water (gallons)	2278.83	1771.83	30225.45	1956.37	1291.62	9380.27	1396.59	2899.05	340.26	828.61	575.51	409.34
Effluent volume of water (gallons)	1100.38	898.08	100857.74	1499.33	636.44	4265.24	835.03	819.96	416.84	1002.48	453.22	333.25
Bypass volume of water (gallons)	0	0	unk	0	0	0	0	0	0	0	0	0
Peak flow rate through treatment system (gpm)	127.52	26.65	2051.74	131.36	12.98	161.04	78.45	24.33	7.51	5.95	15.00	8.83
Influent peak flow rate (gpm)	127.52	26.65	193.45	131.36	12.98	161.04	78.45	24.33	7.51	4.82	15.00	8.83
Effluent peak flow rate (gpm)	72.35	18.36	2051.74	71.27	6.58	37.21	38.68	10.44	7.51	5.95	10.96	6.32
Average flow rate through treatment system	1.88	1.54	84.40	18.28	1.94	7.01	2.88	3.37	1.81	1.49	1.22	0.41
Average influent flow rate (gpm)	1.88	1.54	25.29	18.28	1.94	7.01	2.88	3.37	1.48	1.23	1.22	0.41
Average effluent flow rate (gpm)	0.91	0.78	84.40	14.01	0.95	3.19	1.72	0.95	1.81	1.49	0.96	0.33
Number of influent aliquots	6	4	93	6	4	29	4	9	3	7	5	3
Number of effluent aliquots	6	5	146	9	4	27	5	4	8	19	9	6
Percentage of influent storm volume sampled	79%	73%	100%	88%	77%	98%	69%	88%	62%	72%	70%	53%
Percentage of effluent storm volume sampled	74%	73%	100%	86%	83%	95%	76%	62%	82%	94%	83%	72%

5.0 OPERATION AND MAINTENANCE INFORMATION

No maintenance has been performed on the FocalPoint HPMBS at the time of this interim report. Maintenance will be performed by ACF Environmental, if necessary, in accordance with manufacturer's recommendations. As no maintenance has been performed at the time of this report, no maintenance records have been generated.

6.0 DISCUSSION

6.1 STATISTICAL ANALYSES

There have been 12 storm events that have been sampled to date. All of these 12 events are classified as qualifying storm events, as defined by the QAPP for this research (i.e., qualifying storm event of 0.15 inch or greater rainfall total). From these 12 storm events, there has been an average 31% reduction in runoff volume through the FocalPoint system for the given storms monitored to date.

There were several constituents, namely the nutrients and metals, having influent concentrations below the reporting limit for the given constituent. These data were removed from the qualifying data sets for statistical analyses.

The following is a summary of the statistical analyses for the qualifying data sets. Statistical software packages used for this research include NCSS, Minitab®, and MATLAB®

Pollutant removal efficiency calculations

Removal efficiencies were calculated for each measured constituent using both methods presented below since there are water losses in some storm events within the bioretention system, where influent volume is more than effluent volume, and there are also some events where there are no measured losses from influent to effluent.

Method #1: Individual storm reduction in pollutant concentration

The reduction in pollutant concentration during each individual storm is calculated as:

$$\frac{A-B}{A} x 100$$

where:

A = flow-proportional influent concentration

B = flow-proportional effluent concentration

Method #2: Individual storm reduction in pollutant mass loading

The reduction in pollutant loading during each individual storm is calculated as:

$$\frac{C - D}{C} x100$$

where:

C = (Storm flow-proportional influent concentration) x (Storm influent volume)

D = (Storm flow-proportional effluent concentration) x (Storm effluent volume)

<u>*Statistical evaluation of performance goals*</u>

Performance goals for TSS and TP were developed from TAPE and the Virginia DEQ Guidance Memo No. 14-2009.

TAPE Performance Goals:

The ranges for influent TSS collected to date are from 4.9 mg/L to 238 mg/L. The TAPE performance goal for TSS calls for influent in the range of 20 to 100 mg/L to achieve an effluent concentration < 20 mg/L TSS as determined by the upper 95% confidence limit about the mean. For influent TSS in the range of 100-200 mg/L, the removal efficiency must be greater than or equal to 80% as determined using the lower 95% confidence interval about the mean efficiency. For influent TSS in the range >200 mg/L, the removal efficiency must be greater than 80% as determined using the lower 95% confidence interval about the mean efficiency.

The TAPE performance goal for enhanced treatment assumes that the system treats storm water with TP influent concentrations ranging from 0.1 to 0.5 mg/L. The influent TP concentrations from all storm events sampled to date fell within acceptable TAPE ranges.

Virginia DEQ Performance Goals:

The performance goal is to achieve the maximum removal rate that the Department will allow.

Per the Virginia DEQ Guidance Memo No. 14-2009, the Department assigns up to 40% TP removal if 80% TSS removal is established following the Technology Acceptance Reciprocity Partnership Protocol (TARP) testing protocol. The Department will also consider data from other reports and studies such as TAPE. Under this guidance the maximum percent TP removal that the Department will assign to a manufactured treatment technology is 50%. The removal value for TSS and TP is defined as the change in the average event mean concentration (EMC) of each constituent as runoff flows into and out of the system.

Basic descriptive statistics for influent and effluent water quality are given in Table S1 on a concentration basis and Table S2 on a mass loading basis.

Table S1. Basic descriptive statistics for constituent concentrations

Constituent	N sample size	Mean Influent (mg/L)	*Mean Effluent (mg/L)	Median Influent (mg/L)	*Median Effluent (mg/L)	Influent Std. Dev. (mg/L)	*Effluent Std. Dev. (mg/L)
Suspended Solids	12	84.4	11.4	49.9	9.4	74.8	8.0
TP	7	0.21	0.1	0.18	0.1	0.1	0.01
TKN	6	8.89	0.39	1.46	0.31	18.11	0.18
Total Cu	5	0.013	0.01	0.014	0.01	0.002	0
Total Zn	9	0.14	0.05	0.09	0.05	0.096	0.01
Total Pb	6	0.007	0.005	0.007	0.005	0.003	0.001

*Censored effluent data replaced with the reporting limit value

Table S2. Basic descriptive statistics for constituent mass loadings

Constituent	N sample size	Mean Influent (mg)	*Mean Effluent (mg)	Median Influent (mg)	*Median Effluent (mg)	Influent Std. Dev. (mg)	*Effluent Std. Dev. (mg)
Suspended Solids	**11	394,680	45,733	321,907	27,653	375,007	41,089
TP	7	758.8	313.4	567.7	339.9	533.1	176.9
TKN	6	44,285	1,212	4,490	904	96,939	915
Total Cu	5	70.7	33.1	74.4	34.0	48.0	17.2
Total Zn	9	788	156	668	155	788	83
Total Pb	6	29.1	13.1	19.4	8.5	29.2	8.8

*Censored effluent data replaced with the reporting limit value

**Event 3 influent and effluent volumes were not collected due to instrument error

Based on distribution fitting of the pollutant removal efficiency data, about half of all of the data sets have a skewed distribution (e.g., Weibull or lognormal), with the remaining, small data sets fitting either a logistic or normal distribution the best. 95% confidence intervals for both the mean and the median are presented herein since the median better represents the central tendency of the data from skewed distributions. In addition, while bootstrapping results for confidence intervals are presented herein based on the TAPE protocol requirement, bootstrapping is not the most accurate method for the development of confidence intervals for the mean and median for data sets < 20. Therefore, in addition to presenting the bootstrapping confidence interval results, 95% confidence intervals for the median have also been calculated from Probability Plots (or Q-Q Plots) of the given constituent data sets, fitting each removal efficiency data set for each constituent to the best-fit distribution. All of the removal efficiency data sets currently have less than 20 efficiencies. The probability plot method produces more accurate confidence intervals for data sets < 20 (Helsel, 2015).

Refer to Tables S3 and S4 for 95% confidence intervals for concentration-based and mass-loading-based removal efficiencies, respectively, for TSS.

Table S3: 95% confidence intervals (CI) about the mean and median for concentration-based removal efficiencies (%)

Constituent	Probability Plot 95% CI for Median [LCL, UCL]	Boostrap 95% CI for Median [LCL, UCL]	Boostrap 95% CI for Mean [LCL, UCL]
Suspended Solids	[62.3, 89.5]	[57.8, 91.8]	[65.1, 85.7]

LCL- Lower confidence limit; UCL – Upper confidence limit

Table S4: 95% confidence intervals (CI) about the mean and median for mass-loading-based removal efficiencies (%)

Constituent	Probability Plot 95% CI for Median [LCL, UCL]	Boostrap 95% CI for Median [LCL, UCL]	Boostrap 95% CI for Mean [LCL, UCL]
Suspended Solids	[81.1, 93.0]	[76.8, 94.3]	[82.1, 91.3]

LCL- Lower confidence limit; UCL – Upper confidence limit

Relative to TSS, the influent concentrations measured from the test site range from 4.9 to 238 mg/L. For the 20-100 mg/L influent range, the measured effluent TSS does meet the TAPE-required upper 95% confidence limit about the mean effluent concentration of less than or equal to 20 mg/L (data calculations from the study produced a 16.8 mg/L upper confidence limit concentration via bootstrapping; 14.5 mg/L upper confidence limit for the median from Q-Q plots). For influent TSS in the range of 100-200 mg/L, three events to date, the TAPE minimum 80% removal efficiency requirement is met with a mass loading-based 95% lower confidence limit of 90.5%, as calculated via bootstrapping. Note: Bootstrapping is recommended for sample sizes of n> 20. A better estimate for small data sets is via Probability Plots to estimate the confidence intervals about the median for skewed data such as these. There is currently not enough data to determine the lower 95% confidence limit about the median using Probability Plots for the three sample sets. There was only one event with an influent TSS concentration above 200 mg/L (238 mg/L from December 14, 2015).

<u>*Statistical comparisons of influent and effluent pollutant concentrations and mass loadings*</u>

Interim results of paired group comparisons for influent versus effluent concentrations and mass loadings are presented in Table S5 and Table S6, respectively. Statistical analyses have been performed to determine whether there are significant differences in pollutant concentrations and mass loadings between the influent and effluent stations for each individual, qualifying storm event. The specific null hypothesis (Ho) and alternative hypothesis (Ha) utilized for these analyses were as follows:

Ho: Effluent pollutant concentrations are equal to or greater than influent concentrations.
Ha: Effluent concentrations are less than influent concentrations.

For suspended solids and nitrate data where there are no censored values, a 1-tailed Wilcoxon signed-rank test was used to compare the influent and effluent water quality. The Wilcoxon signed-rank test is a nonparametric analogue to the paired t-test for testing differences in group medians. Statistical significance was assessed based on an alpha (α) level (Type I error) of 0.05. For nutrients and metals data, effluent data for many of the paired data sets are left-censored. Therefore, the Sign Test was used for censored data sets. The Sign Test determines whether paired values from one group are generally higher or lower than the other group (Helsel and

Hirsch, 2002). Due to its paired structure, the Sign Test can be used when there is one reporting limit or censored value per paired data couple (Helsel, 2012). In addition, for censored effluent data sets, the 1-tailed Wilcoxon signed-rank test for differences in medians was also performed after replacing each censored effluent value with the respective reporting limit for the given constituent.

The calculated p-values derived from the group comparison tests for the influent versus effluent concentrations are the same as the p-values derived for the influent versus effluent mass loadings except for suspended solids, nitrate and total copper. The constituents with statistically significant decreases from influent to effluent, based on both concentrations and mass loadings, include suspended solids, TP, TKN, total Zn and total Pb.

Table S5: Paired group comparisons for influent vs effluent concentrations, α= 0.05

Constituent	# of Sample Pairs**	Test Method	p-Value	Reject Null Hypothesis, Ho?
Suspended Solids	12	1-tailed Wilcoxon signed-rank	0.0002	Yes
TP	7	Sign Test	0.0078	Yes
TP	7	1-tailed Wilcoxon signed-rank*	0.0078	Yes
TKN	6	Sign Test	0.0156	Yes
TKN	6	1-tailed Wilcoxon signed-rank*	0.0156	Yes
Total Cu	5	Sign Test	0.0313	Yes (marginal)
Total Cu	5	1-tailed Wilcoxon signed-rank*	<0.05	Yes (marginal)
Total Zn	9	Sign Test	0.002	Yes
Total Zn	9	1-tailed Wilcoxon signed-rank*	0.002	Yes
Total Pb	6	Sign Test	0.0156	Yes
Total Pb	6	1-tailed Wilcoxon signed-rank*	0.0156	Yes

*Censored effluent data replaced with the reporting limit value

** Based on qualifying storms

Table S6: Paired group comparisons for influent vs effluent mass loadings, α= 0.05

Constituent	# of Sample Pairs**	Test Method	p-Value	Reject Null Hypothesis, Ho?
Suspended Solids	11 ^	1-tailed Wilcoxon signed-rank	0.0005	Yes
TP	7	Sign Test	0.0078	Yes
TP	7	1-tailed Wilcoxon signed-rank*	0.0078	Yes
TKN	6	Sign Test	0.0156	Yes
TKN	6	1-tailed Wilcoxon signed-rank*	0.0156	Yes
Total Cu	5	Sign Test	0.1875	No
Total Cu	5	1-tailed Wilcoxon signed-rank*	0.0625	No
Total Zn	9	Sign Test	0.002	Yes
Total Zn	9	1-tailed Wilcoxon signed-rank*	0.002	Yes
Total Pb	6	Sign Test	0.0156	Yes
Total Pb	6	1-tailed Wilcoxon signed-rank*	0.0156	Yes

*Censored effluent data replaced with the reporting limit value

** Based on qualifying storms

^Event 3 influent and effluent volumes were not collected due to instrument error

Even with the small sample sizes, there were several constituent paired group comparisons where the null hypothesis was rejected. With the Type I error set at 0.05, this means there is only a 5% chance that these detected, statistically significant decreases in constituent concentrations and mass loadings are due to random error. The statistical significance of these reductions in constituent concentrations and mass loadings from influent to effluent will be more conclusive and defendable with a larger sample size.

Flow Rate Determination

Based on flow-proportional composite sampling performed as part of this research, aliquot-weighted flow rates for each storm event were determined by averaging the influent flow rate at the time each aliquot was collected for each storm. Refer to Table S7 for aliquot-weighted flows per storm event.

Table S7: Aliquot-weighted influent rates for each storm event

Rain Event	Average Flow of Each (gpm)	Average Ponding Depth above Mulch (inches)
1	39.5	0.69
2	3.4	0.74
3	69.1	2.52
4	61.4	1.08
5	6.7	0.80
6	31.7	1.12
7	36.0	0.95
8	10.3	0.90
9	4.3	0.85
10	3.0	0.87
11	7.0	0.91
12	7.0	1.01

Pollutant removal as a function of flow rate

Linear regression analysis to evaluate pollutant removal performance as a function of influent flow rate for all constituents was performed for this interim report. The linear regression analysis is designed to determine whether the treatment performance increases, decreases, or remains unchanged as a function of influent flow rate.

7.0 CONCLUSIONS

In the fall of 2014, ACF Environmental of Richmond, VA authorized Civil & Environmental Consultants, Inc. (CEC) to perform a full-scale test to assess the water quality performance of the FocalPoint High Performance Modular Biofiltration System (HPMBS). The FocalPoint system full-scale, field trial in Pittsburgh has performed as anticipated to date, with reductions in influent storm water volumes, suspended solids, nutrients, and metals.

For the study period to date (164 Julian Days) there were 57 of days with measurable precipitation and a total rainfall depth of 18.24 inches observed at the site. Of these rainfall events twelve (12) events had samples collected and were qualifying storm events, as defined by the QAPP (i.e., minimum storm depth during the event of 0.15 inch). From these 12 storm events, there has been an average 31% reduction in runoff volume through the FocalPoint system for the given storms monitored to date.

Of the 12 qualifying storm events, 12 events qualified for assessing suspended solids removal efficiencies. Relative to TSS, the influent concentrations measured from the test site range from 4.9 to 238 mg/L. The removal in average event mean concentration (EMC) of TSS was 86% on a concentration basis and 88% on a mass basis. While not required under Part IIB of the Virginia Stormwater Management Program, the TAPE upper and lower one-sided 95% confidence interval around the mean is included for TSS as follows:

- For the 20-100 mg/L influent range, the measured effluent TSS does meet the TAPE-required upper 95% confidence limit about the mean effluent concentration of less than or equal to 20 mg/L (data calculations from the study produced a 16.8 mg/L upper confidence limit concentration via bootstrapping; 14.5 mg/L upper confidence limit for the median from Q-Q plots).
- For influent TSS in the range of 100-200 mg/L, three events to date, the TAPE minimum 80% removal efficiency requirement is met with a mass loading-based 95% lower confidence limit of 90.5%, as calculated via bootstrapping.

For nitrogen-based compounds, removal efficiencies for TKN and nitrate are given. Of the 12 qualifying storm events, 6 events qualified for assessing TKN removal efficiencies and 8 events for nitrate removal efficiencies. The average event mean concentration and mass load reductions were 95% and 97% respectively.

Of the 12 qualifying storm events, seven events qualified for assessing TP. Influent TP concentration ranged from 0.121 mg/L to 0.424 mg/L and fell within the TAPE criteria for TP. The average event mean concentration and mass load reductions were 52% and 59%, respectively, with one (concentration based) and two (mass based) events producing greater than 60% removal

The calculated p-values derived from the paired group comparison tests for the influent versus effluent concentrations are the same as the p-values derived for the influent versus effluent mass loadings, except for suspended solids, nitrates and total copper. The constituents with statistically significant decreases from influent to effluent, based on both concentrations and mass loadings, include suspended solids (TSS), TP, TKN, total Zn and total Pb..

8.0 REFERENCES

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APPENDIX A

INDIVIDUAL STORM REPORTS

General information			
Monitoring site name	Campbells Run	Campbells Run	Campbells Run
Site location (UTM or latitude/longitude)	40.425999°, -80.114740°	40.425999°, -80.114740°	40.425999°, -80.114740°
Drainage area			
Storm information	See below	See below	See below
Storm name or number	1	2	3
Storm name or number	Event 1	Event 2	Event 3
Storm event date	09/12/15 - 09/13/15	09/27/15 - 09/28/15	09/29/15 - 09/30/15
Start	9/12/15 3:52 AM	9/27/15 8:04 PM	9/29/15 9:42 AM
End	9/13/15 12:05 AM	9/28/15 3:13 PM	9/30/15 5:03 AM
Antecedent dry period conditions (days)	1.60	7.97	0.77
Total precipitation depth (inches)	0.66	0.57	4.03
Precipitation duration (hours)	20.22	19.15	19.35
Mean precipitation intensity (inches per hour)	0.033	0.030	0.208
Maximum precipitation intensity (inches per hour)	1.8	0.6	2.4
Hydrologic information			
Influent peak flow rate (gpm)	127.52	26.65	193.45
Effluent peak flow rate (gpm)	72.35	18.36	2051.74
Average influent flow rate (gpm)	1.88	1.54	25.29
Average effluent flow rate (gpm)	0.91	0.78	84.40
Bypass peak flow rate (gpm)	0	0	unk
Max bypass level	0.291	0.070	1.034
Total influent runoff volume (gallons)	2278.83	1771.83	30225.45
Total effluent runoff volume (gallons)	1100.38	898.08	100857.74
Total bypass runoff volume (gallons)	0	0	unk
Data flags for identified QA issues			Event outflow greater than event inflow
Pollutant information			
Number of influent aliquots	6	4	93
Number of effluent aliquots	6	5	146
Percent of storm sampled			
Influent Total Volume (gal) during sampling period	1797.17	1298.29	30106.94
Influent Total Volume (gal) during rain event	2278.83	1771.83	30225.45
Percent of Influent Volume	79%	73%	100%
Effluent Total Volume (gal) during sampling period	816.46	651.67	100660.30
Effluent Total Volume (gal) during rain event	1100.38	898.08	100857.74
Percent of Effluent Volume	74%	73%	100%
Parameters monitored			
Parameter 1	Suspended Solids	Suspended Solids	Suspended Solids
Parameter 2	Nitrate	Nitrate	Nitrate
Parameter 3	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN
Parameter 4	Phosphorus, Total	Phosphorus, Total	Phosphorus, Total
Parameter 5	Copper	Copper	Copper
Parameter 6	Lead	Lead	Lead
Parameter 7	Zinc	Zinc	Zinc
Influent Event Mean Concentrations			
Suspended Solids	46.8	48	26.6
Nitrate	0.219	0.126	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	0.5	< 0.250
Phosphorus, Total	< 0.100	0.121	< 0.100
Copper	0.015	0.0111	< 0.0100
Lead	0.00324	< 0.00500	< 0.00500
Zinc	0.123	0.37	< 0.0500
Effluent Event Mean Concentrations			
Suspended Solids	23.8	16.6	2.54
Nitrate	0.259	0.13	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	< 0.250
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	0.00507	< 0.0100	< 0.0100
Lead	0.00203	< 0.00500	< 0.00500
Zinc	< 0.0250	0.0828	< 0.0500
Removal efficiency			
Suspended Solids	75%	82%	68%
Nitrate	43%	48%	See statistical evaluation
Kjeldahl Nitrogen, TKN	See statistical evaluation	See statistical evaluation	See statistical evaluation
Phosphorus, Total	See statistical evaluation	See statistical evaluation	See statistical evaluation
Copper	84%	See statistical evaluation	See statistical evaluation
Lead	70%	See statistical evaluation	See statistical evaluation
Zinc	See statistical evaluation	89%	See statistical evaluation
Laboratory detection limits			
Suspended Solids	< 2.50	< 2.50	< 2.50
Nitrate	< 0.100	< 0.100	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	< 0.250
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	< 0.00500	< 0.01	< 0.01
Lead	< 0.00200	< 0.005	< 0.005
Zinc	< 0.0250	< 0.05	< 0.05
Data flags for identified QA issues	All sample exceeded the hold time for Nitrate Analysis.		All sample exceeded the hold time for Nitrate Analysis.

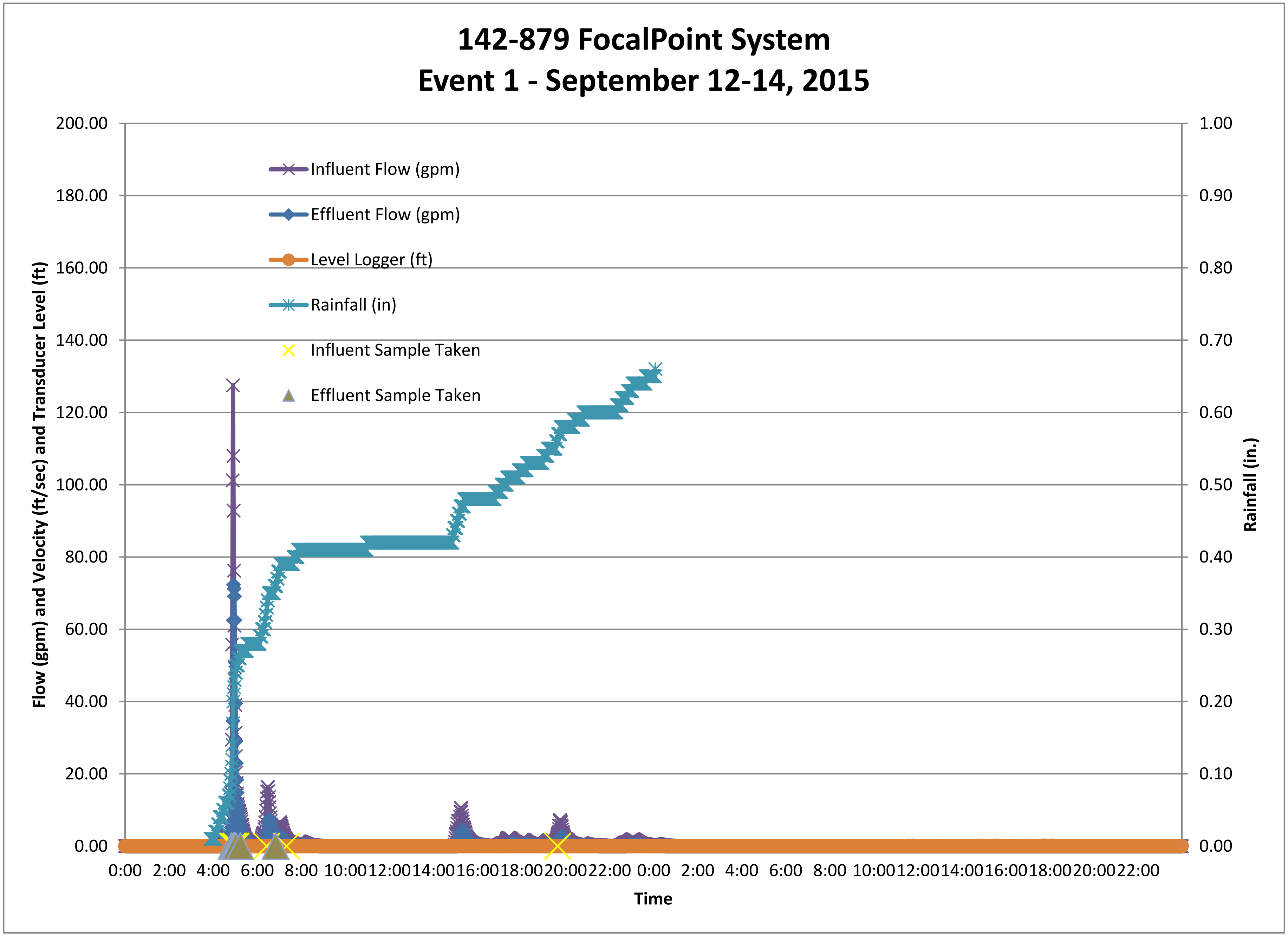
General information			
Monitoring site name	Campbells Run	Campbells Run	Campbells Run
Site location (UTM or latitude/longitude)	40.425999°, -80.114740°	40.425999°, -80.114740°	40.425999°, -80.114740°
Drainage area			
Storm information	See below	See below	See below
Storm name or number	4	5	6
Storm name or number	Event 4	Event 5	Event 6
Storm event date	10/09/15	10/24/15 - 10/25/15	10/27/15 - 10/28/15
Start	10/9/15 11:29 AM	10/24/15 3:35 PM	10/27/15 9:13 PM
End	10/9/15 1:16 PM	10/25/15 2:40 AM	10/28/15 6:58 PM
Antecedent dry period conditions (days)	5.99	1.96	2.77
Total precipitation depth (inches)	0.41	0.46	1.95
Precipitation duration (hours)	1.78	11.08	21.75
Mean precipitation intensity (inches per hour)	0.230	0.042	0.090
Maximum precipitation intensity (inches per hour)	3	0.6	2.4
Hydrologic information			
Influent peak flow rate (gpm)	131.36	12.98	161.04
Effluent peak flow rate (gpm)	71.27	6.58	37.21
Average influent flow rate (gpm)	18.28	1.94	7.01
Average effluent flow rate (gpm)	14.01	0.95	3.19
Bypass peak flow rate (gpm)	0	0	0
Max bypass level	0.405	0.076	0.808
Total influent runoff volume (gallons)	1956.37	1291.62	9380.27
Total effluent runoff volume (gallons)	1499.33	636.44	4265.24
Total bypass runoff volume (gallons)	0	0	0
Data flags for identified QA issues			
Pollutant information			
Number of influent aliquots	6	4	29
Number of effluent aliquots	9	4	27
Percent of storm sampled			
Influent Total Volume (gal) during sampling period	1717.65	989.33	9175.14
Influent Total Volume (gal) during rain event	1956.37	1291.62	9380.27
Percent of Influent Volume	88%	77%	98%
Effluent Total Volume (gal) during sampling period	1291.88	525.93	4032.59
Effluent Total Volume (gal) during rain event	1499.33	636.44	4265.24
Percent of Effluent Volume	86%	83%	95%
Parameters monitored			
Parameter 1	Suspended Solids	Suspended Solids	Suspended Solids
Parameter 2	Nitrate	Nitrate	Nitrate
Parameter 3	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN
Parameter 4	Phosphorus, Total	Phosphorus, Total	Phosphorus, Total
Parameter 5	Copper	Copper	Copper
Parameter 6	Lead	Lead	Lead
Parameter 7	Zinc	Zinc	Zinc
Influent Event Mean Concentrations			
Suspended Solids	197	19.8	4.9
Nitrate	0.265	0.456	< 0.100
Kjeldahl Nitrogen, TKN	1.22	< 0.250	< 0.250
Phosphorus, Total	0.253	< 0.100	< 0.100
Copper	0.014	< 0.0100	< 0.0100
Lead	0.0117	< 0.00500	< 0.00500
Zinc	0.202	< 0.0500	< 0.0500
Effluent Event Mean Concentrations			
Suspended Solids	24.4	9.88	2.5
Nitrate	0.265	0.299	< 0.100
Kjeldahl Nitrogen, TKN	0.531	< 0.250	0.571
Phosphorus, Total	0.11	< 0.100	< 0.100
Copper	< 0.0100	< 0.0100	< 0.0100
Lead	< 0.00500	< 0.00500	< 0.00500
Zinc	< 0.0500	< 0.0500	< 0.0500
Removal efficiency			
Suspended Solids	91%	75%	77%
Nitrate	23%	68%	See statistical evaluation
Kjeldahl Nitrogen, TKN	67%	See statistical evaluation	See statistical evaluation
Phosphorus, Total	67%	See statistical evaluation	See statistical evaluation
Copper	See statistical evaluation	See statistical evaluation	See statistical evaluation
Lead	See statistical evaluation	See statistical evaluation	See statistical evaluation
Zinc	See statistical evaluation	See statistical evaluation	See statistical evaluation
Laboratory detection limits			
Suspended Solids	< 2.50	< 2.50	< 2.50
Nitrate	< 0.100	< 0.100	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	< 0.250
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	< 0.01	< 0.01	< 0.01
Lead	< 0.005	< 0.005	< 0.005
Zinc	< 0.05	< 0.05	< 0.05
Data flags for identified QA issues	The field blank exceeded the hold time for Nitrate Analysis.		

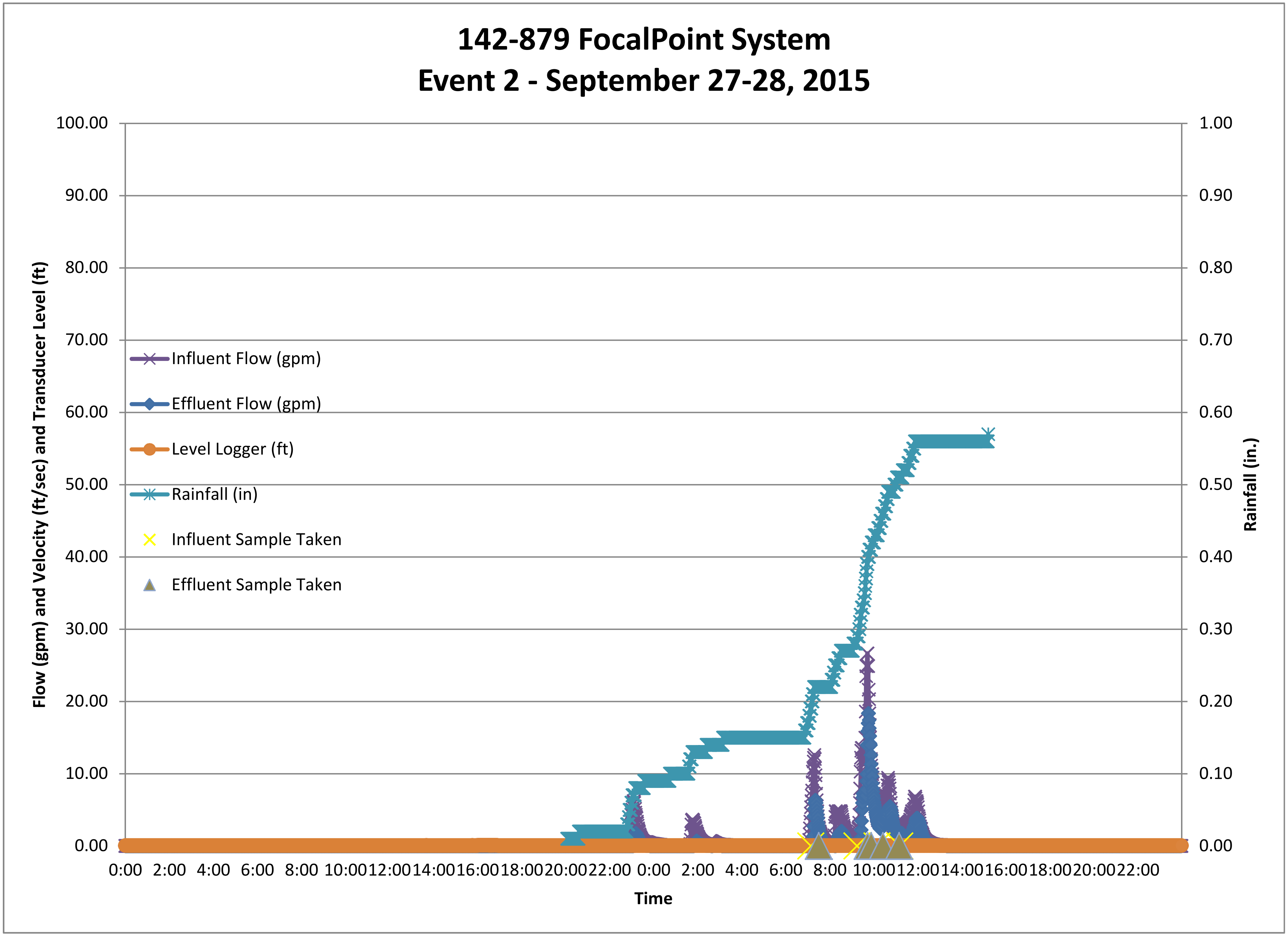
General information			
Monitoring site name	Campbells Run	Campbells Run	Campbells Run
Site location (UTM or latitude/longitude)	40.425999°, -80.114740°	40.425999°, -80.114740°	40.425999°, -80.114740°
Drainage area			
Storm information	See below	See below	See below
Storm name or number	7	8	9
Storm name or number	Event 7	Event 8	Event 9
Storm event date	11/06/15	11/10/15	12/14/15 - 12/15/15
Start	11/6/15 5:26 AM	11/10/15 1:22 AM	12/14/15 3:06 PM
End	11/6/15 1:31 PM	11/10/15 3:42 PM	12/15/15 12:44 AM
Antecedent dry period conditions (days)	4.86	3.49	4.71
Total precipitation depth (inches)	0.3	0.89	0.21
Precipitation duration (hours)	8.08	14.33	9.63
Mean precipitation intensity (inches per hour)	0.037	0.062	0.022
Maximum precipitation intensity (inches per hour)	1.2	0.6	0.6
Hydrologic information			
Influent peak flow rate (gpm)	78.45	24.33	7.51
Effluent peak flow rate (gpm)	38.68	10.44	7.51
Average influent flow rate (gpm)	2.88	3.37	1.48
Average effluent flow rate (gpm)	1.72	0.95	1.81
Bypass peak flow rate (gpm)	0	0	0
Max bypass level	0.313	0.194	0.080
Total influent runoff volume (gallons)	1396.59	2899.05	340.26
Total effluent runoff volume (gallons)	835.03	819.96	416.84
Total bypass runoff volume (gallons)	0	0	0
Data flags for identified QA issues			Event outflow greater than event inflow
Pollutant information			
Number of influent aliquots	4	9	3
Number of effluent aliquots	5	4	8
Percent of storm sampled			
Influent Total Volume (gal) during sampling period	967.35	2555.22	210.48
Influent Total Volume (gal) during rain event	1396.59	2899.05	340.26
Percent of Influent Volume	69%	88%	62%
Effluent Total Volume (gal) during sampling period	631.35	506.71	342.06
Effluent Total Volume (gal) during rain event	835.03	819.96	416.84
Percent of Effluent Volume	76%	62%	82%
Parameters monitored			
Parameter 1	Suspended Solids	Suspended Solids	Suspended Solids
Parameter 2	Nitrate	Nitrate	Nitrate
Parameter 3	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN
Parameter 4	Phosphorus, Total	Phosphorus, Total	Phosphorus, Total
Parameter 5	Copper	Copper	Copper
Parameter 6	Lead	Lead	Lead
Parameter 7	Zinc	Zinc	Zinc
Influent Event Mean Concentrations			
Suspended Solids	84.4	31.2	238
Nitrate	0.104	< 0.100	0.401
Kjeldahl Nitrogen, TKN	45.8	< 0.250	< 0.250
Phosphorus, Total	0.16	< 0.100	0.424
Copper	< 0.0100	< 0.0100	0.0121
Lead	< 0.00500	< 0.00500	0.0106
Zinc	0.127	0.0609	0.0921
Effluent Event Mean Concentrations			
Suspended Solids	19.6	8.91	8
Nitrate	0.167	< 0.100	0.775
Kjeldahl Nitrogen, TKN	0.371	< 0.250	< 0.250
Phosphorus, Total	0.125	< 0.100	< 0.100
Copper	< 0.0100	< 0.0100	< 0.0100
Lead	< 0.00500	< 0.00500	< 0.00500
Zinc	< 0.0500	< 0.0500	< 0.0500
Removal efficiency			
Suspended Solids	86%	92%	96%
Nitrate	4%	See statistical evaluation	-137%
Kjeldahl Nitrogen, TKN	100%	See statistical evaluation	See statistical evaluation
Phosphorus, Total	53%	See statistical evaluation	See statistical evaluation
Copper	See statistical evaluation	See statistical evaluation	See statistical evaluation
Lead	See statistical evaluation	See statistical evaluation	See statistical evaluation
Zinc	See statistical evaluation	See statistical evaluation	See statistical evaluation
Laboratory detection limits			
Suspended Solids	< 2.50	< 2.50	< 2.50
Nitrate	< 0.100	< 0.100	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	< 0.250
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	< 0.01	< 0.01	< 0.01
Lead	< 0.005	< 0.005	< 0.005
Zinc	< 0.05	< 0.05	< 0.05
Data flags for identified QA issues			Negative removal efficiency for Nitrate.

General information			
Monitoring site name	Campbells Run	Campbells Run	Campbells Run
Site location (UTM or latitude/longitude)	40.425999°, -80.114740°	40.425999°, -80.114740°	40.425999°, -80.114740°
Drainage area			
Storm information	See below	See below	See below
Storm name or number	10	11	12
Storm name or number	Event 10	Event 11	Event 12
Storm event date	12/17/15	12/22/15	12/28/15 - 12/29/15
Start	12/17/15 5:17 AM	12/22/15 2:54 AM	12/28/15 1:25 PM
End	12/17/15 4:31 PM	12/22/15 10:47 AM	12/29/15 6:14 AM
Antecedent dry period conditions (days)	2.19	0.22	0.67
Total precipitation depth (inches)	0.56	0.34	0.36
Precipitation duration (hours)	11.23	7.88	16.82
Mean precipitation intensity (inches per hour)	0.050	0.043	0.021
Maximum precipitation intensity (inches per hour)	0.6	0.6	0.6
Hydrologic information			
Influent peak flow rate (gpm)	4.82	15.00	8.83
Effluent peak flow rate (gpm)	5.95	10.96	6.32
Average influent flow rate (gpm)	1.23	1.22	0.41
Average effluent flow rate (gpm)	1.49	0.96	0.33
Bypass peak flow rate (gpm)	0	0	0
Max bypass level	0.082	0.184	0.288
Total influent runoff volume (gallons)	828.61	575.51	409.34
Total effluent runoff volume (gallons)	1002.48	453.22	333.25
Total bypass runoff volume (gallons)	0	0	0
Data flags for identified QA issues	Event outflow greater than event inflow		
Pollutant information			
Number of influent aliquots	7	5	3
Number of effluent aliquots	19	9	6
Percent of storm sampled			
Influent Total Volume (gal) during sampling period	600.58	400.81	217.77
Influent Total Volume (gal) during rain event	828.61	575.51	409.34
Percent of Influent Volume	72%	70%	53%
Effluent Total Volume (gal) during sampling period	943.26	377.00	239.88
Effluent Total Volume (gal) during rain event	1002.48	453.22	333.25
Percent of Effluent Volume	94%	83%	72%
Parameters monitored			
Parameter 1	Suspended Solids	Suspended Solids	Suspended Solids
Parameter 2	Nitrate	Nitrate	Nitrate
Parameter 3	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN	Kjeldahl Nitrogen, TKN
Parameter 4	Phosphorus, Total	Phosphorus, Total	Phosphorus, Total
Parameter 5	Copper	Copper	Copper
Parameter 6	Lead	Lead	Lead
Parameter 7	Zinc	Zinc	Zinc
Influent Event Mean Concentrations			
Suspended Solids	142	122	51.8
Nitrate	0.233	0.508	< 0.100
Kjeldahl Nitrogen, TKN	0.715	1.69	3.42
Phosphorus, Total	0.181	0.184	0.172
Copper	< 0.0100	0.014	< 0.0100
Lead	0.00801	0.00595	0.00518
Zinc	0.0774	0.0934	0.0938
Effluent Event Mean Concentrations			
Suspended Solids	4.8	11.6	3.6
Nitrate	0.32	0.401	0.142
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	0.681
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	< 0.0100	< 0.0100	< 0.0100
Lead	< 0.00500	< 0.00500	< 0.00500
Zinc	< 0.0500	< 0.0500	< 0.0500
Removal efficiency			
Suspended Solids	96%	93%	94%
Nitrate	-66%	38%	See statistical evaluation
Kjeldahl Nitrogen, TKN	See statistical evaluation	See statistical evaluation	84%
Phosphorus, Total	See statistical evaluation	See statistical evaluation	See statistical evaluation
Copper	See statistical evaluation	See statistical evaluation	See statistical evaluation
Lead	See statistical evaluation	See statistical evaluation	See statistical evaluation
Zinc	See statistical evaluation	See statistical evaluation	See statistical evaluation
Laboratory detection limits			
Suspended Solids	< 2.50	< 2.50	< 2.50
Nitrate	< 0.100	< 0.100	< 0.100
Kjeldahl Nitrogen, TKN	< 0.250	< 0.250	< 0.250
Phosphorus, Total	< 0.100	< 0.100	< 0.100
Copper	< 0.01	< 0.01	< 0.01
Lead	< 0.005	< 0.005	< 0.005
Zinc	< 0.05	< 0.05	< 0.05
Data flags for identified QA issues	Negative removal efficiency for Nitrate. The influent and influent duplicate exceeded the hold time for Nitrate Analysis.		

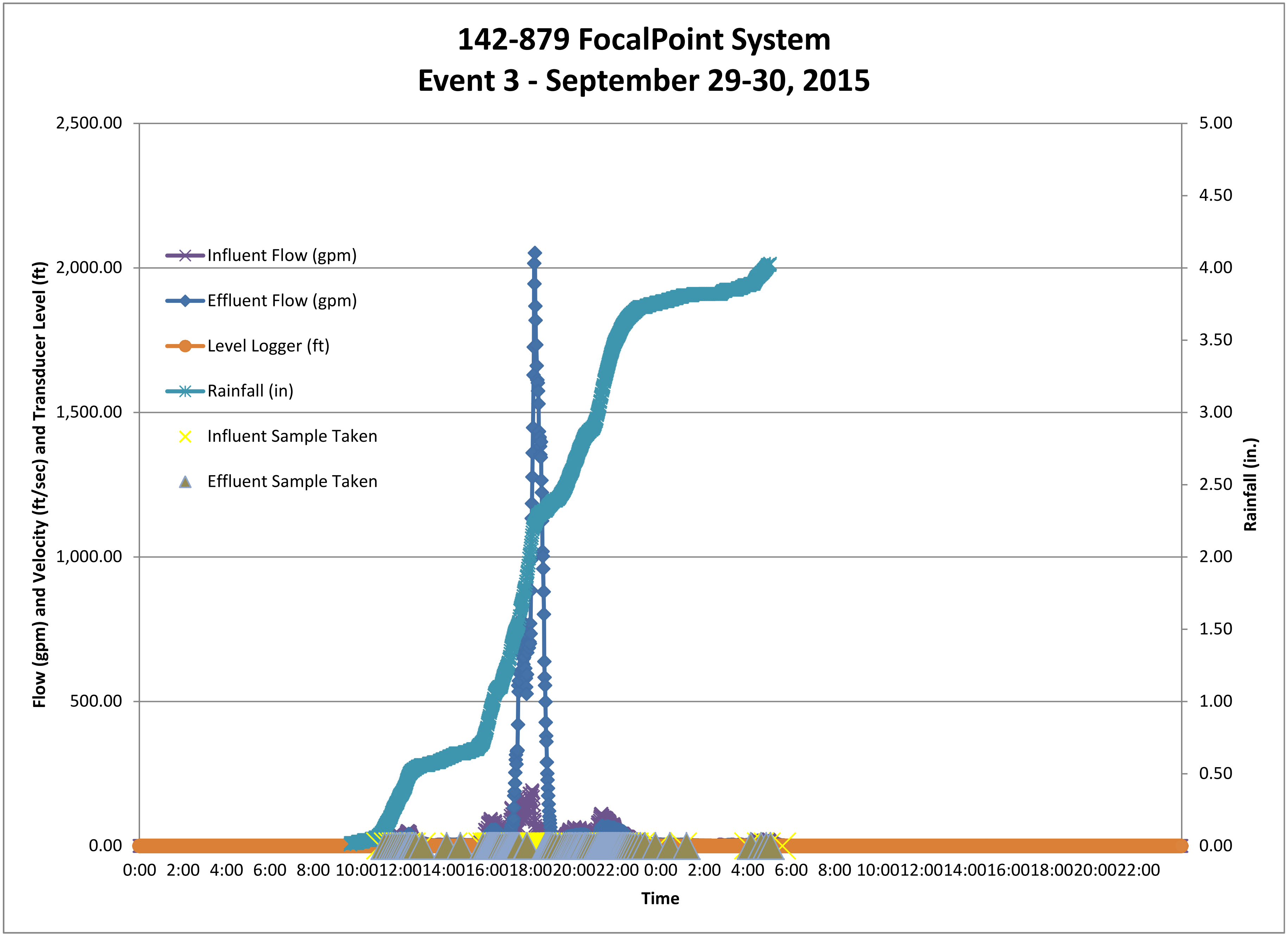
APPENDIX B

EVENT HYDROGRAPHS

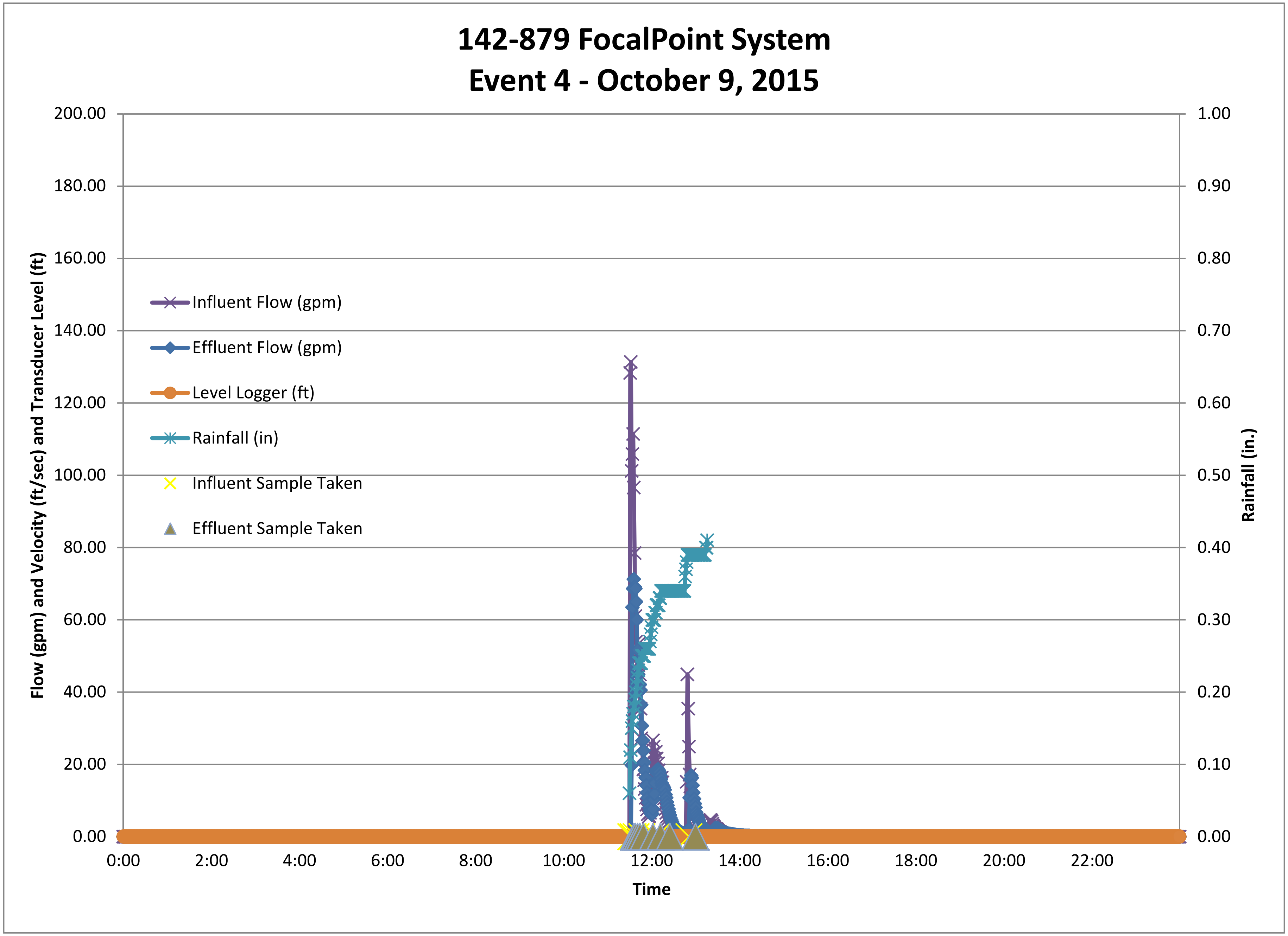

142-879 FocalPoint System
Event 1 - September 12-14, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rainfall (in.)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00
Time

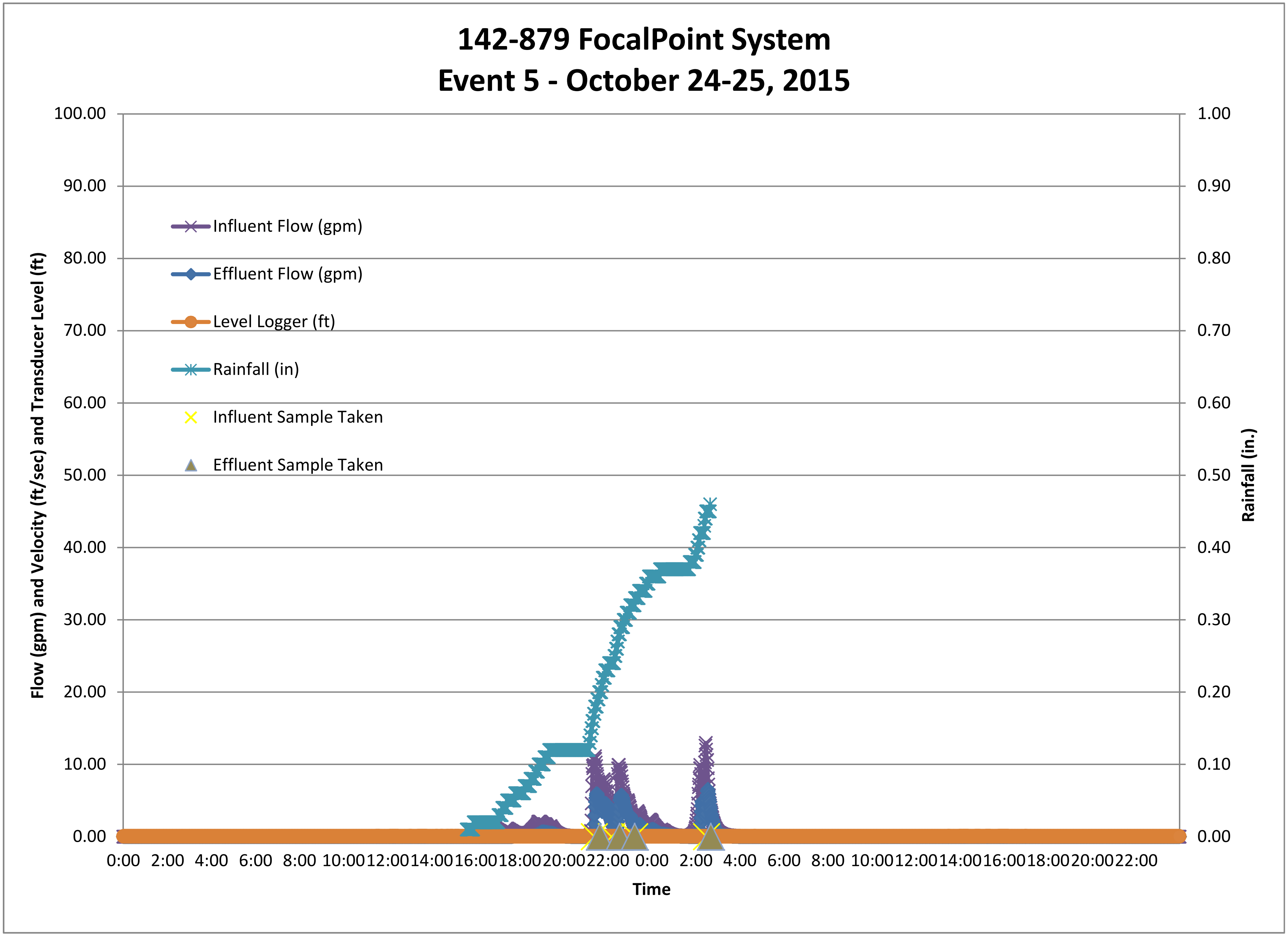


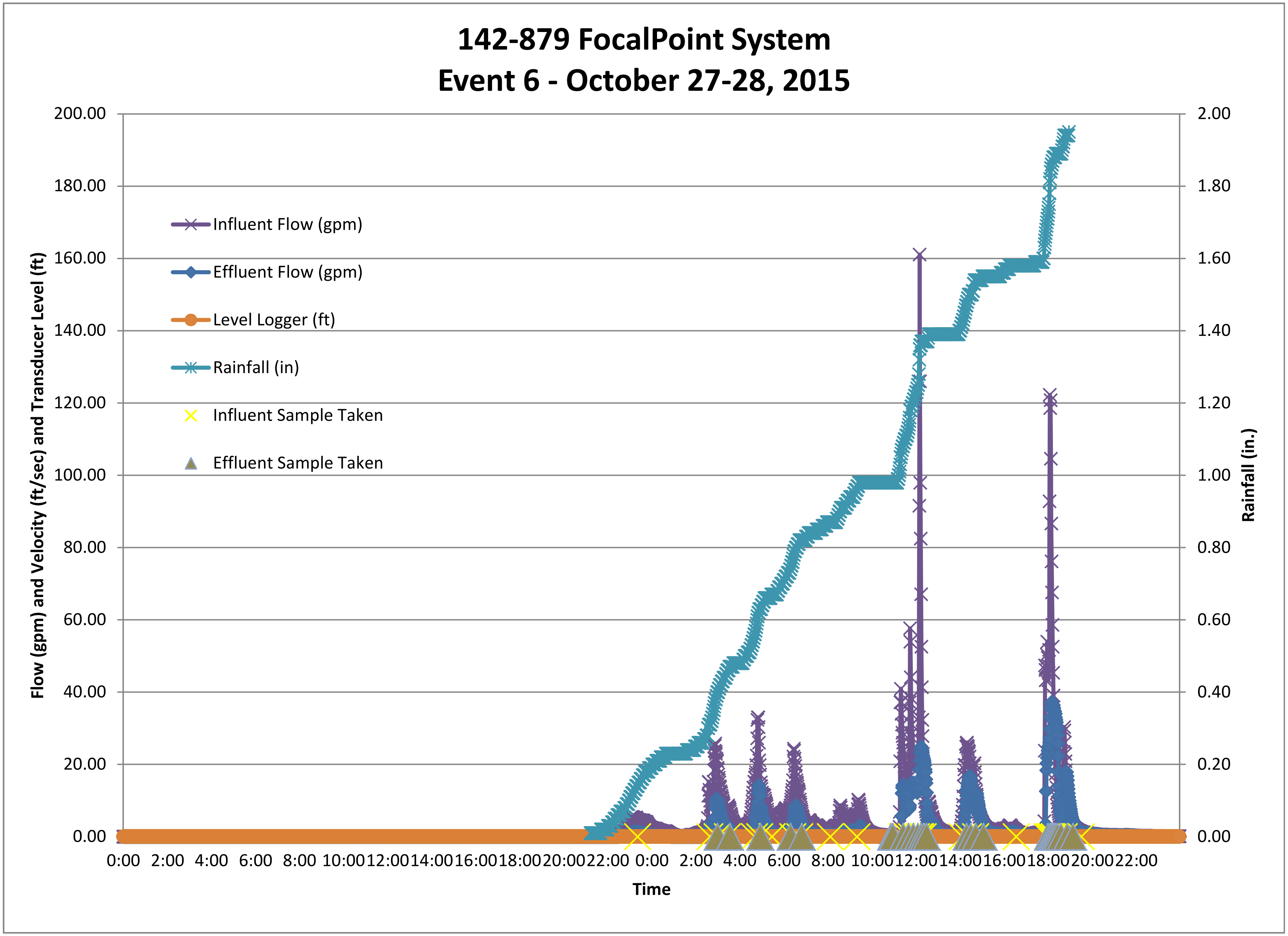
142-879 FocalPoint System
Event 2 - September 27-28, 2015
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken

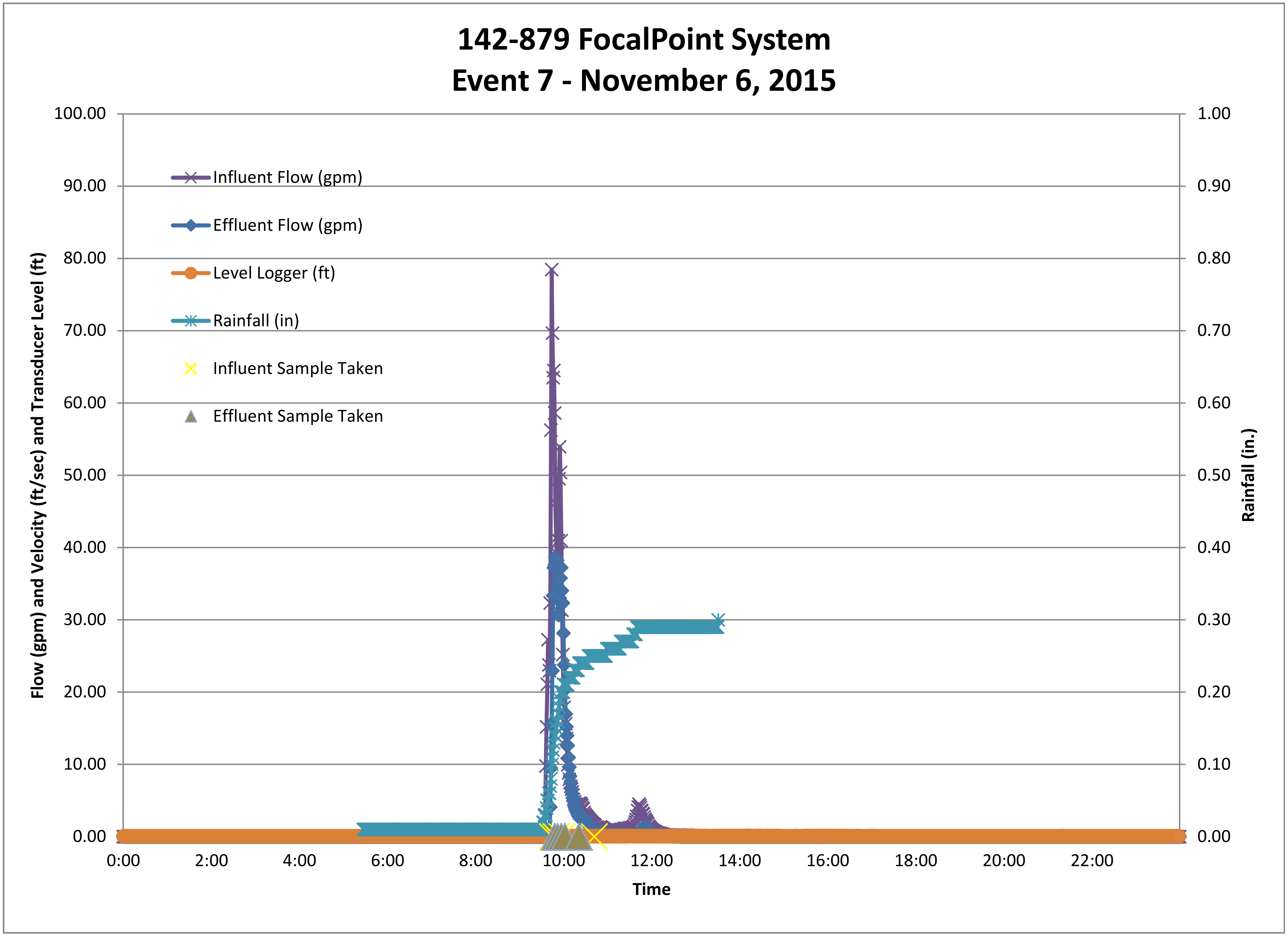


142-879 FocalPoint System
Event 3 - September 29-30, 2015
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
2,500.00
2,000.00
1,500.00
1,000.00
500.00
0.00
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken

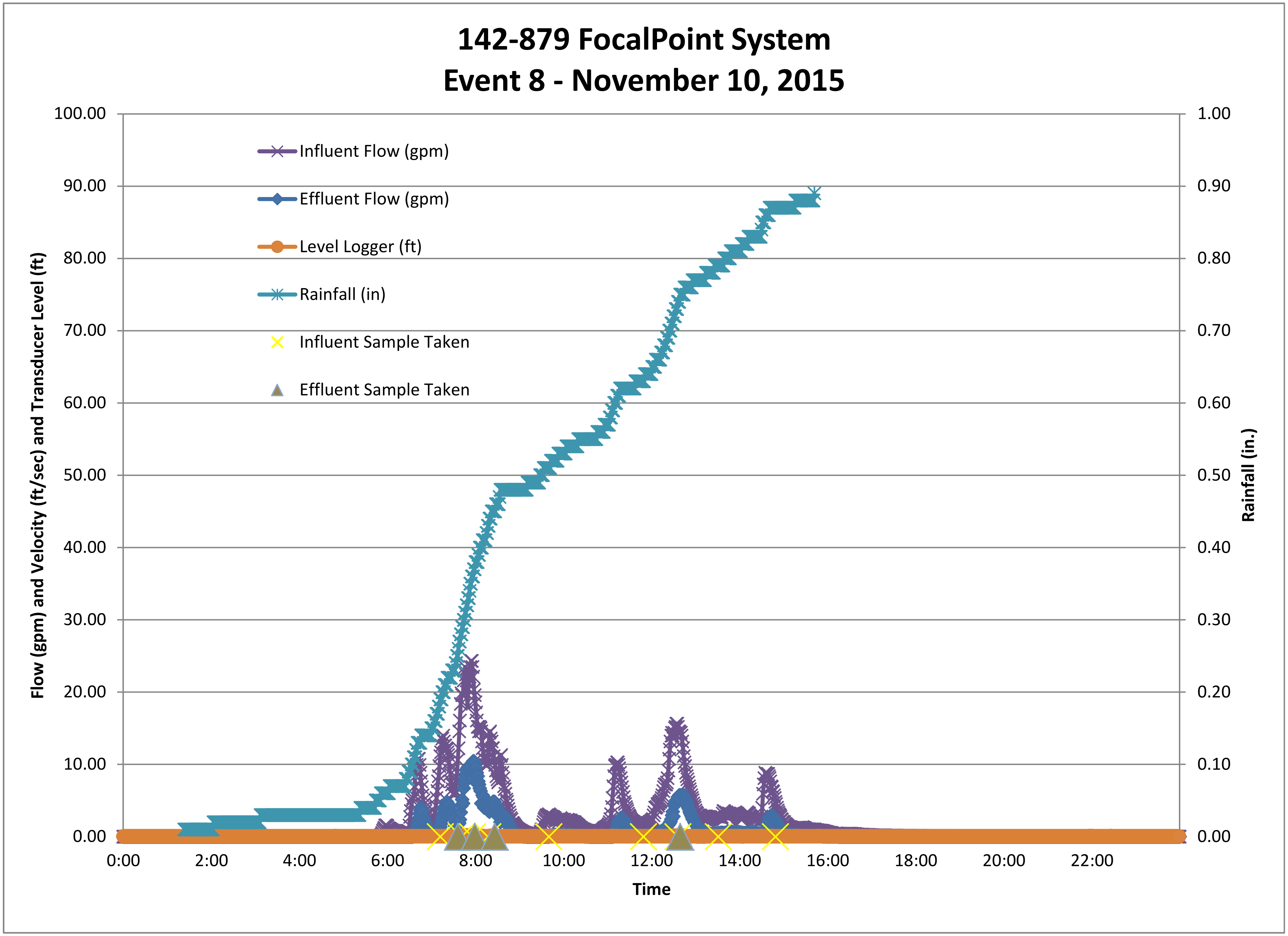

142-879 FocalPoint System
Event 4 - October 9, 2015
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Rainfall (in.)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time

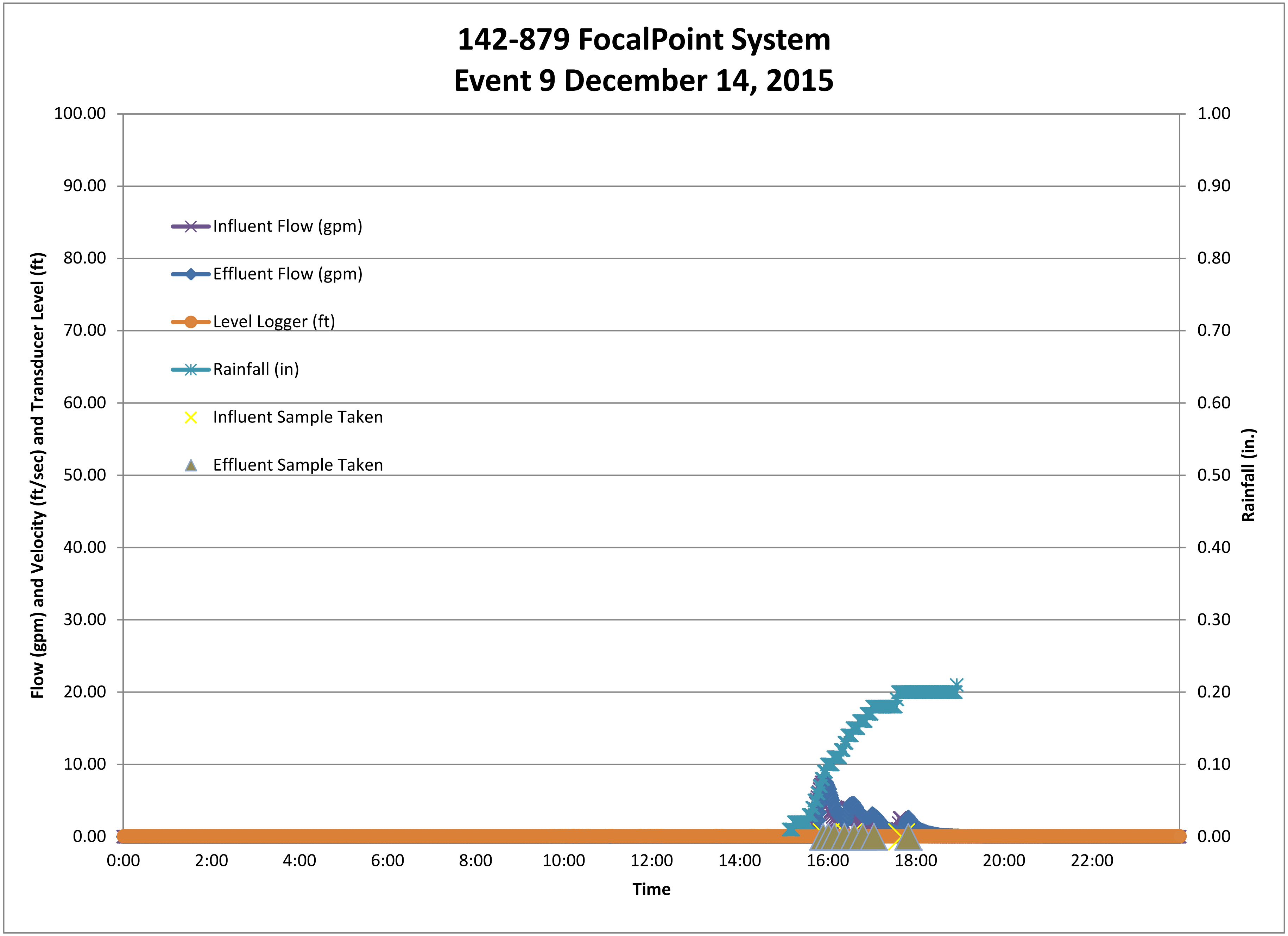

142-879 FocalPoint System
Event 5 - October 24-25, 2015
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00


142-879 FocalPoint System
Event 6 - October 27-28, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

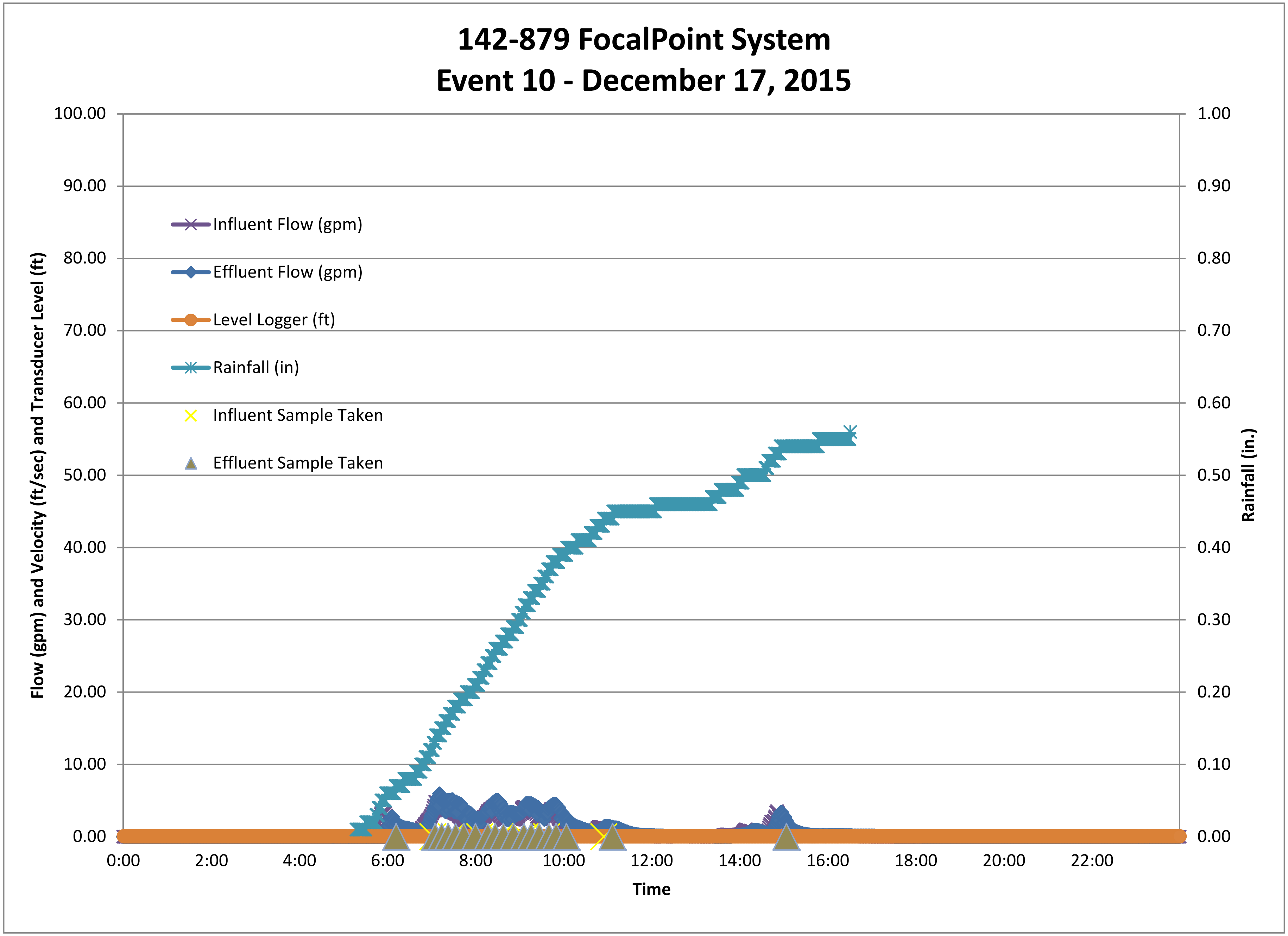


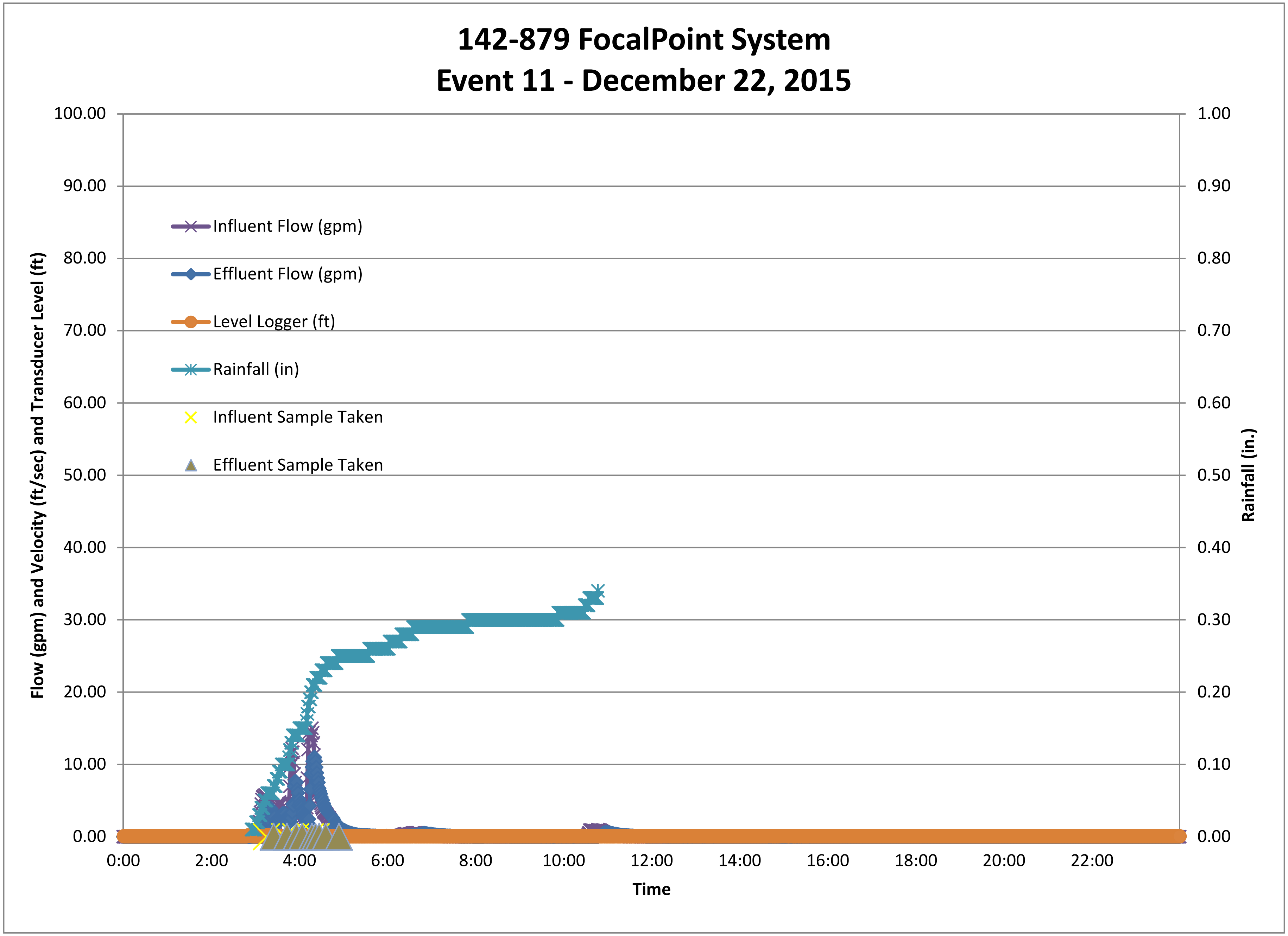
142-879 FocalPoint System
Event 7 - November 6, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00


142-879 FocalPoint System
Event 8 - November 10, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00



142-879 FocalPoint System
Event 9 December 14, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00


142-879 FocalPoint System
Event 10 - December 17, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00


142-879 FocalPoint System
Event 11 - December 22, 2015
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
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0.20
0.10
0.00
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2:00
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16:00
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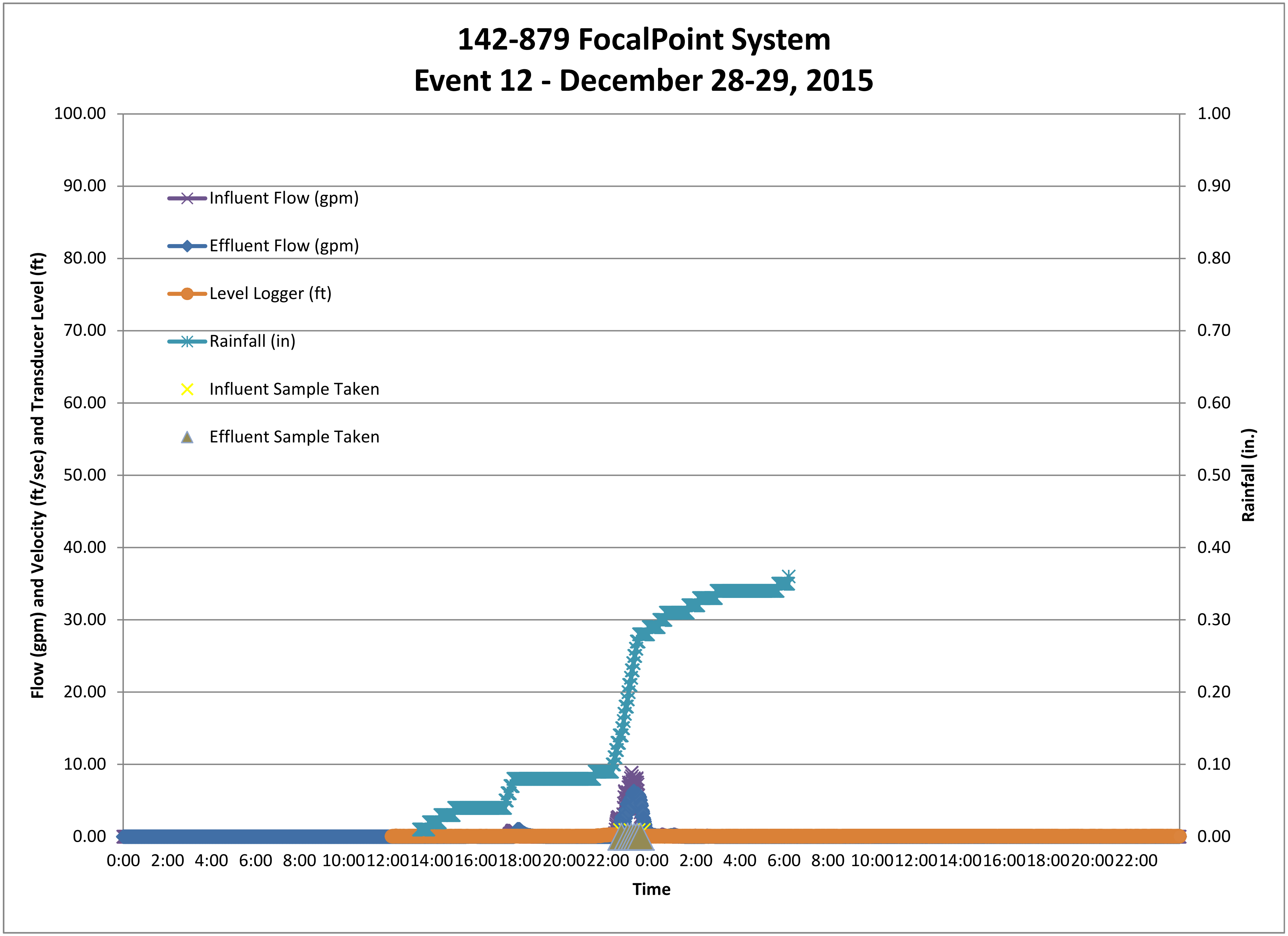

142-879 FocalPoint System
Event 12 - December 28-29, 2015
Influent Flow (gpm)
Effluent Flow (gpm)
Level Logger (ft)
Rainfall (in)
Influent Sample Taken
Effluent Sample Taken
Flow (gpm) and Velocity (ft/sec) and Transducer Level (ft)
Rainfall (in.)
Time
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.00
0.90
0.80
0.70
0.60
0.50
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0.30
0.20
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0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00

APPENDIX C

QAPP

Quality Assurance Project Plan: Field Evaluation of the *FocalPoint High Performance Modular Biofiltration System* Manufactured by Convergent Water Technologies Houston, Texas

May 2015

Prepared By
ACF Environmental, Inc.
Civil & Environmental Consultants, Inc. (CEC)

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2/24/2016 Revised by K. B. Wolfe

I. Project Management

Introduction/ Project Description

The FocalPoint High Performance Modular Biofiltration System is a specialized system of biofiltration media for the treatment of stormwater runoff in bioretention facilities. The FocalPoint system is manufactured by Convergent Water Technologies of Houston, Texas. FocalPoint utilizes physical, chemical and biological mechanisms of a soil, plant and microbe complex to remove pollutants typically found in urban stormwater runoff. The modular treatment system, containing biologically active biofiltration media, is used as a complete, integrated system designed for installation in square foot increments to treat contaminated runoff from impervious surfaces.

FocalPoint is a scalable biofiltration system which combines the efficiency of high flow rate engineered soils with the durability and modularity of a highly pervious, open cell underdrain/storage/infiltration system. The system employs a cross-section that includes a 3-inch uppermost layer of mulch, 18-inch biofiltration media, and 6 inches of washed bridging stone. The stone layer is underlain by an open-mesh geotextile followed by the modular underdrain storage system.

The proposed project and the associated QAPP focuses on the design, execution, and review of a field study to assess the pollutant-removal performance of the FocalPoint High Performance Modular Biofiltration System. The purpose of this QAPP is to document the type and quality of data needed for the project and to describe the methods for collecting and assessing those data. This Project Plan has been created to be in general accordance with Environmental Protection Agency's (EPA) *EPA Requirements for Quality Assurance Project Plans* (QA/R-5; US EPA, 2001).

Civil & Environmental Consultants, Inc. provides consulting services specializing in BMP testing and product research and development and has been contracted by ACF Environmental, Inc. to assist with the QAPP development and execution of this study. Performance data collected as part of the implementation of this QAPP will be submitted to the appropriate agency for review for review and evaluation.

Analytical services will be provided by TestAmerica Laboratory, Pittsburgh, PA or an equivalent accredited laboratory, for all pollutants. TestAmerica is accredited under the National Environmental Laboratory Accreditation Program (NELAP). For this project, specific parameters of interest for evaluation include Total Phosphorous (TP), Total Kjeldahl Nitrogen (TKN-N), Nitrate-Nitrogen (NO_3-N), Total Suspended Solids (TSS), Total Copper (Cu), Total Lead (Pb), and Total Zinc (Zn).

This study will be conducted at the warehouse facility owned by Civil & Environmental Consultants, Inc. on Campbells Run Road in Pittsburgh, PA. The installation of the FocalPoint system and initiation of data collection is targeted for late 2014. The data collection goal for the project is to retrieve water quality samples for a minimum of 20 qualifying storm events, with completion of the data collection phase by the fall of 2015. However, the actual completion date for the data collection phase will depend on seasonal weather conditions directly influencing the number of qualifying storm events during the study.

For this project, due to the small watershed involved, a qualifying storm event has been defined as having a minimum of 0.15 inches of rain. The antecedent rainfall requirements include less than 0.10-inches of rainfall in the previous 24 hours and less than 0.04 inches total rainfall during the 6 hours immediately prior to the start of the storm event. The end of a qualifying storm event is defined as occurring when there is a cumulative depth of less than 0.04 inches rainfall occurring over a consecutive 6 hours period after the storm. Rainfall data will be obtained from a tipping bucket rain gauge with datalogger at the CEC warehouse building. The rain gauge shall be capable of logging data every 1 minute in 0.01-inch increments.

Removal efficiencies for each water-quality parameter of concern will be determined from the inflow and outflow concentrations of the flow-weighted composite samples collected during each storm event. For each qualifying storm event, the removal efficiency for each water-quality parameter will be calculated and reported along with inflow and outflow concentrations. Both inflow and outflow hydrographs along with the associated rainfall hyetograph will be developed and presented as part of the water balance assessment through the FocalPoint system. Descriptive statistics and paired testing for statistically significant differences in influent and effluent concentrations will be carried out as part of the study.

An assessment of maintenance needs and operational issues is also a secondary focus of this QAPP. Both inspection and maintenance records will be developed and presented with the final report for this study. Recommended maintenance by the manufacturer will be performed in accordance with the manufacturer’s recommendations. Inspection and maintenance records will be provided as an appendix in the final project report.

Quality Control Criteria

Data obtained from this project will provide information on the water quality performance of the FocalPoint system. This section addresses quality objectives for precision, bias, detection and reporting limits, sample representativeness, data completeness, and data comparability.

Quality Objectives for Field Activities

<u>Precision</u> -To assess precision in the field, stormwater field duplicates will be collected every qualifying storm event for influent and effluent composite samples submitted to the laboratory for analysis.

<u>Bias</u> - Defining and following standardized sampling methods such as those set forth in this QAPP minimizes error due to bias. Bias in field procedures will be measured by collecting one field blank for each qualifying storm sample collection event. Additionally, bias will be reduced by regularly calibrating field equipment per the recommendation schedule set forth by each manufacturer and consistently following field procedures described in this QAPP. Equipment will be calibrated by the manufacturers prior to installation in the field study.

Representative Sampling and Data Comparability - To ensure representativeness of the data, composite stormwater samples will be collected at inlet and outlet sample points that best represent pollutant constituents in the influent stormwater and treated effluent. Consistent and standard sampling procedures as set forth in this QAPP will be followed. The inlet and outlet sample points will be selected to ensure well-mixed samples that are representative of the storm conditions are collected.

Data Completeness – The required amount of valid data obtained from this project shall include representative influent and effluent composite samples from at least 20 qualifying storms The length of the study period will be extended until the minimum number of acceptable qualifying storms is achieved.

Refer to Table 1 for a summary of quality objectives for field sampling.

Quality Criteria Category	**Quality Control Field Methods**
Precision	Influent and effluent duplicate sample every qualifying storm event.
Bias	Collection of field blanks during each field sampling event.
	Equipment calibration prior to initiating project. Routine equipment inspection and maintenance. Routine re-calibration of equipment per manufacturers' recommendations.
Representative and Comparable Data	Consistent and standard sampling procedures
Data Completeness	Obtaining valid data from a minimum of 10 qualifying storm events.

Table 1 Quality Criteria for Field Sampling

Quality Objectives for Laboratory Analytical

Quality objectives for laboratory analytical for this project shall adhere to the methods shown in Tables 2 and 3.

Quality Criteria Category	Quality Control Laboratory Methods
Precision	Laboratory duplicates at a frequency of one per matrix spike, one per lab control sample, and one per method blank
Bias	Matrix spikes, laboratory control samples, method blanks at a frequency of one sample per standard batch
Representative and Comparable Data	Adherence to standard analytical procedures, analytical methods, units of measurement, and detection limits.

Table 2 Quality Criteria for Laboratory Procedures

Analytical Parameter	EPA Method	Units	**MDL (mg/L)	Duplicate Precision (RPD %)	Bias		
					Matrix Spikes (% Rec.)	^^LCS (% Rec.)	Method Blanks
TSS	2540	mg/L	4	<5	80-120	85-115	<4 mg/L
TP	365.4	mg/L	0.035	<20	85-115	90-110	<0.035mg/L
TKN-N	351.2	mg/L	0.035	<20	90-110	90-110	<0.035mg/L
NO3 -N	300.0	mg/L	0.05	<20	90-110	90-110	<0.05mg/L
Total Cu	6010B	mg/L	0.0053	<20	75-125	80-120	<0.0053mg/L
Total Pb	6010B	mg/L	0.005	<20	75-125	80-120	<0.005mg/L
Total Zn	6010B	mg/L	0.0059	<20	75-125	80-120	<0.0059mg/L

Table 3- Required Quality Criteria for Laboratory Procedures for Stormwater Samples

*SW-Stormwater
**MDL – Method Detection Limit
^LVI-Lowest Value of Interest
^^Laboratory Control Samples
RPD=Relative Percent Difference

Special Training/Certification

All personnel involved in this study must have prior experience and demonstrated aptitude in their area of responsibility. Analytical labs shall be certified in their respective states for the water-quality parameters of concern for this study. Current confined space entry certification shall be required for field personnel involved in site preparation, system maintenance, equipment maintenance, and site restoration work. Personnel involved in data collection activities shall be trained in the proper safety requirements for work involving open manholes in the public right-of-way. The effluent sampling process will require a sample collection manhole for this project.

Data Management/Documents and Records

There are two types of data that will be generated as part of this study: field activity and monitoring data (sample collection, downloads from dataloggers, and equipment maintenance and calibration activities, system maintenance, etc.) and laboratory water quality data.

Field activity data will be recorded in the field notebook. The field notebook will include the following: storm event data field sheets, chain of custody forms, maintenance inspection field sheets, equipment calibration logs, and the maintenance activity logs. The project manager is responsible for updating and storing the field notebook. The field notebook will be photocopied monthly, and a copy shall be scanned into the project files and stored at the CEC Pittsburgh office.

Field data to be collected include flow and sample period data (subsample extraction times and total flow between subsamples) for the inlet and outlet sampling, flow meters, and precipitation data from the rain gauge. Photos shall also be taken during each field visit to provide a documented photo-log of each field visit and sample collection event. Flow and rainfall data will be downloaded by field staff onto a project designated laptop computer and stored in a Flowlink database. Rainfall data will be downloaded as needed and imported into Flowlink by the site manager. The project manager is responsible for maintaining and backing-up the Flowlink database. The Flowlink database will be backed up weekly, with back-up files stored at the Pittsburgh CEC office.

All laboratory reports will be transmitted electronically and via hard copy to the project manager. Laboratory water quality data reported electronically by TestAmerica Laboratory or an equivalent accredited laboratory will be transferred to Excel spreadsheets comprising the project water quality database. The project manager will compile and manage the water quality database and back up the database each time new laboratory data is entered. The laboratory reports will be included as appendices in the final project report.

Documents associated with this study include the following:

- QAPP
- Interim Report (produced after 10 qualifying storm events)
- Final Report

II. Data Generation and Acquisition

The overall goal of the data collection effort is to acquire a set of sampling data that can be utilized to produce a set of pollutant removal efficiencies along with associated bioretention area hydraulic data that are representative of actual field performance of the FocalPoint system through multiple storm events. Additionally, the intent of this study is to perform a water balance assessment of runoff flows through the bioretention system.

Sampling Process Design and Sampling Methods

Data for this study shall be collected over the course of multiple storm events from an urban site incorporating a full-scale FocalPoint bioretention system located in Pittsburgh, PA. The bioretention area will be installed within the 15 ft. x 70 ft. grassed segment located at the entrance to the CEC warehouse along the north portion of the property facing Campbells Run Road (4315 Campbells Run Road, Pittsburgh, PA 15205). Runoff from the crown of Campbells Run Road also will flow back towards the south into the grassed area. The total watershed to the proposed test area is approximately 10,000 to 12,000 ft^2.

The FocalPoint system will be constructed by excavating the grassed portion of the CEC lot to accommodate a 11 ft. x 4 ft. bioretention area. A bottom layer of washed river gravel will be placed initially to provide a level base for the high-performance modular underdrain/storage system. An 8-inch diameter Schedule 40 PVC pipe with perforations will be installed within the bottom river gravel layer, extending along the outside of the entire width of the modular system. The perforated pipe will tee into a non-perforated 8-inch PVC pipe header which will extend to the effluent collection manhole. A 2 ft. x 2 ft. plastic or gum rubber anti-seep collar will be installed around the non-perforated header outside of the gravel media zone with soil compacted around the full extent of the collar and pipe. A layer of open-mesh geotextile will be installed over the modular system followed by a 6-inch layer of washed, bridging stone over the geotextile. Next, an 18-inch layer of high-performance biofiltration media will be placed over the bridging tone. A 3-inch layer of clean, shredded hardwood mulch will be placed over the biofiltration media to complete the system. A mixture of grasses and shrubs will be seeded over the bioretention media in an effort to establish adequate growth prior to the initiation of testing.

Stormwater flow measurements along with influent and effluent stormwater sampling will be carried out using Teledyne ISCO portable automatic samplers equipped with Teledyne ISCO acoustic (Doppler) flow meters positioned at both the influent and effluent channels. The acoustic flow meters' area-velocity sensors will trigger sampling based on the head variations detected behind the weir and corresponding flow rates.

Although the details of how the influent will be collected from the parking lot of the CEC warehouse have not been finalized at this point, the preliminary concept is to construct a collection trough immediately upslope of the proposed bioretention area at the interface of the asphalt pavement and the grassed area adjacent to the road. The trough will convey the runoff through a v-notch or rectangular weir (cut into the side of the trough) and into the top surface zone of the bioretention area. One smaller weir will be constructed for primary flow with a second emergency weir constructed to convey larger flows into the bioretention area to prevent bypassing of inflows. The Teledyne ISCO flow meter sensor and low-flow strainer of the sampler will be positioned within the weir trough. A Solinst Levelogger 3100 transducer with barometric compensation and datalogging capabilities will be anchored over the bioretention mulch surface to measure head fluctuations and infiltration rates into the media. An overflow channel/pipe will be constructed to the east of the bioretention zone with the invert positioned several inches above (minimum of 6 inches) the bioretention mulch surface for passing excess flows from the bioretention area. The transducer will be used to measure when overflows occur and the variations in water levels in the overflow channel/pipe and the associated flow rates.

The 8-inch PVC effluent pipe will be sloped to a collection manhole where the flow-meter sensor and low-flow strainer will be positioned within the effluent pipe, above a plastic v-notch weir that will be glued within the interior of the effluent pipe near the discharge into the manhole. The effluent pipe from the sampling manhole will either be directed to the east to discharge via gravity into Campbells Run or the sampling manhole can be equipped with a dedicated pump to evacuate the collected stormwater below the inlet pipe's invert, with the pump discharging back onto the parking lot downslope of the testing area.

Flow-proportional composite sampling will be used for this study for both influent and effluent flows. Flow-proportional composite sampling is the extraction of sample aliquots on a fixed-volume interval (sampling trigger volumes) and immediately mixing the sample aliquot within a single 4-gallon composite container located within the automatic sampler unit. The samplers and flow meters will be equipped with data logging capabilities in order to log flows and trigger volume-paced sampling. The flow volume increments chosen for programming the samplers will be determined using hydrologic modeling of the test watershed so that at least 10 aliquots (sub-samples) from the influent and 10 aliquots (sub-samples) from the effluent will be taken during each storm event. Flow-composited sampling will be programmed to cover at least 70% of the storm volume during each event. Transducer logging will be programmed to take readings every 1 minute.

The time and date stamps for all data-loggers associated with the automatic samplers, flow meters, and transducers will be synchronized prior to initiating sampling activities. Periodic field checks shall be carried out to ensure time and date stamps for all monitoring equipment is synchronized. Sandbags, Erosion Eels, or other portable diversion devices will be used to divert runoff that is extraneous to the test watershed away from the testing area. The measured flow rates by the acoustic flow meters and head by the transducers for the influent weir, effluent pipe, and the overflow channel/pipe shall be calibrated in the field during construction using flow from a nearby hydrant that is metered or from a metered line from a water truck. The data-logging rain gage will be installed during construction of the bioretention area. An as-built survey of the testing area shall be performed prior to initiating the sampling operations.

Sample Handling and Chain-of-Custody

After each storm event, the samplers will be inspected to determine how much, if any, sample volume was taken in the influent and effluent composite containers. If there is less than 5000 ml of sample in each bottle (1.3 gallons), which is the required sample size for the analysis of the targeted constituents plus a single duplicate of each constituent, the sample is to be discarded. After removal of the sample contents, flush the containers with distilled water and allow to dry before replacing in the sampler. If there is adequate sample volume in the influent and less than the allowable minimum in the effluent composite container, the sampling team will contact the Project Manager immediately for direction.

In order to pull samples for analysis, the sampling team will pull the composite sample containers from the influent and effluent automatic samplers after each event. Clean, empty replacement composite sample containers shall be placed into the sampler units for the sampling the next storm event.

The collected stormwater in the influent and effluent composite sample containers shall be taken immediately inside the CEC warehouse and placed on a magnetic stirrer. A large magnetic stirring bar shall be placed in each container and the stirrer unit shall be turned on. During mixing, samples shall be extracted from the containers using a pipette, filling each lab sample bottle with the required sample volume. After all sample bottles have been filled, the remaining sample volume shall be discarded and the composite sample containers shall be rinsed multiple times with distilled water and stored for later use.

Proper sample collection, handling, preservation, transport, and custody procedures will be followed. Sample containers will be appropriately labeled and a chain of custody form will be completed for all samples delivered to the TestAmerica laboratory. All samples will be iced during collection, stored and transported to the laboratory. All samples will be delivered to the laboratory in less than 48 hours from the onset of collection to ensure the samples are collected and processed before the next storm event. Table 4 gives the sample size, container type, preservation method, and holding times for the stormwater parameters targeted for this project.

Samples shall be labeled using the following convention:

Campbell Run Site/ CEC Project Number	=(CR/xxx-xxx)
Date	= month, day, year
Sample Location	= A (influent) or B (effluent)
Sample Event Number	= numerical order specific to the event

Parameter	**Minimum. Sample Size**	**Container Type**	**Preservation Method**	**Holding Time**
TSS	1000 ml	Plastic	Cool 4 degrees C	7 days
TP	500 ml	Plastic	Cool 4°C (lab – H2SO4 to pH <2)	28 days
TN	500 ml	Plastic	Cool 4°C (lab – H2SO4 to pH <2)	28 days
Total Cu, Pb, Zn	500 ml	Plastic	Cool 4°C (lab – HNO3 to pH <2)	6 months

Table 4: Sample Collection, Handling, and Preservation

Instrument/Equipment Calibration and Frequency

The equipment used in this study shall be pre-calibrated by the manufacturer or supplier. All monitoring equipment will be re-calibrated as required and as recommend by the manufacturer. Calibration and maintenance records will be updated and kept in the field notebook. The stormwater collection trough, weirs and overflow channel/pipe shall be inspected at least weekly for obstructions prior to the next sampling event and clean, as necessary, by pouring water into the troughs and channels from above to flush debris. Automatic samplers, flow meters transducers, and pumps shall be inspected at least monthly to ensure the equipment is effectively operating. All routine maintenance for the automatic samplers and flow meters shall strictly adhere to the Teledyne ISCO maintenance manual provided with the equipment. The maintenance manual will be kept by the project manager.

III. Assessment and Oversight

Assessments and Response Actions

The project manager will assess the field activities for the duration of the project. Due to the proximity of the test site and the CEC Pittsburgh office, the sampling equipment shall be checked during storm events that occur during weekday work hours to ensure the sampling and monitoring equipment and system set-up are working properly. The analytical laboratory QA Officers will routinely assess laboratory activities. Any discrepancies in laboratory QC activities will be identified in a case narrative accompanying water quality results. The project manager will review the laboratory reports for completeness and assess whether field QC samples (i.e., field blanks and field duplicates) meet QAPP specifications. The project manager will take corrective action as needed, in response to concerns associated with sample collection, sample handling, equipment failures, or field data management. The analytical laboratory’s QA Officer is responsible for taking corrective actions to address non-conformance or non-compliance by the analytical laboratory with QA requirements.

The analytical laboratory managers will keep the project manager informed of all QA problems that may jeopardize the quality of the data. The project manager will in turn inform all stakeholders via telephone or email of QA problems that may jeopardize the quality of the data. The project manager will also take corrective actions when field methods are determined to be inappropriate or QC analytical data are found to be outside the predefined limits of acceptability. Corrective actions may include a procedural change, equipment modification or repair, meeting with laboratory personnel, or retesting of any existing samples. All data validation problems and solutions will be documented by the project manager. The project manager and will coordinate equipment repair and replacement as needed.

IV. Data Validation and Usability

Data Review, Verification, and Validation

Data verification involves examination of the QC results for compliance with acceptance criteria. Data validation involves the examination of the complete data package to determine whether the procedures in the QAPP were followed.

The project manager will validate project data by determining whether procedures in the QAPP were followed during data collection. The project manager will review rainfall, flows, and transducer level data for gross errors such as spikes or data gaps to determine completeness of the data set. Rainfall data from the on-site project rain gauge will be verified by comparing with the hyetographs from the nearest NWS and/or USGS rain gauges for consistency during the sampled storm event as well as consistency with previously collected rainfall data for the test location. A comparison between flow measured at the upstream and downstream of the bioretention area will be compared for consistency after each storm. The project manager will validate that stormwater samples were collected in accordance with the targeted volumetric increments for the sample period. The project manager will review all laboratory data to ensure that results fall within reasonable ranges for the parameters. The laboratory QA Officers will verify that laboratory water quality QC results are in compliance with acceptance criteria. At the discretion of the project manager, an alternative analytical laboratory may be sought if quality criteria are consistently exceeded.

Data and quality criteria will be assessed after each storm event, once all field data and analytical data are made available for review by the project manager. This review process will verify that:

- Data sets are complete;
- QC results accompany all analytical results and meet quality criteria;
- Questionable data (anomalous results, missing information) is identified;
- Methods set forth by this plan were followed.

The definition of quality data for this study shall be based upon the ability of the data to support the following outcomes:

1. Representative water quality data of the removal efficiencies for the parameters of TSS, TP, TN, Total Cu, Total Pb, and Total Zn for varying storm rainfall depths and runoff flow rates;
2. Representative hydraulic data of the anticipated infiltration rates versus driving head and reliable water balance data providing information on the relationships of flow inputs to outputs and indications, if any, of filter clogging over time.

Data Analysis

Removal efficiencies will be determined for each parameter for each sample period where water quality samples were collected. Pollutant removal efficiency will be calculated using the following equation to compute treatment efficiency:

*100 * [(flow-weighted influent concentration – flow-weighted effluent concentration) / flow-weighted influent concentration]*

All removal efficiencies for each sample event will be reported in this study. Pollutant removal efficiencies will be examined as a function of inflow concentration and inflow rate, i.e., concentration-based and mass loading-based removal efficiencies will be reported.

At a minimum, basic statistics for removal efficiencies (i.e., 95% confidence limits about the mean and median) will be developed in the statistical analysis. Descriptive statistics for the removal efficiencies with left-censored effluent data will be calculated by setting the censored effluent values to their respective reporting limits. Confidence Limits (95%) for removal efficiencies (both concentration-based and mass loading based) will be calculated using Probability Plots for sample data sets of $n < 20$ values and by bootstrapping for data sets of $n > 20$.

To assess statistical significance between influent and effluent water quality, all storm data, after 20 qualifying storm events, will be pooled to provide an adequate sample size to perform paired testing (to be reported in the final report). Since the inflows and outflows are not independent of each other, and stormwater water quality data typically has a skewed distribution (e.g., lognormal), non-parametric, paired testing using Wilcoxin signed rank-sum tests for significance will be performed for this study for data sets with uncensored data. If any of the effluent data have concentrations below the reporting limit, these data will be treated as left-censored data in paired group statistical comparisons. The “Sign Test” will be performed for paired data sets with censored effluent values. A Type I error of 5% will be used for the paired group comparisons.

Linear regression analysis will be performed after 20 qualifying storm events to assess the linear relationship between influent flow, independent variable, and removal efficiency, dependent variable. Regression will be performed per the TAPE protocol.

Reporting

Project progress and status shall be reported after 10 qualifying storm events in the form of an Interim Report prepared by CEC. The Interim Report shall contain a summary of verified field and laboratory data collected to date, a summary of observations, an assessment of progress towards project objectives, a narrative concerning the methods and any proposed changes, and recommendations for the continuation and the successful completion of the project. Project status relative to the desired outcomes given in the previous section shall be included in the Interim Report in order to agree upon continuation of the study or changes to the project methods and scope.

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Convergent Water Technologies. Retrieved on August 9, 2014 from http://www.convergentwater.com/

Technology Acceptance and Reciprocity Partnership (TARP). 2001. *Protocol for Stormwater Best Management Practice Demonstrations.*

US EPA. 2001. *EPA Requirements for Quality Assurance Project Plans. EPA QA/R-5.* EPA/240/B-01/003. Office of Environmental Information, Washington, DC.

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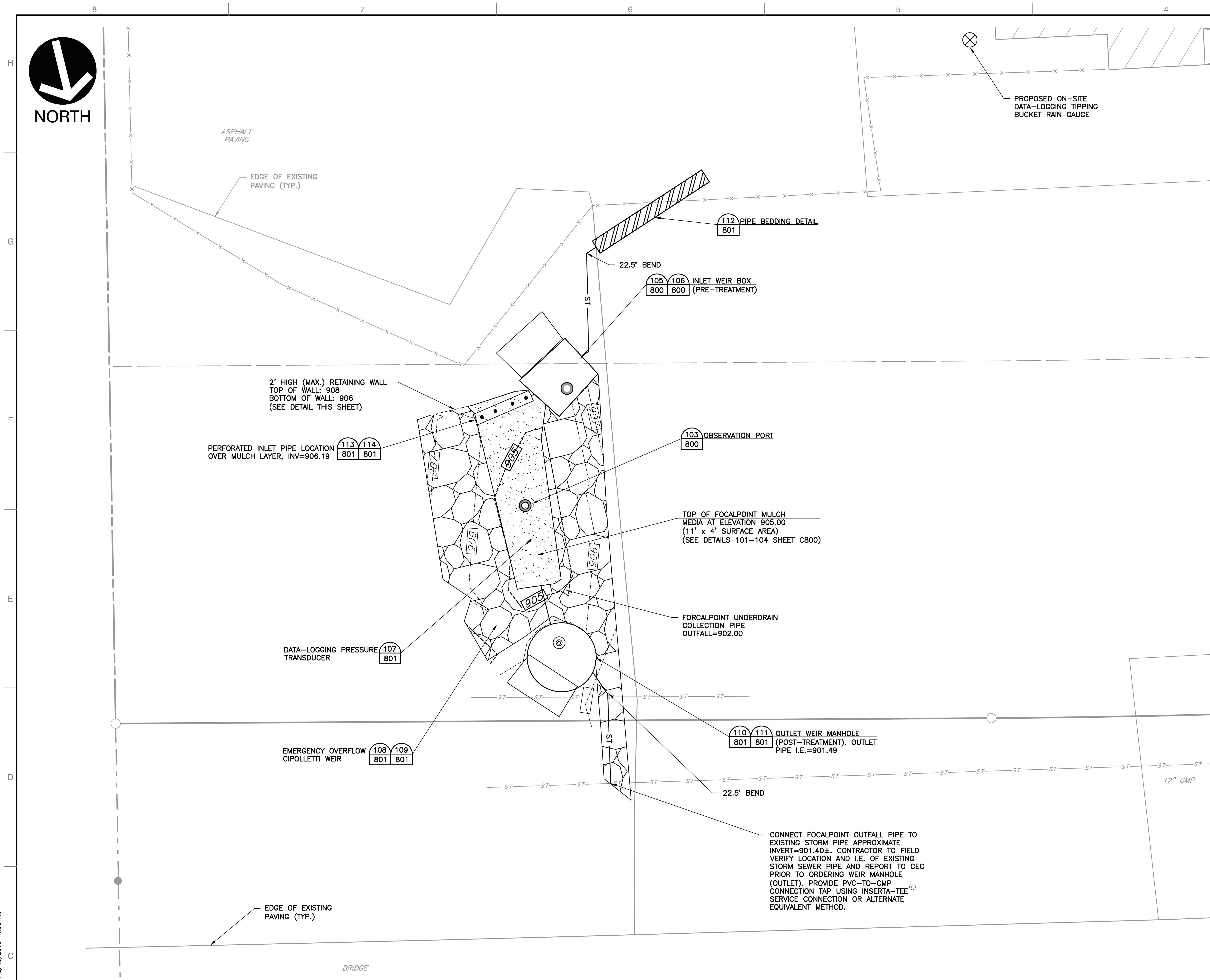
APPENDIX D

AS BUILT DRAWINGS OF STUDY AREA

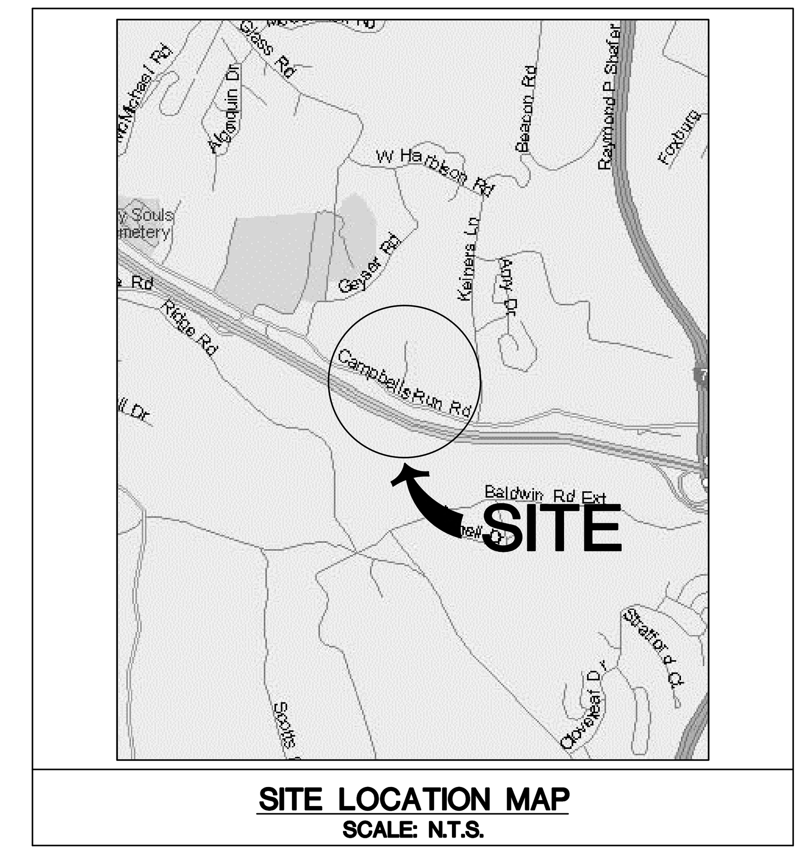


GRADING AND DRAINAGE PLAN

SCALE IN FEET
0 5' 10'

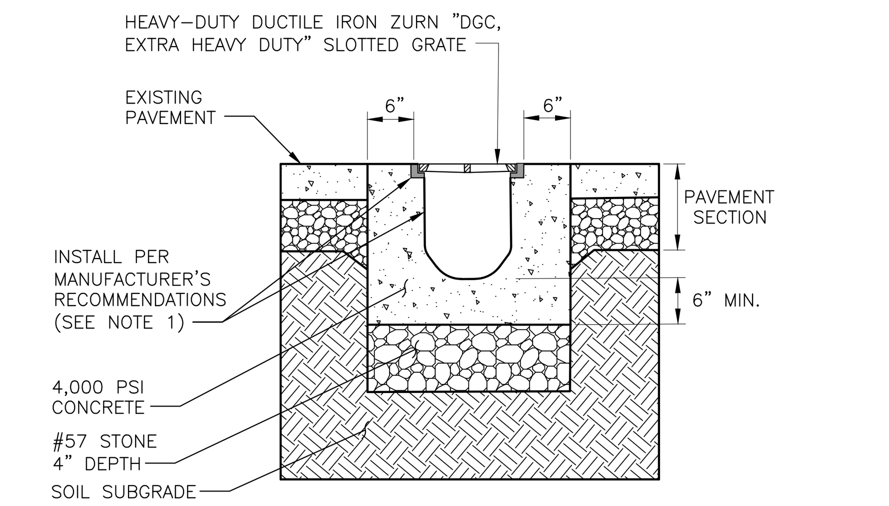
LEGEND

- EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- EXISTING GUIDE RAIL
- EXISTING OVERHEAD WIRE
- EXISTING STORM SEWER LINE
- EXISTING FENCE LINE
- EXISTING ASPHALT PAVEMENT
- EXISTING BUILDING
- EXISTING PARCEL LINE
- EXISTING SETBACK LINE
- TOWNSHIP LINE
- RIGHT-OF-WAY LINE
- AS-BUILT STORM SEWER LINE
- AS-BUILT SAMPLING PORT
- AS-BUILT RETAINING WALL
- AS-BUILT PIPE OUTFALL
- AS-BUILT TRENCH DRAIN
- AS-BUILT FOCALPOINT MEDIA



SITE LOCATION MAP

SCALE: N.T.S.

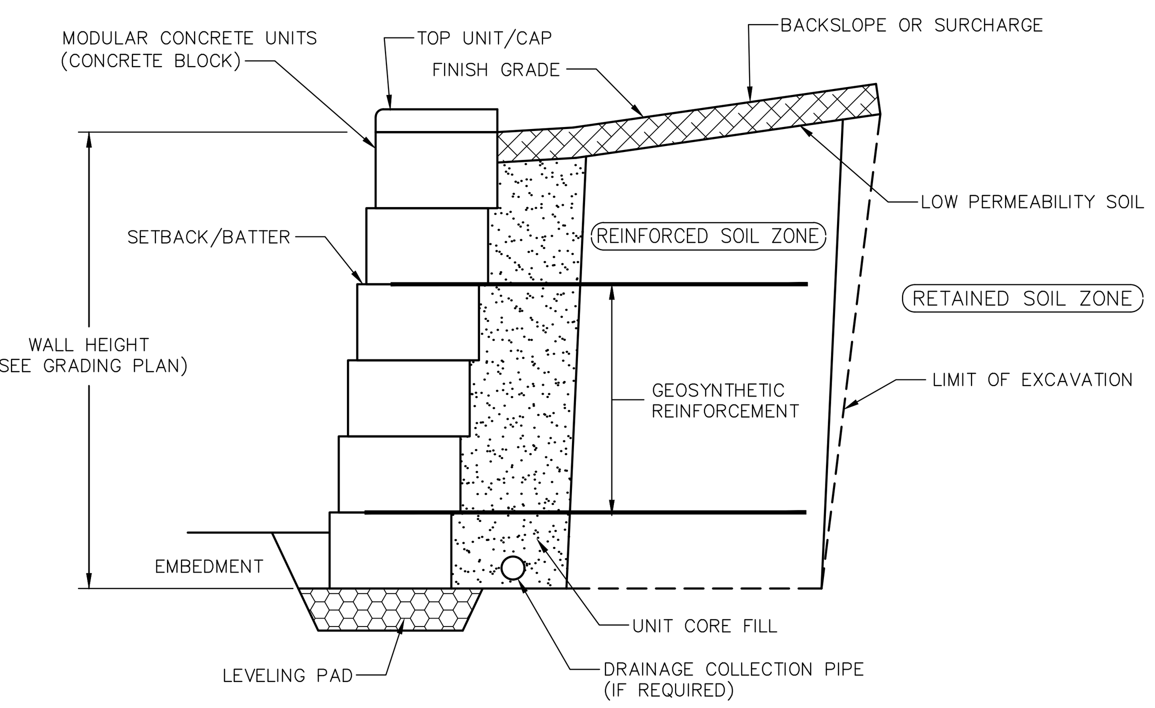


NOTES:

1. CONTRACTOR TO PROVIDE AND INSTALL ZURN "Z812 FLO-THRU" 12" FIBERGLASS TRENCH DRAIN SYSTEM AND ACCESSORIES.
2. PROVIDE 8" DIAMETER BOTTOM OUTLET AT LOCATION SHOWN ON THE PLAN. TRENCH DRAIN TO SLOPE TOWARDS BOTTOM OUTLET PER MANUFACTURER'S RECOMMENDATIONS.
3. PROVIDE WATERTIGHT ACCESSORIES FOR CONNECTIONS.

TRENCH DRAIN

NOT TO SCALE



NOTES:

1. WALL HEIGHT IS THE TOTAL HEIGHT FROM TOP TO BOTTOM.
2. MINIMUM WALL EMBEDMENT IS 6" OR HEIGHT DIVIDED BY 20.
3. SUBSURFACE SOILS MUST BE CAPABLE OF SUPPORTING WALL SYSTEM.
4. UNIT CORE FILL IS 3/4" CLEAN CRUSHED STONE.
5. LEVELING PAD IS CRUSHED STONE BASE MATERIAL.
6. ALL BACKFILL MATERIALS ARE COMPACTED TO 95% MAX. DENSITY.
7. GEOGRIDS MUST BE OF APPROPRIATE TYPE AND LENGTH PER THE DESIGN.
8. FINISHED GRADE MUST PROVIDE POSITIVE DRAINAGE.
9. WALLS OVER 4' HEIGHT TO BE DESIGNED BY AN ENGINEER AND SELECTED WALL MANUFACTURER.
10. WALL DESIGN/BUILD IS THE RESPONSIBILITY OF THE CONTRACTOR. DESIGN TO INCLUDE ALL CAPS, CORNERS, RETURNS, ADHESIVES, ETC., NECESSARY TO PROVIDE A COMPLETE WALL SYSTEM.

MODULAR CONCRETE UNIT RETAINING WALL WITH SOIL REINFORCEMENT DETAIL

NOT TO SCALE

CALL BEFORE YOU DIG!

PENNSYLVANIA LAW REQUIRES 3 WORKING DAYS NOTICE FOR CONSTRUCTION PHASE AND 10 WORKING DAYS IN DESIGN STAGE-STOP CALL PENNSYLVANIA ONE CALL SYSTEM, INC.
1-800-242-1776

PENNSYLVANIA ACT 38 (1991) REQUIRES NO LESS THAN 3 WORKING DAYS NOTICE NOR MORE THAN 10 WORKING DAYS NOTICE FROM EXCAVATORS WHO ARE ABOUT TO: DIG, DRILL, BLAST, AUGER, BORE, GRADE, TRENCH, OR DEMOLISH WHEN IN THE CONSTRUCTION PHASE. FOR LOCATION REQUESTS IN THE STATE OF PENNSYLVANIA, CALL TOLL FREE 1-800-242-1776.UNDERGROUND UTILITIES HAVE BEEN PLOTTED FROM AVAILABLE INFORMATION AND THE LOCATION MUST BE CONSIDERED APPROXIMATE, OTHER UNDERGROUND UTILITIES MAY EXIST WHICH ARE NOT SHOWN. IT WILL BE THE CONTRACTOR'S RESPONSIBILITY TO ASCERTAIN ALL PHYSICAL LOCATIONS OF UTILITY LINES PRIOR TO THE TIME OF CONSTRUCTION. IN NO WAY SHALL THE CONTRACTOR HOLD THE SURVEYOR RESPONSIBLE FOR ANY UTILITY LOCATION SHOWN ON THIS PLAN.

REFERENCE

1. PROPERTY IS LOCATED IN FLOOD ZONE AE BASE ELEVATIONS DETERMINED, ZONE X AREAS WITHIN 500 YEAR FLOOD AND 100 YEAR FLOOD WITH AVERAGE DEPTHS LESS THAN 1 FOOT AND ZONE X AREAS DETERMINED TO BE OUTSIDE 500 YEAR FLOODPLAIN, AS DEPICTED ON FLOOD INSURANCE RATE MAP 42003C0336 E, EFFECTIVE DATE OCTOBER 4, 1995 COUNTY, PENNSYLVANIA. THE FLOOD ZONE SHOWN ARE SCALED FROM THE F.I.R.M. COMMUNITY PANEL AND ARE APPROXIMATE.
2. FIELD TOPOGRAPHIC SURVEY WORK COMPLETED BY CIVIL & ENVIRONMENTAL CONSULTANTS, INC. DATED NOVEMBER 2014.

NOTE:

1. SYSTEM IS DESIGNED TO HANDLE UP TO 10 YR/24 HR STORM EVENT. STORM EVENT OF GREATER MAGNITUDE WILL PRODUCE RUNOFF THAT MAY BE PARTIALLY BYPASSED OVER THE PROPOSED TRENCH DRAIN AND WILL FLOW TO THE EXISTING TRENCH DRAIN @ SURFACE ELEVATION 905.71.
2. CONTRACTOR TO PROVIDE PLASTIC SHELTERS (2 TOTAL) FOR AUTOMATIC SAMPLERS AND FLOW METERS (PLASTIFAB, INC. OR EQUAL). POSITION SAMPLERS IMMEDIATELY ADJACENT TO WEIR BOX AND MANHOLE LOCATIONS.
3. PROVIDE TURF REINFORCEMENT MATTING BELOW EMERGENCY OVERFLOW WEIR OUTFALL TO PREVENT SCOUR. SEE DETAIL 109 SHEET 801.
4. SIDE SLOPES GRADED AROUND FOCALPOINT AREA SHALL BE @ 2(HOR): 1(VERT) MAX. CONTRACTOR SHALL BE RESPONSIBLE FOR STABILIZING ALL DISTURBED AREAS USING ENGINEER-APPROVED GRASS SEED MIXTURES, FERTILIZERS, AND APPROVED APPLICATION RATES. IN ADDITION, IT IS RECOMMENDED THAT THE DISTURBED AREAS BE COVERED WITH TEMPORARY EROSION CONTROL BLANKETS (LANDLOK S1 OR EQUAL) INSTALLED PER MANUFACTURER'S REQUIREMENTS.
5. CONTRACTOR SHALL BE RESPONSIBLE FOR PROVIDING AND INSTALLING ALL NECESSARY SEDIMENT CONTROL MEASURES TO PREVENT OFF-SITE TRANSPORT OF SEDIMENTS.
6. CONTRACTOR SHALL BE RESPONSIBLE FOR THE ACQUISITION OF ALL REQUIRED PERMITS FOR THIS PROJECT.

*HAND SIGNATURE ON FILE

REVISION RECORD

NO	DATE	DESCRIPTION

Civil & Environmental Consultants, Inc.
333 Baldwin Road · Pittsburgh, PA 15205
412-429-2324 · 800-365-2324
www.cecinc.com

ACF ENVIRONMENTAL
FOCAL POINT INSTALLATION
COLLIER TOWNSHIP
ALLEGHENY COUNTY, PENNSYLVANIA

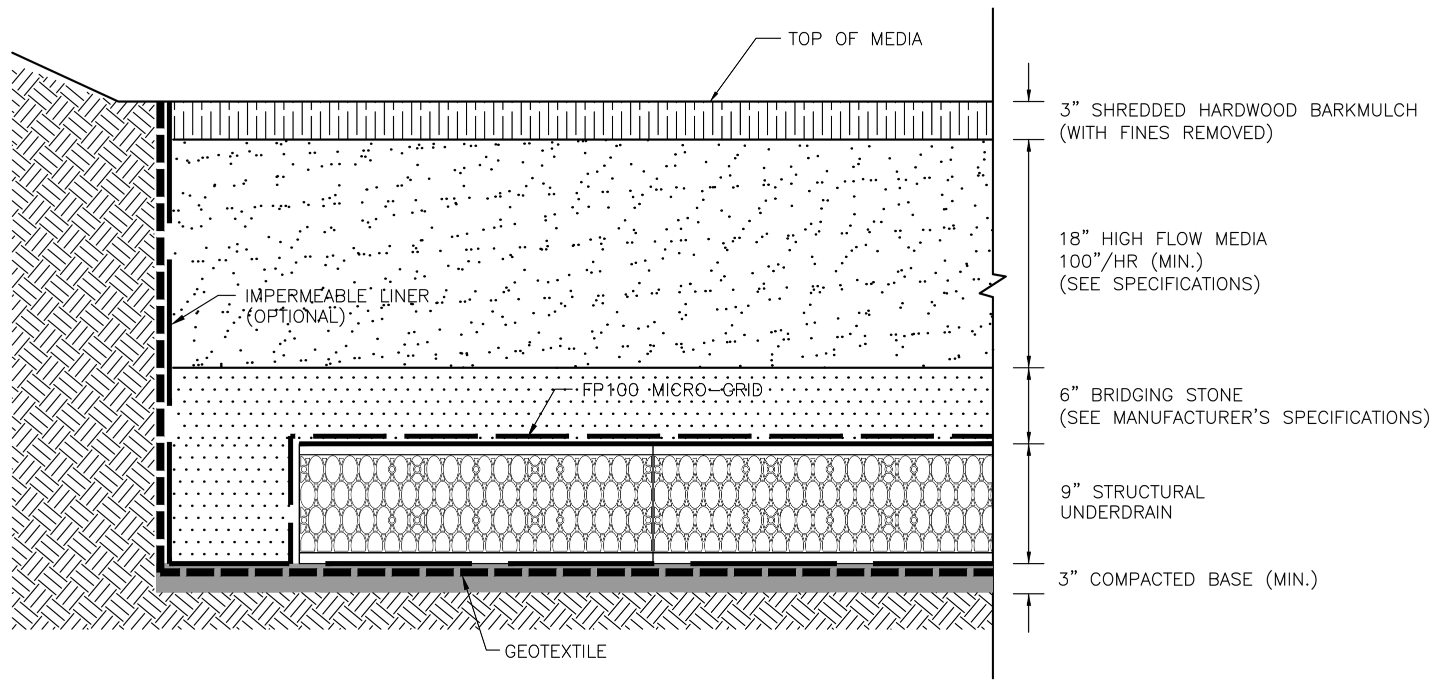
GRADING AND DRAINAGE PLAN

DATE:	JANUARY 21, 2015	DRAWN BY:	KLU
DWG SCALE:	1" = 5'	CHECKED BY:	BRB
PROJECT NO:	142-879.0005	APPROVED BY:	KBW*

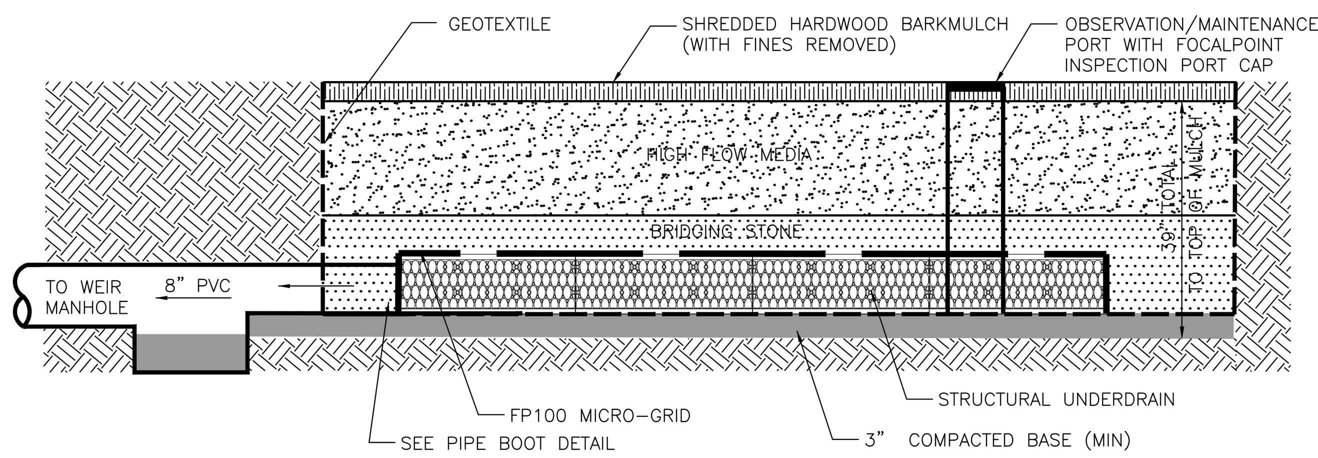
DRAWING NO.:
C300

P:\2014\142-879\-CADD\Dwg\CV01-Rain Garden Demo\AS-BUILT\142879-CV01-C300.dwg{C300}

NOTE:
CONTRACTOR TO INSTALL FOCALPOINT SYSTEM IN STRICT ACCORDANCE WITH MANUFACTURER'S REQUIREMENTS. (CONVERGENT WATER TECHNOLOGIES, INC.)

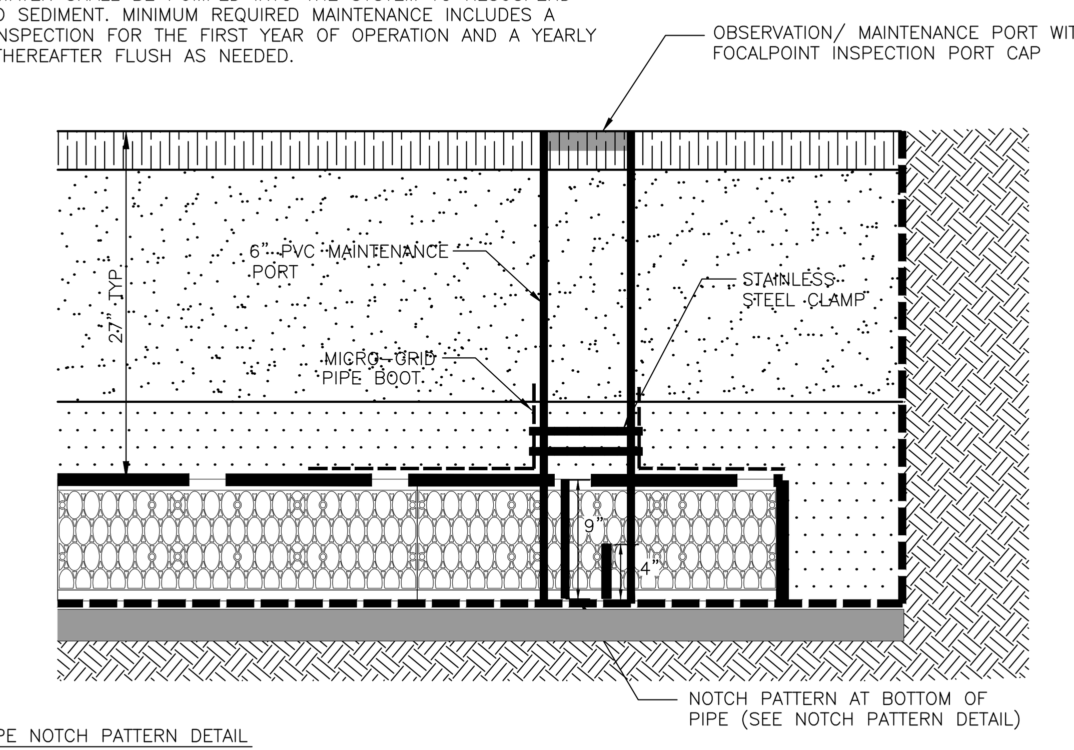


DETAIL 101
SECTION VIEW - FOCALPOINT SYSTEM
NOT TO SCALE

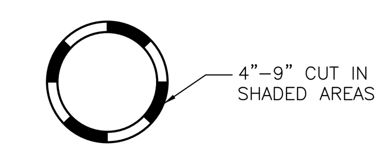


DETAIL 102
SECTION VIEW - FOCALPOINT SYSTEM
NOT TO SCALE

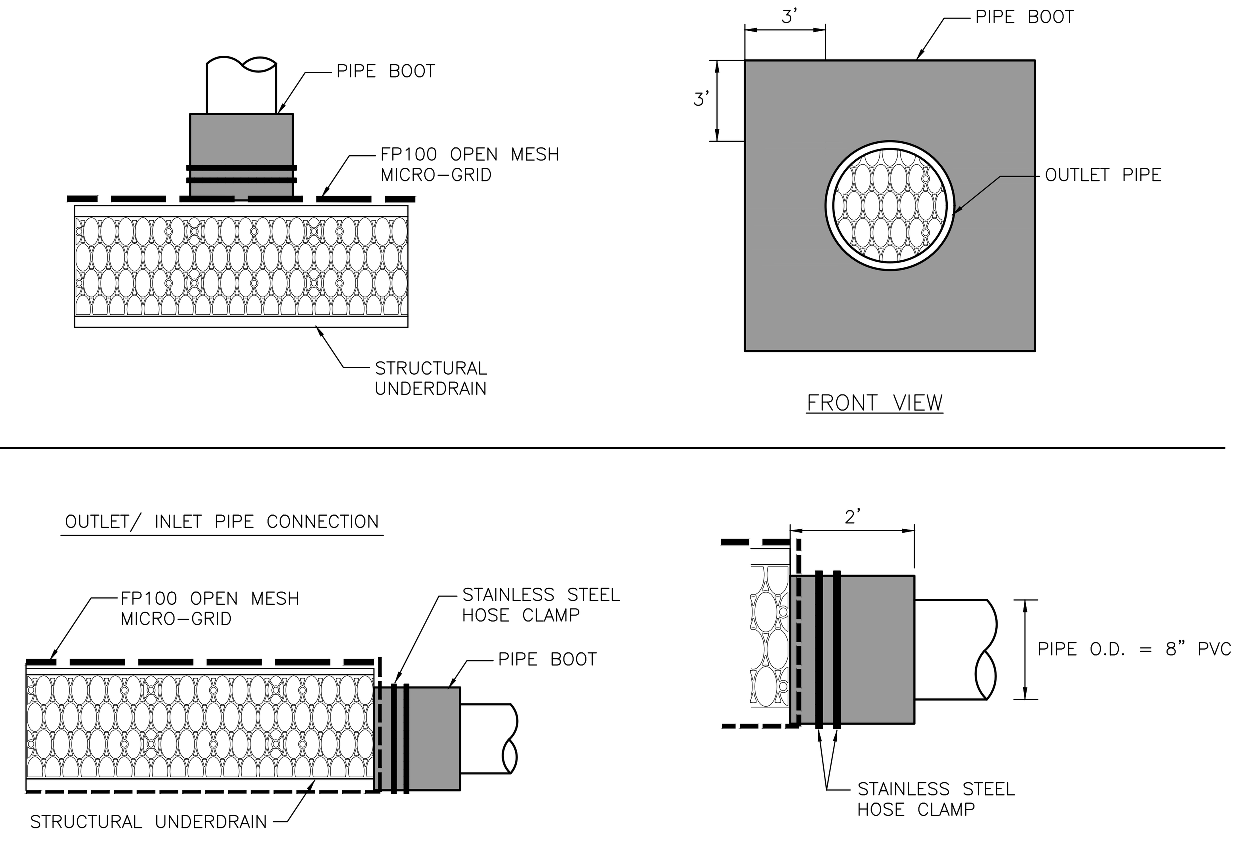
OBSERVATION/ MAINTENANCE PORT
PORT USED FOR INSPECTION PURPOSES AND FOR SYSTEM MAINTENANCE AS REQUIRED. WATER SHALL BE PUMPED INTO THE SYSTEM TO RESUSPEND ACCUMULATED SEDIMENT. MINIMUM REQUIRED MAINTENANCE INCLUDES A QUARTERLY INSPECTION FOR THE FIRST YEAR OF OPERATION AND A YEARLY INSPECTION THEREAFTER FLUSH AS NEEDED.



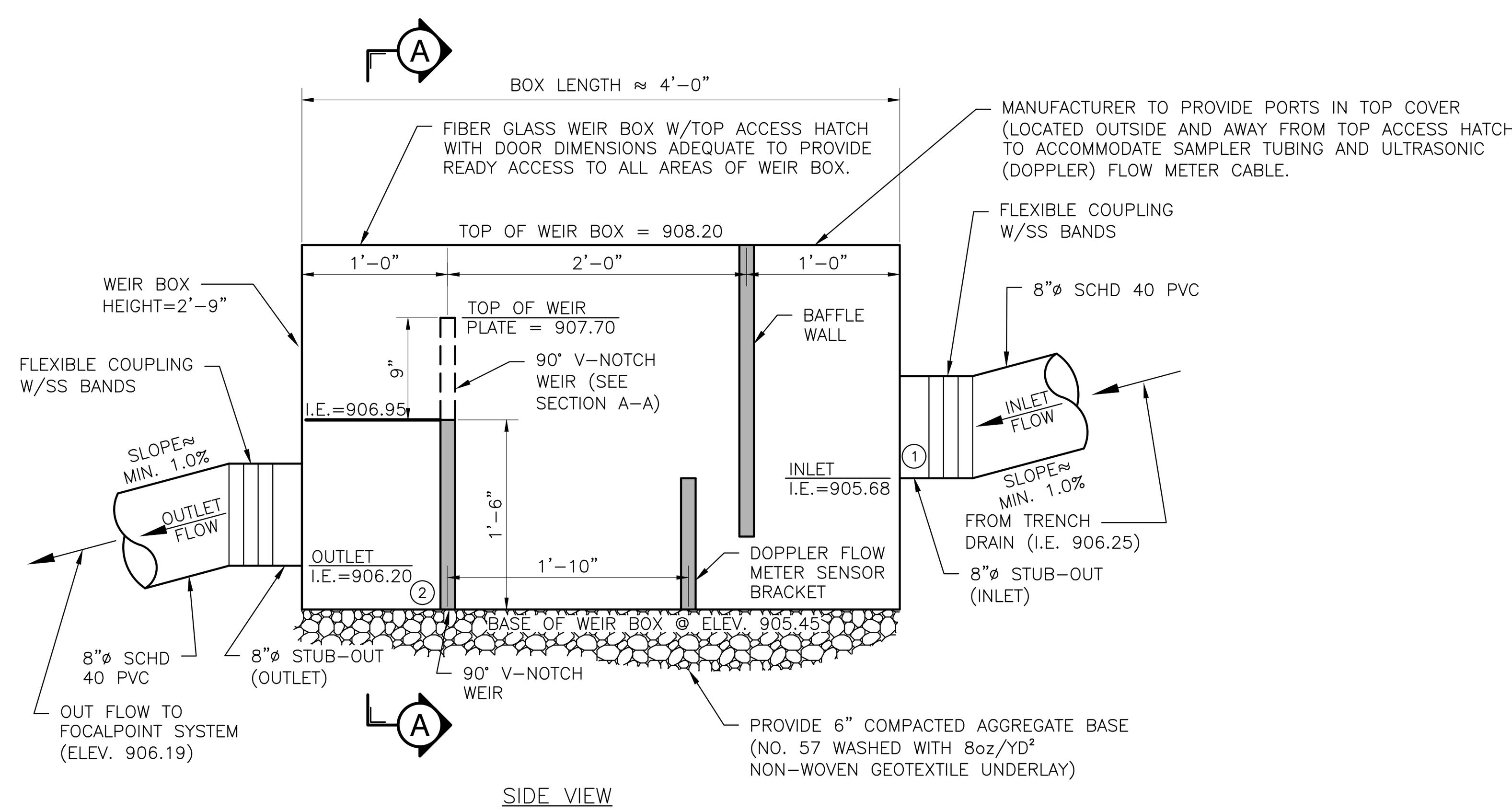
PIPE NOTCH PATTERN DETAIL



DETAIL 103
SECTION VIEW - OBSERVATION PORT
NOT TO SCALE



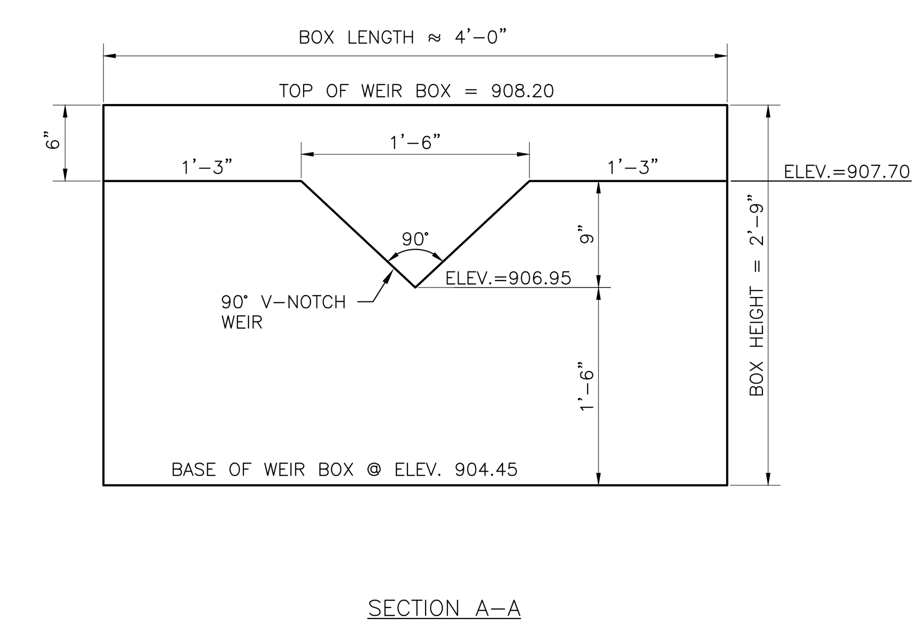
DETAIL 104
OBSERVATION PORT / CONNECTIONS / OUTLET AND INLET PIPE CONNECTIONS
NOT TO SCALE



NOTES:

1. PROVIDE FIBERGLASS WEIR BOX AS MANUFACTURED BY OPEN CHANNEL FLOW, INC. OR EQUAL.
2. INSTALL BOX ON A LEVEL GRADE AND PER MANUFACTURER'S REQUIREMENTS.
3. ISCO AUTOMATIC SAMPLER STRAINER TO BE LOCATED @ 1 OR 2.

DETAIL 105
SIDE VIEW-INLET WEIR BOX
NOT TO SCALE



NOTES:

1. FIBERGLASS WEIR BOX SHALL BE PRE-MANUFACTURED AS SHOWN BY OPEN CHANNEL FLOW, INC. OR EQUAL.

DETAIL 106
SECTION A-A: WEIR BOX
NOT TO SCALE

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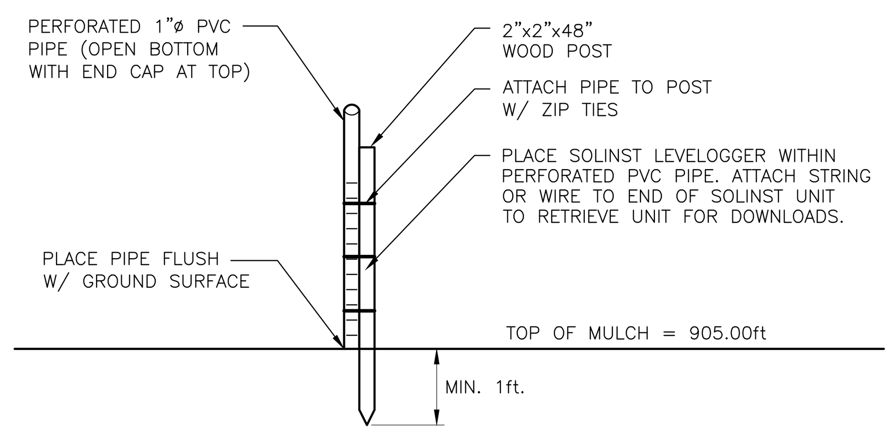
ACF ENVIRONMENTAL
FOCAL POINT INSTALLATION
COLLIER TOWNSHIP
ALLEGHENY COUNTY, PENNSYLVANIA

DETAILS

DATE:	JANUARY 21, 2015	DRAWN BY:	KLU
DWG SCALE:	N.T.S.	CHECKED BY:	BNB
PROJECT NO:	142-879.0005	APPROVED BY:	KBW*

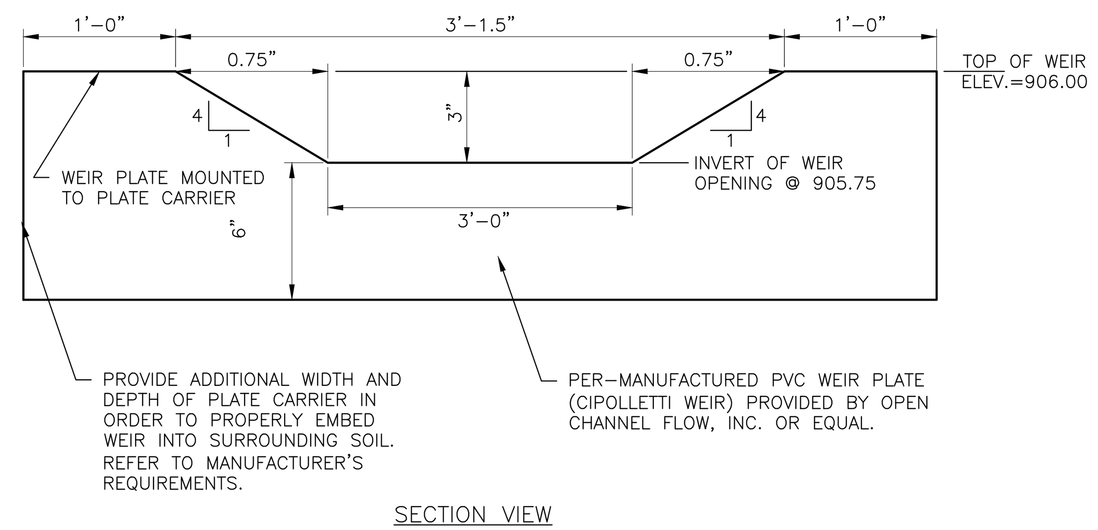
DRAWING NO.:
C800
SHEET OF



NOTES:

1. INSTALL SOLINST BAROLOGGER ON SITE (OUTSIDE OF POTENTIAL BACKWATER AREA). TO PROVIDE BAROMETRIC PRESSURE COMPENSATION FOR TRANSDUCER.

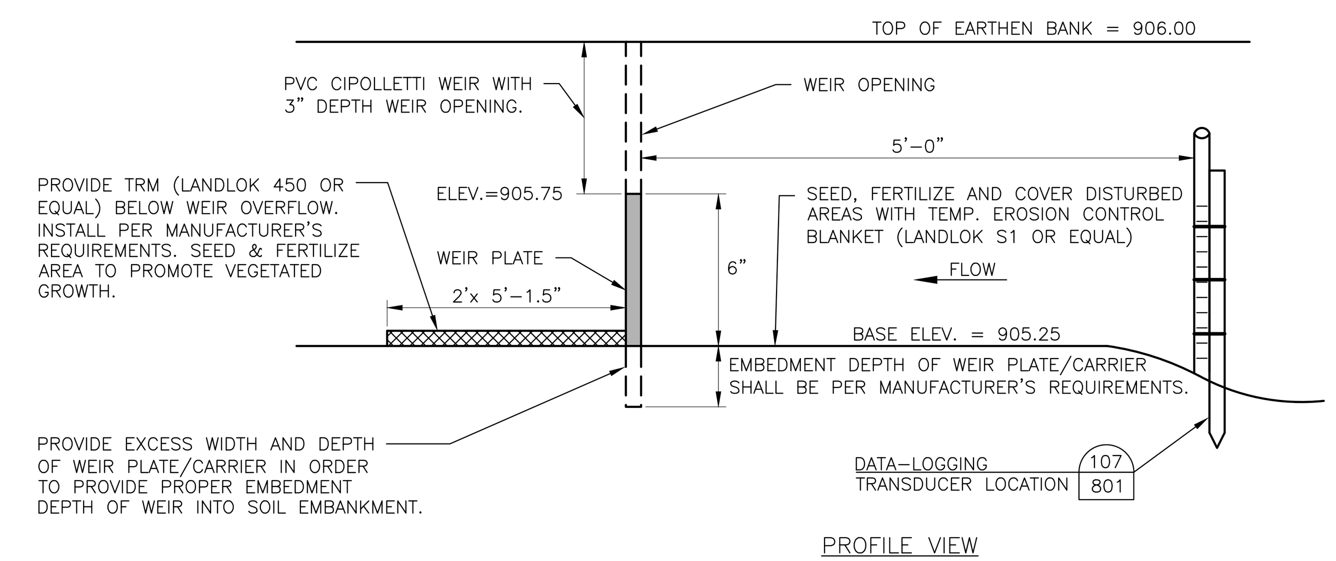
DETAIL 107
DATA-LOGGING PRESSURE TRANSDUCER
NOT TO SCALE



NOTES:

1. INSTALL PVC WEIR PLATE WITHIN EARTHWORK SPILLWAY, PROVIDING AN APPROACH CHANNEL THAT IS UNIFORM AND STRAIGHT FOR AT LEAST 3'-9" BEHIND THE PLATE WITH BASE ELEV.=905.25'
2. SET WEIR OPENING INVERT ≈ 6" ABOVE EARTH CHANNEL BASE ELEVATION.
3. WEIR SHALL BE INSTALLED LEVEL FROM FRONT-TO-BACK AND SIDE-TO-SIDE.
4. PROVIDE VEGETATED TRM SPLASH AREA BELOW WEIR OUTLET (SEE DETAIL 109 THIS SHEET)

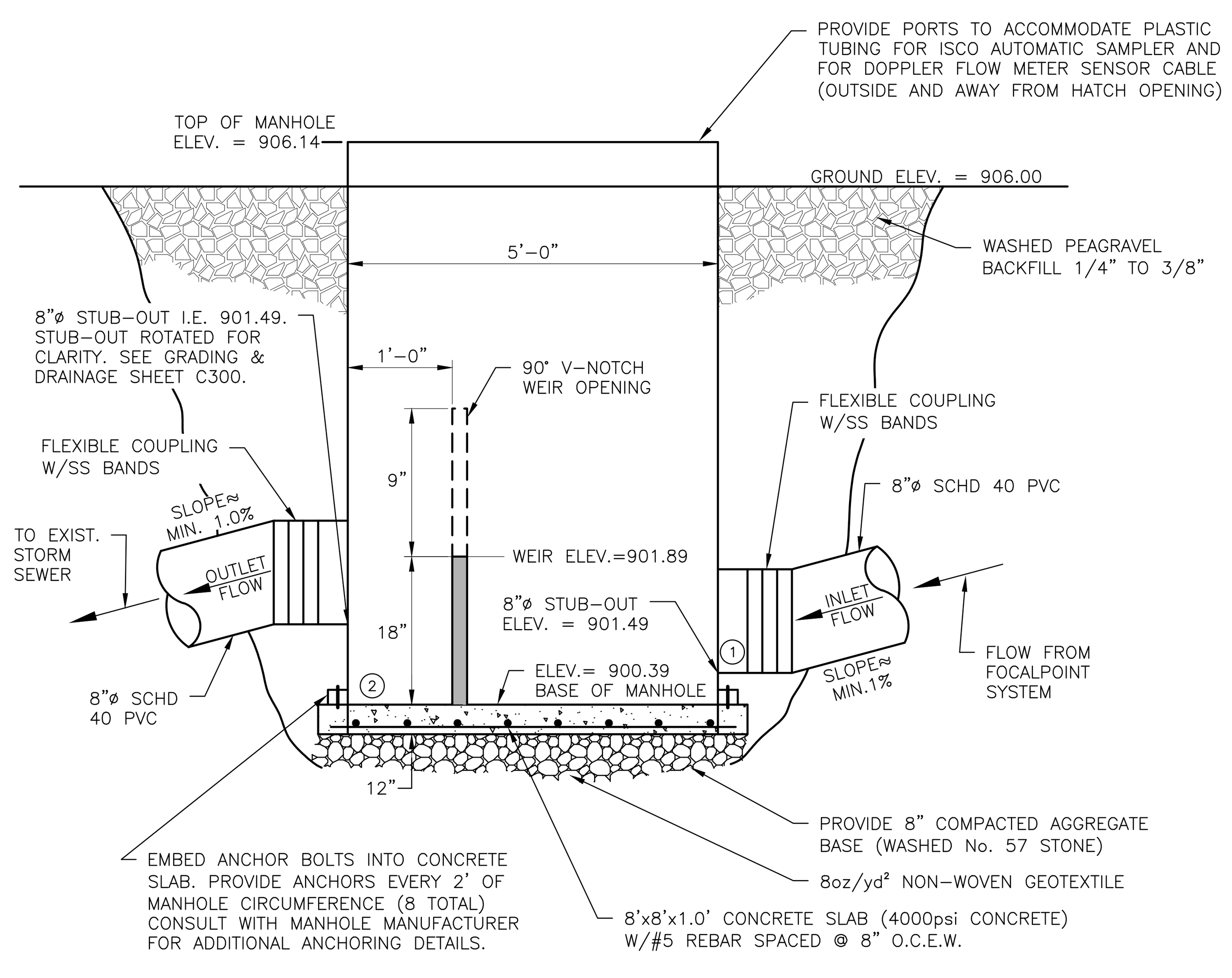
DETAIL 108
EMERGENCY CIPOLLETTI OVERFLOW WEIR
NOT TO SCALE



NOTE:

1. REFER TO NOTES ON 108/801

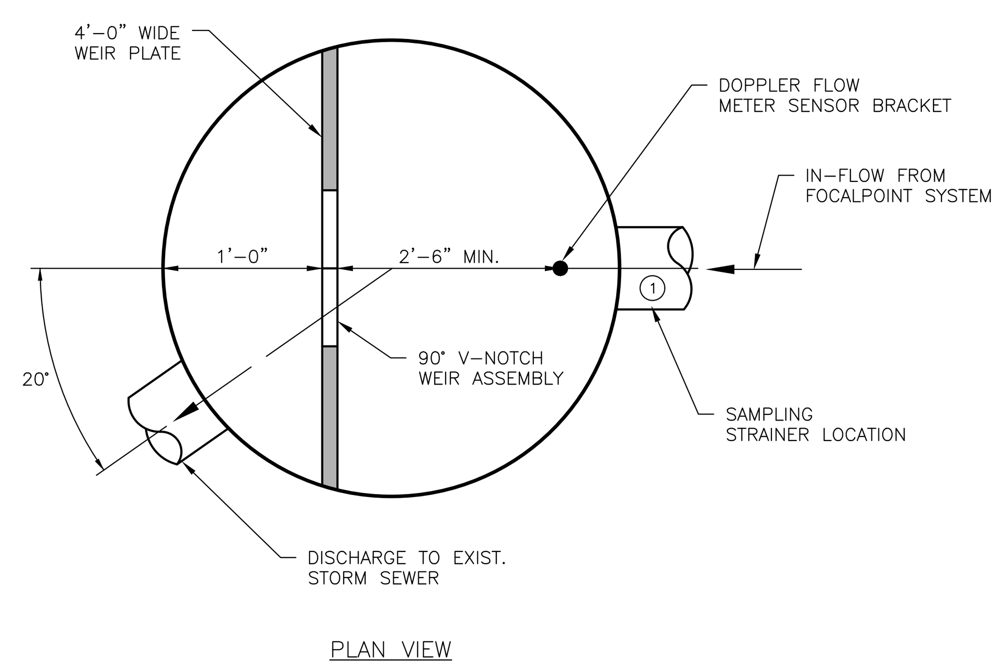
DETAIL 109
PROFILE-EMERGENCY OVERFLOW WEIR (CIPOLLETTI)
NOT TO SCALE



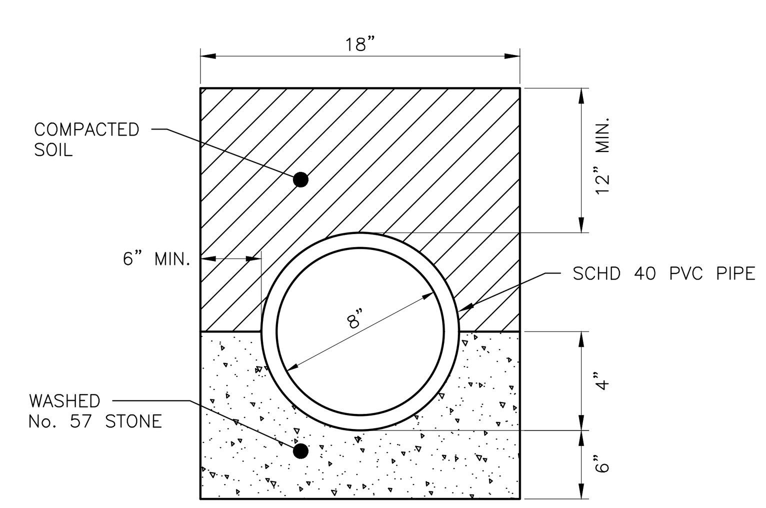
NOTES:

1. PROVIDE WEIR MANHOLE AS MANUFACTURED BY FABCO, OR EQUAL.
2. INSTALL MANHOLE ON A LEVEL GRADE AND PER MANUFACTURER'S REQUIREMENTS.
3. FOR TRENCHING DEPTHS GREATER THAN 5-FEET, CONTRACTOR SHALL PROVIDE SHORING TO PREVENT TRENCH COLLAPSE DURING CONSTRUCTION.
4. SLAB MUST BE LEVEL AND FREE OF EXPOSED AGGREGATE. PLACE FOAM PAD OVER CONCRETE SLAB WHERE MANHOLE WILL REST (FOAM PAD PROVIDED BY MANHOLE MANUFACTURER).
5. PLACE STRAINER FOR ISCO SAMPLER INTO INLET PIPE AT 1 OR 2; INSTALL DOPPLER FLOW METER SENSOR 2'-6" BEHIND WEIR LOCATION.
6. BACKFILL SHALL BE PLACED EVENLY AROUND MANHOLE IN LIFTS OF NO MORE THAN 12". COMPACT BACKFILL TO 85% OF STANDARD PROCTOR DENSITY.

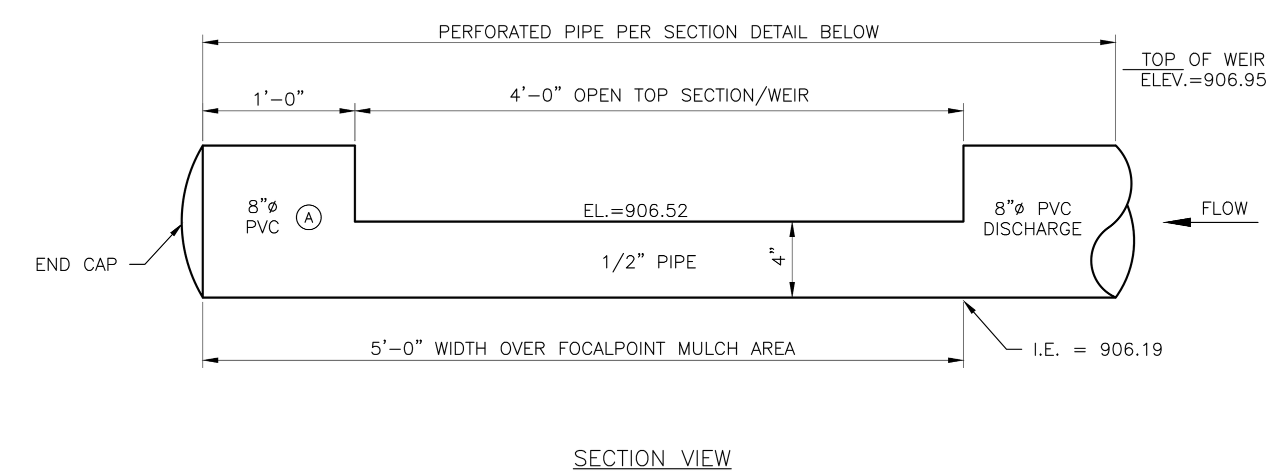
DETAIL 110
OUTFLOW WEIR MANHOLE (6'ø)
NOT TO SCALE



DETAIL 111
OUTFLOW MANHOLE WEIR
NOT TO SCALE



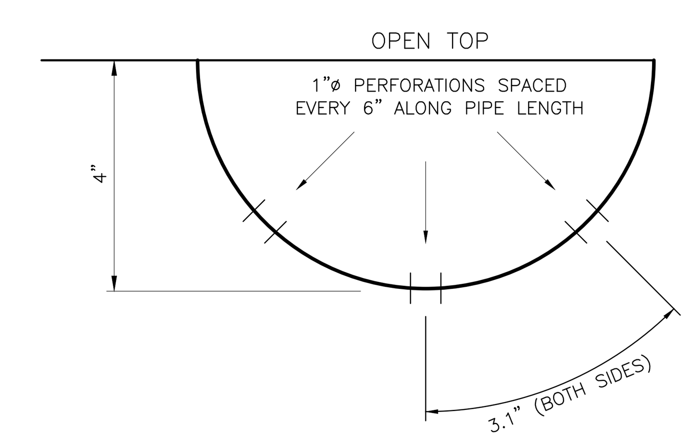
DETAIL 112
PIPE BEDDING DETAIL
NOT TO SCALE



NOTES:

1. MAINTAIN PIPE AT LEVEL GRADE, ELEV. 906.19
2. STAKE DOWN END OF PIPE RUN TO ANCHOR IN PLACE (POINT "A")

DETAIL 113
PROFILE VIEW - PERFORATED PIPE DISCHARGE AT FOCALPOINT MEDIA
NOT TO SCALE



DETAIL 114
SECTION DETAIL - PERFORATED PIPE DISCHARGE AT FOCALPOINT MEDIA
NOT TO SCALE

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NO	DATE	DESCRIPTION

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ACF ENVIRONMENTAL
FOCAL POINT INSTALLATION
COLLIER TOWNSHIP
ALLEGHENY COUNTY, PENNSYLVANIA

DETAILS

DATE:	JANUARY 21, 2015	DRAWN BY:	KLU
DWG SCALE:	N.T.S.	CHECKED BY:	BNB
PROJECT NO:	142-879.0005	APPROVED BY:	KBW*

DRAWING NO.: C801
SHEET OF

APPENDIX E

PHOTOLOG

Photo Number: 1

Description: As Built Site Conditions

Date Taken: 7/21/2015

Photo Number: 2

Description: As Built Site Conditions

Date Taken: 7/21/2015

Photo Number: **3**

Description: **As Built Site Conditions**

Date Taken: **7/21/2015**

Photo Number: **4**

Description: **Event 6 Sample Containers**

Date Taken: **10/29/2015**

Photo Number: 5
Description: Event 6 Effluent Sample Bottles
Date Taken: 10/29/2015

Photo Number: 6
Description: Event 7 Influent Container
Date Taken: 11/6/2015

Photo Number: 7

Description: Event 7 Effluent Container

Date Taken: 11/6/2015

Photo Number: 8

Description: Event 7 Sample Containers

Date Taken: 11/6/2015

Civil & Environmental Consultants, Inc.
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Feild Evaluation of FocalPoint HPMBS

Client Name: ACF Environmental

Project Number: 142-879

Photo Number: 9
Description: Event 7 Influent and Effluent Sample Bottles
Date Taken: 11/6/2015

Photo Number: 10
Description: Event 7 Effluent ISCO Sampler
Date Taken: 11/6/2015

CEC
Civil & Environmental Consultants, Inc.
Pittsburgh, PA 15205
Phone: 800-365-2324
www.cecinc.com

Feild Evaluation of FocalPoint HPMBS

Client Name: ACF Environmental

Project Number: 142-879

Photo Number: **11**

Description: **Event 7 Conditions Post Event**

Date Taken: **11/6/2015**

Photo Number: **12**

Description: **Event 8 Sample Containers**

Date Taken: **11/10/2015**

Civil & Environmental Consultants, Inc.

Pittsburgh, PA 15205

Phone: 800-365-2324

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Feild Evaluation of FocalPoint HPMBS

Client Name: ACF Environmental

Project Number: 142-879

Photo Number: 13

Description: Event 9 During Rain Event

Date Taken: 12/14/2015

Photo Number: 14

Description: Event 9 Influent Container

Date Taken: 12/15/2015

Photo Number: 15
Description: Event 9 Influent Container
Date Taken: 12/15/2015

Photo Number: 16
Description: Event 9 Effluent Container
Date Taken: 12/15/2015

Photo Number: **17**

Description: **Event 9 Effluent Container**

Date Taken: **12/15/2015**

Photo Number: **18**

Description: **Event 9 Post Rain Event**

Date Taken: **12/15/2015**

Photo Number: 19
Description: Event 9 Sample Bottles
Date Taken: 12/15/2015

Photo Number: 20
Description: Event 10 Containers
Date Taken: 12/18/2015

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Feild Evaluation of FocalPoint HPMBS

Client Name: ACF Environmental

Project Number: 142-879

Photo Number: 21

Description: Event 10 Influent Sample Bottles

Date Taken: 12/18/2015

Photo Number: 22

Description: Event 10 Effluent Sample Bottles

Date Taken: 12/18/2015

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Feild Evaluation of FocalPoint HPMBS

Client Name: ACF Environmental

Project Number: 142-879

Photo Number: 23

Description: Event 12 Containers

Date Taken: 12/29/2015