NJCAT TECHNOLOGY VERIFICATION

JELLYFISH® FILTER

Imbrium Systems Corporation

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1. Introduction

1.1 New Jersey Corporation for Advance Technology (NJCAT) Program

NJCAT is a not-for-profit corporation to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization;
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated;
- Facilitate funding and commercial relationships/alliances to bring new technologies to market and new business to the state; and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. Thus, suppliers have the competitive edge of an independent third party confirmation of claims.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) the New Jersey Department of Environmental Protection (NJDEP) and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies that the technology meets the regulatory intent and that there is a net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter into reciprocal environmental technology agreements concerning the evaluation and verification protocols with the United States Environmental Protection Agency, other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

- The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the Energy and Environment Technology Verification Program.

1.2 Interim Certification

Imbrium Systems Corporation (Imbrium) is a leading provider of innovative stormwater treatment solutions, offering a variety of products, maintenance, laboratory, and engineering support to meet stormwater treatment needs. Imbrium's patented product, the Jellyfish® Filter, is a Best Management Practice (BMP) designed to meet federal, state, and local requirements for treating stormwater runoff in compliance with the 1972 Clean Water Act and NPDES Stormwater Amendments, and phosphorus TMDLs in critical or impaired watersheds. The Jellyfish® Filter is typically comprised of a manhole or vault configuration that houses a cartridge deck and multiple high surface area membrane filtration cartridges. The Jellyfish® Filter improves the quality of stormwater runoff before it enters receiving waterways through a combination of hydrodynamic separation pre-treatment followed by filtration to provide enhanced solids removal. (See Section 2 for an additional description of the technology.)

Imbrium received New Jersey Corporation for Advanced Technology (NJCAT) verification of claims for the Jellyfish® Filter in June 2008 and a Conditional Interim Certification was issued by NJDEP in February of 2009. A major condition of this Conditional Interim Certification was the execution of a field evaluation in accordance with the TARP Tier II Protocol (TARP, 2003) and New Jersey Tier II Stormwater Test Requirements—Amendments to TARP Tier II Protocol (NJDEP, 2006). Conditional Interim Certification was extended in September of 2011. A Quality Assurance Project Plan for the Field Evaluation was completed in May of 2010, resulting in the commencement of monitoring activities. The TARP Tier II Protocol is designed to evaluate Total Suspended Solids (TSS) removal on an annual basis. While other pollutant removal efficiencies may be measured during TARP Tier II testing they are not part of the protocol.

1.3 Applicant Profile

Imbrium Systems Corporation, 7564 Standish Place, Suite 112, Rockville, MD 20855, has been actively engaged in the stormwater treatment industry since the introduction of its Stormceptor® product in 1992. Originally established as the Stormceptor Group of Companies, in 2006 the company changed its name to Imbrium Systems. This name change was implemented as the company expanded research and development to deliver new technologies to the stormwater treatment industry.

Imbrium Systems is a global company with U.S. headquarters (Imbrium Systems Corporation) located in Rockville, Maryland and Canadian and International headquarters (Imbrium Systems Incorporated and Imbrium International Limited) located in Toronto, Ontario, Canada, with satellite offices located across North America.

Imbrium Systems is a wholly-owned business of Monteco Ltd. Monteco is a privately-held company headquartered in Toronto, Ontario which focuses on developing innovative clean-tech solutions for application in the air, water and energy industry sectors. Monteco supports its businesses with centralized corporate services including research & development, public relations, government affairs, marketing and communication, human resources and finance.

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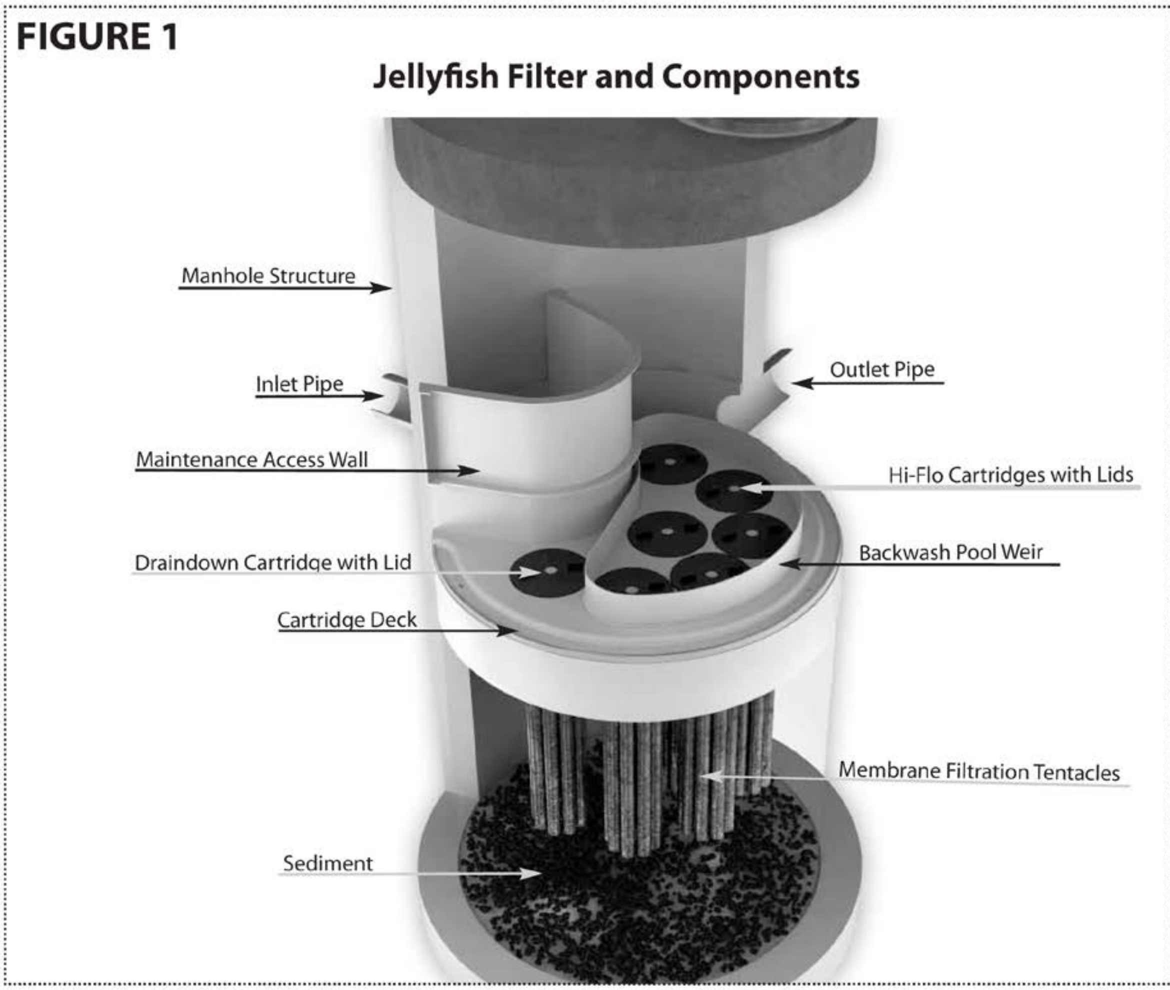
2. The Jellyfish® Filter

The Jellyfish® Filter is an engineered stormwater quality treatment technology that utilizes multiple lightweight membrane filtration cartridges in a compact stand-alone treatment system that removes a high level and wide variety of stormwater pollutants. The Jellyfish® Filter integrates pre-treatment and filtration with passive self-cleaning mechanisms. The system utilizes membrane filtration cartridges with very high filtration surface area and flow capacity, which provide the advantages of high sediment capacity and low filtration flux rate (flow per unit surface area) at relatively low driving head compared to conventional filter systems. Figure 1 shows the Jellyfish® Filter and its major components.

The cartridge deck contains a receptacle for each filter cartridge. The cartridge is lowered down into the receptacle such that the cartridge head plate and rim gasket rest on the lip of the receptacle. A cartridge lid is fastened onto the receptacle to anchor the cartridge. Each cartridge lid contains a flow control orifice. The orifice in the hi-flo cartridge lid is larger than the orifice in the draindown cartridge lid.

Jellyfish® Filter cartridges are designated as either hi-flo cartridges or draindown cartridges, depending on their placement position within the cartridge deck. Cartridges placed within the 6-inch (150 mm) high backwash pool weir that extends above the deck are automatically passively backwashed after each storm event and are designated as the hi-flo cartridges. Cartridges placed outside the backwash pool weir are not passively backwashed but facilitate the draindown of the backwash pool, and these are designated as the draindown cartridges. The design flow rate of a draindown cartridge is controlled by a cartridge lid orifice to one-half the design flow rate of a hi-flo cartridge of similar length. The lower design flow rate of the draindown cartridge reduces the likelihood of occlusion prior to scheduled maintenance.

Figure 1 Jellyfish® Filter and Components



Note: Separator Skirt Not Shown

Each cartridge consists of multiple removable filter elements ("filtration tentacles") attached to a cartridge head plate. Each filtration tentacle consists of a central perforated tube surrounded by a specialized membrane. The cylindrical filtration tentacle has a threaded pipe nipple at the top and is sealed at the bottom with an end cap. A cluster of tentacles is attached to a stainless steel head plate by inserting the top pipe nipples through the head plate holes and securing with removable nuts. A removable oil-resistant polymeric rim gasket is attached to the head plate to impart a watertight seal when the cartridge is secured into the cartridge receptacle with the cartridge lid. The cartridge length is typically either 27 inches (686 mm) or 54 inches (1372 mm), with options for custom lengths if required. A Jellyfish membrane filtration cartridge is depicted in Figure 2.

Figure 2 Jellyfish® Membrane Filtration Cartridge

FIGURE 2

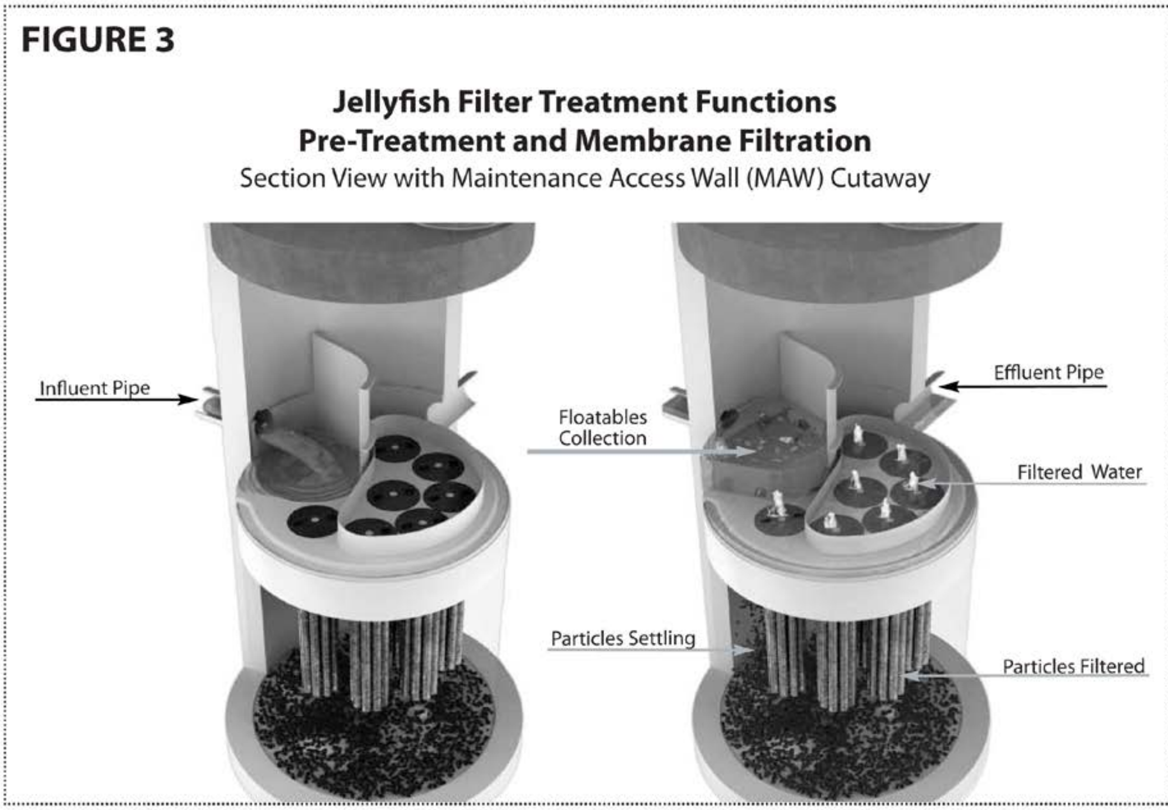
Jellyfish Membrane Filtration Cartridge

The filtration tentacle membranes provide an extremely large amount of surface area, resulting in outstanding flow capacity and suspended sediment removal capacity. A typical Jellyfish cartridge with eleven 54-inch (1372 mm) long filtration tentacles has 381 ft2 (35.4 m2) of membrane surface area. Hydraulic testing on a clean 54-inch (1372 mm) filter cartridge is discussed in **Appendix B**. In addition, the filtration tentacle membrane has anti-microbial characteristics to inhibit the growth of bio-film that might otherwise prematurely occlude the pores of the membrane and restrict hydraulic conductivity.

Inflow events with driving head ranging from less than 1 inch (25 mm) up to the maximum design driving head will cause continuous forward flow and filtration treatment through the draindown cartridges. Inflow events with driving head that exceeds the 6-inch (150 mm) height of the backwash pool weir will cause continuous forward flow and filtration treatment through the hi-flo cartridges. Typically, a minimum 18 inches (457 mm) of driving head is designed into the system but may vary from 12 to 24 inches (305 to 610 mm) depending on specific site requirements.

The Jellyfish® Filter provides both pre-treatment and membrane filtration treatment to remove pollutants from stormwater runoff. These functions are depicted in Figure 3 below.

Figure 3 Jellyfish® Filter Treatment Functions



Pre-treatment removes coarse sediment (particles generally > 50 microns), particulate-bound pollutants attached to coarse sediment (nutrients, toxic metals, hydrocarbons), free oil and floatable trash and debris. These pollutants are removed by gravity separation. Large, heavy particles fall to the sump (sedimentation) and low density pollutants rise to the surface (floatation) within the pre-treatment channel.

Membrane filtration treatment removes suspended particulates (generally < 50 microns) and particulate-bound pollutants (nutrients, toxic metals, hydrocarbons, and bacteria). Laboratory and field performance testing of the Jellyfish® Filter have demonstrated capture of particulates as small as 2 microns. As a layer of sediment builds up on the external membrane surface, membrane pores are partially occluded which serves to reduce the effective pore size. This process, referred to as "filter ripening", significantly improves the removal efficiency of pollutants relative to a brand new or clean membrane. Filter ripening accounts for the ability of the Jellyfish® Filter to remove particles finer than the nominal pore size rating of the membranes.

The Jellyfish® Filter utilizes several self-cleaning processes to remove accumulated sediment from the external surfaces of the filtration membranes, including automatic passive backwash of the hi-flo cartridges, vibrational pulses, and gravity. Combined, these processes extend the cartridge service life and maintenance interval and reduce life-cycle costs.

Automatic passive backwash is performed on the hi-flo cartridge at the end of each runoff event and can also occur multiple times during a single storm event as intensity and driving head varies. During inflow, filtered water exiting the hi-flo cartridges forms a pool above the cartridge deck inside the backwash pool weir. The depth and volume of the back wash pool will vary with the available driving head, ranging from some minimal quantity up to a quantity sufficient to fill and overflow the backwash pool (typical weir height is 6 inches / 150 mm). As the inflow event subsides and forward driving head decreases, water in the backwash pool reverses flow direction and automatically passively backwashes the hi-flo cartridges, removing sediment from the membrane surfaces. Water in the lower chamber (below deck) is displaced through the draindown cartridges.

Vibrational pulses occur as a result of complex and variable pressure and flow direction conditions that arise in the space between the top surface of the cartridge head plate and the underside of the cartridge lid. During forward flow a stream of filtered water exits the top of each filtration tentacle into this space and encounters resistance from the cartridge lid and turbulent pool of water within the space. Water is forced through the cartridge lid flow control orifice with a pulsating fountain effect. The variable localized pressure causes pulses to transmit vibrations to the membranes, thereby dislodging accumulated sediment. The effect appears more pronounced at higher flow rates, and applies to both hi-flo and draindown cartridges.

Gravity continuously applies a force to accumulated sediment on the membranes, both during inflow events and inter-event dry periods. As fine particles agglomerate into larger masses on the membrane surface, adhesion to the membrane surface can lessen, and a peeling effect ensues which ultimately results in agglomerates falling away from the membrane. Complex chemical and biological effects may also play a role in this process.

Standard Models

The Jellyfish® Filter standard model numbers provide information about the manhole inside diameter (expressed in U.S. customary units) and cartridge counts for hi-flo and draindown cartridges. For example, Jellyfish Filter model number JF6-4-1 is a 6-ft diameter manhole with four hi-flo cartridges and one draindown cartridge. Standard model numbers assume the use of 54-inch (1372 mm) long cartridges. Specific designations for non-standard structures or cartridge lengths are noted in the Jellyfish Filter Owner's Manual published by Imbrium Systems and provided to system owners. For the field test that is the subject of this report a Jellyfish Filter JF4-2-1 was used, which is a 4-ft diameter manhole with two 54-inch long hi-flo cartridges and one 54-inch long draindown cartridge.

Design flow capacities and pollutant capacities for standard Jellyfish Filter manhole configurations are shown in Tables 1 and 2.

Table 1 Design Flow Capacities - Standard Jellyfish® Filter Configurations

Manhole Diameter (ft / m) [1]	Model No.	Hi-Flo Cartridges [2] 54 in / 1372 mm	Draindown Cartridges [2] 54 in / 1372 mm	Treatment Flow Rate (gpm / cfs)	Treatment Flow Rate (L/s)
Catch Basin		varies	varies	varies	varies
4 / 1.2	JF4-2-1	2	1	200 / 0.45	12.6
6 / 1.8	JF6-3-1	3	1	280 / 0.62	17.7
	JF6-4-1	4	1	360 / 0.80	22.7
	JF6-5-1	5	1	440 / 0.98	27.8
	JF6-6-1	6	1	520 / 1.16	32.8
8 / 2.4	JF8-6-2	6	2	560 / 1.25	35.3
	JF8-7-2	7	2	640 / 1.43	40.4
	JF8-8-2	8	2	720 / 1.60	45.4
	JF8-9-2	9	2	800 / 1.78	50.5
	JF8-10-2	10	2	880 / 1.96	55.5
10 / 3.0	JF10-11-3	11	3	1000 / 2.23	63.1
	JF10-12-3	12	3	1080 / 2.41	68.1
	JF10-12-4	12	4	1120 / 2.50	70.7
	JF10-13-4	13	4	1200 / 2.67	75.7
	JF10-14-4	14	4	1280 / 2.85	80.8
	JF10-15-4	15	4	1360 / 3.03	85.8
	JF10-16-4	16	4	1440 / 3.21	90.8
	JF10-17-4	17	4	1520 / 3.39	95.9
	JF10-18-4	18	4	1600 / 3.56	100.9
	JF10-19-4	19	4	1720 / 3.83	108.5
12 / 3.6	JF12-20-5	20	5	1800 / 4.01	113.6
	JF12-21-5	21	5	1880 / 4.19	118.6
	JF12-22-5	22	5	1960 / 4.37	123.7
	JF12-23-5	23	5	2040 / 4.54	128.7
	JF12-24-5	24	5	2120 / 4.72	133.8
	JF12-25-5	25	5	2200 / 4.90	138.8
	JF12-26-5	26	5	2280 / 5.08	143.8
	JF12-27-5	27	5	2360 / 5.26	148.9
Vault		varies	varies	varies	varies

[1] Smaller and larger systems may be custom designed
[2] Shorter length cartridge configurations are available

Table 2 Design Pollutant Capacities - Standard Jellyfish® Filter Configurations

Model Diameter (ft / m)	Wet Volume Below Deck (ft^3 / L)	Sediment Capacity [1] (ft^3 / L)	Oil Capacity [2] (gal / L)
Catch Basin	varies	varies	varies
JF4 4 / 1.2	82 / 2313	12 / 0.34	100 / 379
JF6 6 / 1.8	184 / 5205	28 / 0.79	224 / 848
JF8 8 / 2.4	327 / 9252	50 / 1.42	388 / 1469
JF10 10 / 3.0	511 / 14,456	78 / 2.21	608 / 2302
JF12 12 / 3.6	735 / 20,820	113 / 3.20	732 / 2771
Vault	varies	varies	varies

[1] Assumes 12 inches (305 mm) of sediment depth in sump.
Systems may be designed with increased sediment capacity.
[2] Assumes 24 inches (610 mm) of pre-treatment channel depth for oil storage

3. Technology System Evaluation: Project Plan

3.1 Introduction

The TARP field test of Imbrium Systems' Jellyfish® Filter that is the primary subject of this report (Sansalone 2011) was conducted by the University of Florida Engineering School of Sustainable Infrastructure and Environment (UF-ESSIE) in Gainesville, Florida. Prior to initiating the field test at the University of Florida, the source area rainfall and pollutant characteristics and University analytical processes were reviewed with NJCAT and NJDEP and confirmed as acceptable for performing a TARP field study.

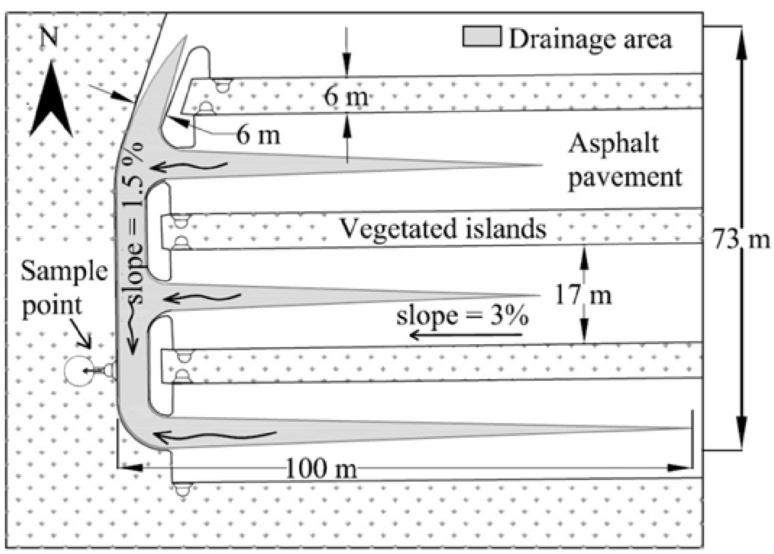
UF-ESSIE prepared a Quality Assurance Project Plan (QAPP) for the proposed field study. The QAPP was submitted to NJCAT for review and was subsequently approved. The QAPP adheres to guidelines established in EPA Requirements for Quality Assurance Project Plans (EPA QA/R-

5), the TARP Protocol for Stormwater Best Management Practice Demonstrations, and the Virginia Technology Assessment Protocol (VTAP) Guidance for Evaluating Stormwater Manufactured Treatment Devices.

3.2 Site and System Description

The Reitz Union parking lot at the University of Florida – Gainesville was the field study site. It is an asphalt-paved source area that functions as a primary parking facility for the University of Florida. The parking lot was built in the 1990s and is designed to provide adequate conveyance of runoff during wet weather events with storm runoff considered with respect to adequate surface drainage. Raised vegetated islands separate parking aisles and drain to the impervious asphalt-paved surface which drains by gravitationally-driven sheet flow to the curb and gutter leading to regularly-spaced catch-basins. The total area of the island is 24.39 % of the entire parking lot and the percentage of pavement is 75.61 %. The islands are mainly planted with magnolia trees, an occasional sycamore tree and grass. These catch-basins concentrate and collect gutter flow and provide entry of runoff into a storm sewer pipe system on the University of Florida campus. All the collected runoff discharges to Lake Alice about 2000 ft away from the parking lot. The combination of impervious asphalt pavement and raised vegetated islands, a very common design for surface parking across North America (Berretta and Sansalone 2011), provides substantial loads of nitrogen, phosphorus, metals, and particulate matter (PM) to runoff from the site.

Figure 4(a) illustrates the drainage for the contributing area and (b) provides an aerial view of the watershed.



4(b) Aerial photo of the Reitz Union surface parking facility at the University of Florida in Gainesville, illustrating the contributing drainage area and influent appurtenance (Inlet A) serving as the feed to the JF4-2-1. North is towards the top of the page. The NW intersection is Museum Road at Center Drive.

Depending on the storm event intensity and wind direction the drainage area can vary from 5,400 to 8,600 ft^2 (0.12 to 0.20 acres) of pavement. The catchment drains to inlet A as shown in Figure 4(b) and 4(a). Runoff captured by inlet A is the source of influent to the downstream Jellyfish Filter.

Data from a 2009 monitoring study (Berretta and Sansalone, 2011) at this identical test site was useful in the selection of a properly sized Jellyfish Filter for the site. The study included runoff flow rate data from 15 storm events. Two of those storms generated peak runoff flow rates that exceeded 200 gpm. Based on this actual historical data, the Jellyfish Filter model JF4-2-1 with 54-inch long filtration cartridges was installed for field testing. The JF4-2-1 is a 4-ft diameter manhole configuration with two hi-flo cartridges, each rated at 80 gpm, and a single draindown cartridge rated at 40 gpm, for a total Maximum Treatment Flow Rate (MTFR) of 200 gpm at 18 inches of driving head. The historical runoff data suggested that over the course of a minimum 20-storm monitoring campaign, several storms would generate peak flow rates that meet or exceed the treatment unit's MTFR. This was indeed the case; two storms generated peak flow rates exceeding 200 gpm during the Jellyfish® Filter monitoring period.

Since the University required a temporary installation of the treatment unit, a fiberglass JF4-2-1 was provided and installed above-ground on a hillside just below the catchment area. The above-ground installation facilitated much easier site construction and minimal site disturbance, and provided advantages for the monitoring personnel in terms of access to sampling points and instrumentation, and direct observation of flow dynamics within the treatment unit. A profile view schematic of the site set-up is shown in Figure 5 and a corresponding photo in Figure 6. The unit was equipped with a side man-way to facilitate manual removal of accumulated PM as well as system inspection at the conclusion of the study.

The JF4-2-1 was configured with a below-deck inlet pipe and deflector plate, which are standard options for the Jellyfish Filter. The test unit contained a circular maintenance access pipe, a feature that has been replaced in later designs by a horseshoe-shaped maintenance access wall. The test unit also contained a pressure relief pipe that could potentially function as an internal bypass, however this feature was rendered nonfunctional by the installation of an external bypass. External bypass piping was configured around the unit such that influent flows attaining a water elevation exceeding 18 inches above deck elevation would be externally bypassed to the downstream drop box where effluent samples were taken. The invert of the horizontal run of bypass piping was set at 18 inches above deck elevation to insure that the design driving head of 18 inches was provided to the Jellyfish Filter. Top view photos of the JF4-2-1 cartridge deck are shown in Figures 7 and 8.

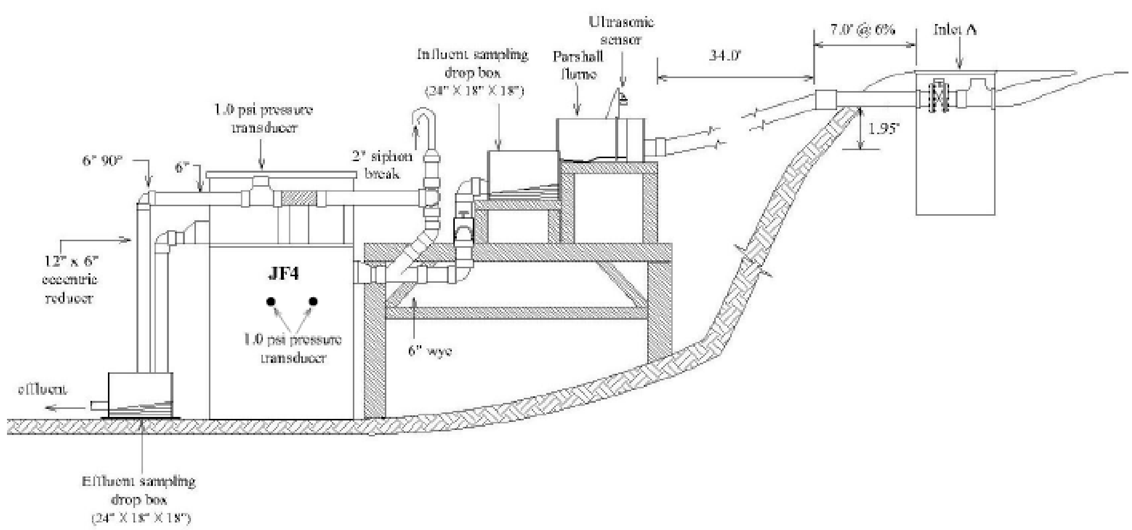


Figure 5 Profile view schematic of the field set-up for the Jellyfish® Filter JF4-2-1

Figure 6 Photo of field test set-up for the Jellyfish® Filter JF4-2-1. Below-deck inlet pipe enters the right side of the vessel and outlet pipe (invert at deck level) exits the left side of the vessel. External bypass piping has invert of horizontal section 18 inches above deck level.

Figure 7 Top view photos of the Jellyfish® Filter JF4-2-1 deck with two hi-flo cartridges and one draindown cartridge installed with cartridge lids off (upper left image) and cartridge lids on (upper right image). The backwash pool weir encloses the hi-flo cartridge. Also shown are the maintenance access pipe (large), pressure relief pipe (small), and the outlet opening (lower right in each image).

Figure 8 Top view photo of the Jellyfish® Filter JF4-2-1 during operation. Filtered water exits the cartridge lid orifice as a pulsating fountain.

3.3 Test Methods, Procedures and Equipment

Field monitoring system design for the Jellyfish® Filter JF4-2-1 included the following:

Monitoring and collection of rainfall-runoff were performed for 25 storm events. Runoff samples were collected manually on a time basis with physical, hydrologic and radar observations. Manual sampling with flow weighting was used. Samples of the whole influent and effluent flows were collected manually at 2-10 minute intervals, depending on storm duration. Manual sampling of the whole flow has a distinct advantage over auto-sampling of a small portion of the cross-section of flow, since sampling of the whole flow provides a more accurate representation of the actual pollutant load transported in the runoff. The flow rate at the time of sampling, and throughout the storm duration, was recorded automatically by the flowmeter, and therefore the flow volume is known for each time interval during the storm. Once the storm event ended, the samples taken at timed intervals across the hydrograph were transported to the laboratory and composited. Compositing was flow volume-weighted based on the volume of runoff corresponding to each respective time interval on the hydrograph. After compositing, analysis was performed.

During events, runoff was conveyed from the catchment to the treatment system after collection by catch basin inlet A. The distance from inlet A to the treatment system was 34 feet. Influent samples were collected at the influent drop box upstream of the treatment unit and effluent samples were collected at the effluent drop box downstream of the unit. The influent sample location was 4 feet upstream, and the effluent sample location was 2 feet downstream, of the unit.

Flow rate measurement utilized a 1 inch (25 mm) Parshall flume equipped with an ultrasonic sensor (model Shuttle Level Transmitter) connected to a data logger (model EasyLog EL-USB). Flow from the flume discharged into the influent drop box, creating a free well-defined discharge for representative manual sampling. The Parshall flume calibration curve is shown in Figure 9.

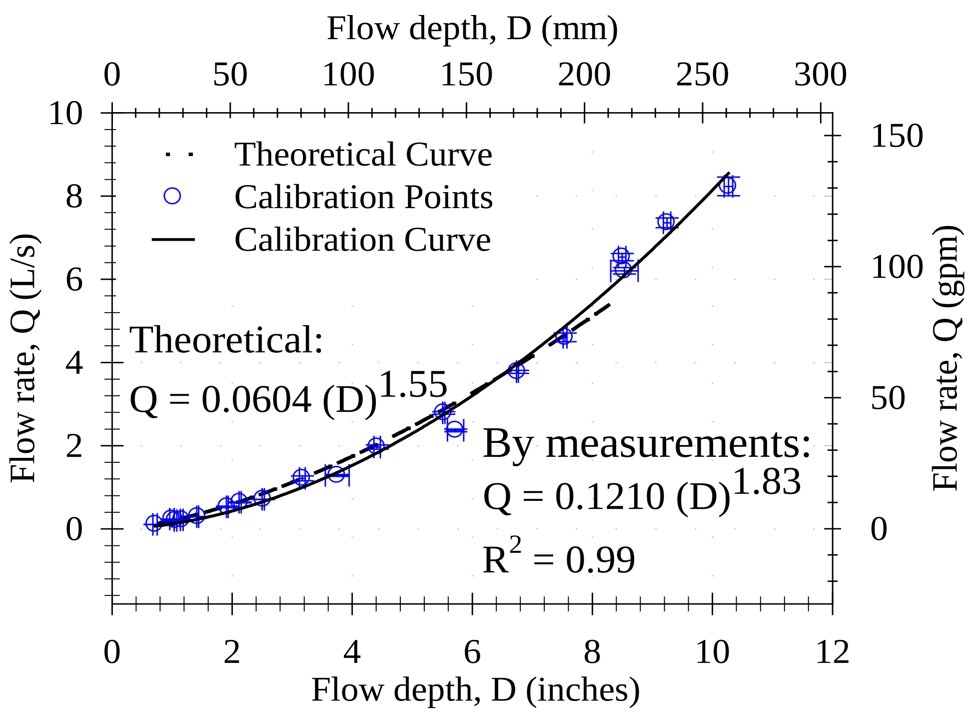


Figure 9 Parshall flume calibration curve

Rainfall measurement utilized a tipping bucket rain gauge manufactured by ISCO Inc. (0.01-inch bucket capacity) equipped with a data logger installed on the roof of the Unit Operations building located 150 meters south of the monitored site. Rainfall data were recorded every five minutes by the data logger.

Head loss measurements utilized monitoring of water pressure/elevation in the inlet and outlet pipes of the treatment unit with two 1-psi pressure transducers (model PDCR 1830 1 psig, manufactured by DRUCK Inc.) connected to a data logger (model CR1000, manufactured by Campbell Scientific Inc.).

pH, conductivity, and temperature measurement utilized a YSI 600XLM-M Multi-Parameter Water Quality Logger installed in the treatment unit's inlet for continuous automatic monitoring.

Sample analyses were performed in the University of Florida analytical labs, which is a NJDEP certified environmental laboratory. Samples were transported to the labs immediately after each storm and all time-sensitive analyses were performed within sample holding times. All samples were handled in accordance with chain-of-custody procedures and analyzed in accordance with Standard Method protocols. A summary of the analytical tests performed is given in Table 3.

Table 3 Summary of Analytical Tests

	Analysis	Test Methods
Water Chemistry Analysis	pH	S.M[1].4500-H^+ B
	Conductivity/TDS/Salinity	S.M.2510
	Oxidation-Reduction Potential	S.M.2580
	Temperature	S.M.2550
	Alkalinity	S.M.2320
Particulate Matter (PM) Analysis	Sediment PM	Sansalone and Kim., (2008)[2]
	Settleable PM	S.M.2540-F
	Suspended PM (as TSS)	S.M.2540-D
	Volatile Suspended PM (VSS)	S.M.2540-E
	Total PM (as SSC)	ASTM D-3977-97
	Turbidity	S.M.2130
	PSD	S.M.2560-D
Phosphorus Analysis	Total Phosphorus (TP)	S.M.4500-P-B Acid Hydrolysis
Nitrogen Analysis	Total Nitrogen (TN)	Persulfate Digestion Method
Metals Analysis	Total Metals (Cu, Cr, Pb, Zn)	S.M.3030 B
Oil and Grease	Total O&G	S.M. 5520
COD	Total COD	Reactor Digestion Method
	Dissolved COD	Reactor Digestion Method

[1]S.M.: Standard Method

[2]J. Sansalone and J-Y Kim, "Transport of Particulate Matter Fractions in Urban Source Area Pavement Surface Runoff", ***J. Environmental Quality***, 37:1883–1893 2008.
[2]J-Y Kim and J. Sansalone, "Event-Based Size Distributions of Particulate Matter Transported During Urban Rainfall-Runoff Events", ***Water Research***, 42(10-11), 2756-2768, May 2008.

3.4 Hydraulic Testing of the Jellyfish® Filter JF4-2-1

Extensive hydraulic testing was conducted at the University of Florida on a new clean 54-inch long Jellyfish® filtration cartridge with various orifice sizes in the cartridge lid. Hydraulic testing was also conducted on the Jellyfish® Filter JF4-2-1 with the standard 70 mm lid orifice on each of the two hi-flo cartridges and the standard 35 mm lid orifice on the single draindown cartridge, and was performed on the system with clean cartridges prior to commissioning as well as with dirty cartridges at the conclusion of the monitoring period (25 monitored storm events and 15 inches of cumulative rainfall).

3.5 Stormwater Data Collection Requirements

Of the 25 qualifying storm events sampled between May of 2010 and June of 2011: 1) the total rainfall was equal to or greater than 0.1 inch for all storm events sampled, 2) the minimum inter-event period was greater than 10 hours for all storm events sampled, 3) flow-weighted composite samples covered 100% of total storm flow for all storm events sampled, 4) the minimum influent/effluent samples collected in the storm events was 8 and the average number of influent samples collected per storm event was 11.1 and the average number of effluent samples per storm event was 10.5, 5) the total sampled rainfall was 15.01 inches, 6) three events exceeded 75% of the design treatment capacity, while two of these events exceeded the design treatment capacity (>100%), and 7) TSS-SM and SSC data were collected for all storm events sampled. All of the events qualified to strict interpretation of the stormwater data collection requirements as per New Jersey Tier II Stormwater Test Requirements—Amendments to TARP Tier II Protocol (NJDEP, 2006) and the NJDEP interpretation of TARP (2003). (**Tables 4** and **5)**.

4. Technology System Performance

4.1 Data Quality Assessment

Data were analyzed using statistical methods in accordance with guidelines in the **TARP Protocol for Stormwater Best Management Practice Demonstrations** and the **VTAP Guidance for Evaluating Stormwater Manufactured Treatment Devices**. Data were examined by statistical and regression analysis, ANOVA statistics, non-parametric analysis, correlations, probability distributions of data, normality testing, standards, and physical data replication.

Data integrity in the laboratory was addressed in a multi-level review process for all analyses conducted. The initial step in this review process was conducted by each lab analyst as tests were conducted. Calibration values and procedures were checked against previous tests to alert the analyst in case of malfunction in equipment or test errors.

The second level of review was conducted by the lab director who collected results and entered these values into the tabular spreadsheets for each test. Each of the results was checked for accuracy of input as well as to appropriateness for the samples which were analyzed. All results were overseen or conducted personally by the lab manager. All preliminary calculations were reviewed. The final level of review was conducted by the project manager who reviewed all results generated within the laboratory.

4.2 Test Results

Hydrology

Event-based hydrologic indices including previous dry hours (PDH), event duration, peak flow rate, median flow rate, mean flow rate, total runoff volume, rainfall depth, initial pavement residence time (IPRT), and runoff coefficient were monitored for a total of 25 TARP and VTAP qualifying storm events occurring over the 13-month period spanning May 28, 2010 to June 27, 2011. Cumulative rainfall depth was 15.01 inches. Data are shown in **Tables 4** and **5**. Individual storm event summaries with hydrographs and hyetographs are detailed in **Appendix A**.

Monitored storm events across the field test program varied in duration from 26 to 691 minutes. Previous dry hours range from 10 to 910 hours. Rainfall ranged from 0.10 to 1.98 inches. IPRT ranged from 1 to 34 minutes. Runoff volume ranged from 54 to 3495 gpm. Maximum rainfall intensity ranged from 0.2 to 5.4 in/hr. Maximum runoff flow rate ranged from 7 to 226 gpm, median flow rate ranged from 0.7 to 87gpm. Two storms (July 15 and August 1) generated peak flow rates that exceeded the Maximum Treatment Flow Rate of 200 gpm for the Jellyfish Filter JF4-2-1.

Table 4 Monitored rainfall-runoff event hydrologic data

Event Date	t_{rain} (min)	d_{rain} (in)	$i_{rain-max}$ (inch/hr)	IPRT (min)	V_{inf} (gal)	V_{eff} (gal)	Runoff Reduction %	Q_p (gpm)	Q_{med} (gpm)	n_{inf}	n_{eff}	TARP& VTAP Qualified
28 May 2010	112	0.81	3.0	10	1972	974	51%	68	15.5	19	8	Yes
16 June	61	0.63	2.4	18	1323	1234	7%	85	10.3	11	10	Yes
21 June	43	0.92	4.8	6	2297	2238	3%	118	86.7	10	10	Yes
30 June	50	0.52	3.0	8	1442	1410	2%	145	52.3	11	11	Yes
15 July	28	0.38	3.6	8	953	872	8%	210	22.9	10	10	Yes
1 August	36	1.18	5.0	5	3163	3089	3%	226	75.1	10	10	Yes
6 August	104	0.14	2.0	5	368	271	27%	108	0.2	10	8	Yes
7 August	48	0.34	2.4	7	693	672	3%	131	6.8	10	10	Yes
23 August	42	0.11	0.6	20	82	51	38%	20	0.2	10	10	Yes
12 September	52	0.27	2.0	18	434	399	8%	61	1.6	10	10	Yes
26 September	78	0.14	0.2	1	298	221	26%	7	4.1	10	10	Yes
27 September	388	0.60	3.6	20	1015	996	2%	173	0.7	10	10	Yes
4 November	43	0.19	1.8	5	263	135	49%	56	1.8	10	10	Yes
16 November	34	0.13	1.0	8	81	44	46%	28	0.3	11	11	Yes
5 January 2011	125	0.84	4.2	3	1532	1309	15%	117	2.6	10	10	Yes
10 January	26	0.20	3.6	4	298	277	7%	53	0.2	8	8	Yes
25 January	389	1.74	0.7	5	3273	3268	0%	65	6.2	10	10	Yes
7 February	306	1.29	1.2	8	3495	3420	2%	35	12.1	11	11	Yes
9 March	691	1.15	0.6	10	2656	2594	2%	50	1.6	12	12	Yes
28 March	66	0.10	1.3	7	138	112	19%	16	0.9	12	10	Yes
30 March	179	0.60	3.0	34	979	973	2%	89	1.6	12	12	Yes
20 April	61	0.14	0.6	9	54	30	44%	52	0.1	12	12	Yes
14 May	295	1.98	5.4	5	2974	2830	2%	119	0.4	19	19	Yes
6 June	69	0.16	0.9	4	254	194	24%	25	0.1	10	10	Yes
27 June	50	0.45	1.7	2	894	840	6%	53	2.0	10	10	Yes
Sum		15.0			30,830	28,453						

Difference between influent and effluent volume: 30,830 – 28,453 = 2,407 gal.

PDH: Previous dry hours
t_{rain}: Event duration
d_{rain}: Rainfall depth
$i_{rain-max}$: Maximum rainfall intensity
IPRT: Initial pavement residence time
V_{runoff}: Runoff volume
Q_p: Maximum flow rate
Q_{med}: Median flow rate
n_{inf}: Number of influent samples
n_{eff}: Number of effluent samples
CRD: Cumulative rainfall depth

Table 5 Rainfall-runoff data collection requirements

Event Date	Sampling Coverage (nearest 10%)	Number of Composited samples	d_{rain} (in)	PDH (hr)	V_{runoff} (gal)	Q_p (gpm)	% of Treatment Design at Q_p	TARP& VTAP Qualified
28 May 2010	100	27(19i) (8e)	0.81	96	1972	68	34	Yes
16 June	100	21(11i) (10e)	0.63	288	1323	85	43	Yes
21 June	100	20(10i) (10e)	0.92	96	2297	118	59	Yes
30 June	100	22(11i) (11e)	0.52	288	1442	145	72	Yes
15 July	100	20(10i) (10e)	0.38	96	953	210	105	Yes
1 August	100	20(10i) (10e)	1.18	24	3163	226	113	Yes
6 August	100	18(10i) (8e)	0.14	120	368	108	54	Yes
7 August	100	20(10i) (10e)	0.34	24	693	131	65	Yes
23 August	100	20(10i) (10e)	0.11	48	82	20	10	Yes
12 September	100	20(10i) (10e)	0.27	172	434	61	30	Yes
26 September	100	20(10i) (10e)	0.14	40	298	7	4	Yes
27 September	100	20(10i) (10e)	0.60	10	1015	173	87	Yes
4 November	100	22(11i) (11e)	0.19	910	263	56	28	Yes
16 November	100	22(11i) (11e)	0.13	286	81	28	14	Yes
5 January 2011	100	20(10i) (10e)	0.84	72	1532	117	58	Yes
10 January	100	16(8i) (8e)	0.20	106	298	53	26	Yes
25 January	100	20(10i) (10e)	1.74	365	3273	65	32	Yes
7 February	100	22(11i) (11e)	1.29	12	3495	35	18	Yes
9 March	100	24(12i) (12e)	1.15	79	2656	50	25	Yes
28 March	100	22(11i) (11e)	0.10	438	138	16	8	Yes
30 March	100	24(12i) (12e)	0.60	48	979	89	44	Yes
20 April	100	24(12i) (12e)	0.14	196	54	52	26	Yes
14 May	100	38(19i) (19e)	1.98	188	2974	119	60	Yes
6 June	100	20(10i) (10e)	0.16	541	254	25	12	Yes
27 June	100	20(10i) (10e)	0.45	88	894	53	27	Yes
Sum			15.01		30,830			

("i" stands for influent, "e" stands for effluent)

Particle Size Distributions

Particle size distribution was analyzed for all 25 storm events using laser diffraction and M1e scattering theory (Dickenson and Sansalone 2009, Garofalo and Sansalone 2011). The % finer by mass, d_{10}, d_{50}, and d_{90}, are shown in **Table 6**. The d_{50} represents the particle diameter for which 50 percent of the particles by mass are smaller than or the same size as that diameter. Similarly, the d_{10} and the d_{90} represent the particle diameters for which 10 and 90 percent of the particles by mass are smaller than or the same size as those diameters. For the 25 events monitored in this study, influent runoff d_{10} ranges from 2 to 54 µm with a median of 9 µm. Effluent runoff d_{10} ranges from <1 to 2 µm with a median of 1 µm. Influent runoff d_{50} ranges from 22 to 263 µm with a median of 82 µm. Effluent runoff d_{50} ranges from 1 to 11 µm with a median of 3 µm. Influent runoff d_{90} ranges from 173 to 1016 µm with a median of 401 µm. Effluent runoff d_{90} ranges from 2 to 52 µm with a median of 12 µm.

Recognizing that intensity is only one parameter (others are deposition, volume, previous dry hours) impacting the complexity of transport, it was generally observed that larger particles were mobilized during the more intense rain events of 14 May 2011, 21 June and 1 August 2010, with peak rainfall intensities of 5.4, 4.8 and 5.0 in/hr (137.2, 121.9, and 127.0 mm/hr) and median flows of 0.4, 87 and 75 gpm (0.02, 5.4 and 4.7 L/s), respectively;. The 21 June event had the largest influent d_{10} and d_{50} values of 54 and 263 µm, respectively. The least intense events were 23 August, 26 September, 2010, 9 March and 20 April, 2011 with peak rain intensities of 0.6, 0.2, 0.6 and 0.6 in/hr (15.0, 5.1, 15.0 and 15.0 mm/hr) and median flow rates of 0.2, 4.1,1.6 and 0.1 gpm (0.01, 0.26, 0.1 and 0.006 L/s), respectively. The 20 April 2011 event had the smallest influent d_{10} and d_{50} values of 0.3 and 1 µm, respectively.

Particulate Matter Fractions and Removal Efficiency

Removal efficiencies for event-based particulate matter (PM) fractions including Turbidity, PM < 25µm, TSS, PM < 500 µm, PM < 1000 µm, PM < 2000 µm, and SSC were measured for the 25 storm events as shown in **Table 7** and **Table 8**. Detailed procedures of the physical granulometric separation are in Sansalone and Kim (2008), Kim and Sansalone (2008) and Sansalone et. al.(2009).

For the 25 qualifying storms, TSS removal efficiency ranged 71-98% with a median of 89%, and SSC removal efficiency ranged 89-100% with a median of 99%. Turbidity removal efficiency ranged 34-98% with a median of 85%. Influent runoff turbidity ranged from 5 to 171 NTU with a median of 33 NTU. Effluent runoff turbidity ranged from 1 to 14 NTU with a median of 5 NTU.

Total Phosphorus and Total Nitrogen

The event-based concentrations of Total Phosphorus (TP) and Total Nitrogen (TN) for the 25 events are presented in **Table 9**. For the 25 qualifying storms, TP removal efficiency ranged from 11-92% with a median of 59%. TN removal efficiency ranged from (-11) to 88% with a median of 51%.

Total Metals

The event-based influent and effluent concentrations and removal efficiencies of Total Chromium, Total Copper, Total Lead, and Total Zinc for the 25 events are presented in **Table 10**. For the 25 qualifying storms, Total Chromium removal efficiency ranged from (-24) to 98%

with a median of 36%. Total Copper removal efficiency ranged from 55 to 100% with a median of 90%. Total Lead removal efficiency ranged from (-27) to 100% with a median of 81%. Total Zinc removal efficiency ranged from 4 to 99% with a median of 70%.

Negative Percent Removal Rates

For treatment devices that are not designed to remove the dissolved fraction of constituents such as nutrients and metals, it is not unusual to observe a negative percent removal for such pollutants for some of the treated storms during a monitoring campaign. The JF4 is designed to remove PM and the associated particulate-bound fraction of such constituents. Within a storm flow, and within a treatment unit such as the JF4, there is a complex and dynamic combination of chemical, biological, and physical (advection and dispersion) as well as kinetics phenomena that affect the partitioning of constituents between the particulate-bound and dissolved phases. In most urban areas the source materials for nutrients are anthropogenic or biogenic PM that partition into solution as a function of time

There is a hetero-disperse distribution of PM sizes in the influent. Each of these PM size fractions has an initial concentration [mg/g] of particulate-bound nitrogen, phosphorus, or metal associated with it. This concentration varies by PM size fraction due to the varying surface area per unit mass of different PM size fractions. The kinetics of partitioning is such that there is a mass transfer of nitrogen, phosphorus, or metal from the particulate-bound phase to the dissolved phase when the flow enters a treatment unit. The process of partitioning occurs in the opposite direction as well, back to the particulate-bound phase that favors a higher concentration of constituent on the smaller PM fractions that have higher surface area per unit mass. In this way the finer suspended and colloidal PM fractions become preferentially enriched. These enriched fine PM size fractions are more readily flushed from any treatment unit by subsequent intra-event flows and subsequent storms (inter-event re-distribution keeps occurring).

Additionally, all treatment units sustain varying microbial populations, and microbial cells are both enriched with nitrogen and of a small size; by comparison in the fine suspended-size range and of a specific gravity not much greater than 1.0. High microbe concentration eluted in the effluent, relative to the influent, would therefore tend to decrease the percent removal of nitrogen and in part depend on the hydrology, inter-event microbial competition and water chemistry within the treatment unit. In comparison, phosphorus has much more rapid kinetics than TN and partitions back to PM, typically of a larger size range and of much more inorganic nature and therefore with a specific gravity in the range of 2 to 2.7. As a consequence the JF4 demonstrates a significantly higher removal for TP across the entire monitoring campaign and does not exhibit any event-based negatives. While there is phosphorus uptake by the microbial population, once phosphorus re-partitions back to the PM size distribution, TP is far more stable, less leachable, less reactive through microbial mediation, and less mobile as compared to TN in such a complex and temporally-varying environment of a treatment unit.

Table 6 Event-based particle size distributions (PSD)

Event Date	Influent PSD (μm)			Effluent PSD (μm)		
	d_{10}	d_{50}	d_{90}	d_{10}	d_{50}	d_{90}
28 May 2010	7	69	915	2	11	34
16 June	28	242	1016	1	6	16
21 June	54	263	769	1	6	34
30 June	8	75	271	1	5	17
15 July	40	225	628	2	6	17
1 August	26	213	693	2	6	17
6 August	16	231	984	1	3	18
7 August	19	186	737	1	4	12
23 August	14	190	714	2	4	40
12 September	9	89	328	1	2	8
26 September	4	35	173	1	3	52
27 September	15	136	723	1	3	11
4 November	3	68	401	1	2	9
16 November	5	51	610	1	2	12
5 January 2011	15	110	794	1	3	12
10 January	8	117	227	1	2	6
25 January	7	63	308	0	1	2
7 February	7	68	369	1	3	18
9 March	6	57	278	1	3	7
28 March	4	32	200	1	3	8
30 March	6	44	176	1	3	7
20 April	2	22	310	0	1	8
14 May	10	80	705	1	3	8
6 June	10	99	345	1	2	7
27 June	10	82	310	1	6	14
Mean	13	114	519	1	4	16
Median	9	82	401	1	3	12
Std. dev.	12	74	270	0	2	12

Table 7 Removal efficiencies for particulate matter (PM) fractions

Event Date	PM < 25 µm			TSS			%Volatile		Particulate Matter, PM Fractions < 500 µm			Particulate Matter, PM Fractions < 1000 µm		Particulate Matter, PM Fractions < 2000 µm		SSC		
	EMC_i [mg/L]	EMC_e [mg/L]	PR (%)	EMC_i [mg/L]	EMC_e [mg/L]	PR (%)	EMV_i (%)	EMV_e (%)	EMC_i [mg/L]	EMC_e [mg/L]	PR (%)	EMC_i [mg/L]	EMC_e [mg/L]	EMC_i [mg/L]	EMC_e [mg/L]	EMC_i [mg/L]	EMC_e [mg/L]	PR (%)
28 May 2010	43.7	11.9	87	89.3	18.7	90	49.0	59.8	261.0	11.3	96	383.4	13.3	525.0	15.4	532.3	15.4	99
16 June	40.2	19.7	53	79.3	21.7	74	34.9	73.6	240.4	13.9	94	534.9	16.0	868.2	18.1	1401.7	18.1	99
21 June	18.4	9.9	48	105.5	15.2	86	21.3	72.6	209.2	5.5	97	374.6	6.5	556.2	7.4	1162.9	7.4	99
30 June	12.2	5.8	53	25.2	7.4	71	15.9	66.9	233.8	4.0	98	289.5	4.7	345.8	5.4	444.5	5.4	99
15 July	23.7	6.9	73	91.8	8.3	92	25.3	34.1	276.6	6.4	98	451.2	7.4	640.7	8.4	812.2	8.4	99
1 August	18.5	6.9	64	130.2	15.4	89	70.5	52.7	83.9	5.5	93	120.6	6.6	161.0	7.7	245.1	7.7	97
6 August	48.0	12.1	82	77.5	15.0	86	51.3	0.3	95.3	5.4	94	145.1	6.4	203.3	7.3	308.4	7.3	98
7 August	13.1	7.0	49	45.3	12.2	74	42.3	30.8	25.0	10.8	57	37.2	12.4	50.6	13.9	117.1	13.9	89
23 August	38.3	5.0	92	74.2	8.2	93	69.1	46.9	265.1	3.5	99	392.6	4.1	532.8	4.7	555.8	4.7	100
12 September	45.2	11.6	76	91.2	15.7	84	56.3	40.7	106.0	4.6	96	143.2	5.2	183.4	5.8	261.5	5.8	98
26 September	11.2	2.2	85	16.3	4.7	79	58.5	80.0	61.3	3.8	94	84.1	4.4	107.0	5.0	117.9	5.0	97
27 September	44.5	5.0	89	51.1	3.2	94	55.1	37.9	312.2	4.7	98	484.7	5.3	669.8	6.0	765.1	6.0	99
4 November	93.6	6.7	96	39.9	4.2	95	46.2	53.0	226.5	8.3	96	294.1	9.3	367.5	10.4	477.1	10.4	99
16 November	119.6	9.2	96	261.0	11.8	98	42.6	11.4	303.5	11.9	96	409.8	12.0	524.8	12.2	543.6	12.2	99
5 January 2011	68.6	13.0	84	152.2	15.9	91	69.4	52.2	170.6	6.7	96	234.6	7.7	307.3	8.7	693.2	8.7	99
10 January	20.7	3.1	86	80.7	6.6	92	68.0	24.8	86.1	2.4	97	131.5	2.7	179.4	3.0	211.1	3.0	99
25 January	32.3	3.5	89	69.8	7.1	90	68.1	30.1	48.1	3.7	92	64.8	3.9	82.4	4.1	105.8	4.1	96
7 February	20.4	4.4	79	34.8	5.3	85	75.8	54.5	128.7	6.3	95	202.7	6.9	285.9	7.6	438.3	7.6	98
9 March	22.0	4.3	81	30.5	8.3	73	57.8	31.2	29.4	2.3	92	38.8	2.6	48.7	2.8	78.2	2.8	97
28 March	56.5	11.6	84	68.4	12.7	86	54.5	24.8	64.8	3.5	95	83.3	4.5	102.8	5.6	102.8	5.6	96
30 March	44.9	5.1	89	104.5	7.3	93	60.2	5.6	206.7	5.7	97	278.6	6.5	361.6	7.3	443.7	7.3	98
20 April	65.7	7.9	93	143.7	11.4	96	44.7	22.8	343.0	4.6	99	466.5	5.3	606.7	6.1	921.7	6.1	100
14 May	33.9	11.3	67	77.1	12.5	84	65.7	10.2	255.9	5.3	98	357.9	5.3	470.6	5.3	487.3	5.3	99
6 June	54.2	10.6	85	85.6	13.2	88	54.9	25.4	93.5	5.4	94	125.1	5.9	158.9	6.4	237.5	9.0	97
27 June	54.3	10.1	82	131.4	12.8	91	62.5	29.6	297.8	7.4	98	391.5	8.6	487.5	9.8	591.7	9.8	98
Mean	41.7	8.2	78	86.3	11.0	87	52.8	38.9	177.0	6.1	94	260.8	6.9	353.1	7.8	482.3	7.9	98
Median	40.2	7.0	84	79.3	11.8	89	55.1	34.1	206.7	5.4	96	278.6	6.4	345.8	7.3	444.5	7.3	99
Std. dev.	25.9	4.0	15	51.4	4.8	8	15.8	21.8	100.9	3.0	8	156.3	3.4	225.5	3.8	338.3	3.8	2

Table 8 Event-based values for alkalinity, COD, and turbidity

Event Date	Alkalinity [mg/L as $CaCO_3$]		Total COD [mg/L]		Turbidity (NTU)		
	EMV_i	EMV_e	EMV_i	EMV_e	EMV_i	EMV_e	PR%
28 May 2010	29.2	22.7	80.9	68.2	35.6	14.1	60%
16 June	21.5	34.5	93.3	63.7	32.7	10.7	67%
21 June	12.6	19.1	27.5	21.8	4.7	3.0	36%
30 June	9.1	24.8	14.3	20.6	9.8	6.5	34%
15 July	17.0	42.8	56.3	34.0	31.2	7.1	77%
1 August	5.9	17.0	37.8	30.1	14.8	3.9	74%
6 August	26.0	42.2	94.1	14.4	51.9	1.4	97%
7 August	14.6	29.8	20.8	41.9	15.6	3.8	76%
23 August	28.5	83.5	95.8	38.7	46.6	5.3	89%
12 September	23.3	79.6	99.3	51.8	27.9	3.6	87%
26 September	39.6	84.1	132.2	48.0	21.4	3.3	85%
27 September	27.1	42.2	51.4	53.1	14.1	5.1	64%
4 November	36.5	125.1	135.7	55.3	82.5	5.5	93%
16 November	45.2	102.9	486.1	51.6	171.0	10.8	94%
5 January 2011	18.2	41.1	40.7	51.9	65.7	10.1	85%
10 January	15.9	38.9	66.6	26.7	38.0	3.3	91%
25 January	21.3	20.2	21.5	12.4	28.2	6.8	76%
7 February	13.5	18.1	39.3	23.9	30.0	5.9	80%
9 March	23.1	36.4	34.9	24.8	19.4	2.4	88%
28 March	47.3	114.4	459.4	51.6	61.1	3.5	94%
30 March	22.3	50.2	118.1	53.6	70.7	4.6	93%
20 April	6.5	30.4	364.3	58.9	112.2	2.4	98%
14 May	3.1	6.7	58.7	57.6	19.9	5.6	72%
6 June	9.7	89.3	219.3	96.1	38.4	3.7	90%
27 June	32.0	119.2	344.6	74.2	63.8	3.4	95%
Mean	22.0	52.6	127.7	45.0	44.3	5.4	80%
Median	21.5	41.1	80.9	51.6	32.7	4.6	85%
Std. dev.	11.9	35.8	137.5	20.3	36.7	3.1	17%

Table 9 Event-based values for Total Phosphorus and Total Nitrogen

Event Date	TN			TP		
	EMV_i [µg/L]	EMV_e [µg/L]	PR (%)	EMV_i [µg/L]	EMV_e [µg/L]	PR (%)
28 May 2010	4906	3378	66	2405	762	84
16 June	3110	1610	51	3256	876	74
21 June	4818	1885	62	5883	472	92
30 June	1885	1751	9	1216	619	50
15 July	2716	2202	26	3548	731	81
1 August	2033	1234	41	2342	920	62
6 August	5503	1566	79	2040	920	67
7 August	1170	763	37	1407	955	35
23 August	3424	2112	62	1570	883	65
12 September	2520	2628	-4	2135	1537	34
26 September	2716	1647	55	3035	1485	64
27 September	2265	760	67	3063	1730	45
4 November	3401	1122	83	5011	2409	76
16 November	5695	1252	88	8793	2574	84
5 January 2011	1879	553	75	3947	2104	54
10 January	1238	1118	16	3853	2496	39
25 January	1399	733	48	4497	1146	75
7 February	1182	816	32	2952	1177	60
9 March	1300	1195	10	887	806	11
28 March	6511	2955	64	7056	3751	58
30 March	4024	1345	67	4364	2474	44
20 April	10479	6500	66	6504	4769	59
14 May	3940	2202	45	2994	1480	51
6 June	4305	4388	23	2769	2368	35
27 June	5564	6579	-11	3228	2758	20
Mean	3519	2092	47	3550	1688	57
Median	3110	1610	51	3063	1480	59
Std. dev.	2161	1614	27	1914	1060	21

Table 10 Event-based values for Total Metals

Event Date	Total Zinc			Total Copper			Total Lead			Total Chromium		
	EMC_i [µg/L]	EMC_e [µg/L]	PR (%)	EMC_i [µg/L]	EMC_e [µg/L]	PR (%)	EMC_i [µg/L]	EMC_e [µg/L]	PR (%)	EMC_i [µg/L]	EMC_e [µg/L]	PR (%)
28 May 2010	BDL	BDL	----	BDL	BDL	----	24.0	37.6	22	BDL	BDL	----
16 June	BDL	BDL	----	20.9	BDL	----	26.8	35.9	-27	BDL	BDL	----
21 June	1100	11	99	646.6	24.8	96	118.0	23.5	81	BDL	BDL	----
30 June	100	68	32	75.0	BDL	----	23.0	BDL	----	2.6	1.9	30
15 July	1500	BDL	----	880.4	BDL	----	114.1	BDL	----	8.2	BDL	----
1 August	100	2	98	7.2	0.3	96	8.6	3.5	60	7.1	1.8	75
6 August	1500	345	77	361.0	0.1	100	98.4	5.0	96	5.7	0.2	98
7 August	700	217	69	149.6	0.1	100	38.9	2.0	95	1.6	0.2	89
23 August	1500	375	75	5.5	0.1	99	19.1	4.4	86	42.3	44.1	35
12 September	2000	880	56	3.1	0.1	96	9.4	1.5	86	55.5	55.3	8
26 September	6400	640	90	14.6	BDL	----	3.9	4.6	12	33.9	30.7	33
27 September	1200	1116	7	56.6	4.7	92	46.9	6.1	87	104.9	99.4	8
4 November	1600	400	75	79.5	0.4	100	71.7	4.5	97	49.7	41.4	58
16 November	1500	420	72	77.8	18.2	87	13.1	4.1	83	28.7	11.8	78
5 January 2011	2600	702	73	112.1	48.5	63	75.1	91.1	-6	122.5	108.5	23
10 January	3000	2760	8	46.5	14.1	72	34.9	9.3	75	42.9	29.6	36
25 January	4400	528	88	619.0	6.9	99	150.1	93.1	38	105.9	94.6	11
7 February	1300	793	39	113.7	51.3	55	104.5	62.8	40	78.0	97.3	-24
9 March	1500	450	70	366.5	44.7	88	20.1	0.1	100	82.8	65.8	23
28 March	1100	715	35	133.2	35.4	79	24.6	4.8	85	88.6	59.7	46
30 March	7600	760	90	85.2	13.3	85	120.2	9.4	92	117.7	66.3	44
20 April	1600	1536	4	197.3	20.4	94	249.1	127.8	72	157.9	105.2	63
14 May	600	270	55	57.5	17.7	70	27.8	6.5	77	96.2	56.9	42
6 June	1300	507	61	100.6	39.8	70	71.3	76.1	19	95.0	103.1	18
27 June	600	546	9	72.7	18.1	77	120.4	3.8	97	70.3	33.6	55
Mean	1948	638	58	178.4	17.9	86	64.6	26.8	64	63.5	52.7	40
Median	1500	518	70	82.4	15.9	90	38.9	6.1	81	62.9	55.3	36
Std. dev.	1852	594	31	231.4	17.5	14	58.4	37.0	37	45.0	37.9	30

Oil and Grease

The event-based influent and effluent concentrations and removal efficiencies of Total Oil and Grease for the 25 events are presented in **Table 11**. For the 25 qualifying storms, Total Oil and Grease removal efficiency ranged from 0 to 100% with a median of 62%.

Runoff water chemistry

Event-based water chemistry indices including pH, redox potential, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), alkalinity, and total chemical oxygen demand (COD) were measured for a total of 25 storm events as shown in **Tables 8** and **12**. Raw influent and treated effluent samples were analyzed. Additionally, pH, redox potential, conductivity, salinity, and TDS inside the treatment unit were also continuously monitored during each storm event.

Influent runoff pH ranges from 6.5 to 7.5 with a median of 7.1, and the effluent pH ranges from 6.2 to 7.2 with a median of 6.8. Redox potential is a measure of a chemical species' tendency to acquire electrons and be reduced. Water with a high potential tends to gain electrons from new species introduced to the system and water with a low potential can lose electrons to new species; both paths are important for speciation. For the 25 events monitored in this study, influent runoff redox ranges from 285 to 443 mV with a median of 366 mV. Effluent runoff redox ranges from 291 to 488 mV with a median of 364 mV.

Electrical conductivity is a measure of the ability of water to transmit an electric current. Influent runoff conductivity ranges from 18.9 to 186.7 µS/cm with a median of 56.6 µS/cm. Conductivity is nearly doubled during treatment due to contact with stored high conductivity runoff in the JF4-2-1. Effluent runoff conductivity ranges from 41.2 to 422.6 µS/cm with a median of 97.8 µS/cm. Given that TDS is highly correlated to conductivity, TDS follows the same pattern. Influent runoff TDS ranges from 9.3 to 91.3 mg/L with a median of 29.8 mg/L. Effluent runoff TDS ranges from 20.1 to 206.9 mg/L with a median of 48.5 mg/L.

Influent runoff alkalinity ranges from 3.1 to 47.3 mg/L as $CaCO_3$ with a median of 21.5 mg/L. An increase in alkalinity is observed during treatment due to contact with stored runoff in the JF4-2-1, which has high alkalinity. Effluent runoff alkalinity ranges from 6.7 to 125.1 mg/L as $CaCO_3$ with a median of 41.1 mg/L.

Influent runoff total COD ranges from 14.3 to 486.1 mg/L with a median of 80.9 mg/L. Effluent runoff total COD ranges from 12.4 to 96.1 mg/L with a median of 51.6 mg/L. Influent runoff DO ranges from 3.3 to 8.4 mg/L with a median of 6.7 mg/L. Effluent runoff DO ranges from 2.8 to 8.4 mg/L with a median of 4.7 mg/L.

Head Loss

The peak and median driving head over the Jellyfish Filter JF4-2-1 deck level for each event is tabulated in **Table 13**. As shown, the driving head increases as the flow rate increases. For the 25 qualifying events, the median value of event-based median driving head over deck level is 83 mm (3.25 inches), and the median value of event-based peak driving head over deck level is 204 mm (8.05 inches). No water was bypassed around the treatment unit during the entire monitoring period, including during the two storms events which generated peak flow rates slightly in excess of the Maximum Treatment Flow Rate of 200 gpm.

Table 11 Event-based values for Total Oil and Grease

Event Date	Total Oil and Grease		
	EMC_i [mg/L]	EMC_e [mg/L]	PR (%)
28 May 2010	0.20	0.08	62
16 June	0.93	0.43	54
21 June	0.35	0.35	0
30 June	0.64	0.62	2
15 July	1.10	0.35	68
1 August	0.96	0.55	43
6 August	1.04	0.47	55
7 August	0.73	0.55	25
23 August	0.20	0.00	100
12 September	0.61	0.00	100
26 September	0.44	0.00	100
27 September	0.99	0.08	92
4 November	0.46	0.00	100
16 November	0.93	0.00	100
5 January 2011	0.61	0.00	100
10 January	0.55	0.16	72
25 January	0.64	0.00	100
7 February	1.04	0.00	100
9 March	1.56	1.45	7
28 March	4.06	1.17	71
30 March	2.34	2.32	1
20 April	1.74	0.78	55
14 May	1.74	1.56	10
6 June	1.74	0.78	55
27 June	1.16	0.78	33
Mean	1.07	0.50	60
Median	0.93	0.35	62
Std. dev.	0.82	0.60	37

Table 12   Event-based water chemistry values (all results are not concentrations, but are values)

Event Date	pH		Redox (mV)		DO (mg/L)		Temperature (ºC)		Conductivity (µS/cm)		TDS (mg/L)	
	EMV_i	EMVe	EMV_i	EMVe	EMV_i	EMVe	EMV_i	EMVe	EMV_i	EMVe	EMV_i	EMVe
28 May 2010	7.0	7.0	391	386	6.1	6.3	23.9	24.1	60.5	69.1	29.8	33.9
16 June	7.1	6.7	368	366	4.5	3.6	25.0	25.0	49.5	81.9	24.2	40.2
21 June	7.1	6.6	383	438	6.7	4.7	23.4	24.6	24.2	43.1	11.9	21.1
30 June	6.9	6.5	376	376	5.7	4.4	25.7	25.3	23.9	57.3	11.9	28.0
15 July	7.3	6.8	355	355	7.2	5.8	27.7	26.2	32.6	96.3	15.8	43.6
1 August	6.5	6.5	366	364	7.5	7.1	25.7	25.6	18.9	42.4	9.3	20.6
6 August	7.3	6.5	386	393	6.3	4.2	27.6	26.7	69.2	87.9	33.9	43.3
7 August	7.0	6.5	386	360	7.1	4.3	25.7	26.0	34.6	71.7	16.9	35.1
23 August	7.0	6.8	340	329	6.4	4.2	26.7	25.7	74.1	177.7	36.3	88.0
12 September	7.4	6.8	407	431	6.8	5.0	27.0	26.2	62.1	174.2	30.3	85.3
26 September	6.6	6.7	422	488	3.3	2.8	24.5	24.5	107.6	182.9	52.6	89.6
27 September	7.1	6.7	443	465	6.6	5.4	23.6	23.8	54.0	98.9	26.2	48.5
4 November	7.2	7.0	366	412	6.6	4.5	22.0	21.9	103.5	298.7	50.6	127.7
16 November	7.2	6.8	352	376	7.1	4.4	22.1	22.6	174.0	225.0	85.5	110.3
5 January 2011	7.5	6.7	399	364	8.3	7.4	21.4	22.1	38.6	107.1	18.9	52.5
10 January	7.2	6.8	331	350	8.3	5.0	19.8	20.2	47.0	97.8	32.9	68.0
25 January	7.1	7.0	336	323	8.1	7.6	18.8	19.9	48.4	65.7	26.7	25.5
7 February	7.2	7.2	353	356	8.3	8.4	22.2	23.1	30.6	41.2	15.2	20.1
9 March	7.4	7.1	357	366	8.4	8.3	17.8	17.8	40.6	86.7	20.1	42.6
28 March	7.1	7.1	321	315	7.2	5.3	22.8	22.3	186.7	257.3	91.3	126.0
30 March	7.2	7.0	379	321	7.5	6.1	21.8	21.7	62.1	121.5	30.3	60.1
20 April	6.9	6.5	375	384	5.5	4.4	24.3	23.0	159.8	422.6	78.3	206.9
14 May	7.4	7.2	352	363	4.6	4.3	24.8	23.9	56.6	88.9	27.8	43.4
6 June	7.2	7.0	303	300	6.7	4.7	26.7	26.2	109.2	391.5	53.5	191.7
27 June	7.0	6.2	285	291	6.3	4.3	26.4	25.6	95.0	322.9	46.6	158.2
Mean	7.1	6.8	365	371	6.7	5.3	23.9	23.8	70.5	148.4	35.1	72.4
Median	7.1	6.8	366	364	6.7	4.7	24.3	24.1	56.6	97.8	29.8	48.5
Std. dev.	0.2	0.3	35	48	1.3	1.5	2.7	2.3	46.6	110.8	22.7	53.4

Table 13 Event-based driving head over deck level

Event Date	Median head over deck level (inch)	Median head over deck level (mm)	Peak head over deck level (inch)	Peak head over deck level (mm)
28 May 2010	1.56	40	6.22	158
16 June	4.23	108	7.79	198
21 June	6.67	170	9.89	251
30 June	2.01	51	15.55	395
15 July	5.78	147	16.89	429
1 August	8.41	214	20.92	531
6 August	5.75	146	12.04	306
7 August	4.58	116	12.23	311
23 August	1.47	37	4.58	116
12 September	2.07	53	6.17	157
26 September	1.45	37	2.48	63
27 September	1.16	30	15.70	399
4 November	3.08	78	6.72	171
16 November	1.77	45	6.82	173
5 January 2011	2.40	61	11.72	298
10 January	1.49	38	8.05	204
25 January	3.25	83	6.88	175
7 February	5.43	138	12.18	309
9 March	2.73	69	7.23	184
28 March	3.36	85	6.02	153
30 March	6.96	177	15.69	398
20 April	4.59	117	6.42	163
14 May	4.25	108	19.65	499
6 June	0.65	16	6.56	167
27 June	5.61	143	16.76	426
Mean	3.63	92	10.45	265
Median	3.25	83	8.05	204
Std. dev.	2.11	54	5.06	129

Hydraulic Testing

Hydraulic testing was conducted on the clean system with fresh filter cartridges prior to commencement of the monitoring campaign, and was repeated at the conclusion of the field study on the system with dirty cartridges. Curves of head loss versus flow rate were nearly identical for the system with fresh cartridges and dirty cartridges, indicating no loss of hydraulic capacity despite the capture of 166 pounds of dry basis PM mass by the JF4 equipped with 3 cartridges. These results suggest the combination of very high cartridge surface area, vertical configuration and self-cleaning mechanisms are effective in maintaining hydraulic capacity. The system had a volumetric capacity for PM that was not exceeded during the period of this study.

Results of hydraulic testing of the Jellyfish® Filter JF4-2-1 prior to commissioning (new filter cartridges) and at the conclusion of the monitoring period (dirty filter cartridges) are detailed in **Appendix B**.

4.3 System Maintenance and Residual Solids Assessment Results

Maintenance

No maintenance was required or carried out during the 13-month monitoring period spanning May 28, 2010 to June 27, 2011.

PM Recovery and Mass Balance

Mass balance results showed a 94.5% mass recovery rate for the 25 qualifying events providing confidence in the test methods, procedures and equipment employed during the monitoring program. The "theoretical mass" that should have been collected in the JF4-2-1 is calculated by the difference between the influent and effluent mass, which is 176 lbs. for the 25 qualifying events. The actual mass collected is calculated by summing the mass recovered from the sump and the filter cartridges, which are 158 lbs. and 8 lbs., respectively, in this project. See **Appendix B** for further discussion and details.

4.4 Summary

Between May of 2010 and June of 2011, 25 storm events were monitored and were determined to meet the storm data collection requirements as per New Jersey Tier II Stormwater Test Requirements—Amendments to TARP Tier II Protocol (NJDEP, 2006) and the NJDEP interpretation of TARP (2003). Total rainfall depth for qualified events was 15.01 inches and three events exceeded 75% of the design treatment capacity (including two storms that generated flow rates exceeding the maximum design flow rate of 200 gpm), thus satisfying TARP Tier II and NJDEP completeness criteria.

Median SSC and TSS removal efficiency results were 99% and 89%, respectively. While not part of the TARP Tier II Protocol several other pollutant removal rates, i.e. metals, total nitrogen and total phosphorus, were measured during this field study. These results are included to document, for this specific field study, Jellyfish® performance for these parameters. Median removal efficiency was 59% for Total Phosphorus and 51% for Total Nitrogen. For Total Copper and Total Zinc, median removal efficiencies were 90% and 70%, respectively, while median removal efficiencies for Total Lead and Total Chromium were 81% and 36%.

While both median and mean statistics are presented throughout the report, results are primarily log-normally distributed and therefore the median values are utilized to assess performance (Berretta and Sansalone 2011, Kim and Sansalone 2010, Van Buren et al., 2009).

5. Performance Verification

Field testing of an Imbrium Systems' Jellyfish® Filter model JF4-2-1 with second-generation filtration cartridges was conducted in accordance with the TARP and VTAP field test protocols to document Jellyfish® Filter performance with respect to suspended solids removal and quantify water treatment performance. The field monitoring was carried out on the University of Florida campus with the full-scale unit loaded by rainfall-runoff from a surface parking watershed. A total of 25 monitored storm events, with 15 inches of cumulative rainfall depth, were treated by the JF4 during this study. These 25 storms produced the total runoff through the JF4 during the 13-month monitoring period. Of the 25 storms treated, two storms generated flows exceeding the maximum design flow of 200 gpm. No maintenance was required or conducted during the 13-month monitoring period spanning May 28, 2010 to June 27, 2011. The median d_{50} for influent and effluent particle sizes were 82 and 3 μm, respectively. ***Treatment results generated median SSC and TSS removal efficiency results of 99% and 89%, respectively.***

At the completion of the monitoring campaign, a 94.5% mass balance was obtained on particulate matter (PM) which validates the testing methods used throughout this study. This mass balance on PM is an independent approach that validates particulate influent and effluent monitoring. The results obtained in this field study demonstrated that the Jellyfish® Filter's particulate removal performance is reasonably insensitive to incoming particle size distribution (PSD) and runoff event duration.

6. Net Environmental Benefit

The Jellyfish® Filter requires no input of raw material, has no moving parts and therefore uses no water or energy other than that provided by stormwater runoff. For the 25 storm events monitored during the 13-month monitoring period the mass of materials captured and retained by the Jellyfish® Filter was 166 lbs. This material would otherwise have been released to the environment during the 25 rain events.

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APPENDIX A

INDIVIDUAL STORM REPORTS

Table A1: JF4 Summary: 28 May 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	28 May 2010	Influent Volume:	7465 L (1972 gal)
Previous Dry Hours:	96	Event Duration:	112 min
Maximum Flow Rate:	4.30 L/s (68.2 gpm)	Number of Influent Samples:	19
Median Flow Rate:	0.98 L/s (15.5 gpm)	Number of Effluent Samples:	8
Mean Flow Rate:	1.12 L/s (17.8gpm)	Peak Rainfall Intensity:	76 mm/hr (3.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	21 mm (0.81 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

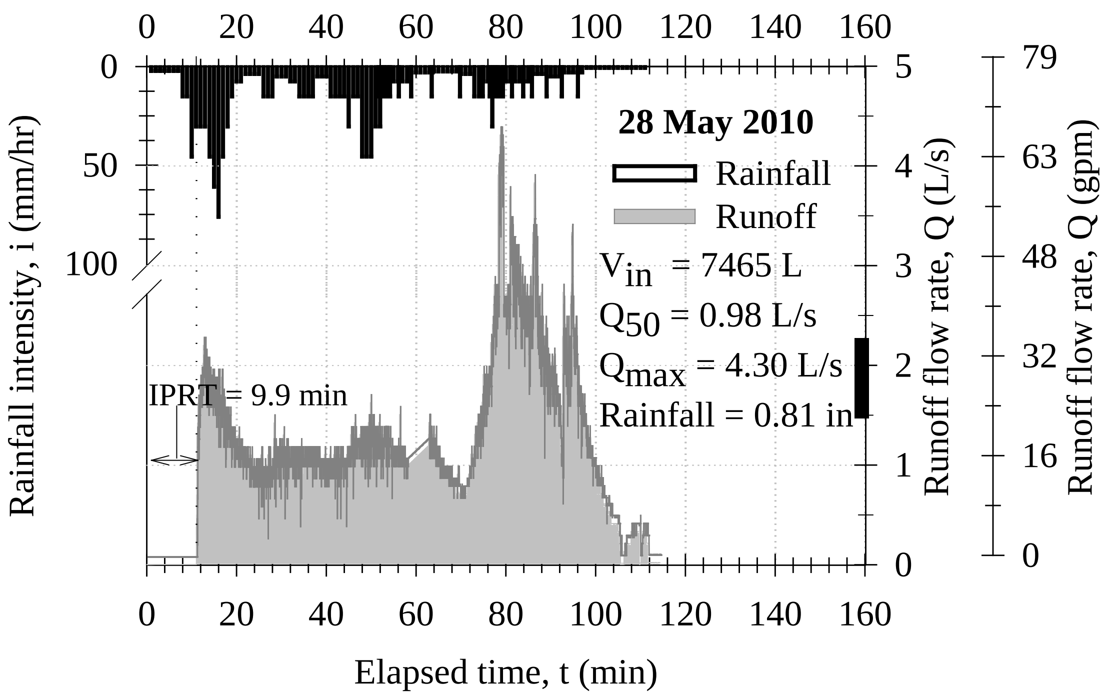

Figure A1: Hydrograph and hyetograph for 28 May 2010 event

On May 28, 2010, the Jellyfish Filter JF4-2-1 treated its first rainfall-runoff event, starting with a clean empty unit. The event occurred after 96 dry hours. The peak rainfall intensity is 3.0 in/hr and rainfall depth is 0.81 inches. The storm lasted approximately 112 minutes. The maximum, median, and mean runoff flow rates are 68 gpm, 16 gpm, and 18 gpm, respectively. The influent runoff volume is 1,972 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 19 and 8, respectively. Fewer effluent than influent samples are collected since the JF4 unit is filling up for a substantial part of the storm. The influent and effluent TSS is 89.3 mg/L and 18.7 mg/L, respectively, and the removal efficiency is 90%. The influent and effluent SSC is 532.3 mg/L and 15.4 mg/L, respectively, and the removal efficiency is 99%.

Table A2: JF4 Summary: 16 June 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	16 June 2010	Influent Volume:	5006 L (1323 gal)
Previous Dry Hours:	288	Event Duration:	61 min
Maximum Flow Rate:	5.36 L/s (85.0 gpm)	Number of Influent Samples:	11
Median Flow Rate:	0.65 L/s (10.3 gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	2.21 L/s (35.1 gpm)	Peak Rainfall Intensity:	61 mm/hr (2.4 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	16 mm (0.63 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

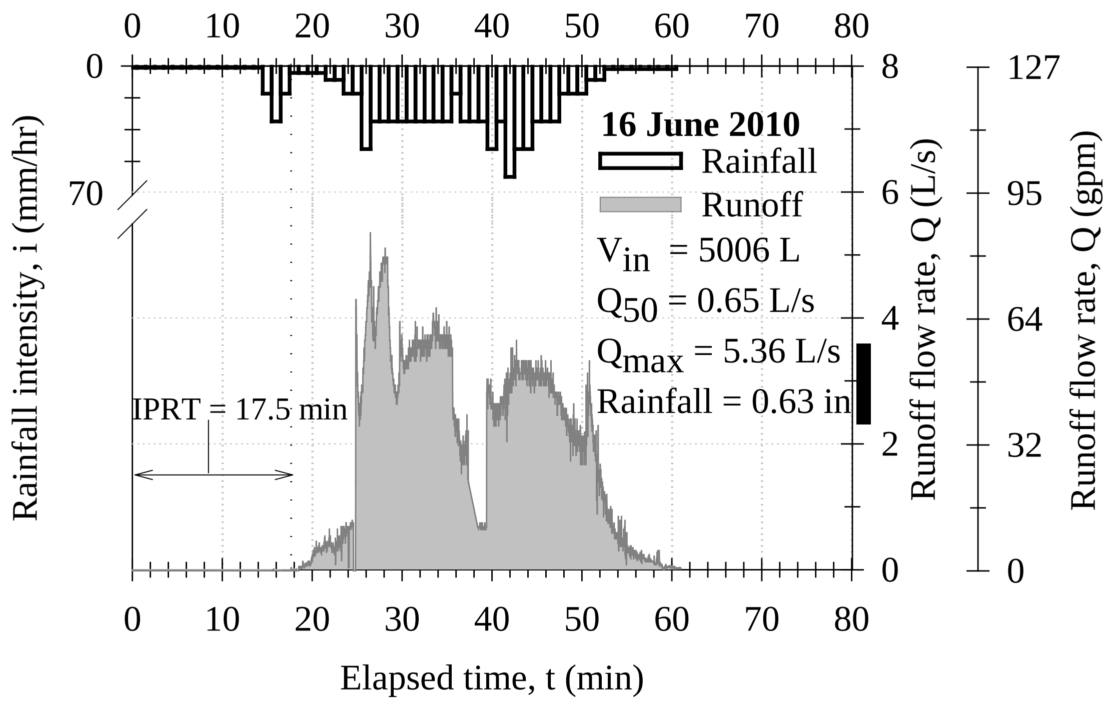

Figure A2: Hydrograph and hyetograph for 16 June 2010 event

On June 16, 2010, the JF4 unit treated its second rainfall-runoff event. The event occurred after 288 dry hours. The peak rainfall intensity is 2.4 in/hr and rainfall depth is 0.63 inches. The storm lasted approximately 61 minutes. The maximum, median, and mean runoff flow rates are 85 gpm, 10 gpm, and 35 gpm, respectively. The influent runoff volume is 1,323 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 11 and 10, respectively. The influent and effluent TSS is 79.3 mg/L and 21.7 mg/L, respectively, and the removal efficiency is 74%. The influent and effluent SSC is 1401.7 mg/L and 18.1 mg/L, respectively, and the removal efficiency is 99%.

Table A3: JF4 Summary: 21 June 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	21 June 2010	Influent Volume:	8695 L (2297 gal)
Previous Dry Hours:	96	Runoff Duration:	43 min
Maximum Flow Rate:	7.46 L/s (118.3 gpm)	Number of Influent Samples:	10
Median Flow Rate:	5.47 L/s (86.7 gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	5.09 L/s (80.7 gpm)	Peak Rainfall Intensity:	122 mm/hr (4.8 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	23 mm (0.92 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

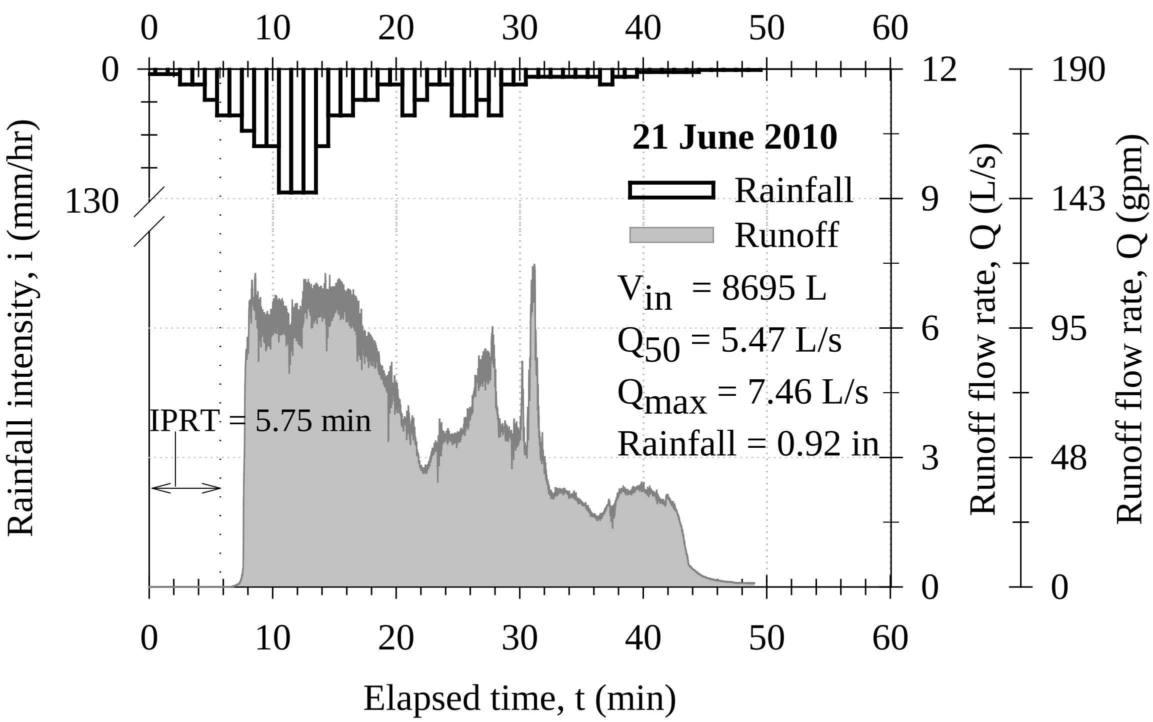

Figure A3: Hydrograph and hyetograph for 21 June 2010 event

On June 21, 2010, the JF4 unit treated its third rainfall-runoff event. The event occurred after 96 previous dry hours. The peak rainfall intensity is 4.8 in/hr and rainfall depth is 0.92 inches. The storm lasted approximately 43 minutes. The maximum, median, and mean runoff flow rates are 118 gpm, 87 gpm, and 81 gpm, respectively. The influent runoff volume is 2297 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 105.5 mg/L and 15.2 mg/L, respectively, and the removal efficiency is 86%. The influent and effluent SSC is 1162.9 mg/L and 7.4 mg/L, respectively, and the removal efficiency is 99%.

Table A4: JF4 Summary: 30 June 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	30 June 2010	Influent Volume:	5459 L (1442 gal)
Previous Dry Hours:	288	Runoff Duration:	50 min
Maximum Flow Rate:	9.13 L/s (144.8 gpm)	Number of Influent Samples:	11
Median Flow Rate:	3.30 L/s (52.3 gpm)	Number of Effluent Samples:	11
Mean Flow Rate:	3.95 L/s (62.6 gpm)	Peak Rainfall Intensity:	76 mm/hr (3.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	13 mm (0.52 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

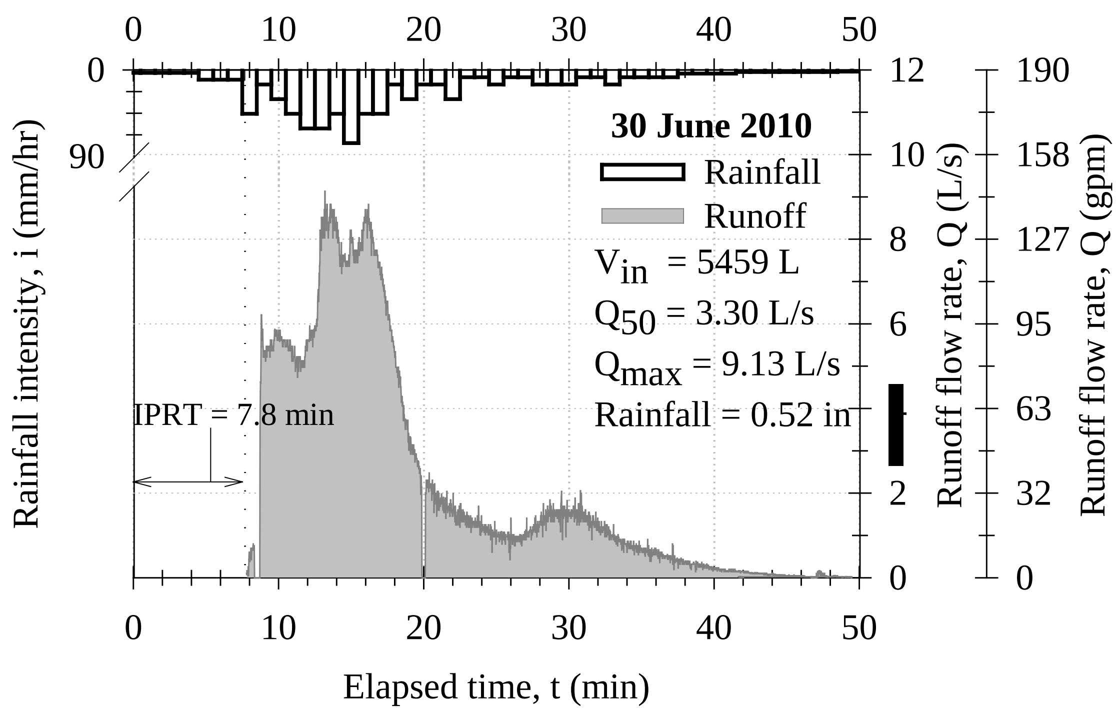

Figure A4: Hydrograph and hyetograph for 30 June 2010 event

On June 30, 2010, the JF4 unit treated its fourth rainfall-runoff event. The event occurred after 288 dry hours. The peak rainfall intensity is 3 in/hr and rainfall depth is 0.52 inches. The storm lasted approximately 50 minutes. The maximum, median, and mean runoff flow rates are 145 gpm, 52 gpm, and 63 gpm, respectively. The influent runoff volume is 1442 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 11 and 11, respectively. The influent and effluent TSS is 25.2 mg/L and 7.4 mg/L, respectively, and the removal efficiency is 71%. The influent and effluent SSC is 444.5 mg/L and 5.4 mg/L, respectively, and the removal efficiency is 99%.

Table A5: JF4 Summary: 15 July 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	15 July 2010	Influent Volume:	3608 L (953 gal)
Previous Dry Hours:	96	Runoff Duration:	28 min
Maximum Flow Rate:	13.26 L/s (210.2 gpm)	Number of Influent Samples:	10
Median Flow Rate:	1.44 L/s (22.9 gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	3.12 L/s (49.4gpm)	Peak Rainfall Intensity:	91 mm/hr (3.6 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	10 mm (0.38 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

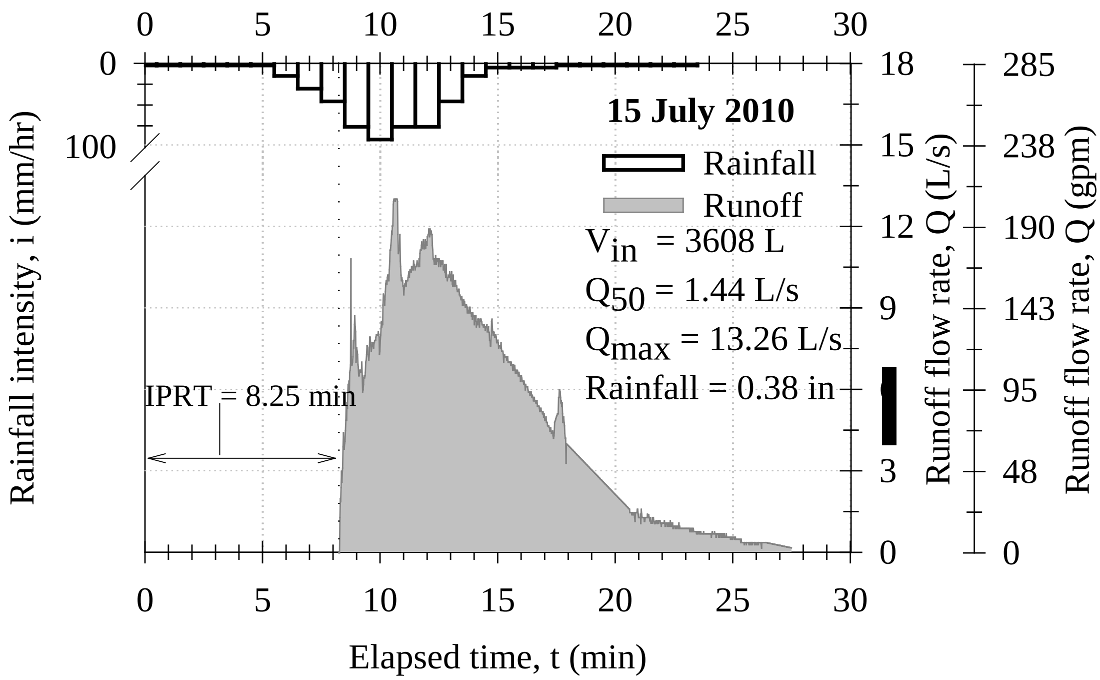

Figure A5: Hydrograph and hyetograph for 15 July 2010 event

On July 15, 2010, the JF4 unit treated its fifth rainfall-runoff event. The event occurred after 96 dry hours. The peak rainfall intensity is 3.6 in/hr and rainfall depth is 0.38 inches. The storm lasted approximately 28 minutes. The maximum, median, and mean runoff flow rates are 210 gpm, 23 gpm, and 49 gpm, respectively. The influent runoff volume is 953 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 91.8 mg/L and 8.3 mg/L, respectively, and the removal efficiency is 92%. The influent and effluent SSC is 812.2 mg/L and 8.4 mg/L, respectively, and the removal efficiency is 99%.

Table A6: JF4 Summary: 1 August 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	01 August 2010	Influent Volume:	11973 L (3163 gal)
Previous Dry Hours:	24	Event Duration:	36 min
Maximum Flow Rate:	14.25 L/s (225.9gpm)	Number of Influent Samples:	10
Median Flow Rate:	4.74 L/s (75.1gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	5.47 L/s (86.7gpm)	Peak Rainfall Intensity:	127 mm/hr (5.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	30 mm (1.18 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

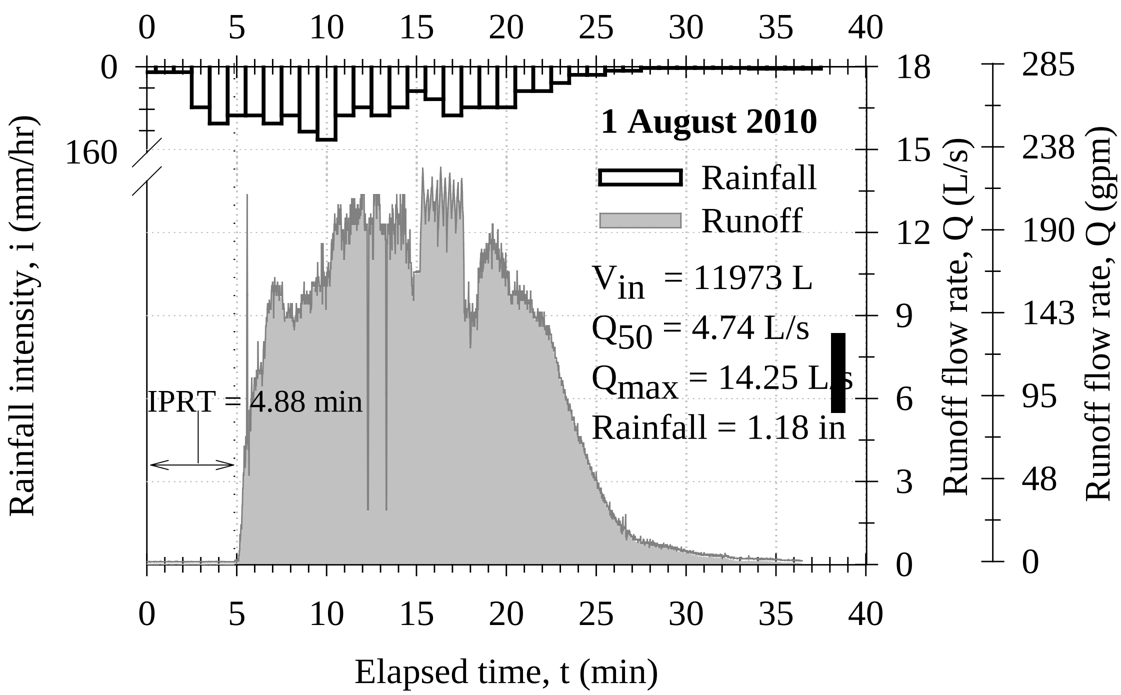

Figure A6: Hydrograph and hyetograph for 1 August 2010 event

On August 1, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 24 dry hours. The peak rainfall intensity is 5.0 in/hr and rainfall depth is 1.18 inches. The storm lasted approximately 36 minutes. The maximum, median, and mean runoff flow rates are 226gpm, 75 gpm, and 87 gpm, respectively. The influent runoff volume is 3163 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 130.2 mg/L and 15.4 mg/L, respectively, and the removal efficiency is 89%. The influent and effluent SSC is 245.1 mg/L and 7.7 mg/L, respectively, and the removal efficiency is 97%.

Table A7: JF4 Summary: 6 August 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	6 August 2010	Influent Volume:	1395 L (368 gal)
Previous Dry Hours:	120	Event Duration:	104 min
Maximum Flow Rate:	6.80 L/s (107.8gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.01 L/s (0.2gpm)	Number of Effluent Samples:	8
Mean Flow Rate:	0.27 L/s (4.3gpm)	Peak Rainfall Intensity:	51mm/hr (2.0inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	4 mm (0.14 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

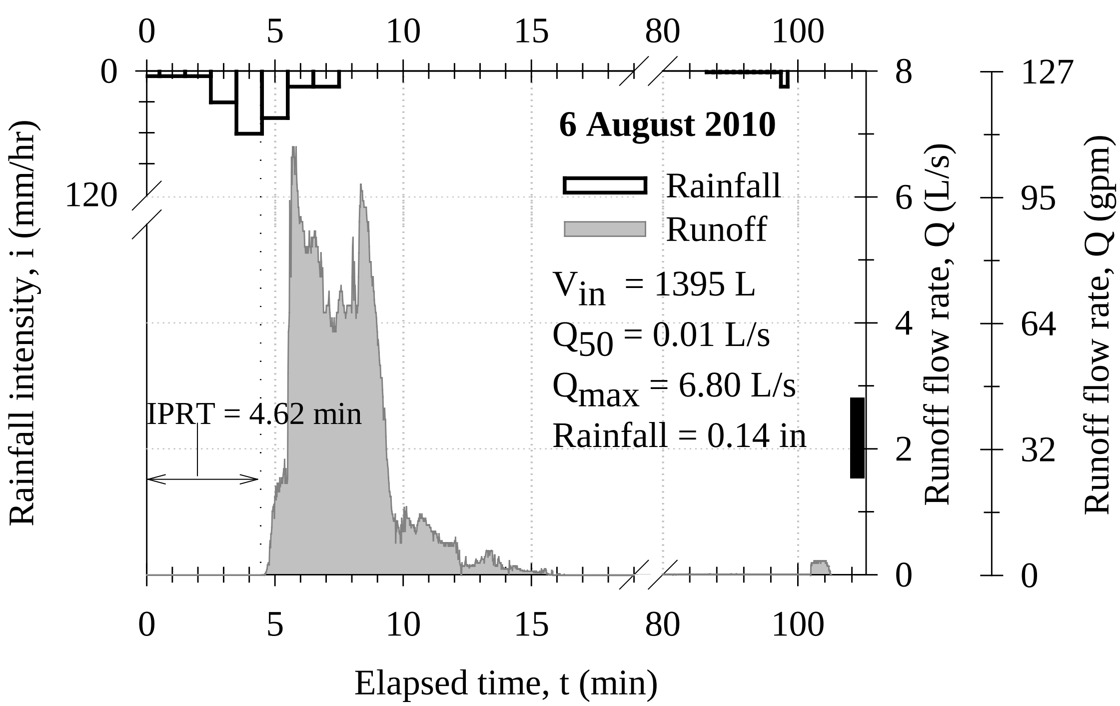

Figure A7: Hydrograph and hyetograph for 6 August 2010 event

On August 6, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 120 dry hours. The peak rainfall intensity is 2.0 in/hr and rainfall depth is 0.14 inch. The storm lasted approximately 104 minutes. The maximum, median, and mean runoff flow rates are 108 gpm, 0.2 gpm, and 4.3 gpm, respectively. The influent runoff volume is 368 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 77.5 mg/L and 15.0 mg/L, respectively, and the removal efficiency is 86%. The influent and effluent SSC is 308.4 mg/L and 7.3 mg/L, respectively, and the removal efficiency is 98%.

Table A8: JF4 Summary: 7 August 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	7August 2010	Influent Volume:	2622 L (693 gal)
Previous Dry Hours:	24	Runoff Duration:	48 min
Maximum Flow Rate:	8.24L/s (130.6gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.43 L/s (6.8gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.90 L/s (14.3gpm)	Peak Rainfall Intensity:	61 mm/hr (2.4 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	9 mm (0.34 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

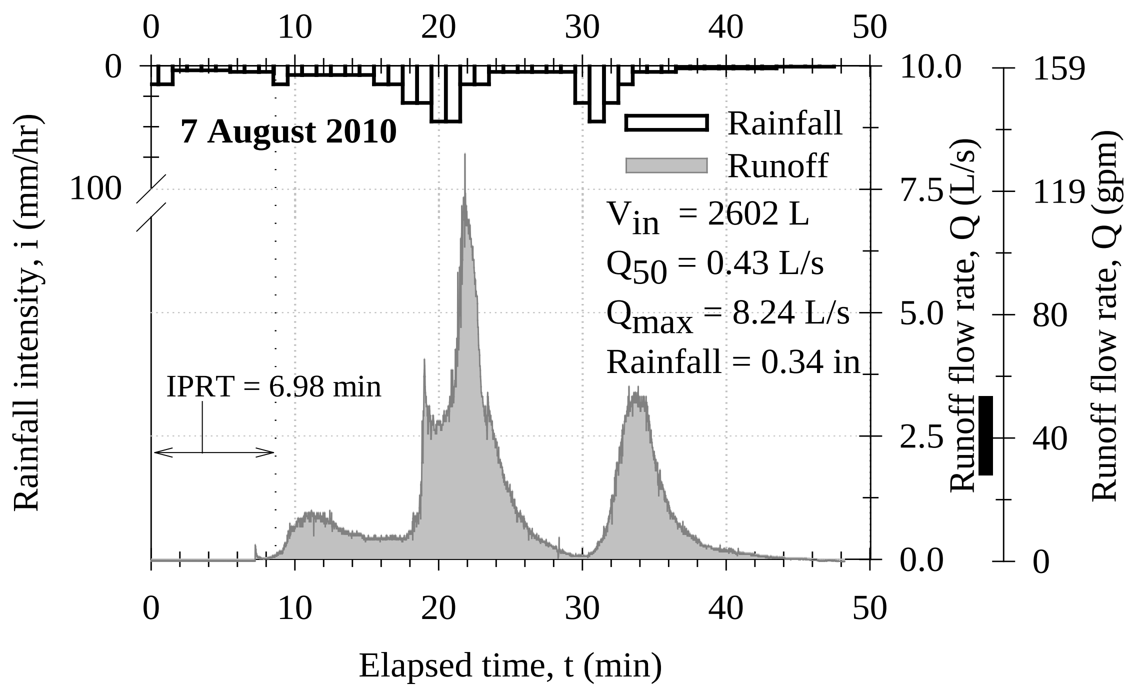

Figure A8: Hydrograph and hyetograph for 7 August 2010 event

On August 7, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 24 dry hours. The peak rainfall intensity is 2.4 in/hr and rainfall depth is 0.34 inch. The storm lasted approximately 48 minutes. The maximum, median, and mean runoff flow rates are 131gpm, 7gpm, and 14gpm, respectively. The influent runoff volume is 693 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 45.3 mg/L and 12.2 mg/L, respectively, and the removal efficiency is 74%. The influent and effluent SSC is 117.1 mg/L and 13.9 mg/L, respectively, and the removal efficiency is 89%.

Table A9: JF4 Summary: 23 August 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	23 August 2010	Influent Volume:	312 L (82 gal)
Previous Dry Hours:	48	Runoff Duration:	42 min
Maximum Flow Rate:	1.25 L/s (19.8 gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.01 L/s (0.2gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.12 L/s (2.0gpm)	Peak Rainfall Intensity:	15 mm/hr(0.6 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	3 mm (0.11 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

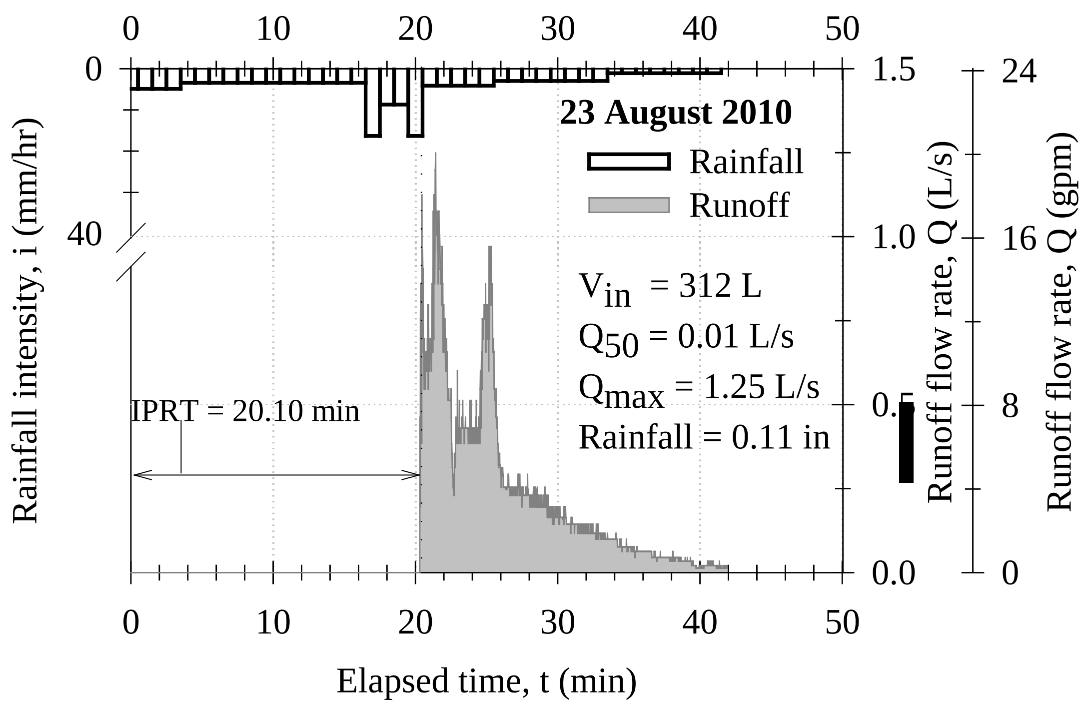

Figure A9: Hydrograph and hyetograph for 23 August 2010 event

On August 23, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 48 dry hours. The peak rainfall intensity is 0.6 in/hr and rainfall depth is 0.11 inch. The storm lasted approximately 42 minutes. The maximum, median, and mean runoff flow rates are 20 gpm, 0.2 gpm, and 2 gpm, respectively. The influent runoff volume is 82 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 74.2 mg/L and 8.2 mg/L, respectively, and the removal efficiency is 93%. The influent and effluent SSC is 555.8 mg/L and 4.7 mg/L, respectively, and the removal efficiency is 100%.

Table A10: JF4 Summary: 12 September 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	12September 2010	Influent Volume:	1643 L (434 gal)
Previous Dry Hours:	172	Runoff Duration:	52 min
Maximum Flow Rate:	3.85L/s (61.0 gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.10L/s (1.6 gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.53L/s (8.4 gpm)	Peak Rainfall Intensity:	51 mm/hr (2.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	7 mm (0.27 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

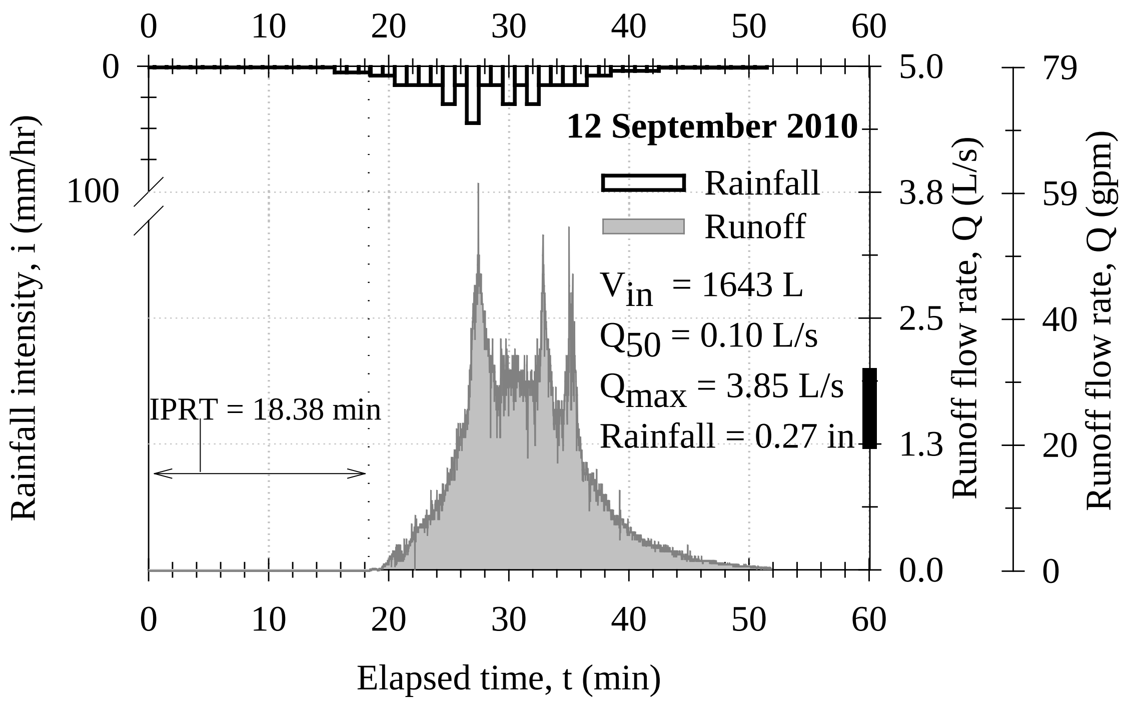

Figure A10: Hydrograph and hyetograph for 12 September 2010 event

On September 12, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 172 dry hours. The peak rainfall intensity is 2.0 in/hr and rainfall depth is 0.27 inch. The storm lasted approximately 52 minutes. The maximum, median, and mean runoff flow rates are 61gpm, 2 gpm, and 8 gpm, respectively. The influent runoff volume is 434 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 91.2 mg/L and 15.7 mg/L, respectively, and the removal efficiency is 84%. The influent and effluent SSC is 261.5 mg/L and 5.8 mg/L, respectively, and the removal efficiency is 98%.

Table A11: JF4 Summary: 26 September 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	26September 2010	Influent Volume:	1129 L (298 gal)
Previous Dry Hours:	40	Runoff Duration:	78 min
Maximum Flow Rate:	0.45 L/s (7.1 gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.26L/s (4.1 gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.24L/s (3.8 gpm)	Peak Rainfall Intensity:	5 mm/hr (0.2 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	4 mm (0.14 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

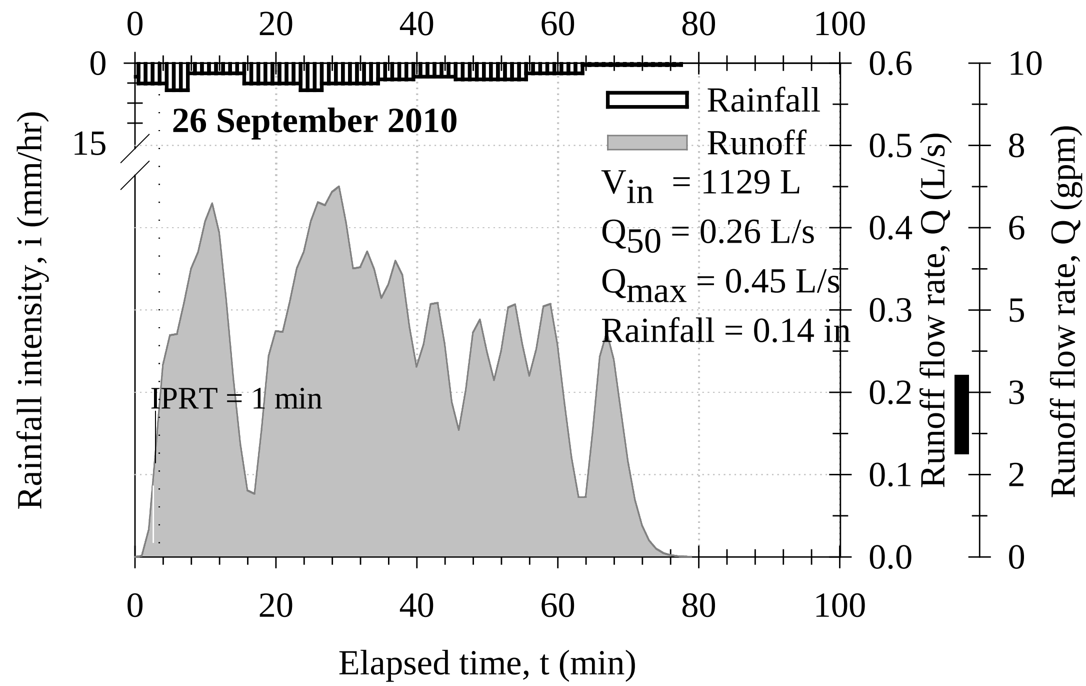

Figure A11: Hydrograph and hyetograph for 26 September 2010 event

On September 26, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 40 dry hours. The peak rainfall intensity is 0.2 in/hr and rainfall depth is 0.14 inch. The storm lasted approximately 78 minutes. The maximum, median, and mean runoff flow rates are 7 gpm, 4 gpm, and 4 gpm, respectively. The influent runoff volume is 298 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 16.3 mg/L and 4.7 mg/L, respectively, and the removal efficiency is 79%. The influent and effluent SSC is 117.9 mg/L and 5.0 mg/L, respectively, and the removal efficiency is 97%.

Table A12: JF4 Summary: 27 September 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	27September 2010	Influent Volume:	3841 L (1015 gal)
Previous Dry Hours:	10	Runoff Duration:	388 min
Maximum Flow Rate:	10.94L/s (173.4gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.04L/s (0.7gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.16L/s (2.6 gpm)	Peak Rainfall Intensity:	91 mm/hr (3.6 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	15 mm (0.6 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

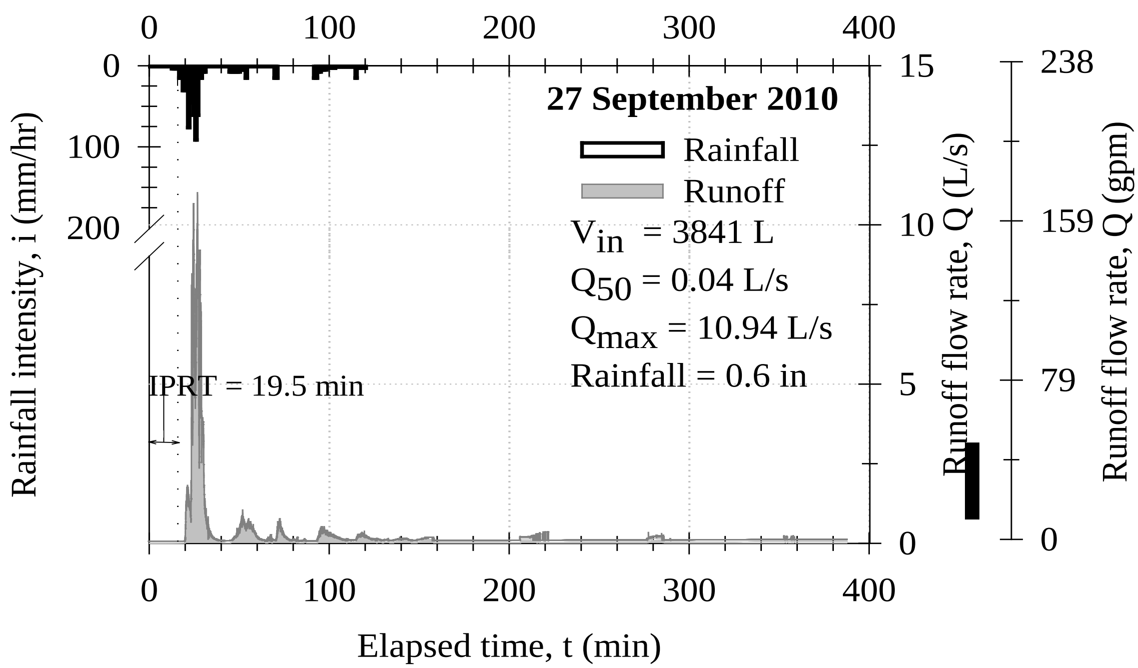

Figure A12: Hydrograph and hyetograph for 27 September 2010 event

On September 27, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 10 dry hours. The peak rainfall intensity is 3.6 in/hr and rainfall depth is 0.60 inch. The storm lasted approximately 388 minutes. The maximum, median, and mean runoff flow rates are 173gpm, 0.7gpm, and 2.6gpm, respectively. The influent runoff volume is 1015 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 51.1 mg/L and 3.2 mg/L, respectively, and the removal efficiency is 94%. The influent and effluent SSC is 765.1 mg/L and 6.0 mg/L, respectively, and the removal efficiency is 99%.

Table A13: JF4 Summary: 4 November 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	4November 2010	Influent Volume:	994 L (263 gal)
Previous Dry Hours:	910	Runoff Duration:	43 min
Maximum Flow Rate:	3.53 L/s (56.0 gpm)	Number of Influent Samples:	11
Median Flow Rate:	0.12 L/s (1.8gpm)	Number of Effluent Samples:	11
Mean Flow Rate:	0.38 L/s (6.0gpm)	Peak Rainfall Intensity:	46 mm/hr (1.8 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	5 mm (0.19 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

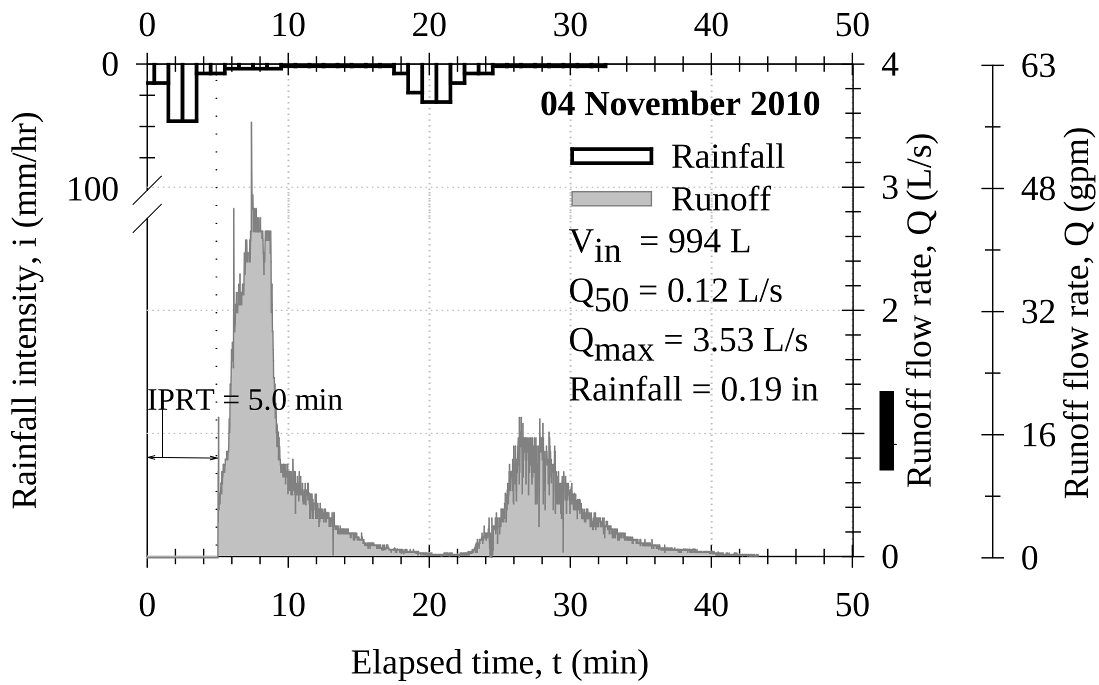

Figure A13: Hydrograph and hyetograph for 4 November 2010 event

On November 4, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 910 dry hours. The peak rainfall intensity is 1.8 in/hr and rainfall depth is 0.19 inch. The storm lasted approximately 43 minutes. The maximum, median, and mean runoff flow rates are 56 gpm, 2 gpm, and 6 gpm, respectively. The influent runoff volume is 263 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 11 and 11, respectively. The influent and effluent TSS is 39.9 mg/L and 4.2 mg/L, respectively, and the removal efficiency is 95%. The influent and effluent SSC is 477.1 mg/L and 10.4 mg/L, respectively, and the removal efficiency is 99%.

Table A14: JF4 Summary: 16 November 2010 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	16November 2010	Influent Volume:	305 L (81 gal)
Previous Dry Hours:	286	Runoff Duration:	34 min
Maximum Flow Rate:	1.75 L/s (27.7 gpm)	Number of Influent Samples:	11
Median Flow Rate:	0.02 L/s (0.3gpm)	Number of Effluent Samples:	11
Mean Flow Rate:	0.13 L/s (2.1gpm)	Peak Rainfall Intensity:	25 mm/hr (1.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	3 mm (0.13 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

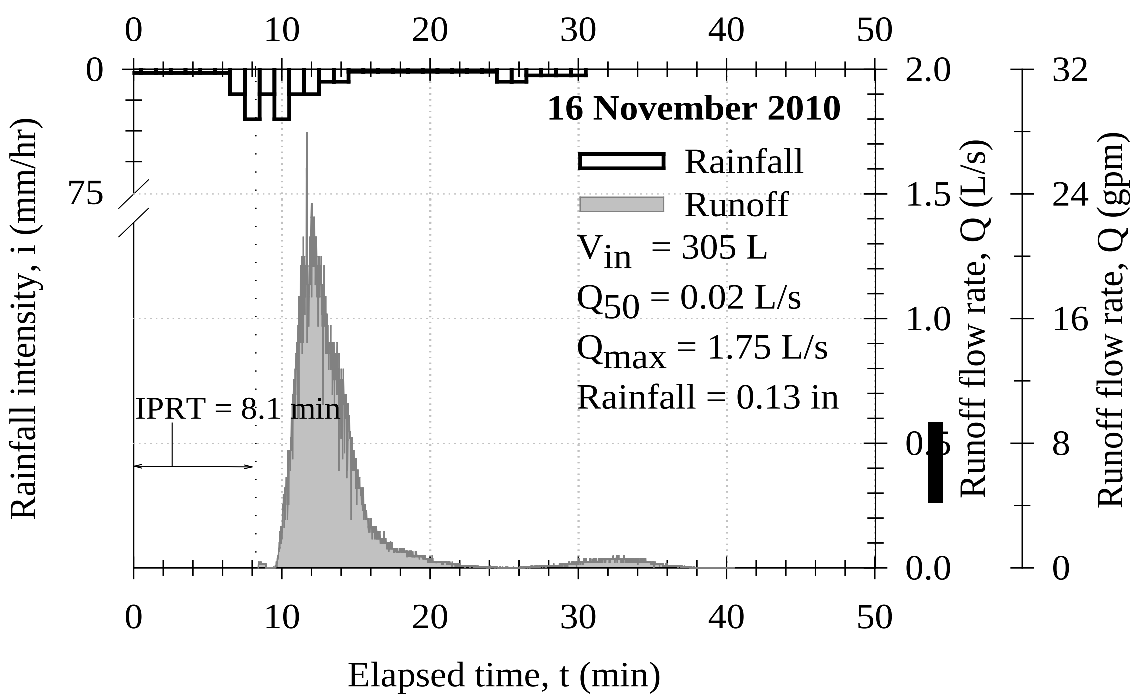

Figure A14: Hydrograph and hyetograph for 16 November 2010 event

On November 16, 2010, the JF4 unit treated a rainfall-runoff event. The event occurred after 286 dry hours. The peak rainfall intensity is 1.0 in/hr and rainfall depth is 0.13 inch. The storm lasted approximately 34 minutes. The maximum, median, and mean runoff flow rates are 28 gpm, 0.3gpm, and 2 gpm, respectively. The influent runoff volume is 81 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 11 and 11, respectively. The influent and effluent TSS is 261.0 mg/L and 11.8 mg/L, respectively, and the removal efficiency is 98%. The influent and effluent SSC is 543.6 mg/L and 12.2 mg/L, respectively, and the removal efficiency is 99%.

Table A15: JF4 Summary: 5 January 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	05 January 2011	Influent Volume:	5800 L (1532 gal)
Previous Dry Hours:	72 hr	Event Duration:	125 min
Maximum Flow Rate:	7.36 L/s (116.7gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.16 L/s (2.6gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	1.14 L/s (18.1gpm)	Peak Rainfall Intensity:	107 mm/hr (4.2 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	21 mm (0.84 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

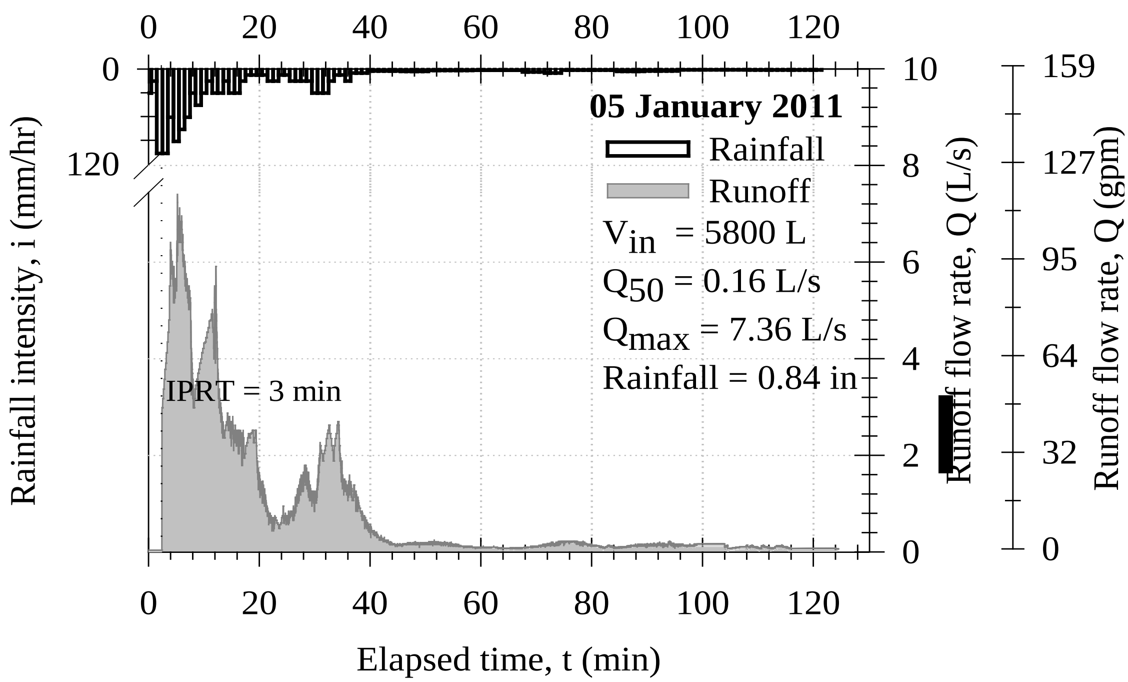

Figure A15: Hydrograph and hyetograph for 5 January 2011 event

On January 5, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 72 dry hours. The peak rainfall intensity is 4.2 in/hr and rainfall depth is 0.84 inches. The storm duration is 125 minutes. The maximum, median, and mean runoff flow rates are 117 gpm, 3 gpm, and 18 gpm, respectively. The influent runoff volume is 1532 gallons. Sampling occurred during the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. This is a The influent and effluent TSS is 152.2 mg/L and 15.9 mg/L, respectively, and the removal efficiency is 91%. The influent and effluent SSC is 693.2 mg/L and 8.7 mg/L, respectively, and the removal efficiency is 99%.

Table A16: JF4 Summary: 10 January 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	10 January 2011	Influent Volume:	1129 L (298 gal)
Previous Dry Hours:	106 hr	Event Duration:	26 min
Maximum Flow Rate:	3.32 L/s (52.6 gpm)	Number of Influent Samples:	8
Median Flow Rate:	0.01 L/s (0.2 gpm)	Number of Effluent Samples:	8
Mean Flow Rate:	0.41 L/s (6.5 gpm)	Peak Rainfall Intensity:	91 mm/hr (3.6inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	5 mm (0.20 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

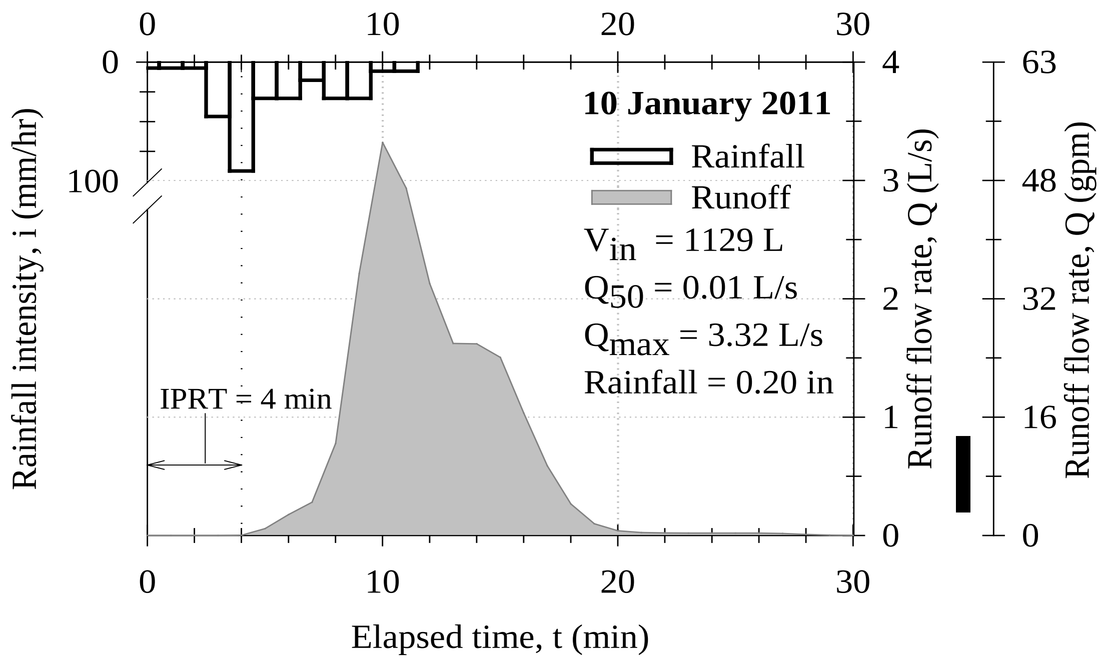

Figure A16: Hydrograph and hyetograph for 10 January 2011 event

On January 10, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 106 dry hours. The peak rainfall intensity is 3.6 in/hr and rainfall depth is 0.20 inch. The storm lasted approximately 26 minutes. The maximum, median, and mean runoff flow rates are 53 gpm, 0.2 gpm, and 7 gpm, respectively. The influent runoff volume is 298 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 8 and 8, respectively. The influent and effluent TSS is 80.7 mg/L and 6.6 mg/L, respectively, and the removal efficiency is 92%. The influent and effluent SSC is 211.1 mg/L and 3.0 mg/L, respectively, and the removal efficiency is 99%.

Table A17: JF4 Summary: 25 January 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	25 January 2011	Influent Volume:	12387 L (3273 gal)
Previous Dry Hours:	365 hr	Runoff Duration:	389 min
Maximum Flow Rate:	4.09L/s (64.8gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.39 L/s (6.2gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.53L/s (8.4gpm)	Peak Rainfall Intensity:	18mm/hr (0.7 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	44mm (1.74 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

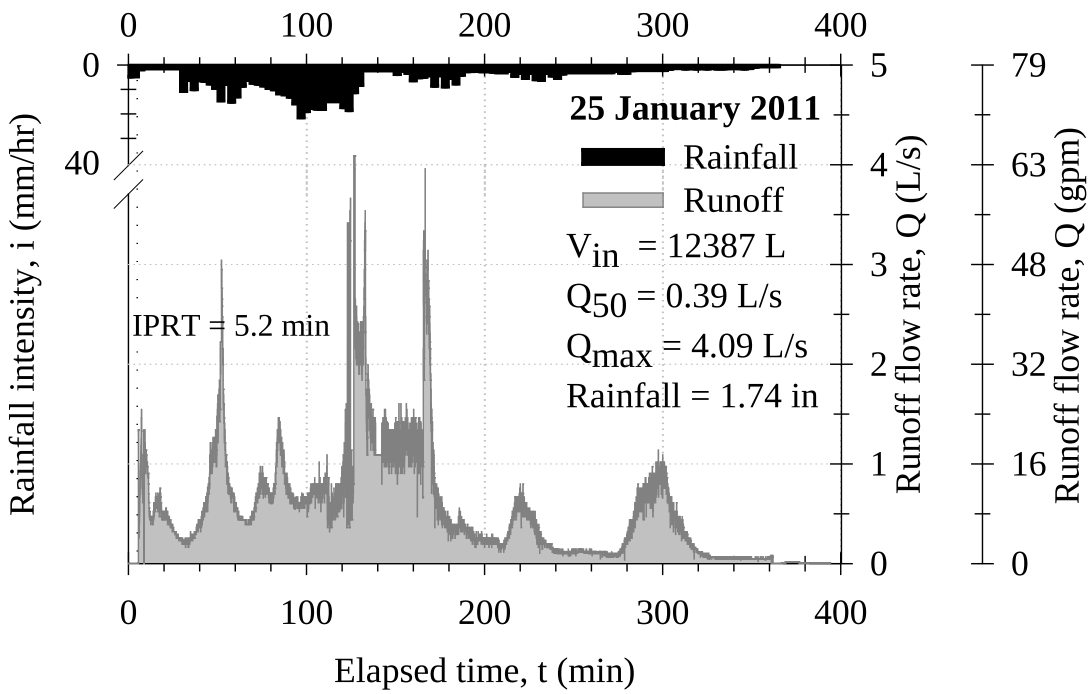

Figure A17: Hydrograph and hyetograph for 25 January 2011 event

On January 25, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 365 dry hours. The peak rainfall intensity is 0.7 in/hr and rainfall depth is 1.74 inch. The storm lasted approximately 389 minutes. The maximum, median, and mean runoff flow rates are 65 gpm, 6 gpm, and 8 gpm, respectively. The influent runoff volume is 3273 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 69.8 mg/L and 7.1 mg/L, respectively, and the removal efficiency is 90%. The influent and effluent SSC is 105.8 mg/L and 4.1 mg/L, respectively, and the removal efficiency is 96%.

Table A18: JF4 Summary: 7 February 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	07 February 2011	Influent Volume:	13229 L (3495 gal)
Previous Dry Hours:	12 hr	Runoff Duration:	306 min
Maximum Flow Rate:	2.22 L/s (35.2gpm)	Number of Influent Samples:	11
Median Flow Rate:	0.77 L/s (12.1gpm)	Number of Effluent Samples:	11
Mean Flow Rate:	0.71 L/s (11.2gpm)	Peak Rainfall Intensity:	30 mm/hr (1.2 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	32.8 mm (1.29 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

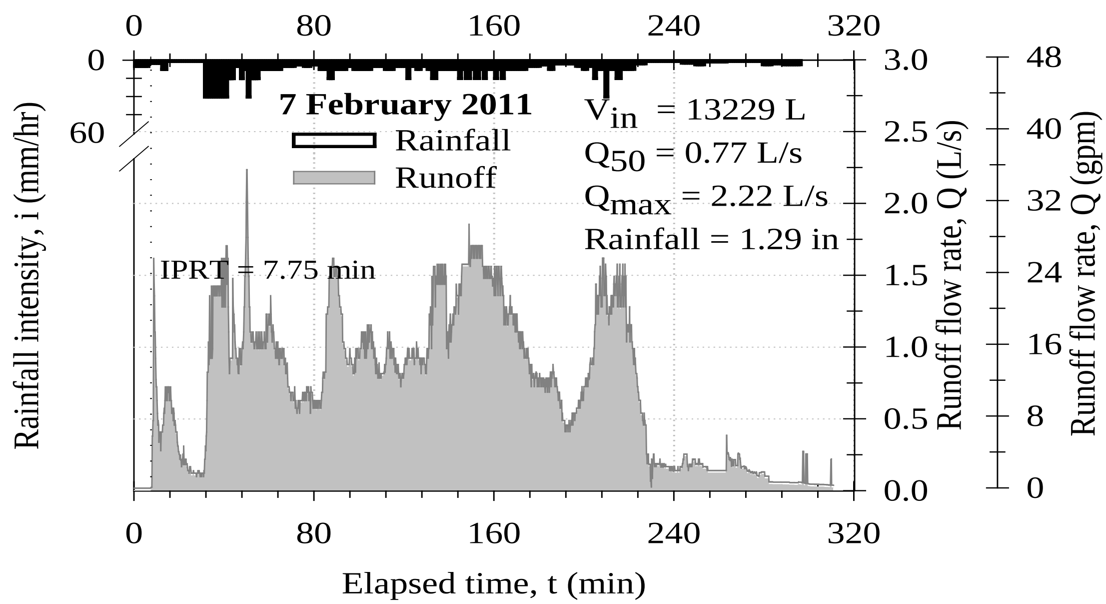

Figure A18: Hydrograph and hyetograph for 7 February 2011 event

On February 7, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 12 dry hours. The peak rainfall intensity is 1.2 in/hr and rainfall depth is 1.29 inch. The storm lasted approxi[redacted]ately 306 minutes. The maximum, median, and mean runoff flow rates are 35 gpm, 12 gpm, and 11 gpm, respectively. The influent runoff volume is 3495 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 11 and 11, respectively. The influent and effluent TSS is 34.8 mg/L and 5.3 mg/L, respectively, and the removal efficiency is 85%. The influent and effluent SSC is 438.3 mg/L and 7.6 mg/L, respectively, and the removal efficiency is 98%.

Table A19: JF4 Summary: 9 March 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	09 March 2011	Influent Volume:	10051 L (2656gal)
Previous Dry Hours:	79 hr	Runoff Duration:	691min
Maximum Flow Rate:	3.13L/s (49.7 gpm)	Number of Influent Samples:	12
Median Flow Rate:	0.10L/s (1.6 gpm)	Number of Effluent Samples:	12
Mean Flow Rate:	0.24L/s (3.8 gpm)	Peak Rainfall Intensity:	15mm/hr (0.6 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	29.2 mm (1.15 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

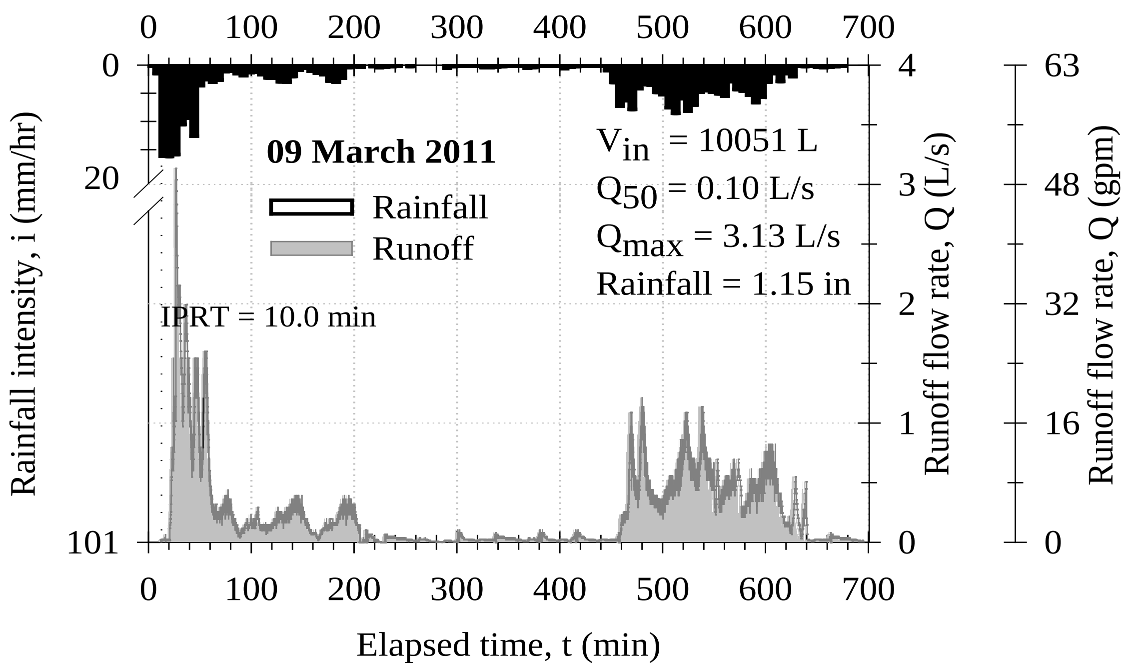

Figure A19: Hydrograph and hyetograph for 9 March 2011 event

On March 9, 2010, the JF4 unit treated a rainfall-runoff event. The event occurr[redacted]d after 79 dry hours. The peak rainfall intensity is 0.6 in/hr and rainfall depth is 1.15 inch. The storm [redacted]lasted approximately 691 minutes. The maximum, median, and mean runoff flow rates are 50 gpm, 2 gpm, and 4 gpm, respectively. Influent volume is 2656 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 12 and 12, respectively. The influent and effluent TSS is 30.5 mg/L and 8.3 mg/L, respectively, and the removal efficiency is 73%. The influent and effluent SSC is 78.2 mg/L and 2.8 mg/L, respectively, and the removal efficiency is 97%.

Table A20: JF4 Summary: 28 March 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	28 March 2011	Influent Volume:	522 L (138 gal)
Previous Dry Hours:	438 hr	Event Duration:	66 min
Maximum Flow Rate:	1.03 L/s (16.4gpm)	Number of Influent Samples:	12
Median Flow Rate:	0.06 L/s (0.9gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.13 L/s (2.1gpm)	Peak Rainfall Intensity:	33 mm/hr (1.3 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	2.5 mm (0.10 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

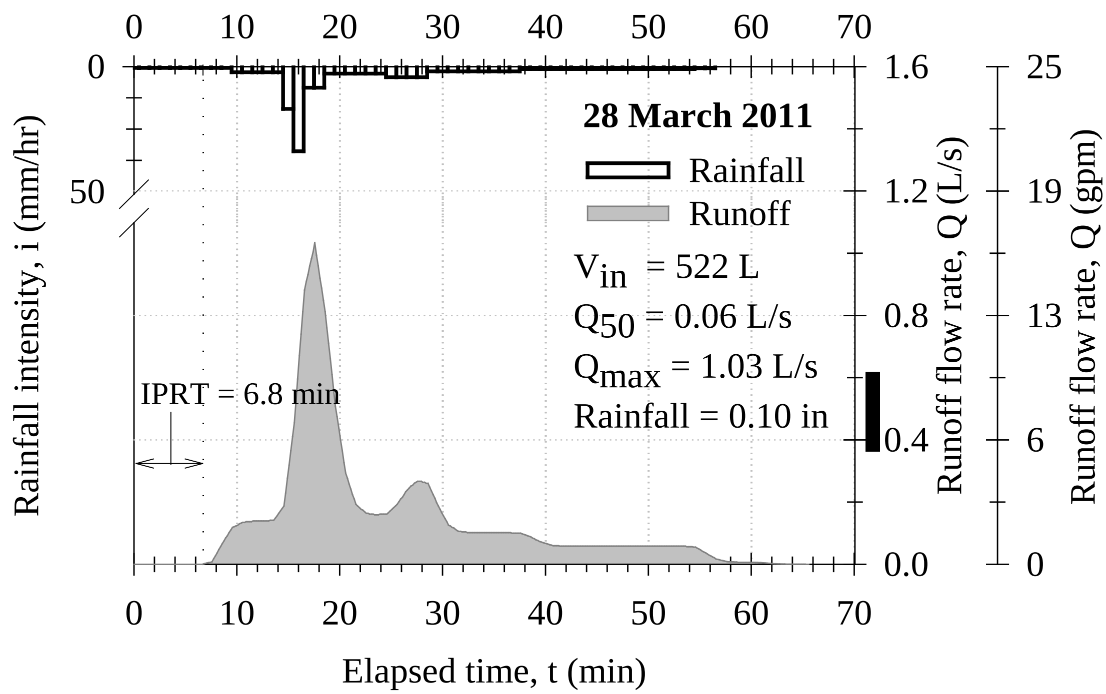

Figure A20: Hydrograph and hyetograph for 28 March 2011 event

On March 28, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 438 dry hours. The peak rainfall intensity is 1.3 in/hr and rainfall depth is 0.10 inch. The storm lasted approximately 66 minutes. The maximum, median, and mean runoff flow rates are 16 gpm, 1 gpm, and 2 gpm, respectively. The influent runoff volume is 138 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 12 and 10, respectively. The influent and effluent TSS is 68.4 mg/L and 12.7 mg/L, respectively, and the removal efficiency is 86%. The influent and effluent SSC is 102.8 mg/L and 5.6 mg/L, respectively, and the removal efficiency is 96%.

Table A21: JF4 Summary: 30 March 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	30 March 2011	Influent Volume:	3707L (979gal)
Previous Dry Hours:	48 hr	Event Duration:	179 min
Maximum Flow Rate:	5.61 L/s (89.0gpm)	Number of Influent Samples:	12
Median Flow Rate:	0.10 L/s (1.6gpm)	Number of Effluent Samples:	12
Mean Flow Rate:	0.29 L/s (4.5gpm)	Peak Rainfall Intensity:	76 mm/hr (3.0 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	15 mm (0.60 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

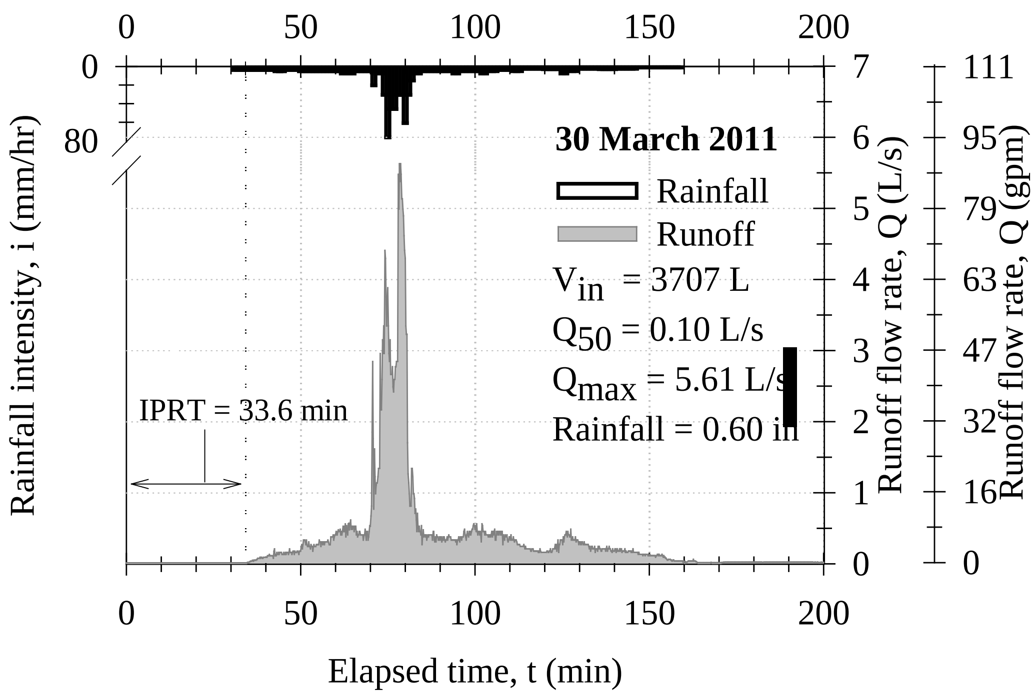

Figure A21: Hydrograph and hyetograph for 30 March 2011 event

On March 30, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 48 dry hours. The peak rainfall intensity is 3 in/hr and rainfall depth is 0.60 inch. The storm lasted approximately 179 minutes. The maximum, median, and mean runoff flow rates are 89 gpm, 2 gpm, and 5 gpm, respectively. The influent runoff volume is 979 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 12 and 12, respectively. The influent and effluent TSS is 104.5 mg/L and 7.3 mg/L, respectively, and the removal efficiency is 93%. The influent and effluent SSC is 443.7 mg/L and 7.3 mg/L, respectively, and the removal efficiency is 98%.

Table A22: JF4 Summary: 20 April 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	20 April 2011	Influent Volume:	206 L (54 gal)
Previous Dry Hours:	196 hr	Event Duration:	61 min
Maximum Flow Rate:	3.28 L/s (52.0gpm)	Number of Influent Samples:	12
Median Flow Rate:	0.01 L/s (0.1gpm)	Number of Effluent Samples:	12
Mean Flow Rate:	0.06 L/s (0.9gpm)	Peak Rainfall Intensity:	15 mm/hr (0.6 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	4 mm (0.14 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

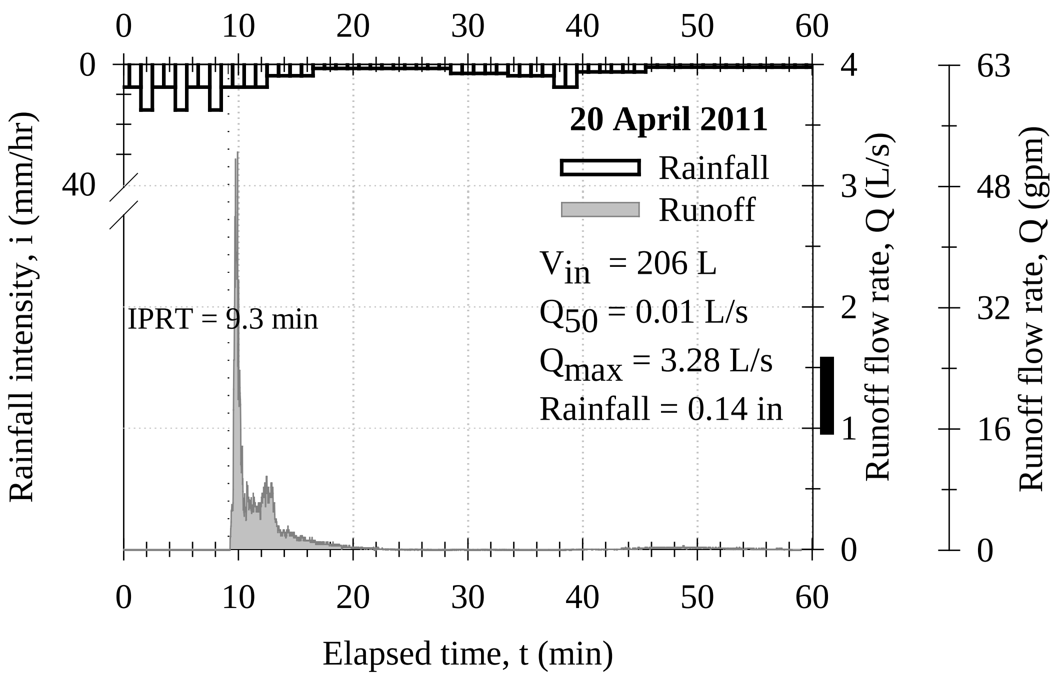

Figure A22: Hydrograph and hyetograph for 20 April 2011 event

On April 20, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 196 dry hours. The peak rainfall intensity is 0.6 in/hr and rainfall depth is 0.14 inch. The storm lasted approximately 61 minutes. The maximum, median, and mean runoff flow rates are 52 gpm, 0.1 gpm, and 0.9 gpm, respectively. The influent runoff volume is 54 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 12 and 12, respectively. The influent and effluent TSS is 143.7 mg/L and 11.4 mg/L, respectively, and the removal efficiency is 96%. The influent and effluent SSC is 921.7 mg/L and 6.1 mg/L, respectively, and the removal efficiency is 100%.

Table A23: JF4 Summary: 14 May 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	14May 2011	Influent Volume:	11256 L (2974 gal)
Previous Dry Hours:	188 hr	Event Duration:	295 min
Maximum Flow Rate:	7.53 L/s (119.3gpm)	Number of Influent Samples:	19
Median Flow Rate:	0.02 L/s (0.36gpm)	Number of Effluent Samples:	19
Mean Flow Rate:	0.63 L/s (9.98gpm)	Peak Rainfall Intensity:	137 mm/hr (5.4 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	50 mm (1.98 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

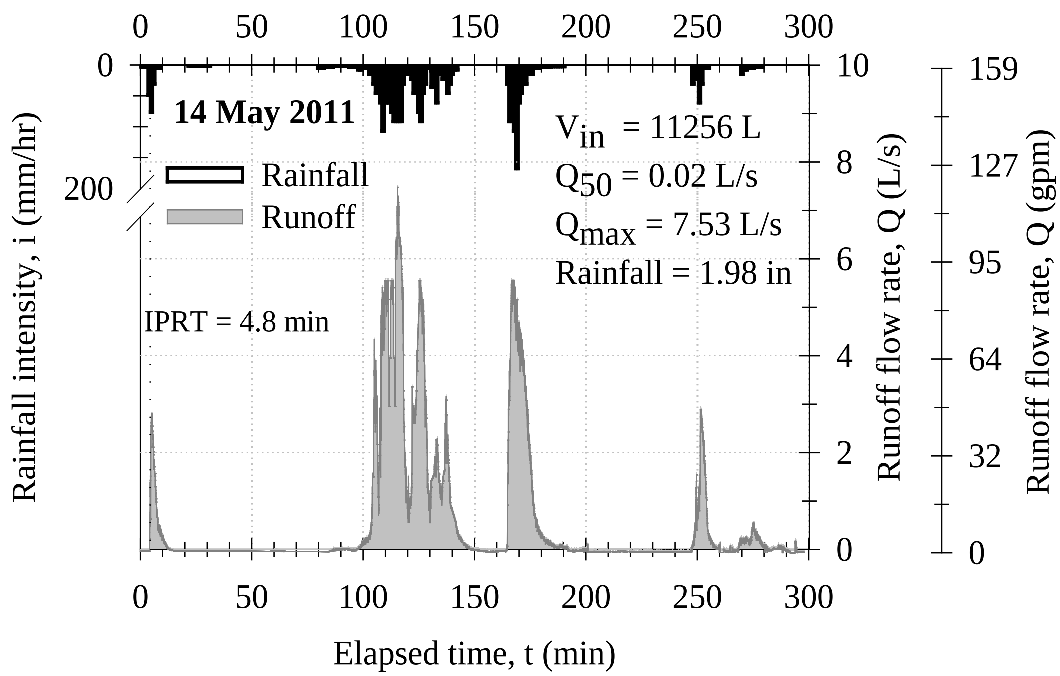

Figure A23: Hydrograph and hyetograph for 14 May 2011 event

On May 14, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 188 dry hours. The peak rainfall intensity is 5.4 in/hr and rainfall depth is 1.98 inch. The storm lasted approximately 295 minutes. The maximum, median, and mean runoff flow rates are 119.3gpm, 0.4 gpm, and 10.0gpm, respectively. The influent runoff volume is 2,974 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 19 and 19, respectively. The influent and effluent TSS is 77.1 mg/L and 12.5 mg/L, respectively, and the removal efficiency is 84%. The influent and effluent SSC is 487.3 mg/L and 5.3 mg/L, respectively, and the removal efficiency is 99%.

Table A24: JF4 Summary:6 June 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	6 June 2011	Influent Volume:	960 L (254 gal)
Previous Dry Hours:	541 hr	Event Duration:	69 min
Maximum Flow Rate:	1.55 L/s (24.5gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.01 L/s (0.1gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.23 L/s (3.7gpm)	Peak Rainfall Intensity:	23 mm/hr (0.9 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	4 mm (0.16 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

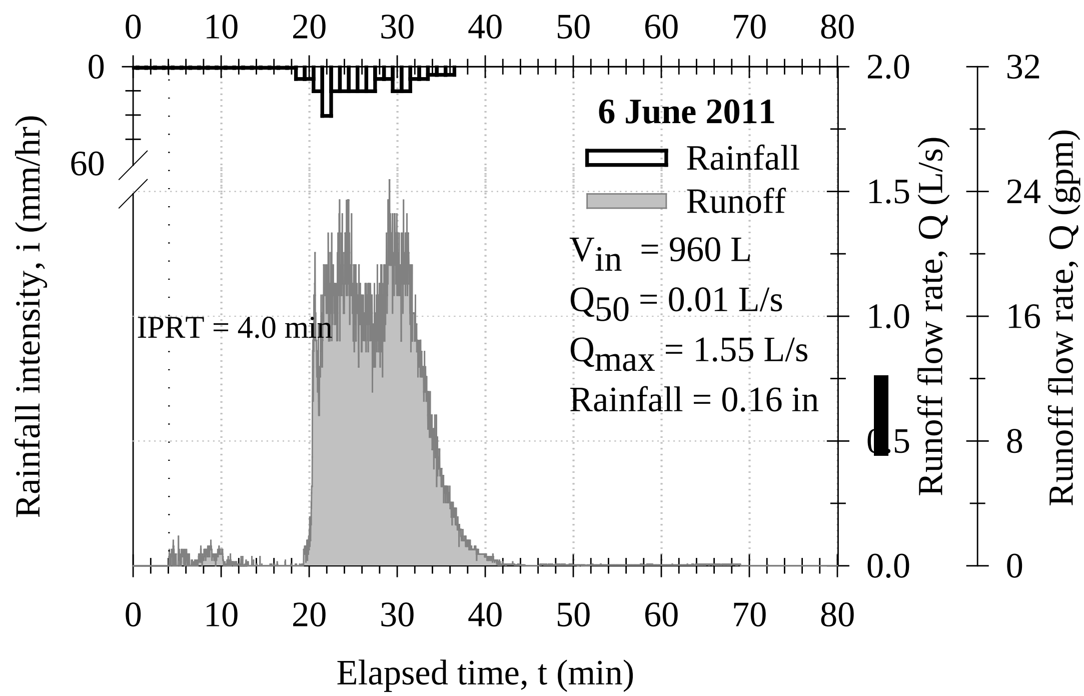

Figure A24: Hydrograph and hyetograph for 6 June 2011 event

On June 6, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 541 dry hours. The peak rainfall intensity is 0.9 in/hr and rainfall depth is 0.16 inch. The storm lasted approximately 69 minutes. The maximum, median, and mean runoff flow rates are 24.5 gpm, 0.1 gpm, and 3.7 gpm, respectively. The influent runoff volume is 254 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 85.6 mg/L and 13.2 mg/L, respectively, and the removal efficiency is 88%. The influent and effluent SSC is 237.5 mg/L and 9.0 mg/L, respectively, and the removal efficiency is 97%.

Table A25: JF4 Summary: 27 June 2011 Hydrology

Event Information		JF4 Unit Treatment Run information	
Event Date:	27 June 2011	Influent Volume:	3383 L (894 gal)
Previous Dry Hours:	88 hr	Event Duration:	50 min
Maximum Flow Rate:	3.35 L/s (53.2gpm)	Number of Influent Samples:	10
Median Flow Rate:	0.12 L/s (2.0gpm)	Number of Effluent Samples:	10
Mean Flow Rate:	0.64 L/s (10.1gpm)	Peak Rainfall Intensity:	43 mm/hr (1.7 inch/hr)
Experimental Site:	UF Engineering Surface Parking	Rainfall Depth:	11 mm (0.45 inch)
TARP Qualifying:	YES	Site Location:	Gainesville, FL

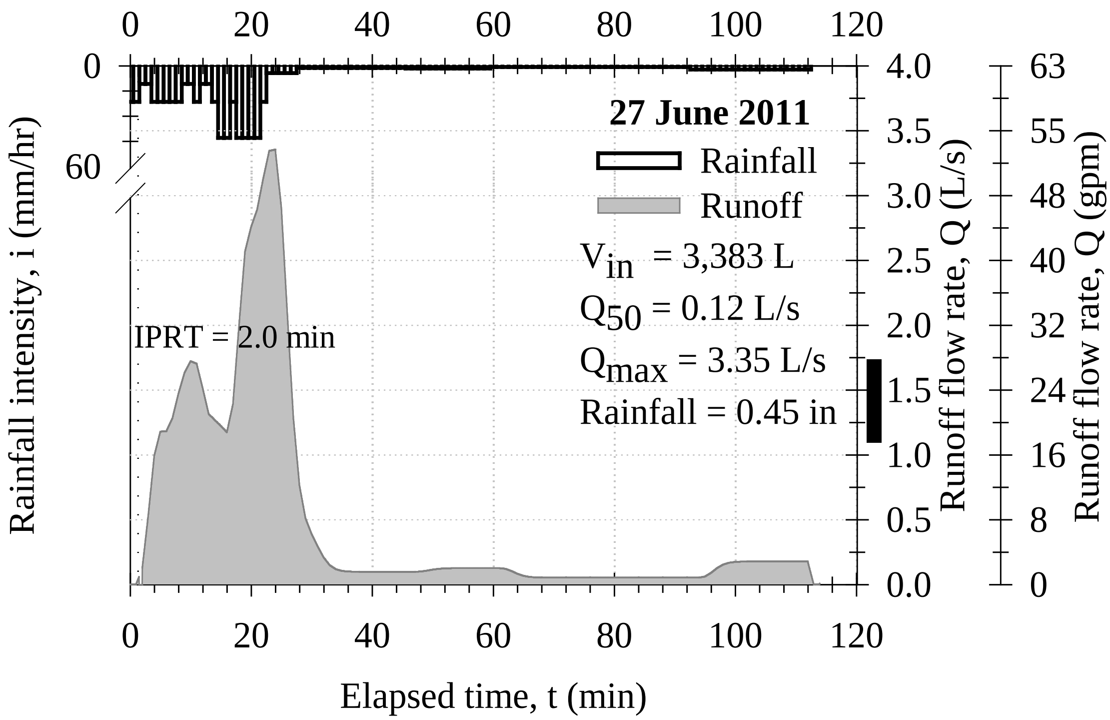

Figure A25: Hydrograph and hyetograph for 27 June 2011 event

On June 27, 2011, the JF4 unit treated a rainfall-runoff event. The event occurred after 88 dry hours. The peak rainfall intensity is 1.7 in/hr and rainfall depth is 0.45 inch. The storm lasted approximately 50 minutes. The maximum, median, and mean runoff flow rates are 53gpm, 2gpm, and 10 gpm, respectively. The influent runoff volume is 894 gallons. Sampling occurred throughout the entire duration of the storm and the number of influent and effluent samples taken is 10 and 10, respectively. The influent and effluent TSS is 131.4 mg/L and 12.8 mg/L, respectively, and the removal efficiency is 91%. The influent and effluent SSC is 591.7 mg/L and 9.8 mg/L, respectively, and the removal efficiency is 98%.

APPENDIX B

HYDRAULIC TESTING

Extensive hydraulic testing was conducted at the University of Florida on a new clean 54-inch long Jellyfish® filtration cartridge with the standard orifice sizes in the cartridge lid (35 mm orifice for the draindown cartridge and 70 mm for the hi-flo cartridge). In addition, hydraulic testing was conducted on the Jellyfish® Filter JF4-2-1 with clean cartridges prior to commissioning as well as with dirty cartridges at the conclusion of the monitoring period (25 monitored storm events and 15 inches of cumulative rainfall).

Figure B1 depicts the hydraulic response curve for a new clean 54-inch Jellyfish® filtration cartridge with a 35 mm orifice in the cartridge lid, which is the standard lid orifice for the draindown cartridge. Test results demonstrate a flow capacity of 44 gpm at 18 inches of driving head. Imbrium Systems assigns a design treatment flow rate of 40 gpm to the draindown cartridge used in the Jellyfish® Filter JF4-2-1.

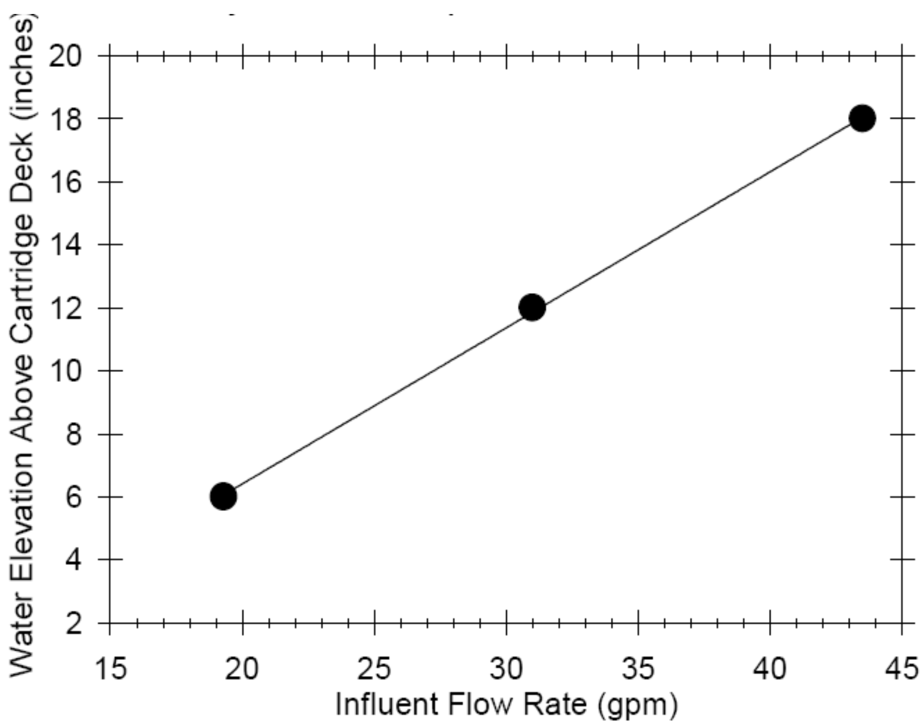

Figure B1: Hydraulic response of a clean 54-inch long Jellyfish filtration cartridge with a 35 mm lid orifice, used as the draindown cartridge in the JF4-2-1.

Figure B2 depicts the hydraulic response curve for a new clean 54-inch Jellyfish filtration cartridge with a 70 mm orifice in the cartridge lid, which is the standard lid orifice for each of the hi-flo cartridges. Test results demonstrate a flow capacity of 116 gpm at 18 inches of driving head and 88 gpm at 12 inches of driving head. Since each hi-flo cartridge is located within the 6-inch high backwash pool weir, the net available driving head for the hi-flo cartridge is 12 inches. Imbrium Systems assigns a design treatment flow rate of 80 gpm to each hi-flo cartridge used in the Jellyfish® Filter JF4-2-1.

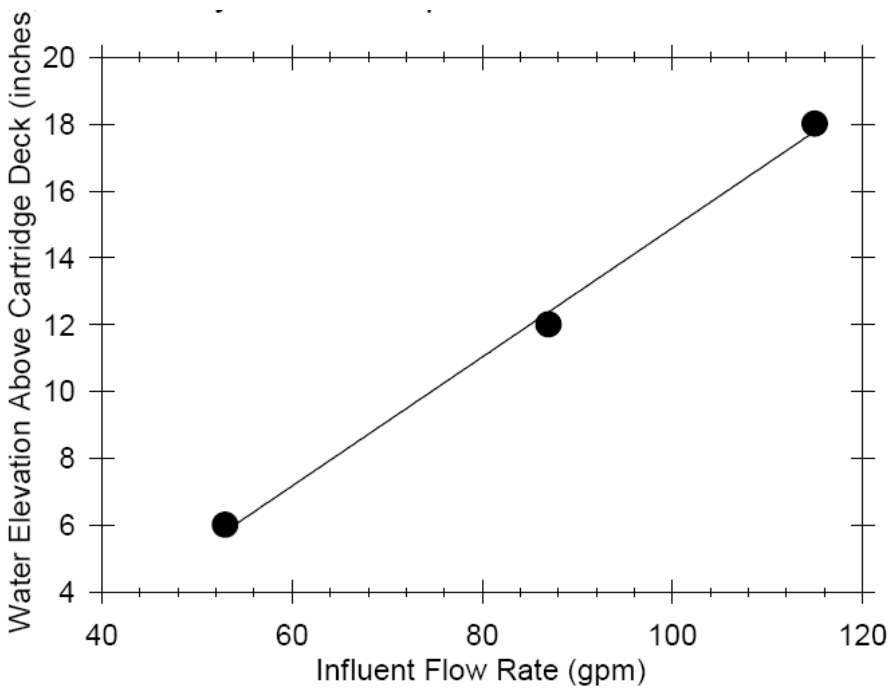

Figure B2: Hydraulic response of a clean 54-inch long Jellyfish filtration cartridge with a 70 mm lid orifice, used for each hi-flo cartridge in the JF4-2-1.

Figure B3 depicts the hydraulic response curves for the Jellyfish® Filter JF4-2-1, which uses three 54-inch long Jellyfish filtration cartridges, one deployed as the draindown cartridge and two deployed as hi-flo cartridges. Hydraulic testing was performed with clean new cartridges prior to commissioning the system for field testing, and with dirty cartridges at the conclusion of monitoring after 25 storm events and 15 inches of cumulative rainfall. Test results demonstrate a flow capacity of 200 gpm at 18 inches of driving head for the JF4-2-1 with clean cartridges, which is the design treatment flow rate of the system. The hydraulic response curves are virtually identical for the system with clean cartridges and with dirty cartridges up to 18 inches of driving head.

The divergence of the curves beyond 18 inches of driving head is attributed to a difference in the height of the pressure relief pipe during the hydraulic tests. During hydraulic testing with clean cartridges, the pressure relief pipe height was 18 inches. At driving head greater than 18 inches, the pressure relief pipe began to overflow, resulting in a relatively flat response curve from that point forward as flow rate increased. The pressure relief pipe height was subsequently increased to 24 inches prior to commissioning the system in order to eliminate any possibility of internal bypassing of water during the monitoring period, An external bypass was installed around the treatment unit and configured to begin bypassing influent if driving head exceeded 18 inches during a storm event. Hydraulic testing was performed on the JF4-2-1 with the dirty cartridges after the external bypass was disassembled and with the 24-inch high pressure relief pipe intact, resulting in a response curve with gradually increasing slope as flow rate increased with driving head between 18 and 24 inches.

After completing hydraulic testing on the JF4-2-1 with dirty cartridges, the draindown time of water within the 6-inch high backwash pool weir was measured and ranged from 101-120 seconds. The backwash pool is designed as a passive self-cleaning mechanism, and provides a reverse flow of water through the hi-flo cartridges when influent flow ceases. Water below the cartridge deck is displaced through the draindown cartridge and discharged to the top of the cartridge deck and subsequently to the outlet pipe. The backwash pool draindown time of approximately 2 minutes indicated that the degree of PM occlusion on the dirty hi-flo and draindown cartridges did not appear to significantly impede water flow through the cartridges during passive backwash.

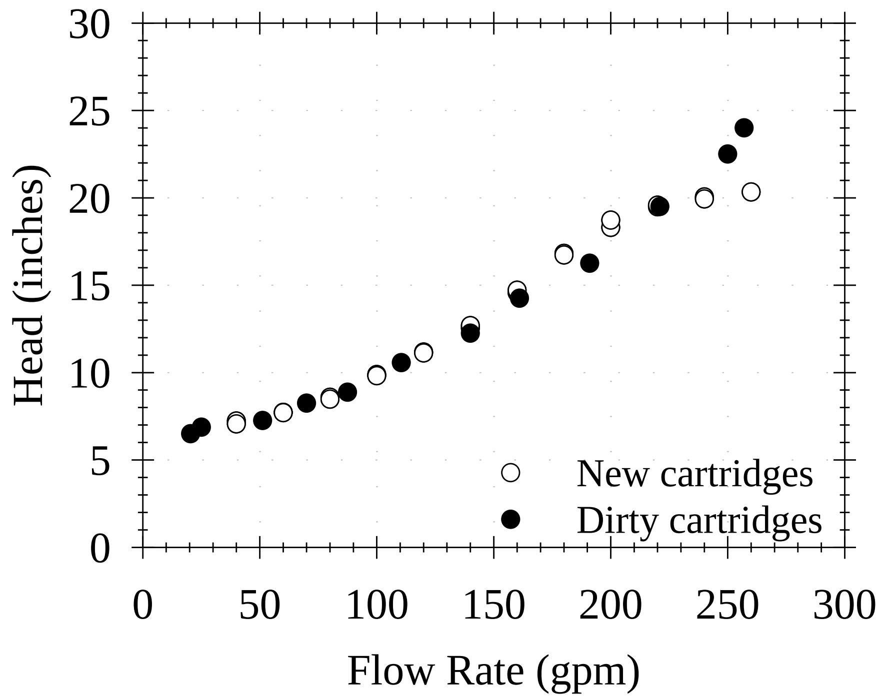

Figure B3: Hydraulic response of the Jellyfish® Filter JF4-2-1 with clean cartridges prior to commissioning and with dirty cartridges after the monitoring period (25 storm events, 15 inches of cumulative rainfall, 29,851 gallons of treated runoff, and 166 pounds of captured PM mass)

After completing hydraulic testing of the JF4-2-1 with the dirty cartridges, a manual back-flush of the dirty cartridges was performed using a Jellyfish® Cartridge Back-flush Pipe to simulate a typical annual maintenance activity. The back-flush pipe is a 40-inch tall, 12-inch diameter hollow tube fitted with a flush valve and flapper on the inside bottom, and a compressible gasket on the lower end. In order to manually back-flush a cartridge, the cartridge lid is removed and the back-flush pipe is placed over the cartridge receptacle with the compressible gasket resting squarely on the receptacle. The pipe is filled with clean water using a hose, and the weight of the water causes the compressible gasket to form a water-tight seal on the receptacle. A wire connected to the internal flapper valve is then pulled, which raises the flapper and allows the contents of the pipe to drain out and back-flush the cartridge. Since the pipe is 40 inches tall, the head of back-flush water is significantly higher than the typical 18 inches of driving head that a cartridge might experience during peak treatment forward flow. The pipe is designed to provide a significant back-flush volume and relatively high back-flush flow rate in order to effectively remove accumulated sediment from the filter surfaces. The back-flush pipe holds approximately 18 gallons of water when full, with 14 gallons of that total in the uppermost 30 inches of pipe, which is the distance from the top of the pipe to the top of the flapper valve when in the open position.

The time to drain the uppermost 30 inches of back-flush pipe volume (14 gallons) was measured for all three cartridges and determined to be approximately 8 seconds in each case, which equates to an average back-flush flow rate of approximately 105 gpm for each cartridge. Hydraulic testing was subsequently performed on the JF4-2-1 with the manually back-flushed cartridges. As expected, the hydraulic response curve was virtually identical to the system with clean new cartridges and with dirty cartridges as determined earlier. This indicates that the degree of sediment occlusion on the dirty cartridges was not significant enough to result in an increase in hydraulic capacity after manual back-flushing. Prior to manual back-flushing of the cartridges, 158 pounds of dry basis pollutant mass was recovered from the sump. After manual back-flushing of the cartridges, a very small amount of additional pollutant mass (0.1 pounds dry basis) was recovered from the sump. This indicates that each dirty cartridge contained sufficient porosity to allow passage of a relatively high back-flush flow rate such that minimal PM was dislodged from the cartridges, despite the presence of 2.6 pounds of PM mass on each cartridge (established by later manual rinsing of each cartridge as described below).

After completing hydraulic testing of the JF4-2-1 with manually backwashed cartridges, the cartridges were removed from the system and rinsed with a garden hose sprayer as part of the PM mass recovery and to simulate a typical maintenance activity. Accumulated PM was easily removed from the cartridges with rinsing, and a pollutant mass of 2.6 pounds (dry basis) was recovered from each cartridge, for a total of approximately 8 pounds. PM mass recovered from the sump was 158 pounds, for a total dry basis PM mass recovery of 166 pounds. Data are shown in **Table B-1**. The uniform and relatively low quantity of pollutant mass found on the cartridges indicates that self-cleaning mechanisms are effective in removing accumulated PM from both the hi-flo cartridges and the draindown cartridge.

Hydraulic testing was subsequently performed on the JF4-2-1 with the manually rinsed cartridges. As expected, the hydraulic response curve was virtually identical to the system with clean new cartridges, with dirty cartridges, and with manually backwashed cartridges as determined earlier. **Figure B4.**

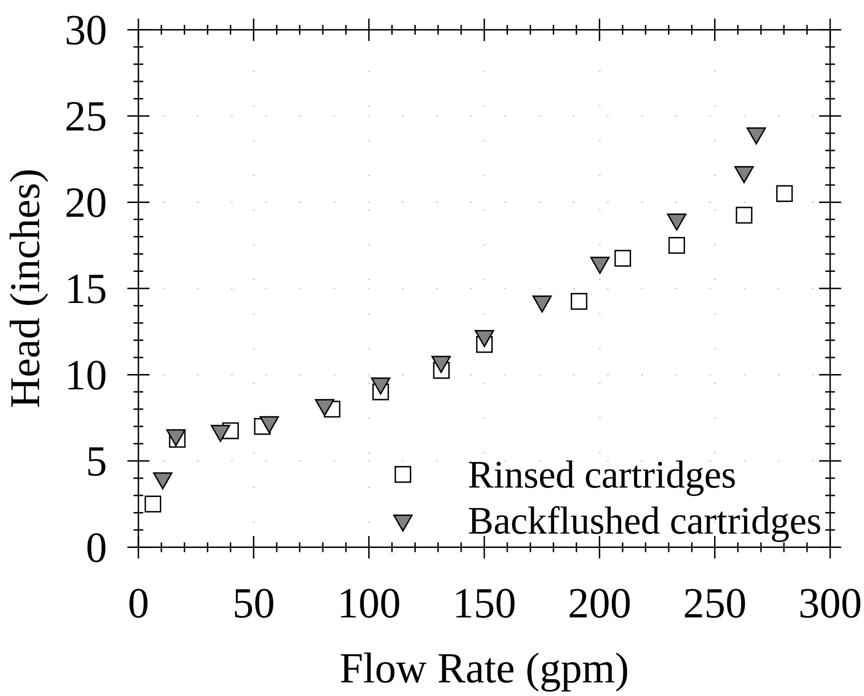

Figure B4: Hydraulic response of the JF4-2-1 with manually back-flushed cartridges and with manually rinsed cartridges

Table B-1 Mass balance results utilizing measured functional and granulometric fractions of sediment, settleable and suspended PM

Rainfall-runoff Event	Influent									Effluent							
	Vol.	Sediment PM		Settleable PM		Suspended PM		Total PM		Vol.	Sediment PM		Settleable PM		Suspended PM		Tota
		EMC	Mass	EMC	Mass	EMC	Mass	EMC	Mass		EMC	Mass	EMC	Mass	EMC	Mass	EMC
	L	mg/L	g	mg/L	g	mg/L	g	mg/L	g	L	mg/L	g	mg/L	g	mg/L	g	mg/L
28-May-10	7454	435.9	3249.6	45.4	338.6	43.7	325.9	525.1	3914.2	3682	6.2	22.9	6.9	25.2	11.9	43.8	25.0
16-Jun	4997	1333.5	6663.5	66.9	334.5	67.9	339.3	1468.3	7337.3	4665	7.1	33.2	2.0	9.4	20.1	93.6	29.2
21-Jun	8683	1781.6	15469.0	22.2	192.5	13.7	119.2	1817.5	15780.7	8460	5.6	47.6	1.8	15.1	9.9	83.7	17.3
30-Jun	5451	504.0	2747.3	20.6	112.5	19.2	104.9	543.9	2964.7	5330	8.0	42.5	1.5	8.2	5.7	30.5	15.2
15-Jul	3602	938.6	3381.1	68.2	245.6	23.7	85.3	1030.5	3712.0	3296	5.2	17.0	1.4	4.6	6.9	22.9	13.5
1-Aug	11990	243.2	2916.0	22.8	272.8	18.5	222.2	284.5	3411.0	11676	4.8	55.9	8.4	98.4	6.9	80.9	20.1
6-Aug	1395	390.3	544.4	29.5	41.2	48.0	66.9	467.8	652.5	1024	13.1	13.5	2.9	3.0	12.0	12.3	28.1
7-Aug	2620	222.5	582.9	32.3	84.5	13.1	34.3	267.9	701.8	2540	1.6	4.0	5.1	13.1	6.9	17.5	13.6
23-Aug	310	533.9	165.5	41.9	13.0	44.6	13.8	620.4	192.3	193	2.6	0.5	3.1	0.6	4.7	0.9	10.4
12-Sep	1641	165.0	270.7	68.7	112.7	67.4	110.6	301.2	494.1	1508	2.7	4.1	4.1	6.2	11.5	17.4	18.4
26-Sep	1126	224.5	252.9	0.9	1.0	2.0	2.2	227.4	256.1	835	7.9	6.6	2.2	1.8	2.0	1.7	12.1
27-Sep	3837	875.1	3357.4	50.0	192.0	44.5	170.8	969.6	3720.2	3765	3.2	11.9	2.1	7.8	5.0	18.7	10.2
4-Nov	994	486.4	483.5	38.6	38.4	92.8	92.3	617.8	614.2	510	3.7	1.9	2.9	1.5	6.5	3.3	13.1
16-Nov	306	318.4	97.5	131.9	40.4	118.2	36.2	568.6	174.1	166	18.0	3.0	2.4	0.4	8.4	1.4	28.9
5-Jan-11	5791	841.4	4872.3	49.8	288.4	40.9	236.8	932.1	5397.5	4948	3.2	15.7	2.8	14.1	12.9	63.9	18.9
10-Jan	1126	454.0	511.4	60.1	67.7	20.8	23.4	534.9	602.5	1047	1.4	1.5	3.6	3.8	3.1	3.2	8.1
25-Jan	12387	410.6	5085.8	37.7	467.3	32.4	401.8	480.7	5954.9	12353	1.1	14.0	2.1	25.4	2.0	24.6	5.2
7-Feb	13211	738.5	9756.9	16.7	221.2	23.0	304.4	778.3	10282.5	12928	2.4	31.1	0.8	10.8	4.2	54.7	7.5
9-Mar	10036	69.6	699.0	8.5	85.6	13.3	133.5	91.5	918.1	9805	0.5	5.3	0.6	5.8	0.9	9.1	2.1
28-Mar	522	65.4	34.1	13.0	6.8	36.4	19.0	114.8	59.9	423	1.9	0.8	2.1	0.9	8.0	3.4	12.0
30-Mar	3761	386.9	1455.3	54.3	204.3	34.0	127.7	475.2	1787.3	3678	0.8	3.0	1.8	6.6	4.6	16.7	7.2
20-Apr	204	1010.4	206.2	30.9	6.3	24.8	5.1	1066.1	217.6	113	1.8	0.2	2.6	0.3	7.1	0.8	11.5
14-May	10864	790.9	8591.9	59.6	647.5	44.5	483.6	895.0	9723.0	10697	2.0	21.2	1.3	14.0	11.2	119.5	14.5
6-Jun	964	307.6	296.5	30.8	29.7	53.3	51.4	391.7	377.6	733	1.1	0.8	2.5	1.8	10.4	7.6	13.9
27-Jun	3379	514.8	1739.7	67.6	228.6	47.6	161.0	630.1	2129.3	3175	4.6	14.6	2.3	7.3	8.9	28.2	15.8

Total influent PM = 81.4 kg (179 lb)
Total effluent PM = 1.4 kg (3 lb)
Mass difference between influent and effluent = 79.9 kg (176 lb)
Independent PM Recovery based on cleaning out and backwashing unit and recovering PM = 75.5 kg (166 lb)
% mass recovery = 94.5%

Notes: Sediment PM includes all biogenic material including leaves, sticks, detritus.
Settleable PM based on SM 2540F.
Suspended PM based on 60 min. quiescent settling in Imhoff cone.

References for details: Sansalone and Kim (2008), Kim and Sansalone (2008) and Sansalone et. al. (2009)