NJCAT TECHNOLOGY VERIFICATION

Up-Flo® Filter 285R
(Ribbon Membrane)

Hydro International

December 2016

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1. Description of Technology

The Up-Flo® Filter is a stormwater remedial device that incorporates gravitational separation of floating and settling materials, and filtration of polluted stormwater to offer treatment train capabilities in a standalone device. Each Up-Flo® Filter consists of a highly configurable array of modules containing engineered filtration media that can be employed as an upward flow media bed filter or as an upward flow membrane filter that utilizes filter ribbons as the media type (**Figure 1**). The Up-Flo Filter® with filter ribbons was tested and used for this verification report.

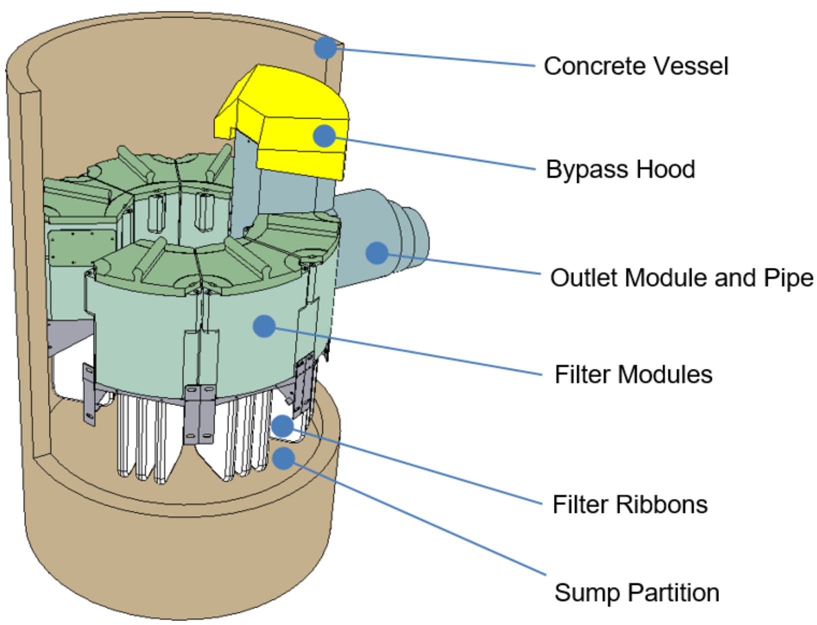


Figure 1 Up-Flo® Filter Configured with Filter Ribbons

Operation of the Up-Flo® Filter is initiated during a rainfall event when stormwater is conveyed into the chamber from a pipe or grated inlet. As flow enters the chamber, internal components act as baffles to force gross debris and sediment to settle into the sump and floating debris to rise to the surface.

Depending on the runoff rate entering the chamber, a water column builds within the concrete vessel until it reaches a bypass weir elevation. This water column provides the potential energy to drive flow upward through the engineered media (**Figure 2**). Filtered water exits the Filter Module(s) into the Outlet Module via a conveyance channel located above the filter ribbons. Flow in excess of the design filtration capacity discharges over a bypass weir located inside the manhole or adjacent to the vault installation.

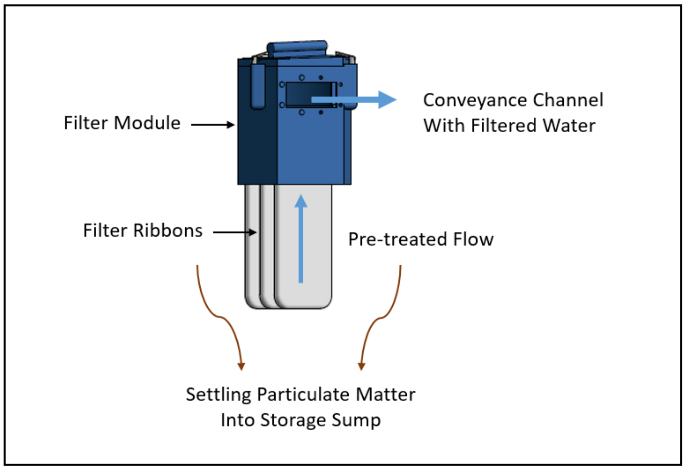
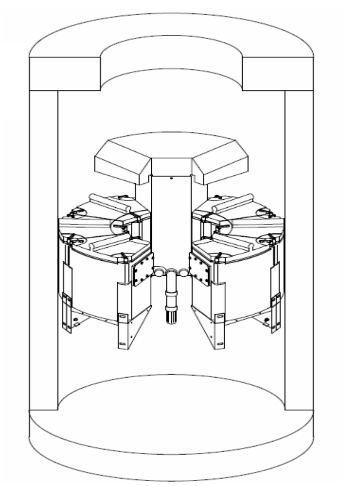


Figure 2 Up-Flo® Filter Module with Filter Ribbons

The Up-Flo® Filter can be retrofit into an existing storm-drain manhole or supplied as a complete system housed in a 4-ft diameter manhole or precast vault. Manhole configurations (**Figure 3A**) consist of a single ring assembly containing one to six Filter Modules. Vaulted systems (**Figure 3B**) may contain single or multiple filter bays each consisting of one to 19 Filter Modules.

A



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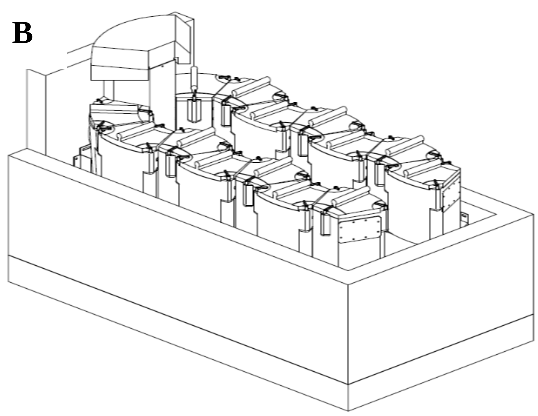

Figure 3 Up-Flo® Filter in a Typical Manhole Configuration (A) and in a Vaulted Configuration (B)

2. Laboratory Testing

The New Jersey Department of Environmental Protection (NJDEP) maintains a list of certified stormwater manufactured treatment devices (MTDs) that can be installed on newly developed or redeveloped sites to achieve stormwater treatment requirements for Total Suspended Solids (TSS). Manufactured treatment devices are evaluated for certification according to the *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices (January, 2013*) (heretofore referred to as "NJDEP Approval Process"). The NJDEP Approval Process requires that TSS treatment devices operating on filtration principles be tested according to the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device* (heretofore referred to as "NJDEP Protocol"). In addition, the NJDEP Approval Process requires submittal of a Quality Assurance Project Plan (QAPP) to the New Jersey Corporation for Advanced Technology (NJCAT) for review and approval prior to testing to ensure that all laboratory procedures will be conducted in strict accordance with the NJDEP Protocol. The QAPP was submitted and approved by NJCAT in August 2016 prior to commencement of testing.

Testing was conducted in August 2016 by Hydro International at the company's full-scale hydraulic testing facility in Portland, Maine. Since testing was carried out in-house, Hydro International contracted with FB Environmental to provide third party oversight. Representatives from FB Environmental Associates, also in Portland, Maine, were present during all testing procedures. The test program was conducted in accordance with the NJDEP Protocol in two phases: removal efficiency testing and sediment mass loading capacity.

2.1 Test Setup

The laboratory setup consisted of a recirculating closed loop system with an 8-inch submersible Flygt pump that conveyed water from a 23,000-gallon tap water reservoir through a PVC pipe network to the 4-ft diameter Up-Flo® Filter. The flow rate of the pump was controlled by a GE Fuji Electric AF-300 P11 Adjustable Frequency Drive and measured by an EMCO Flow Systems 4411e Electromagnetic Flow Transmitter. A series of two flow isolation valves were located between the Flygt pump and the Up-Flo® Filter, which allowed flow to bypass the Up-Flo® Filter if fully opened (**Figure 4**). These valves were installed as part of the piping network prior to the installation of the Up-Flo® Filter to direct flow to two other manufactured stormwater and wastewater treatment systems installed at the test facility along the same piping network. The flow isolation valves remained fully closed throughout the entire period when the Up-Flo® Filter testing was conducted.

A background sampling port was located 90 inches upstream of the Up-Flo® Filter inlet pipe. Flow from the inlet pipe passed through a dissipater before entering the vessel. The Up-Flo® Filter effluent discharged freely from the outlet chute, where grab samples were taken. The free discharge flowed through a filter box fitted with one-micron filter bags prior to returning to the tap water reservoir.

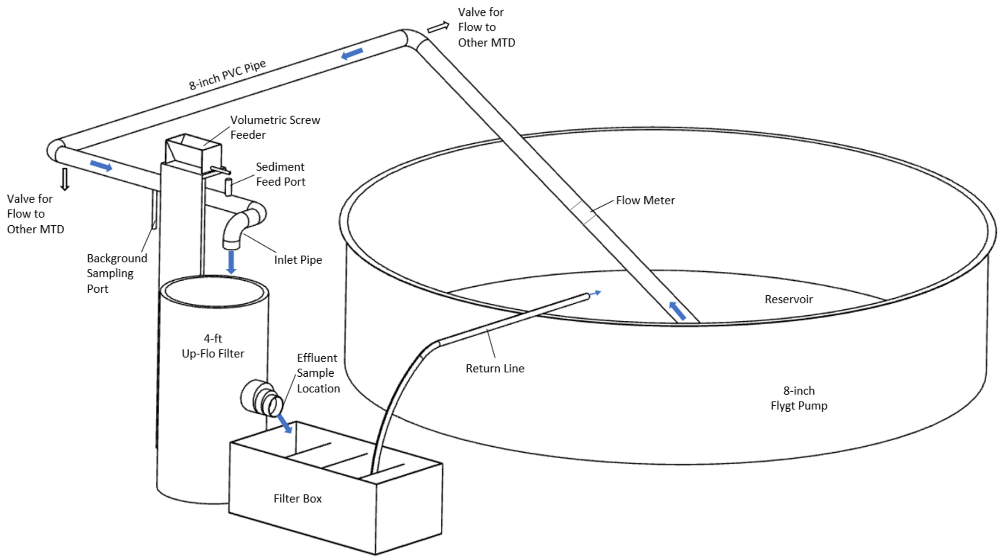

Figure 4 Laboratory Testing Arrangement

The water temperature within the reservoir was regulated by a Hayward 350FD pool heater, which was used to reduce any volatility in the test data that could potentially be caused by variability in water temperatures between test runs. The night before a test run the Hayward 350FD was set to 75°F. The test reservoir temperature was recorded at 30 second intervals by a Lascar thermometer and temperature logger over the duration of each test.

Test Unit Description

The test unit was comprised of a full-scale, six (6) filter module Up-Flo® Filter that is commercially available. The filter modules were fitted with filter ribbon model 285 and installed in a 4-ft diameter concrete manhole (**Figure 5** and **Figure 6**). The inlet pipe conveyed flow into the Up-Flo® Filter and included ports or access locations for sampling background concentrations and feeding test sediment. Filtered (effluent) flow freely discharged from the filter modules into an internal Outlet Module with stub that protrudes through the precast manhole. The sump depth or height from the outlet stub invert to floor was 2-ft. to allow for the filter ribbons to be 6-inches above the sump floor. Effluent was sampled from the stub prior to discharging into a baffled filter box used to minimize residual test sediment entering the reservoir.

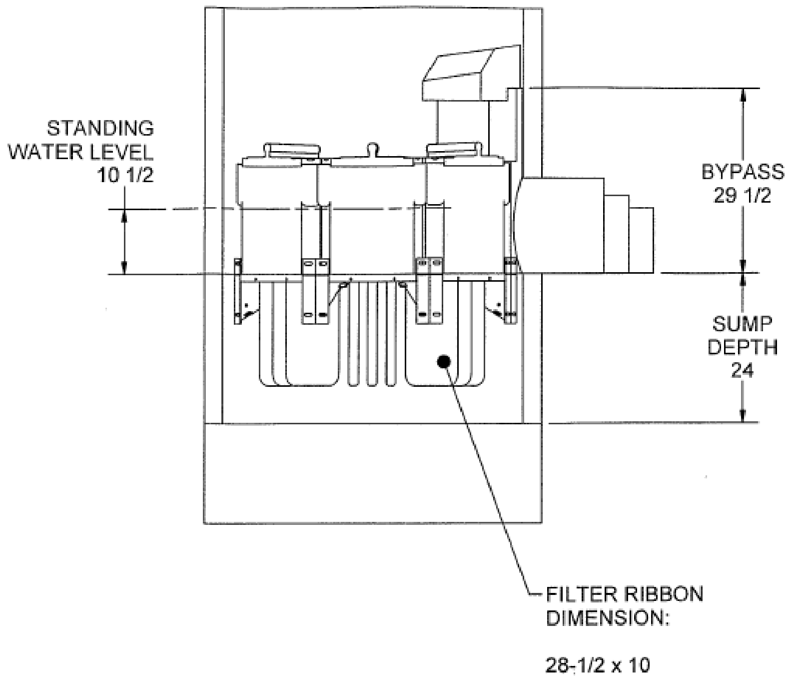

Figure 5 Elevation View of Test Manhole

Figure 6 View of Interior of Test Manhole

2.2 Test Sediment

The test sediment was a blend of commercially available silica sand grades supplied by AGSCO Corporation and US Silica Company. The sediment was blended by Hydro International and the particle size distribution was independently verified by GeoTesting Express to certify that the test material met specification requirements and was within tolerance as described in Section 5B of the NJDEP protocol. Results of particle size gradation testing is shown in **Table 1** and **Figure 7**.

Table 1 Particle Size Distribution Results of Test Sediment Samples

Particle Size (µm)	% Finer					Difference from Protocol
	Protocol	Sample 1	Sample 2	Sample 3	Test Sediment Average	
1000	100	100.0	100.0	100.0	100.0	0.0%
500	95	96.0	96.0	96.0	96.0	1.0%
250	90	90.0	90.0	90.0	90.0	0.0%
150	75	81.0	81.0	81.0	81.0	6.0%
100	60	62.6	62.6	61.6	62.2	2.2%
75	50	54.0	54.0	53.0	53.7	3.7%
50	45	49.4	49.3	49.4	49.4	4.4%
20	35	42.5	39.9	42.9	41.8	6.8%
8	20	25.5	25.8	27.0	26.1	6.1%
5	10	19.1	19.4	19.1	19.2	9.2%
2	5	8.2	8.3	8.6	8.4	3.4%

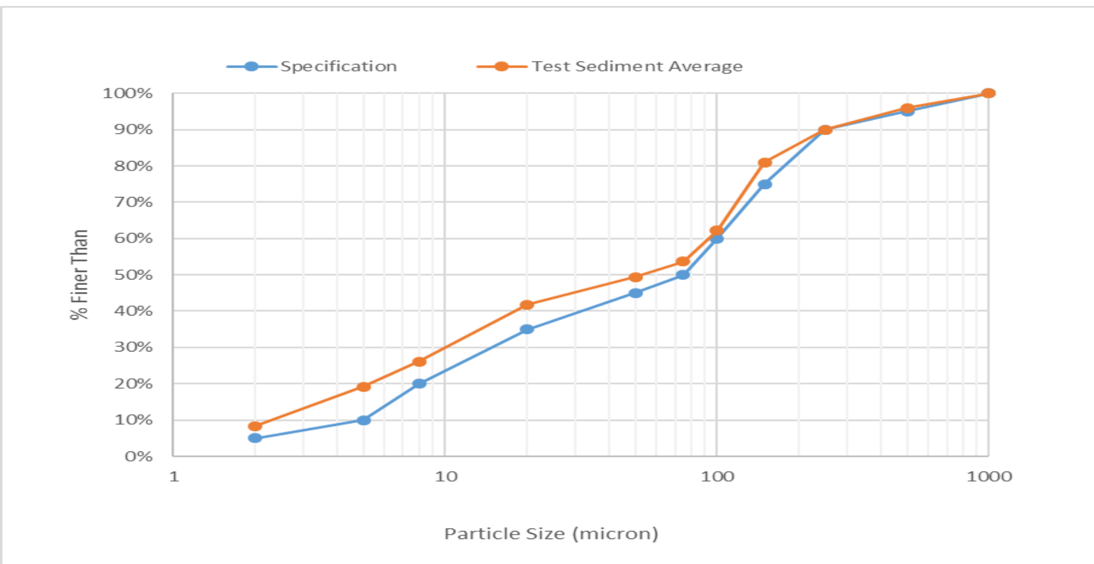

Figure 7 Average PSD of Test Sediment Compared to Protocol Specification

2.3 Sediment Removal Efficiency Testing

The Up-Flo® Filter performance was determined by testing its sediment removal efficiency. In accordance with the NJDEP filtration protocol Section 5, this was tested in the laboratory by seeding the system with a known test sediment gradation and determining what proportion of the material is retained within the filtration device. The removal efficiency testing occurred by repeatedly testing the unit at the maximum treatment flow rate (MTFR) until the design operating head was reached, which was determined from the sediment mass load tests.

Background samples were taken at the background sample port located upstream of the Up-Flo® Filter test setup. Influent background samples were taken in correspondence with the odd numbered effluent samples (first, third, and fifth). The time each background and effluent sample was collected was recorded. The background data was used to adjust the effluent samples for background concentration.

The test sediment feed rate and total mass of test sediment introduced during each test run was a known quantity and was introduced at a rate within 10% of the targeted value of 200 mg/L influent concentration. Test sediment was injected using an Auger Feeder Model VF-2 volumetric screw feeder providing a consistent, calibrated concentration of solids. The sediment injection port was located at the crown of the 8-inch influent pipe, 40 inches from the test vessel. Three calibration samples were taken from the injection point at the start, middle and just prior to the conclusion of dosing during each test. Each sample was collected in a clean one-liter container over an interval timed to the nearest second. Each sample was a minimum of 0.1 liters or the collection interval did not exceed one minute, whichever came first. Samples were weighed to the nearest milligram and the concentration coefficient of variance (COV) did not exceed 0.10.

A flow meter was located upstream of the MTD. The flow meter data logger recorded flows at a minimum of once per minute and the average flow rate was reported. Water levels were read from a pressure tap installed below the outlet invert. Head readings were taken at five minute intervals to the nearest 1/8 inch with a measuring rule.

This test used the Effluent Grab Sampling Method. The average influent TSS concentration was calculated using the total mass of the test sediment added during dosing divided by the volume of water that flowed through the MTD during dosing (**Equation 1**). The volume of water that flows through the MTD was calculated by multiplying the average flow rate by the time of sediment injection only.

$$\textbf{Average Influent Concentration} = \frac{\text{Total mass added}}{\text{Total volume of water flowing through the MTD during addition of test sediment}}$$

Equation 1 Equation for Calculating Average Influent Concentration

Once a constant feed of test sediment and flow rate was established, the first effluent sample was collected after a minimum of three MTD detention times passed. The effluent samples were collected in half-liter bottles using the grab sample method as described in Section 5G of the protocol. All sampling times were recorded throughout each 30-minute test run.

The time interval between sequential samples was evenly spaced during the test sediment feed period to achieve six samples. However, if the test sediment feed was interrupted for measurement, the next effluent sample was collected following a minimum of three MTD detention times. An example timetable is given in **Table 2**. The six effluent samples were taken from the free discharge point of the Up-Flo® Filter outlet. The time interval between effluent samples did not exceed 15 minutes. The drawdown volume was sampled at two equally spaced volumes (Table 2 – "1/3 and 2/3 empty") as the head fell from the final operating head to the system's static water level.

All effluent samples were analyzed for TSS in accordance with ASTM 3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples" by Maine Environmental Laboratory. Removal efficiency was calculated as per the equation shown in **Equation 2**.

$$\textit{Removal Eff.}(\%) = \frac{\begin{pmatrix}\textit{Avg.Inf.TSS Conc.}\times\\ \textit{Total Vol.of}\\ \textit{Test Water}\end{pmatrix} - \begin{pmatrix}\textit{Adj.Eff.TSS Conc.}\times\\ \textit{Total Vol.of}\\ \textit{Eff.Water}\end{pmatrix} - \begin{pmatrix}\textit{Avg.Drawdown TSS Conc.}\times\\ \textit{Total Vol.of Drawdown}\end{pmatrix}}{\textit{Avg.Inf.TSS Conc.}\times \textit{Total Vol.of Test Water}} \times 100$$

Equation 2 Equation for Calculating Removal Efficiency

Table 2 Example Sampling Time for TSS Removal Efficiency Test

Sampling Schedule						
Elapsed Time Based on Driving Head				Sample		
<17"	17"-22"	22"-26"	>26"	Influent	Effluent	Background
0:00	0:00	0:00	0:00	1		
9:00	10:00	11:00	11:30		1	1
12:00	12:30	13:00	13:15		2	
15:00	15:00	15:00	15:00	2	3	2
24:00	25:00	26:00	26:30		4	
27:00	27:30	28:00	28:15		5	3
30:00	30:00	30:00	30:00	3	6	
1/3 empty					7	
2/3 empty					8	

2.4 Sediment Mass Loading Capacity

Upon completing the Removal Efficiency Testing, the protocol continued with Sediment Mass Loading Capacity testing used to determine the maximum mass of test sediment that can be captured by the MTD at 90% MTFR prior to passing the design operating head.

2.5 Scour Testing

No scour testing was conducted. Although the 4-ft diameter Manhole Up-Flo® Filter installation is commercially provided with an internal bypass, this feature was not tested for certification. The efficiency measurements produced will be applicable to off-line configurations that are designed to divert flows in excess of the MTFR away from the filter modules.

2.6 Quality Objectives and Criteria

Samples sent to the external lab were shipped to the lab for analysis as soon as possible following the test run. Samples analyzed in-house were observed by the third-party witness and were conducted immediately following sample collection.

A Chain of Custody form was used for externally analyzed samples to record sample containers and sampling date and time for each test run. A copy of these forms was also maintained by Hydro. Sample bottles were labeled to identify the test run and sample type (background or effluent), which corresponded to the sample identification on the Chain of Custody form. All sample marking and transportation was observed by the third-party witness.

Data were recorded and maintained in accordance with standard laboratory procedures used at Hydro. Hard copies of all original data sets are maintained on site. The individual conducting the tests was responsible for managing the data sheets that accompany all tests. Data analysis was primarily done in Microsoft Excel.

Failing the following quality criteria were considered reason to discard the results from an individual test run:

- Background TSS concentrations exceed 20 mg/L
- Temperature of test water exceeds 80 degrees Fahrenheit
- Variation in calculated influent concentration exceeds ±10% of 200 mg/L target concentration
- COV of dry calibration samples exceeds 0.10

The 2013 protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device published by the NJDEP specifies that flow rates used in testing HDS systems must not vary more than 10% from the target flow rate and must maintain a COV of 0.03. This guidance and prior filtration testing precedent was used as a guideline for the filter test program.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the Up-Flo® Filter, the following are the performance claims made by Hydro International.

Total Suspended Solids (TSS) Removal Efficiency

The Up-Flo® Filter with 6-Filter Modules with filter ribbon media, housed in a 4-ft. diameter manhole with a 2-ft. sump depth, operating under a hydraulic loading rate of 15 gpm per Filter Module and evaluated in complete accordance with the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device*, achieves removal efficiencies of the NJDEP specified gradation of silica of 82%.

Maximum Treatment Flow Rate (MTFR)

The 4-ft. diameter, 6 Filter Module Up-Flo® Filter system tested with ribbon model 285R has an MTFR of 90 gpm or 15 gpm per module. Table A-1 includes the design specifications for the tested filter ribbon model.

Maximum Sediment Storage Depth and Volume

The maximum sediment storage depth for the Up-Flo® Filter is 6 in. This corresponds to a volume of 6.3 cu. ft. for the 4-ft. diameter Up-Flo® Filter configuration tested.

Wet Volume and Detention Time

The Wet Volume is defined as the sump and wet influent piping of a filtration MTD. The resulting Wet Volume of the tested Up-Flo® Filter is 234 gallons (31.3 cu. ft.). This corresponds to 5.17 cu. ft. of wet volume per module and a detention time of 156 seconds at the MTFR.

Effective Sedimentation Area

The effective sedimentation area is the surface area of a 4-ft manhole and equates to 12.57 sq. ft.

Effective Filtration Area

Each filter ribbon model 285R installed in a Filter Module is 28.5-inches long and 10-inches wide and can accept flow from both sides. There are three filter ribbons per module. This equates to 11.87 sq.-ft per Filter Module and 71.22 sq.-ft for the eighteen ribbons installed in the test set up.

Minimum Sedimentation Area

As tested, the minimum sedimentation area for filter ribbon model 285R is 12.57 sq.-ft of sedimentation area per 71.22 sq.-ft of filter ribbon or 0.176 sq.-ft sedimentation area per filter ribbon area.

Sediment Mass Load Capacity

Considering the change in operating head relative to the sediment mass captured, the 6 Filter Module Up-Flo® Filter with filter ribbon 285R has a mass loading capacity of 50 lbs.

Maximum Allowable Inflow Drainage Area

To ensure the drainage area and expected annual sediment load does not cause higher than intended bypass flows, the sediment mass capture capacity of 50 pounds of sediment (8.33 pounds per module) is used to limit the treatable drainage area per module. Given the protocol requirements for “Maximum Allowable Inflow Drainage Area”, the Up-Flo® Filter with filter ribbon 285R can effectively treat 0.014 acres per module at 600 lbs per acre of drainage area annually.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013a) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that “copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc.” be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report. This information was provided to NJCAT and is available upon request.

4.1 Removal Efficiency Testing

During initial testing, twelve (12) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate and influent sediment concentration were 90 gpm (with a COV< 0.03) and 200 mg/L ± 10% (with a COV< 0.10) respectively.

Run 1 could not be used since its influent concentration exceeded the target sediment concentration and the flow rate COV was 0.04. Since the first test run was not in compliance and raised questions about its effect on subsequent removal efficiency and mass loading capacity test results, another five test runs (1A, 1B, 1C, 1D, and 1E) were completed after the initial twelve. The results from runs 2-11 were used to calculate the average removal efficiency of the 6 Filter Module Up-Flo® Filter. The second set of five test runs was used to assess if the large mass added in the first test run materially influenced the results.

Run 12 was excluded from the average efficiency removal calculation since the increase rate in head was high relative to the increase rate in mass load within 19-minutes into the test or with about 10 minutes remaining in the test. The test was not stopped and continued at 100% MTFR. The actual peak water elevation for Run 12 was 36-inches.

The electromagnetic flow meter and data logger took a reading every thirty seconds. The flow rate data has been summarized in **Table 3** including the compliance to the QA/QC acceptance criteria. The average flow rate for all removal efficiency runs was 91.6 gpm. The temperature data are summarized in **Table 4**.

Influent Sediment Concentrations are summarized in **Table 5,** Background Sediment Concentrations are summarized in **Table 6,** and Adjusted Effluent Concentrations are summarized in **Table 7**, along with compliance to NJDEP protocol QA/QC criteria.

All the effluent and background samples for SSC were analyzed by Maine Environmental

Laboratories of Yarmouth, Maine. The required background SSC concentration was less than 20 mg/l. The limit of detection for the analytical method was 1 mg/L. An unknown issue caused the first sample (Run 2) background concentration to register 30 mg/L. This result was discarded as an error because it was much higher than the next two measurements and all subsequent runs indicated much lower background concentrations.

Table 3 Flow Rates

Run #	Average Flow Rate (gpm)	COV	QA/QC Compliance (COV < 0.03)
1	89.8	0.04	No
1A	92.1	0.03	Yes
1B	92.0	0.03	Yes
1C	91.9	0.02	Yes
1D	91.6	0.03	Yes
1E	91.6	0.04	No[1]
2	90.0	0.03	Yes
3	91.0	0.02	Yes
4	91.6	0.03	Yes
5	92.3	0.03	Yes
6	92.0	0.02	Yes
7	92.2	0.02	Yes
8	91.9	0.03	Yes
9	91.9	0.03	Yes
10	92.0	0.03	Yes
11	92.2	0.03	Yes
12	91.9	0.02	Yes
Average Flow	**91.7**	**gpm**	

[1] 1E and 2 are essentially duplicates with respect to total mass loading

Table 4 Temperatures

Run #	Maximum Temperature (°F)	COV	QA/QC Compliance (Max < 80°F)
1	75.0	0.002	Yes
1A	75.5	0.001	Yes
1B	75.5	0.003	Yes
1C	75.5	0.003	Yes
1D	75.5	0.003	Yes
1E	75.5	0.003	Yes
2	75.5	0.003	Yes
3	75.5	0.003	Yes
4	75.5	0.003	Yes
5	75.0	0.003	Yes
6	75.0	0.003	Yes
7	74.5	0.003	Yes
8	75.5	0.003	Yes
9	75.0	0.000	Yes
10	75.0	0.002	Yes
11	75.0	0.003	Yes
12	75.5	0.000	Yes
Average Temp	**75.3**	**°F**	

Table 5 Influent Sediment Concentrations

Run #	Influent Sediment Concentration (mg/L)			COV	QA/QC Compliance
	Min	Max	Average		
1	829	844	838*	0.01	No – Out of Range
1A	206	216	210	0.02	Yes
1B	187	197	194	0.03	Yes
1C	175	197	185	0.06	Yes
1D	199	202	200	0.01	Yes
1E	195	199	197	0.01	Yes
2	204	213	210	0.02	Yes
3	209	213	211	0.01	Yes
4	206	211	209	0.01	Yes
5	199	202	200	0.01	Yes
6	199	204	202	0.01	Yes
7	199	210	203	0.03	Yes
8	198	202	200	0.01	Yes
9	185	194	190	0.02	Yes
10	193	205	198	0.03	Yes
11	204	215	208	0.03	Yes
12	199	209	203*	0.03	Yes
Overall Average Concentration			**201 mg/L**		

* Run 1 and Run 12 excluded from average

Table 6 Background Sediment Concentrations

Run #	Background Sediment Concentration (mg/L)			QA/QC Compliance (Max < 20 mg/L)
	1	2	3	
1A	3	4	6	Yes
1B	7	8	9	Yes
1C	1	2	3	Yes
1D	3	4	5	Yes
1E	6	7	8	Yes
2	30*	4	4	Yes*
3	11	6	7	Yes
4	10	10	11	Yes
5	3	7	5	Yes
6	6	6	8	Yes
7	12	11	13	Yes
8	1	2	3	Yes
9	5	5	5	Yes
10	8	8	10	Yes
11	1	2	3	Yes
12	2	2	3	Yes

* An unknown issue caused the first sample to register 30 mg/L. This result was discarded as not representative and the average of the other two samples (4 mg/L) was substituted.

Table 7 Adjusted Effluent Concentrations

Run #	Suspended Sediment Concentration (mg/L)								QA/QC Compliance
	Effluent #	1	2	3	4	5	6	Average	
1A	Background	3		4		6		4	Yes
	Effluent	42	43	45	48	51	55	47	N/A
	Adjusted Average Sediment Concentration							**43**	
1B	Background	7		8		9		8	Yes
	Effluent	38	44	47	47	45	43	44	N/A
	Adjusted Average Sediment Concentration							**36**	
1C	Background	1		2		3		2	Yes
	Effluent	29	33	31	32	31	29	31	N/A
	Adjusted Average Sediment Concentration							**29**	
1D	Background	3		4		5		4	Yes
	Effluent	32	34	38	33	36	34	35	N/A
	Adjusted Average Sediment Concentration							**31**	
1E	Background	6		7		8		7	Yes
	Effluent	35	37	39	38	35	40	37	N/A
	Adjusted Average Sediment Concentration							**30**	
2	Background	30*		4		4		4	Yes
	Effluent	44	42	44	42	41	46	43	N/A
	Adjusted Average Sediment Concentration							**39**	
3	Background	11		6		7		8	Yes
	Effluent	43	47	47	47	50	51	48	N/A
	Adjusted Average Sediment Concentration							**40**	
4	Background	10		10		11		11	Yes
	Effluent	44	53	50	57	48	50	50	N/A
	Adjusted Average Sediment Concentration							**40**	
5	Background	3		7		5		5	Yes
	Effluent	38	38	44	44	40	43	41	N/A
	Adjusted Average Sediment Concentration							**36**	

6	Background	6		6		8		7	Yes
	Effluent	37	48	44	42	44	46	44	N/A
	Adjusted Average Sediment Concentration							**37**	
7	Background	12		11		13		12	Yes
	Effluent	46	48	47	50	57	51	50	N/A
	Adjusted Average Sediment Concentration							**38**	
8	Background	1		2		3		2	Yes
	Effluent	32	33	39	38	37	39	36	N/A
	Adjusted Average Sediment Concentration							**34**	
9	Background	5		5		5		5	Yes
	Effluent	31	35	40	37	41	39	37	N/A
	Adjusted Average Sediment Concentration							**32**	
10	Background	8		8		10		9	Yes
	Effluent	37	40	40	41	37	39	39	N/A
	Adjusted Average Sediment Concentration							**30**	
11	Background	1		2		3		2	Yes
	Effluent	35	34	33	34	35	35	34	N/A
	Adjusted Average Sediment Concentration							**32**	
12	Background	2		2		3		3	Yes
	Effluent	29	29	34	33	33	34	32	N/A
	Adjusted Average Sediment Concentration							**30**	

Table 8 Removal Efficiency Results

Run #	Influent Sediment Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)	Volume of Test Water (L)	Drawdown Sediment Concentration (mg/L)	Volume of Drawdown Water (L)	Removal Efficiency (%)
1A	210	43	9766	47.5	20	80*
1B	194	36	9750	43.0	20	81*
1C	185	29	9738	29.5	21	84*
1D	200	31	9705	35.0	23	84*
1E	197	30	9722	38.0	23	85*
2	210	39	9542	46.5	24	81
3	211	40	9649	49.5	26	81
4	209	40	9710	56.0	28	81
5	200	36	9783	42.5	30	82
6	202	37	9755	49.0	34	82
7	203	38	9772	50.0	43	81
8	200	34	9744	37.0	62	83
9	190	32	9744	36.5	62	83
10	198	30	9750	41.0	219	84
11	208	32	9778	32.0	283	84
12	203	30	9744	29.0	581	84*
Average Removal Efficiency						**82%**

* Runs 1A-1E excluded for calculating the average removal efficiency; Run 12 excluded due to the rate of increase in operating head relative to the increase in sediment mass load.

4.2 Sediment Mass Loading Capacity

The Sediment Mass Loading Capacity study was a continuation of the removal efficiency study. As required by the protocol, all aspects of the testing remained the same, except for the flow rate which was reduced to 90% of the MTFR to a target flow rate of 81 gpm for Run 13. Similar to test Run 12, at approximately 18-minutes into the 30-minute test run, the operating head was increasing quickly relative to the mass load increase. The removal efficiency for the test run was 88% and was consistent with the overall increasing trend observed. Hence the mass loading capacity was reached after Run 11. The relationship between removal efficiency and sediment mass loading is illustrated in **Figure 8** which plots data for Runs 2-11. The additional five test runs (1A → 1E) are shown with orange data points. As shown, each of the five test runs had an essentially even distribution of mass added. The two data sets demonstrate that 80% efficiency and higher is achieved in both cases.

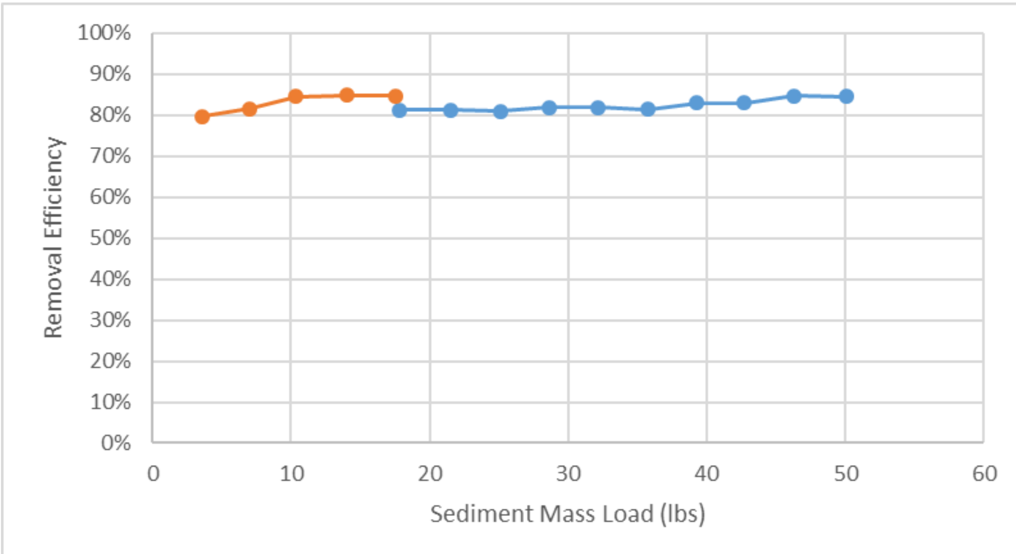

Figure 8 Sediment Mass Load Captured vs. Removal Efficiency

Since the rate of increase in the water elevation between Runs 11 and 13 was high relative to the increase in the mass captured, Run 12 and Run 13 were not included in the sediment mass load capacity. A summary of the Sediment Mass Loading Capacity is shown in **Table 9**. The total mass load captured during test Runs 1 and 2 was 17.8 lbs compared to 17.6 lbs that was captured during test Runs 1A-1F. The total mass captured for the 11 test runs was 50 lbs. Since the additional test runs showed there was no influence to performance, test Runs 1A-1F were not used to calculate to the total mass captured.

Variability in the influent mass was due to the auger speed adjustment setting. Prior to each test run, the hopper was filled with test sand and the auger speed set for each test run, rather than being set once for all thirteen runs. While there was variability in the influent mass load between runs, excluding the first run, the concentration coefficient of variance (COV) did not exceed 0.10 and the influent concentration met the protocol requirements of 200 mg/L ± 10%. Given how much higher the mass was in the first run, the first run auger speed control was not correctly set and more attention was paid to it for the remaining test runs.

Table 9 Sediment Mass Loading Capacity Summary

Run #	Operating Head (inch)	Influent Mass (lbs)	Captured Mass (lbs)
1	12.500	17.6	14.3
1A	12.250	4.5	3.6
1B	12.250	4.2	3.4
1C	12.375	4.0	3.4
1D	12.500	4.3	3.6
1E	12.500	4.2	3.6
2	12.625	4.4	3.6
3	12.750	4.5	3.6
4	13.000	4.5	3.6
5	13.125	4.3	3.5
6	13.500	4.3	3.5
7	14.250	4.4	3.6
8	16.000	4.3	3.6
9	18.750	4.1	3.4
10	23.250	4.2	3.5
11	25.625	4.5	3.8
Total*		**61.1***	**50.0***

*Excludes Runs 1A-1E

4.3 Filter Operating Head

Operating head is defined as the water column height in the vessel, measured from the invert of the Outlet Module stub, at the end of a test run. As depicted in **Figure 9**, the operating head increases with sediment mass load. The additional five test runs are shown with orange data points. Given the consistent trend with these test runs, the operating head is not influenced by the mass added until the total mass captured exceeds about 30 pounds compared to the total 50 lbs, which was the total mass added.

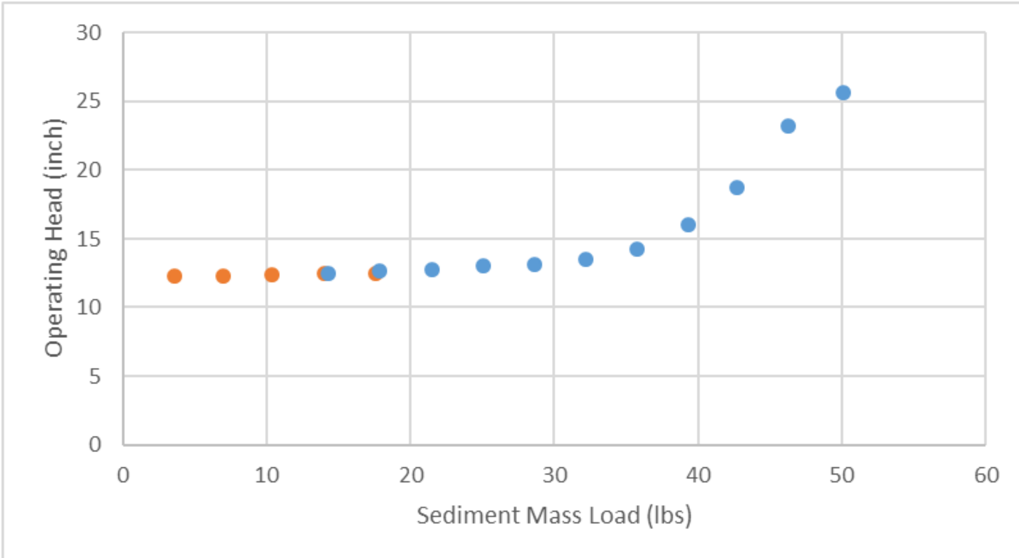

Figure 9 Sediment Mass Load Captured vs. Operating Head

For off-line configurations, an external bypass weir can be used to increase or decrease the design operating head. The operating head did not exceed 25.625 inches for the first eleven test runs used to determine the sediment mass capture.

5. Design Limitations

When the Up-Flo® Filter is designed and installed correctly, there is minimal possibility of failure. The system will be designed to convey stormwater up to the maximum flow rate of the storm sewer system. Like any other correctly designed treatment technology, a change in the characteristics of the contributing drainage area can lead to poor performance. An increase in imperviousness can result in higher peak flows which can exceed the treatment capacity of the Up-Flo® Filter. A change in land use can result in higher solids loading or a change in the type of stormwater pollutants. High solids loading could result in unrealistic maintenance intervals. Different stormwater pollutants may not be treatable with the engineered media that was originally specified. Caution should obviously be used during the design of any stormwater treatment system if changes in the contributing area are expected.

Required Soil Characteristics

All Up-Flo® Filters are pre-assembled in concrete structures manufactured by ISO certified precast facilities in accordance with all applicable ASTM specifications and regional regulations. Subsequently all systems are designed to accommodate any site-specific limitations or constraints imposed by soil type, conditions or characteristics. In addition, all internal filter components are molded from polyethylene while support frames and assembly hardware consist of minimum grade 304 stainless steel for corrosion resistance.

Slope

The Up-Flo® Filter outlet module permanently mounts in a fixed horizontal position running through the precast wall either directly outside of the vault or into an outlet chamber. In configurations where the outlet module pipe stub connects directly to the outlet pipe, slope is restricted to that permitted by the connecting coupling.

Maximum Filtration Rate

The maximum filtration rate of each Up-Flo® Filter system is contingent on the area of the filter, but more specifically the number of Filter Modules and total filter ribbon surface area. Given the test results, the Up-Flo® Filter with filter ribbon model 285R will be sized to ensure the maximum filtration rate per module will be 1.264 gpm per ft^2 of filtration area or 0.176 sq.-ft of sedimentation area per square foot of filter ribbon area.

Maintenance Requirements

Up-Flo® Filter maintenance requirements vary according to site characteristics such as runoff area, types of surfaces (e.g., paved and/or landscaped), site activities (e.g., short-term or long-term parking), and site maintenance (e.g., sanding and sweeping). At a minimum, Hydro International recommends that inspection and maintenance should be conducted at intervals of no more than six months during the first year of operation. Observations made during these initial service events may be used to derive a lasting site-specific inspection and maintenance program

Operating Head

The maximum operating head for the Up-Flo® Filter with filter ribbon model 285R is 25.625 inches above the outlet pipe invert. This is the maximum head required to maintain the MTFR and annual sediment load. Since the flow is not controlled within the Filter Module, higher treated flows will occur at lower operating heads until the ribbons reach the anticipated annual mass load. To ensure the MTFR is not exceeded, flow control prior to the Up-Flo filter is required.

Installation Limitations

Hydro International provides installation instructions as well as product specific manufacturer specifications with each project submittal. Prior to scheduling delivery Hydro notifies the contractor with pick weights and specific handling instructions of/for the structure. Hydro International provides remote technical assistance for contractors as well as offering onsite engineering to facilitate/oversee proper installation.

Configurations

The Up-Flo® Filter has modular components to allow for differences in precast manufacture and preferences for source control design. In general, there are two configurations including 4-ft diameter precast manholes or vaults that have 1-4 filter bays and internal conveyance channels to manage peak bypass flows. The tested configuration submitted for verification corresponds with offline use of filter modules equipped with filter ribbons.

Structural Load Limitations

All Up-Flo® Filters are pre-assembled in concrete structures manufactured by ISO certified precast facilities in accordance with all applicable ASTM specifications and/or site-specific loading requirements. All precast structures will have a minimum wall thickness sufficient to sustain HS20-44 loading requirements.

Pre-treatment Requirements

The Up-Flo® Filter is designed as a stand-alone device and requires no additional upstream treatment. However, for source control applications having high pollutant loads, inclusion of pretreatment can extend filter media longevity and reduce annual service requirements.

Limitations in Tailwater

Tailwater conditions are carefully evaluated for each application. Ideally, the tailwater will be lower than 11-inches from the Outlet Invert. When the tailwater is higher than this, additional head will be required.

Depth to Seasonal High Water Table

The Up-Flo® Filter is designed to be connected as part of a self-contained storm sewer network. The precast structure housing each Up-Flo® Filter is sealed according to regional specifications and designed to account for buoyancy forces.

6. Maintenance

Maintenance activities can be categorized by those that can be performed from outside the Up-Flo® Filter vessel and those that are performed inside the vessel. Maintenance performed from outside the vessel includes removal of floatables and oils that have accumulated on the water surface and removal of sediment from the sump. Maintenance performed inside the vessel includes removal and replacement of the filter ribbons. A vactor truck is required for removal of oils, water, sediment, and to enter the vessel for performing inside maintenance.

Inspection

The frequency of inspection and maintenance can be determined in the field after installation.

Based on site characteristics such as contributing area, types of surfaces (e.g., paved and/or landscaped), site activities (e.g., short-term or long-term parking), and site maintenance (e.g., sanding and sweeping), inspection and maintenance should be conducted at intervals of no more than six months during the first year of operation. Typically, maintenance is recommended once per year thereafter.

By removing the manhole cover during a storm and monitoring the water level in the manhole or vault, site personnel can determine whether the filter is in bypass. A properly-sized filter (on-line or off-line) that is in bypass during a storm that is producing runoff at, or below, the filter's design filtration rate needs maintenance. Otherwise, scheduled inspections will determine when one or more of the following maintenance thresholds have been reached:

- *Sediment depth at sump storage capacity*
  A sediment depth of 6-in. indicates the sump has reached its maximum capacity for Up-Flo® Filter installations configured with filter ribbons. A sediment probe, such as the Sludge-Judge®, can be used to determine the depth of the solids in the sump.

- *Blinding of Filter Ribbons*
  Observing water elevations and inspecting the filter ribbons is required to determine when they require replacement. If the water elevation is higher than the top of the module, the filter should be drained down, inspected and replaced if there is heavy loading or slime coating the filter ribbons.

- *Oil forming a measurable thickness on the surface of the water*
  The Up-Flo® Filter will prevent free oils from passing through the Filter Modules. However, storing volatile hydrocarbons is not recommended. Any free oils on the water surface in excess of 1 inch should be removed.

The site-specific solids loading rate in the sump and for the filter ribbons will be determined during the first year of Up-Flo® Filter operation. Starting with a clean sump, the solids loading rate in the sump can be calculated by measuring the sediment depth in the sump and dividing the depth by the correlating interval of time since it was cleaned. Note: The filter ribbons may be occluded before the sump capacity is reached but cannot be known unless the ribbons are inspected when the sediment accumulation in the sump is measured.

After completion of the first year of operation, the inspection and maintenance intervals for cleaning the sump and replacing filter ribbons will be established. Removal of oils and floatables will occur at the same frequency unless the first year of operation indicates otherwise. Keeping to the established maintenance intervals is critical for long term performance of any filtration system.

Maintenance Procedures

The access port located at the top of the manhole or vault provides access to the Up-Flo® Filter vessel for maintenance personnel to enter the vessel and comfortably remove and replace the filter ribbons. The same access would be used for maintenance personnel working from the surface to net or skim debris and floatables or to vactor out sediment, oil, and water. Unless the Up-Flo® Filter has been installed in a very shallow unit, it is necessary to have personnel with OSHA-confined space entry performing the maintenance that occurs inside the vessel.

Maintenance activities include inspection, floatables removal, oil removal, sediment removal, and replacement of the ribbon assemblies. Maintenance intervals are determined from monitoring the Up-Flo® Filter during its first year of operation. Depending on the site, some maintenance activities are required with greater frequency than others. In the case of floatables removal, a vactor truck is not required. Otherwise, a vactor truck is normally required for oil removal, removal of sediment from the sump, and to dewater the vessel for replacing filter ribbons. All inspection and maintenance activities should be recorded in an inspection and maintenance log.

In general, good housekeeping practices upstream of any treatment practice will extend its longevity. For example, sweeping paved surfaces, collecting leaves and grass trimmings, and protecting bare ground from the elements will reduce loading to the system. Filter ribbons should not be installed in the Filter Modules until construction activities are complete and site stabilization is effective.

Solids Disposal

Sediment, floatables, gross debris, and spent filter ribbons can generally be disposed of at the local landfill in accordance with local regulations. The toxicity of the residues produced will depend on the activities in the contributing drainage area. Testing of the residues may be required if they are considered potentially hazardous.

Sump water can generally be disposed of at a licensed water treatment facility. But the local sewer authority should be contacted for permission prior to discharging the liquid. Significant accumulations of oils removed separately from sump water should be transported to a licensed hazardous waste treatment facility for proper treatment or disposal.

In all cases, local regulators should be contacted about disposal requirements.

7. Statements

The following signed statements from the manufacturer (Hydro International), third-party observer (FB Environmental) and NJCAT are required to complete the NJCAT verification process.

In addition, it should be noted that this report has been subjected to public review (e.g. stormwater industry) and all comments and concerns have been satisfactorily addressed.

Stormwater Solutions

Turning Water Around...®

September 20, 2016

Dr. Richard Magee, Sc.D., P.E., BCEE
Technical Director
New Jersey Corporation for Advanced Technology
c/o Center for Environmental Systems
Stevens Institute of Technology
One Castle Point on Hudson
Hoboken, NJ 07030

Re: Manufacturers Statement of Compliance

Dear Dr. Magee:

Hydro International has completed verification testing for the Up-Flo® Filter with filter ribbon media in accordance with the "*New Jersey Department of Environmental Protection (NJDEP) Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device"* (January 25, 2013). As required by the "*NJDEP Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology (NJCAT)",* this letter serves as Hydro International's statement that all procedures and requirements identified in the aforementioned protocol and process document were met or exceeded.

Specifically, a 4-ft diameter, 6-module Up-Flo® Filter fitted with filter ribbon media was tested at Hydro International's laboratory in Portland, Maine for efficacy and sediment mass loading. To ensure that all procedures and methods were met, a test plan was completed and submitted to NJCAT for review and approval, all testing and sample collection was conducted under the direct supervision of the independent observer, FB Environmental Associates, and all collected samples were sent to either of two independent and certified laboratories; GeoTesting Express for particle size analysis or Maine Environmental Laboratories for measuring suspended solid concentrations. With this in mind, the preparation of the verification report and the documentation contained therein fulfill the submission requirements of the process document and protocol.

If you have any questions or comments regarding the verification please do not hesitate to contact us.

Sincerely,

David Scott

David Scott, CPSWQ
Technical Product Manager

Hydro International (Stormwater), 94 Hutchins Drive, Portland ME 04102
Tel: (207) 756-6200 Fax: (207) 756-6212 Web: www.hydro-int.com

STATEMENT OF THIRD PARTY OBSERVER

To: **Dave Scott, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: **Third Party Witness of Hydro International Up-Flo®Filter**

Date: November 29, 2016

cc: Andrew Gwinn, Hydro International; Jeremy Fink, Hydro International
Margaret Burns, FB Environmental Associates

Statement of Third Party Observer

FB Environmental served as the third-party observer for the tests performed on the Up-Flo® Filter by Hydro International in August of 2016 and for five additional tests in November 2016 to achieve certification through the New Jersey Department of Environmental Protection (NJDEP) according to the *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices*. The test was performed by Hydro International staff at their laboratory located at 94 Hutchinson Drive in Portland, Maine. A member of our staff verified compliance with the laboratory test protocol above, and our staff member was physically present to observe the full duration of the laboratory test.

A member of our staff verified compliance with the laboratory test protocol above, and our staff member was physically present to observe the full duration of all laboratory testing. We have also reviewed the data, calculations, and conclusions associated with the removal efficiency testing in the *NJCAT Technology Verification: Up-Flo® Filter* report by Hydro International, dated November 2016, and state that they conform to what we saw during our supervision as third-party observer.

Forrest Bell (signature) November 29, 2016

Signed: Date:

STATEMENT OF DISCLOSURE – THIRD PARTY OBSERVER

To: **Dave Scott, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: **Third Party Observer Statement of Disclosure under *New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices***

Date: November 29, 2016

cc: Andrew Gwinn, Hydro International; Jeremy Fink, Hydro International; Margaret Burns, FB Environmental Associates

---

Statement of Disclosure – Third Party Observer

FB Environmental has no financial conflict of interest regarding the test results of the stormwater device testing outlined in the *NJCAT Technology Verification: Up-Flo® Filter* report by Hydro International, dated November 2016.

Disclosure Record

FB Environmental has provided the service of third party observer for tests performed by Hydro International in August and five additional tests in November of 2016. The tests assessed the removal efficiency of the Up-Flo® Filter using gravitational separation of floating and settling materials, screening, and filtering of polluted stormwater. Beyond this, FB Environmental and Hydro International have no relationships that would constitute a conflict of interest. For example, we have no ownership stake, do not receive commissions, do not have licensing agreements, and do not receive funds or grants beyond those associated with the testing program.

Forrest Bell — November 29, 2016

Signed: Date:

Center for Environmental Systems
Stevens Institute of Technology
One Castle Point
Hoboken, NJ 07030-0000

November 28, 2016

Titus Magnanao
NJDEP
Division of Water Quality
Bureau of Non-Point Pollution Control
401-02B
PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Magnanao,

Based on my review, evaluation and assessment of the testing conducted on a full-scale, commercially available Hydro International 4-ft Up-Flo® Filter with six filter modules with filter ribbon media, installed in a 4-ft concrete manhole at Hydro's full-scale hydraulic testing facility in Portland, Maine, with FB Environmental Consultants providing independent third-part oversight, the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) were met with two exceptions as noted below. Specifically:

Sample Size

The protocol requires that the minimum sample size (effluent, background, drawdown) collected is 500 milliliters or 0.5 liters. Based on the recommendation of the outside analytical laboratory half-liter bottles were used for sample collection. This resulted in 30 of the 80 samples collected having volumes less than 500 ml. An in-depth analysis of these 30 samples was conducted by Hydro International and NJCAT and it was determined that the smaller sample size did not impact the performance claims from the testing. The two public commenters accepted NJCAT's assessment to go forward with the verification report despite this deviation from the protocol requirements.

Test Sediment Feed

The test sediment was a blend of commercially available silica sand grades supplied by AGSCO Corporation and US Silica Company. The sediment was blended by Hydro International. The particle size distribution was independently verified by GeoTesting Express certifying that the supplied silica meets the specification within tolerance as described in Section 5B of the NJDEP protocol and was acceptable for use.

Removal Efficiency Testing

Ten (10) removal efficiency testing runs were completed in accordance with the NJDEP test protocol. The target flow rate and influent sediment concentration were 90 gpm and 200 mg/L respectively. All ten runs met the protocol requirements for flow rate COV and influent sediment concentration COV. Maximum temperature and background sediment concentrations met protocol requirements as well. The average sediment removal efficiency for the ten runs was 82%.

Sediment Mass Loading Capacity

The Sediment Mass Loading Capacity study was a continuation of the removal efficiency study. All aspects of the testing remained the same, except for the flow rate which was reduced to 90% of the 90 gpm MTFR for a target flow rate of 81 gpm for Run 13 as required by the protocol. For the tested Up-Flo® Filter with filter ribbon media model, the maximum water elevation required is 25.625 inches. During Run 12 this head was exceeded, necessitating the reduction in MTFR. Around 18-minutes, during Run 13, the operating head again exceeded 25.625-inches. Hence, to be conservative, the sediment mass loading capacity was determined from Runs 1-11 only. Run 1 had a sediment concentration loading that exceeded protocol requirements. Subsequent additional testing demonstrated that this higher concentration did not impact the mass capacity loading or operating head performance so the initial test results were accepted.

Scour Testing

No scour testing was conducted. Consequently, the Up-Flo® Filter is only being offered for off-line installation.

Sincerely,

Richard S. Magee, Sc.D., P.E., BCEE

8. References

ASTM D422-63. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D3977-97. *Standard Test Methods for Determining Concentrations in Water Samples*.

Hydro International Limited 2016. *NJCAT Technology Verification: Up-Flo Filter*. Prepared by Hydro International. September, 2016.

Hydro International Limited 2016. *Quality Assurance Project Plan for NJDEP Testing: Up-Flo Filter*. Prepared by Hydro International. August, 2016.

NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology.* Trenton, NJ. January 25, 2013.

NJDEP 2013b. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device.* Trenton, NJ. January 25, 2013.

NJDEP 2013c. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device.*
Trenton, NJ. January 25, 2013.

NJDEP 2013d. *NJCAT Technology Verification: Up-Flo Filter.* Trenton, NJ. November, 2008.

NJDEP 2013e. *NJCAT Technology Verification: Up-Flo Filter.* Trenton, NJ. January, 2015.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydro International, 94 Hutchins Drive, Portland, ME 04102. *General Phone: (207)756-6200*. *Website:* www.hydro-int.com/us.
- MTD – Up-Flo™ Filter verified models are shown in **Table A-2**.
- TSS Removal Rate – 80%
- Media – Filter Ribbons
- Off-line installation

Detailed Specification

- Up-Flo® Filter design specifications, configurations, and NJDEP sizing tables are attached (**Table A-1** and **Table A-2**). The Sizing Table is valid for NJ following NJDEP Water Quality Design Storm Event of 1.25" in 2 hours (NJAC 7:8-5.5(a)).
- Maximum inflow drainage area
    - The maximum inflow drainage area is governed by the maximum treatment flow rate of each model as presented in **Table A-2**.
- The operating head is the water elevation or height within the vessel housing the filtration modules, measured from the Outlet Module stub invert. In the field, the operating head changes throughout a storm event depending on the difference between the incoming flow rate and filtration rate. In an offline design, there are internal weir walls used to set the maximum water elevation. For the tested Up-Flo® Filter with filter ribbon media, the maximum water elevation required is 25.625 inches. This will vary depending on the number of filter modules, storm-drain depth, peak bypass flow rates and related hydraulic influence. In the case when less than 25.625 inches of depth is available, additional modules are provided. Hydro International provides design support for each project, working with consultants to ensure that the water quality runoff flow rate is treated prior to bypass.
- See Hydro's Up-Flo® Filter Operation and Maintenance Manual for I&M procedures at: http://www.hydro-int.com/sites/default/files/nj_uff_inspection_and_maintnenance.pdf
- This certification does not extend to the enhanced removal rates under NJAC 7:8-5.5 through the addition of settling chambers (such as hydrodynamic separators) or media filtration practices (such as a sand filter).

Table A-1 Up-Flo® Filter Design Specifications

Ribbon Model	Filter Ribbon Length (in)	Filtration Area per Module	Max. Flow per Module	Max. Flow per Filtration Area	Minimum Sedimentation Area per Module	Min. Wet Volume per Module	Mass Capture Capacity per Module	Max Allowable Inflow Area[1] per Module	Min. Sump Depth	Max. Operating Head
	(in)	(ft^2)	(gpm/module)	(gpm/ft^2)	(ft^2/module)	(ft^3/module)	(lbs)	(acres)	(in.)	(in.)
285R	28.5	11.87	15	1.264	2.094	5.217	8.33	0.014	24	25.625

[1] Maximum Allowable Inflow Area = (8.33 lbs/module)/600 lbs per acre of drainage area annually

Table A-2 Up-Flo® Filter Configurations and NJDEP Sizing Table

Configuration	Model Size	Number of Filter Modules	Max. Filtration Rate[2]	Min. Sedimentation Area[2,3]	Min. Wet Volume[2,3]	Total Filtration Area[2]	Total Mass Capture[2]	Max. Allowable Inflow Area[2]
			(gpm)	(ft^2)	(ft^3)	(ft^2)	(lbs)	(acres)
MANHOLE	UFF-MH-285R	6	90	12.57	31.30	71.22	50.0	0.083
VAULT	UFF-ZV-19-285R	19	285	39.79	99.12	225.5	158	0.264
VAULT	UFF-ZV-38-285R	38	570	79.59	198.2	451.1	317	0.528
VAULT	UFF-ZV-57-285R	57	855	119.4	297.4	676.6	475	0.792

[2] Refer to Table A-1: UFF Design Specifications for the design parameters

[3] The precast structure housing the filter modules shall have at least the “Min. Sedimentation Area”