NJCAT TECHNOLOGY VERIFICATION

First Defense® HC Stormwater Treatment Device

Hydro International

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1. Description of Technology

The First Defense® HC (FDHC) is a vortex separator designed and supplied by Hydro International. The FDHC is installed as part of typical drainage network systems to capture particulate pollutants that have entered the system from surface runoff. The FDHC has patented flow-modifying internal components that create a swirling flow path within the treatment chamber, which serves to supplement gravitational settling forces with additional vortex forces for enhanced settling performance. The FDHC chamber is a precast concrete manhole. The internal components are rotationally molded high density polyethylene. The internal components include an internal bypass weir to divert peak flows over the treatment chamber to prevent captured particles from being resuspended and washed out (**Figure 1**).

1. Inlet pipe
2. Vortex treatment chamber
3. Sediment storage sump
4. Internal bypass chamber
5. Internal bypass weir
6. Outlet pipe
7. Concrete Manhole

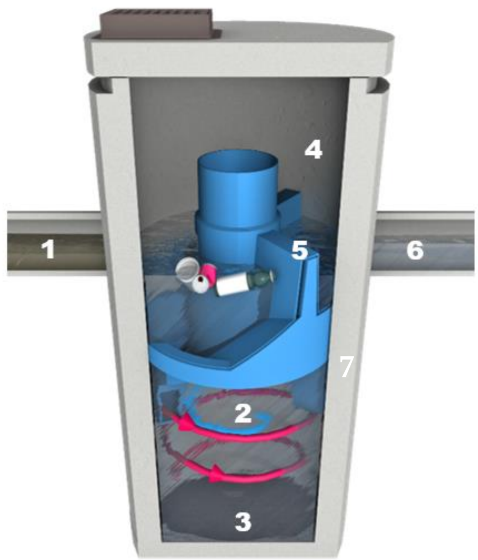


Figure 1 First Defense HC

Stormwater enters the FDHC through an inlet pipe and/or a surface grate. Hydrocarbons and other floatable solids rise to the surface where they are captured on the inlet side of the internal bypass weir. Stormwater is conveyed through a submerged inlet chute designed to initiate a spiraling flow path within the vortex treatment chamber. Suspended solids are captured in the sediment storage sump. Treated water exits the vortex treatment chamber via an outlet chute and exits the FDHC via an outlet pipe.

As many development sites in New Jersey require more than 50% TSS removal, the FDHC can be used as a pretreatment component in a treatment train when higher TSS removals are required and polishing BMPs such as infiltration or bio-infiltration are designed downstream.

2. Laboratory Testing

This testing was conducted to independently verify the FDHC such that it could be certified by the New Jersey Department of Environmental Protection (NJDEP) as a 50% Total Suspended Solids removal device.

The FDHC was tested to the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP 2013). The testing was conducted in Portland, Maine at Hydro International's hydraulics laboratory under the supervision of FB Environmental Associates, Inc., who served as the independent observer. FB Environmental is a Portland, Maine based environmental engineering consultancy with prior experience serving as the independent observer for several hydrodynamic separators previously tested to this protocol.

The particle size distribution of the removal efficiency test sediment samples were analyzed by the independent analytical laboratory GeoTesting Express in Acton, Massachusetts. The particle size distribution samples for the scour testing test sediment were analyzed at the Hydro International laboratory under the supervision of the independent observer. All water quality samples for both the removal efficiency testing and the washout testing were collected, labeled and sealed under the direct supervision of the independent observer from FB Environmental and analyzed by Maine Environmental Laboratory in Yarmouth, Maine.

2.1 Test Unit

The test unit was a 4-ft FDHC comprised of full scale, commercially available 4-ft FDHC internal components installed in a 4-ft round plastic manhole chamber consistent in all key dimensions with the precast chambers used for commercial sales (**Figure 2**). Both the inlet and outlet pipe diameters of the test model were 24 inches, which is the standard pipe size for a 4-ft FDHC.

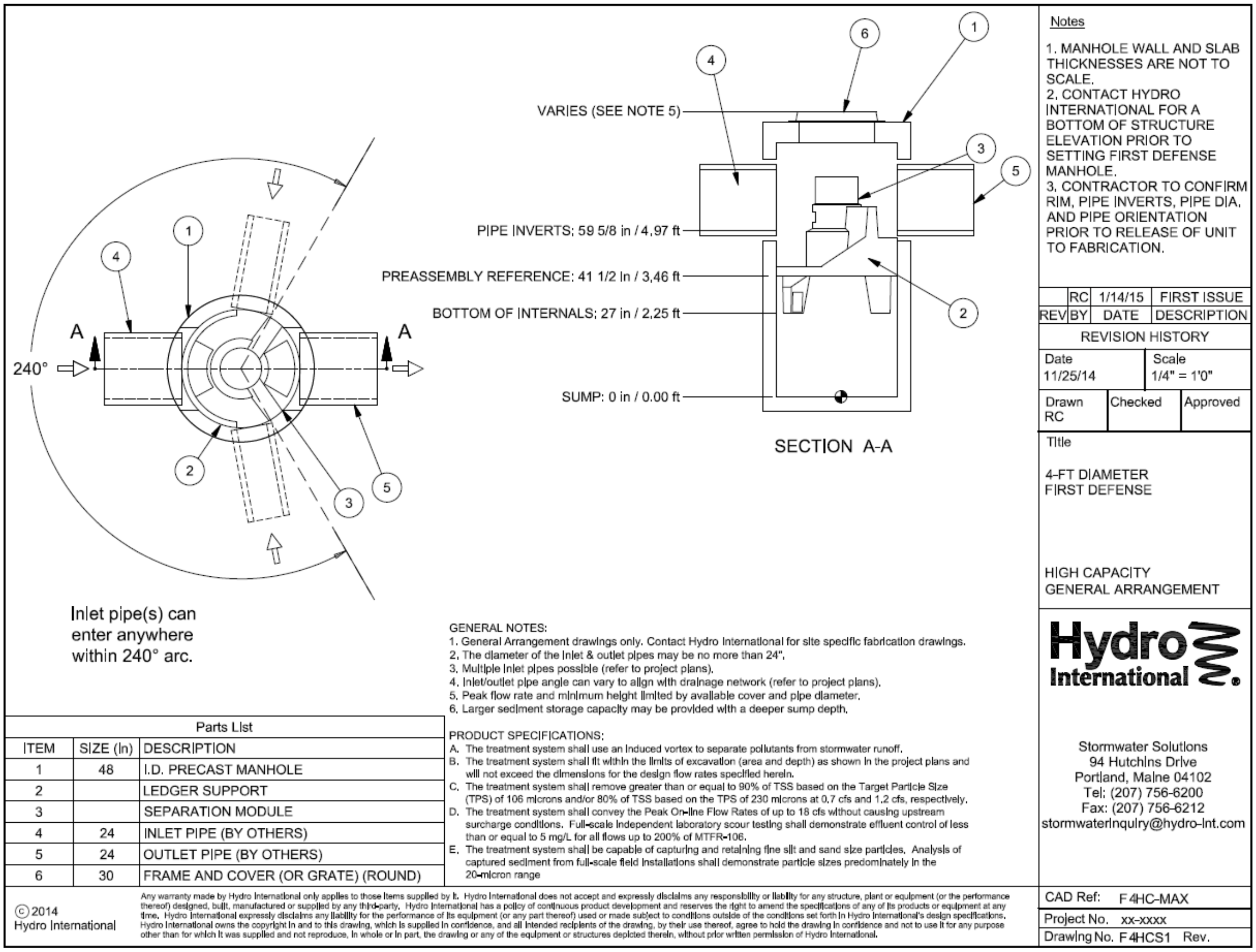


Figure 2 4-ft FDHC

The test vessel, unlike a commercial FDHC, had a rectangular access port located on the sump wall (**Figure 3a-b**). The access port eliminated the need for complete removal of the internal components and confined space entry into the FDHC to clean the unit between test events.

To ensure dimensional consistency with a commercial unit, the inside of the sump access port was fitted with an insert fabricated to be flush with the interior of the cylindrical manhole wall (**Figure 4**). Therefore the access port did not provide any additional sump storage capacity, did not alter the flow path within the vortex treatment chamber and ensured that the test vessel was dimensionally consistent to a standard commercial FDHC.

Prior to the beginning of the testing program, Hydro International laboratory technicians measured and recorded the key dimensions of the test vessel in the presence of the independent observer to ensure that the test unit assembly and test vessel dimensions were consistent with a commercial 4-ft FDHC.

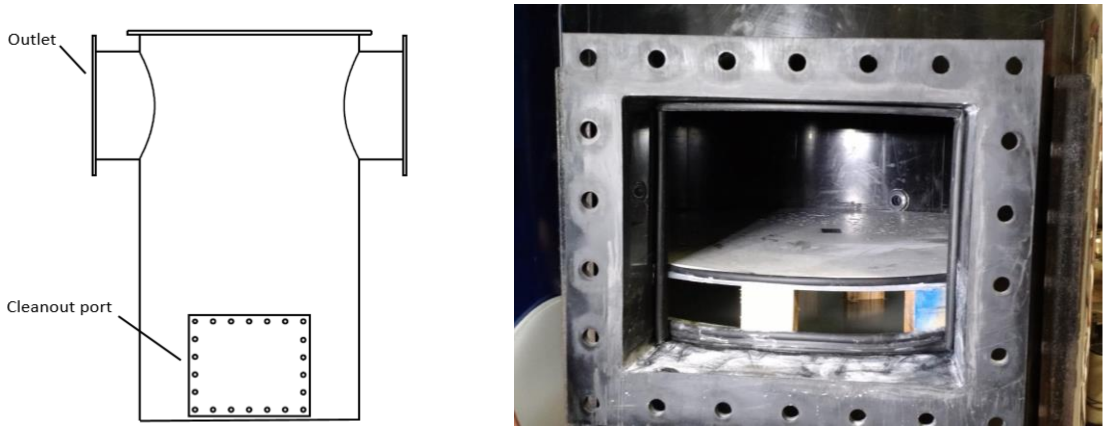


Figure 3 Schematic Drawing and Photo of Sump Access Port

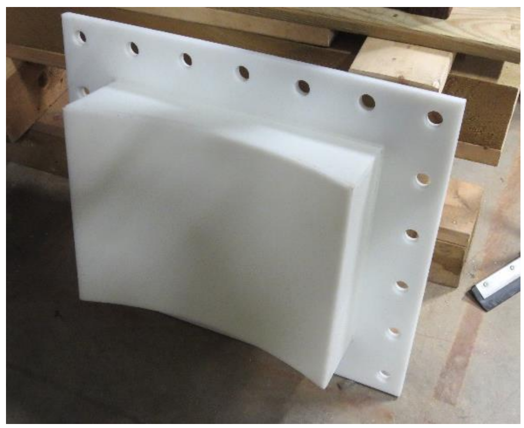


Figure 4 Sump Access Port sits Flush with Interior Manhole Wall

2.2 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 reservoir through a PVC pipe network to the 4-ft FDHC (**Figure 5**). 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.

The water temperature within the reservoir was regulated by a Hayward 350FD pool heater, which was used to reduce the possibility of 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 heater was set to 80°F. In the morning, the heater was turned off at least one hour before testing began. The heater then remained off throughout the entire duration of each test run. The Hayward 350FD assembly includes a small recirculation pump that causes a gentle current in the reservoir, which could potentially cause high background concentration readings during testing by carrying sediment discharged during a test run back to the main reservoir feed pump more quickly. Turning the heater off allowed any water movement in the reservoir to stop before the beginning of testing. The test reservoir temperature was recorded at 30 second intervals by a Lascar thermometer and temperature logger over the duration of each test.

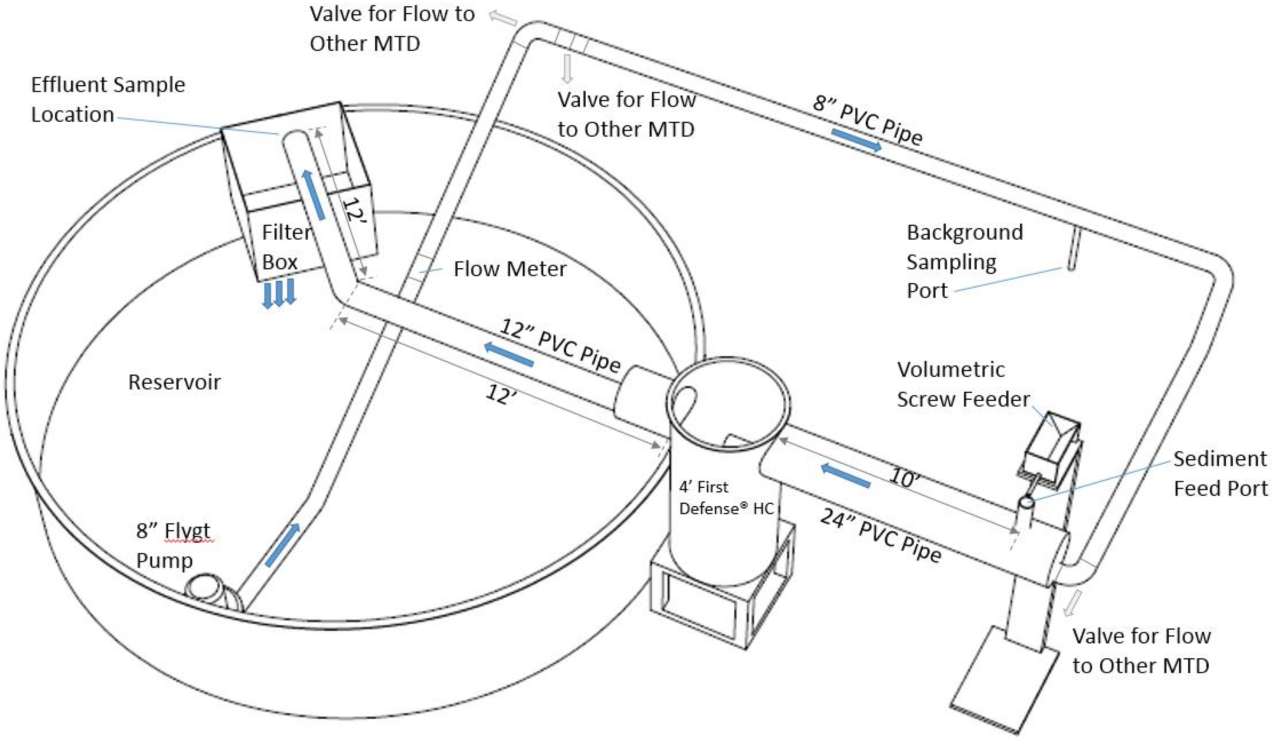


Figure 5 Laboratory Testing Arrangement

Three flow isolation valves were located between the Flygt pump and the FDHC, which would allow flow to bypass the FDHC if fully opened. These valves were installed as part of the piping network to direct flow to three other manufactured stormwater and wastewater treatment systems installed at the test facility along the same piping network, and were fully closed throughout the entire period when the FDHC testing was conducted.

A background sampling port was installed about 27 feet upstream of the FDHC. The FDHC effluent discharged freely from the effluent pipework, where grab samples were taken. The free discharge flowed through a filter box fitted with 1 micron filter socks in order to remove the majority of fine sediment that remained in the flow stream (**Figure 6**). The filter box was located on the opposite side of the reservoir as the submersible pump in order to keep the background concentration from surpassing the maximum allowable limit over the duration of the removal efficiency tests.

Figure 6 Effluent Sampling Location Situated above the Filter Box

Total Suspended Solids Removal Efficiency Laboratory Test Setup

For the removal efficiency test runs, test sediment was introduced into the flow at a consistent, calibrated rate by an Auger Feeder Model VF-2 volumetric screw feeder situated atop a 4-inch port in the 2 foot diameter inlet pipe located 10 feet upstream of the FDHC test unit. The location of the port is shown in **Figure 7**.

Figure 7 Influent Feed Port for TSS Removal Efficiency Testing

The FDHC sump measures 18 inches in height from the bottom of the sump. In line with the protocol requirements, it was fitted with a false bottom positioned 9 inches from the true sump bottom to simulate a 50% full condition (**Figure 8**). It was secured to the chamber and sealed around the edges to prevent any material from collecting below.

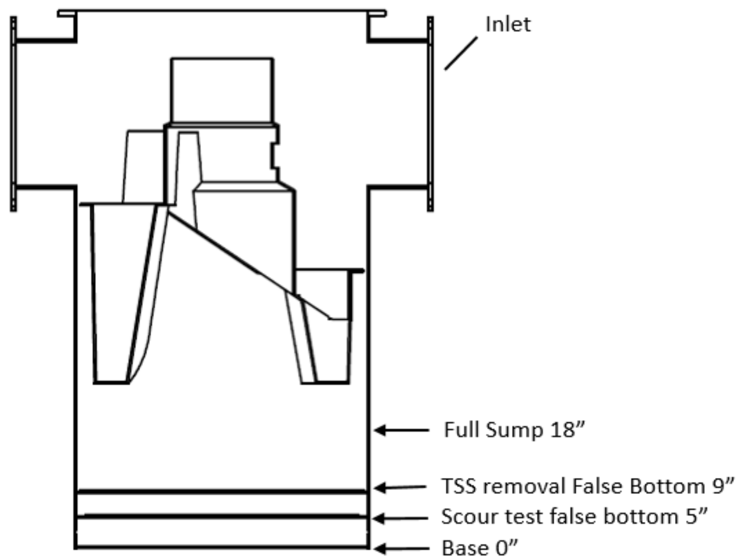


Figure 8 False Bottom Positions used during FDHC Testing

Scour Test Laboratory Setup

To simulate the 50% full condition for the scour test, the false bottom was set 5 inches above the sump floor (**Figure 8**) and 4 inches of the scour test sediment blend was pre-loaded on top of the false bottom, bringing the level of sump contents to 9 inches from the sump bottom.

2.3 Test Sediment

Test Sediment Feed for Suspended Solids Removal Efficiency Testing

The test sediment used for the Suspended Solids Removal Efficiency Testing was an in-house blend of high purity silica (SiO_2 99.8%) supplied by AGSCO Corporation and U.S. Silica, Inc., both commercial silica suppliers. Prior to the start of the removal efficiency testing, a total of five batches of test sediment were blended by Hydro International. Three sediment samples and one spare sample approximately 400 mL in volume were composited from 80 mL subsamples collected from each of the 5 batches under the supervision of the independent observer. The 4 samples were sealed, signed and packaged for independent transport to the outside laboratory under the supervision of the independent observer. After the samples were taken, the 5 batches were sealed and set aside until use. The independent laboratory, GeoTesting Express, analyzed the particle size distribution of each of the 3 samples and the spare sample using ASTM D 422-63. The particle size distributions of each of the 3 samples were averaged and reported as the overall particle size distribution. The particle size distribution of the spare sample was found to meet the protocol specification, however it was not included in the reported average particle size distribution (PSD) because the protocol specifically states that three samples shall be analyzed and averaged.

Scour Test Sediment

The test sediment used for the Scour Testing was high purity (99.8% SiO_2) silica blended by AGSCO Corporation, an independent commercial silica supplier, to meet the specified particle size distribution of the protocol. The scour test sediment was delivered to Hydro International prepackaged, in sealed 50-lb bags. Under observation of the independent observer, three 250 mL subsamples were taken from randomly selected areas of the sump. The subsamples were then sealed and signed under observation of the independent observer and analyzed at the Hydro International laboratory for PSD analysis under the observation of the independent observer at a later date. The reported PSD is the average of the three subsample particle size distributions.

2.4 Removal Efficiency Testing Procedure

Removal efficiency testing was conducted in accordance with Section 5 of the NJDEP Laboratory Protocol for HDS MTDs. A total of five flow rates were tested: the 25%, 50%, 75%, 100% and 125% Maximum Treatment Flow Rate (MTFR). FB Environmental acted as the independent observer for the duration of all testing and water quality sample collection, sealing and packaging for transportation to the independent laboratory. Captured sediment was removed from the sump between each flow rate trial.

The test sediment mass was fed into the flow stream at a known rate using a screw auger with a calibrated funnel. Sediment was introduced at a rate within 10% of the targeted value of 200 mg/L influent concentration throughout the duration of the testing.

Six calibration samples were taken from the injection point. The calibration samples were timed at evenly spaced intervals over the total duration of the test for each tested flow rate and timed such that no collection interval would exceed 1 minute in duration. Each calibration sample was a minimum of 100 mL collected in a clean 1-liter container over an interval timed to the nearest second. These samples were weighed to the nearest milligram. 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 mass extracted for calibration samples was subtracted from the total mass introduced to the system when removal efficiency was subsequently calculated. 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 Calculation for Average Influent Concentration

During each flow rate test, the flow meter data logger recorded flow rate at a minimum of once per minute. The Effluent Grab Sampling Method was used as per Section 5D of the protocol. Once a constant rate of flow and test sediment feed were established, a minimum of three MTD detention times passed before the first effluent sample was collected. All effluent samples were collected in clean half-liter bottles using a sweeping grab sampling motion through the effluent discharge as described in Section 5D of the protocol. Samples were then time stamped and placed into a box for transportation to the analytical laboratory.

The time interval between sequential samples was evenly spaced during the test sediment feed period to obtain 15 samples for each flow rate. The water temperature was recorded at 30 second intervals to ensure that it did not exceed 80 degrees Fahrenheit at any time.

Background samples were taken at the background sample port located upstream of the FDHC test setup. Influent background samples were taken at the same time as odd numbered effluent grab samples (first, third, fifth, etc.). The collection time for each background and effluent sample was recorded. Each collected sample was time stamped, sealed and signed by the independent observer.

At the conclusion of the test all of the collected effluent and background water quality samples were placed into a delivery box, the box was sealed and the seal was signed by the independent observer. All samples were analyzed by Maine Environmental Laboratory in accordance with ASTM D3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples".

The background data were plotted on a curve for use in adjusting the effluent samples for background concentration. The FDHC removal efficiency for each tested flow rate was calculated as per **Equation 2**.

$$\textbf{Removal Efficiency (\%)} = \frac{\left(\begin{array}{c}\text{Average Influent}\\ \text{Concentration}\end{array} - \begin{array}{c}\text{Adjusted}\\ \text{Average Effluent*}\\ \text{Concentration}\end{array}\right)}{\text{Average Influent Concentration}} \times 100$$

* Adjusted for background concentration

Equation 2 Equation for Calculating Removal Efficiency

2.5 Scour Testing Procedure

To simulate a 50% full sump condition, the FDHC sump false bottom was set to a height of 5 inches and then topped with 4 inches of scour test sediment. The sediment was leveled, then the FDHC was filled with clear water at a slow rate as to not disturb the sediment prior to the beginning of testing. In line with the protocol, scour testing was begun less than 96 hours after the sump was pre-loaded with test sediment. All setup measurements, testing and sample collection procedures were observed by the independent observer.

Scour testing began by slowly introducing flow and, in less than 5 minutes, ramping up the flow rate until it reached >200% of the MTFR. The flow rate was recorded at a minimum of once per minute so that the effluent samples could be compared to corresponding flow rates. The flow rate remained constant at the target maximum flow rate for the remainder of the test duration.

Effluent samples were collected and time stamped every 2 minutes after the target flow rate was reached. A minimum of 15 effluent samples were taken over the duration of the test. The effluent samples were collected in half liter bottles using the grab sampling method as described in Section 5D of the protocol. Temperature readings of the test water were recorded every 30 seconds to ensure it did not exceed 80 degrees Fahrenheit at any point during the test.

Eight background samples were collected at evenly spaced intervals throughout the duration of the target maximum flow rate testing. The background samples were drawn from the background sample port located upstream of the FDHC.

At the conclusion of the test all of the collected effluent and background water quality samples were placed into a delivery box, the box was sealed and the seal was signed by the independent observer. All samples were analyzed by Maine Environmental Laboratory in accordance with ASTM D3977-97 (re-approval 2007) “Standard Test Methods for Determining Sediment Concentrations in Water Samples”.

3. Performance Claims

In line with the NJDEP verification procedure, FDHC performance claims are outlined below.

Total Suspended Solids Removal Rate

The TSS removal rate of the FDHC is dependent upon flow rate, particle density and particle size. For the particle size distribution and weighted calculation method required by the NJDEP HDS MTD protocol, the 4-ft FDHC at a MTFR of 1.50 cfs will demonstrate at least 50% TSS removal efficiency.

Maximum Treatment Flow Rate

The MTFR for the 4-ft FDHC was demonstrated to be 673 gpm (1.50 cfs), which corresponds to a surface loading rate of 53.6 gpm/sf.

Sediment Storage Depth and Volume

The maximum sediment storage depth of the FDHC is 18 inches. Available sediment storage volume varies with each FDHC model, as FDHC model dimensions increase in diameter. The available sump volume for a 4-ft FDHC model is 0.70 cubic yards. The maximum sediment storage depth is 9 inches, which corresponds to a 50% full sump capacity (or 0.35 cubic yards) for the standard model. Refer to **Table A-2** in the Verification Appendix for the 50% sump full capacities for other FDHC model sizes.

Effective Treatment Area and Effective Sedimentation Area

The effective treatment and sedimentation area of the FDHC model varies with model size, as it corresponds to the surface area of the FDHC model diameter. The tested 4-ft FDHC model has a treatment surface area of 12.56 square feet.

Detention Time and Volume

The detention time of the FDHC depends on flow rate and model size. The detention time is calculated by dividing the treatment volume by the flow rate. The treatment volume is defined as the volume between the pipe invert and the top of the sediment storage zone. For the tested 4-ft FDHC model at the MTFR of 1.50 cfs, the detention time is 29 seconds.

Online or Offline Installation

Based on the results of the Scour Testing shown in Section 4.4, the FDHC qualifies for online installation.

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.

4.1 Test Sediment PSD Analysis – Removal Efficiency Testing

Hydro International purchased two different grades of high purity silica (SiO_2 99.8%) supplied by two different commercial silica suppliers. These silica blends were mixed together at the proportions required to generate a test sediment that complied with the particle size distribution requirements specified in the NJDEP HDS MTD protocol.

Prior to the start of removal efficiency testing trials conducted in November 2015, 5 batches of test sediment were blended by Hydro International. Three composite sediment samples and one spare sample approximately 400 mL in volume were blended using 80 mL of sediment collected from 6 subsamples drawn from each of the 5 batches under the supervision of the independent observer. The samples were also sealed and packaged for independent transport to the outside laboratory under the supervision of the independent observer. The independent laboratory GeoTesting Express analyzed the particle size distribution of each sample using ASTM D 422-63. The test sediment was found to be slightly finer than the protocol specified sediment blend. The results and the comparison to the protocol specification are shown in **Table 1** and **Figure 9.**

Table 1 - Particle Size Distribution Results of Test Sediment Samples

Particle Size	% Finer					Difference from Protocol %
µm	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	80.0	80.0	80.0	80.0	-5.0
100	60	61.1	61.9	60.4	61.1	-1.1
75	50	54.0	54.0	54.0	54.0	-4.0
50	45	49.5	49.1	49.4	49.3	-4.3
20	35	39.1	37.8	37.9	38.3	-3.3
8	20	23.2	22.8	22.2	22.7	-2.7
5	10	15.3	15.9	15.1	15.4	-5.4
2	5	5.5	6.5	5.5	5.8	-0.8

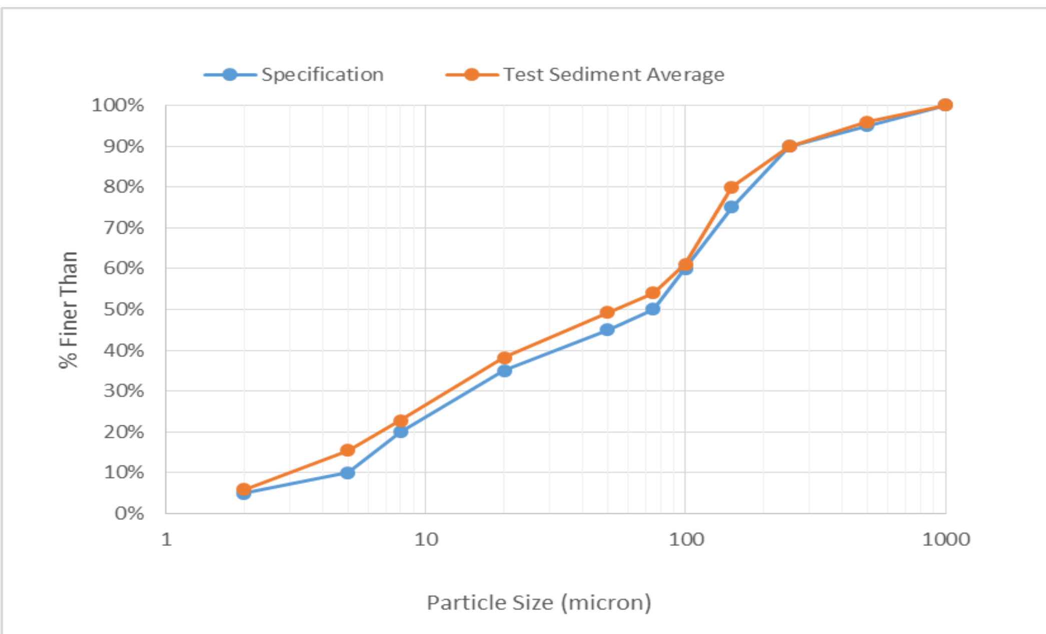


Figure 9 Average Test Sediment PSD vs Protocol Specification

4.2 Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the First Defense® HC 4-ft. unit in order to establish the ability of the FDHC to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. The target MTFR was 673 gpm (1.50 cfs). This target was chosen based on the ultimate goal of demonstrating greater than 50% annualized weighted solids removal as defined in the Protocol.

All results reported in this section were derived from test runs that fully complied with the terms of the protocol. None of the collection intervals of the calibration samples exceeded one minute in duration for any of the reported tests. The inlet feed concentration coefficient of variance (COV) did not exceed 0.10 for any flow rate trials.

The mean influent concentration was calculated using Equation 1 from *Section 2.4 Removal Efficiency Test Procedure.* The mean effluent concentration was adjusted by subtracting the measured background concentrations. No background TSS concentrations exceeded the 20 mg/L maximum allowed by the protocol. At no point did the water temperature exceed 80 ^{o}F.

25% MTFR Results

The 25% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.38 cfs. A summary of test readings, measurements and calculations are shown in **Table 2**. Feed calibration results are shown in **Table 3**. Background and effluent sampling measurements are shown in **Table 4**.

The 4-ft FDHC removed 61.1% of the test sediment at a flow rate of 0.38 cfs. **Table 5** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol.

Table 2 - Summary of 4-ft FDHC 25% MTFR Test

Trial Date	Target Flow (cfs)/(gpm)	Detention Time (sec)	Target Sediment Concentration (mg/L)	Target Feed Rate (mg/min)	Test Duration (Min)
11/02/2015	0.38 /168.4	116	200	130,995	44:36
Measured Values					
Mean Flow Rate (cfs)/(gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °C / °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
0.38 /169.0	205.0	25.5 / 77.9	79.7	61.1%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 3 - 4-ft FDHC 25% MTFR Test Calibration Results

Target Concentration	200 mg/L	Target Feed Rate		130,995 mg/min	
Sample ID	**Sample Time (min)**	**Sample Mass (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	136.255	60	136,255	213
Feed Rate 2	8:42	128.774	60	128,774	201
Feed Rate 3	17:24	129.323	60	129,323	202
Feed Rate 4	26:06	130.640	60	130,640	204
Feed Rate 5	34:48	129.336	60	129,336	202
Feed Rate 6	43:29	135.498	60	135,498	212
			Mean	131,638	**206**

Table 4 – 4-ft FDHC 25% MTFR Background and Effluent Measurements

Sample ID	Time (min)	Concentration (mg/L)		
Background 1	7:42	2		
Background 2	8:42	2		
Background 3	16:54	2		
Background 4	25:06	6		
Background 5	26:06	7		
Background 6	34:18	8		
Background 7	42:29	12		
Background 8	43:29	12		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	7:42	81	2	79
Effluent 2	8:12	81	2	79
Effluent 3	8:42	79	2	77
Effluent 4	16:24	80	2	78
Effluent 5	16:54	77	2	75
Effluent 6	17:24	80	4	76
Effluent 7	25:06	83	6	77
Effluent 8	25:36	83	6.5	77
Effluent 9	26:06	86	7	79
Effluent 10	33:48	90	7.5	83
Effluent 11	34:18	90	8	82
Effluent 12	34:48	89	10	79
Effluent 13	42:29	92	12	80
Effluent 14	42:59	98	12	86
Effluent 15	43:29	102	12	90
	Mean	**86.1**	**6.3**	**79.7**

Table 5 – 4-ft FDHC 25% MTFR Trial QA/QC Results

Flow Rate			
Target (cfs / gpm)	Mean (cfs / gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
0.38 / 168.4	0.38 / 169.0	0.019	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
130,995	131,638	0.025	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	205	0.025	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	12	6.3	<20

50% MTFR Results

The 4-ft FDHC 50% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 0.75 cfs. The 50% MTFR test results are shown in **Table 6**. Calibration results are shown in **Table 7**. Background and effluent results are shown in **Table 8**.

The 4-ft FDHC removed 53.8% of the test sediment at a flow rate of 0.75 cfs. **Table 9** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol.

Table 6 – Summary of 4-ft FDHC 50% MTFR Test

Trial Date	Target Flow (cfs) / (gpm)	Detention Time (sec)	Target Sediment Concentration (mg/L)	Target Feed Rate (mg/min)	Test Duration (Min)
11/04/2015	0.75 / 336.8	58	200	261,990	24:56
Measured Values					
Mean Flow Rate (cfs) / (gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °C / °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
0.75 / 337.5	204.7	25.1 / 77.2	94.6	53.8%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 7 – 4-ft FDHC 50% MTFR Test Calibration Results

Target Concentration	200 mg/L	Target Feed Rate		261,990 mg/min	
Sample ID	**Sample Time (min)**	**Sample Mass (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	132.832	30	265,664	208
Feed Rate 2	4:51	135.837	30	271,674	213
Feed Rate 3	9:42	129.512	30	259,024	203
Feed Rate 4	14:33	134.162	30	268,324	210
Feed Rate 5	19:24	129.638	30	259,276	203
Feed Rate 6	24:15	129.169	30	258,338	202
			Mean	**263,717**	**206**

Table 8 – 4-ft FDHC 50% MTFR Background and Effluent Measurements

Sample ID	Time (min)	Concentration (mg/L)
Background 1	3:51	2
Background 2	4:51	2
Background 3	9:12	2
Background 4	13:33	2
Background 5	14:33	2
Background 6	18:54	5
Background 7	23:15	12
Background 8	24:15	16

Sample ID	Time (min)	Concentration (mg/L)	Associated Background Concentration (mg/L)	Adjusted Concentration (mg/L)
Effluent 1	3:51	90	2	88
Effluent 2	4:21	94	2	92
Effluent 3	4:51	99	2	97
Effluent 4	8:42	98	2	96
Effluent 5	9:12	100	2	98
Effluent 6	9:42	98	2	96
Effluent 7	13:33	95	2	93
Effluent 8	14:03	96	2	94
Effluent 9	14:33	95	2	93
Effluent 10	18:24	98	3.5	95
Effluent 11	18:54	103	5	98
Effluent 12	19:24	102	8.5	94
Effluent 13	23:15	106	12	94
Effluent 14	23:45	113	14	99
Effluent 15	24:15	108	16	92
	Mean	**99.7**	**5.1**	**94.6**

Table 9 – 4-ft FDHC 50% MTFR Trial QA/QC Results

Flow Rate			
Target (cfs / gpm)	Mean (cfs / gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
0.75 / 336.8	0.75 / 337.5	0.008	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
261,990	263,717	0.021	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	204.7	0.021	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	16	5.4	<20

75% MTFR Results

The 4-ft FDHC 75% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 1.13 cfs (507 gpm). The 75% MTFR test results are shown in **Table 10**. Calibration results are shown in **Table 11**. Background and effluent results are shown in **Table 12.**

The 4-ft FDHC removed 51.3% of the test sediment at a flow rate of 1.13 cfs. **Table 13** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol.

Table 10 – Summary of 4-ft FDHC 75% MTFR Test

Trial Date	Target Flow (cfs) / (gpm)	Detention Time (sec)	Target Sediment Concentration (mg/L)	Target Feed Rate (mg/min)	Test Duration (Min)
11/06/2015	1.13 / 507.2	39	200	393,600	18:34
Measured Values					
Mean Flow Rate (cfs / gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °C / °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
1.13 / 507.5	191.7	24.9 / 76.8	93.3	51.3%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 11 – 4-ft FDHC 75% MTFR Test Calibration Results

Target Concentration	200 mg/L	Target Feed Rate		393,600 mg/min	
Sample ID	**Sample Time (min)**	**Sample Mass (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	132.141	20	396,423	206
Feed Rate 2	3:34	129.181	20	387,543	202
Feed Rate 3	7:08	127.602	20	382,806	199
Feed Rate 4	10:42	121.658	20	364,974	190
Feed Rate 5	14:16	122.327	20	366,981	191
Feed Rate 6	17:50	122.845	20	368,535	192
			Mean	**377,877**	**197**

Table 12 – 4-ft FDHC 75% MTFR Background and Effluent Measurements

Sample ID	Time (min)	Concentration (mg/L)
Background 1	2:34	2
Background 2	3:34	2
Background 3	6:38	2
Background 4	9:42	2
Background 5	10:42	2
Background 6	13:46	14
Background 7	16:50	14
Background 8	17:50	15

Sample ID	Time (min)	Concentration (mg/L)	Associated Background Concentration (mg/L)	Adjusted Concentration (mg/L)
Effluent 1	2:34	87	2	85
Effluent 2	3:04	95	2	93
Effluent 3	3:34	96	2	94
Effluent 4	6:08	96	2	94
Effluent 5	6:38	98	2	96
Effluent 6	7:08	104	2	102
Effluent 7	9:42	99	2	97
Effluent 8	10:12	93	2	91
Effluent 9	10:42	100	2	98
Effluent 10	13:16	103	8	95
Effluent 11	13:46	98	14	84
Effluent 12	14:16	100	14	86
Effluent 13	16:50	102	14	88
Effluent 14	17:20	111	14.5	97
Effluent 15	17:50	115	15	100
	Mean	**99.8**	**6.5**	**93.3**

Table 13 – 4-ft FDHC 75% MTFR Trial QA/QC Results

Flow Rate			
Target (cfs / gpm)	Mean (cfs / gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
1.13 / 507.2	1.13 / 507.5	0.006	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
393,600	377,877	0.034	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	191.7	0.034	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	15	6.6	<20

100% MTFR Results

The 4-ft FDHC 100% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 1.50 cfs (675 gpm). The 100% MTFR test results are shown in **Table 14**. Calibration results are shown in **Table 15**. Background and effluent results are shown in **Table 16.**

The 4-ft FDHC removed 46.0% of the test sediment at a flow rate of 1.50 cfs. **Table 17** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol.

Table 14 – Summary of 4-ft FDHC 100% MTFR Test

Trial Date	Target Flow (cfs) / (gpm)	Detention Time (sec)	Target Sediment Concentration (mg/L)	Target Feed Rate (mg/min)	Test Duration (Min)
11/10/2015	1.50 / 675.2	29	200	523,980	15:50
Measured Values					
Mean Flow Rate (cfs / gpm)	**Mean Influent Concentration (mg/L)[1]**	**Max. Water Temperature °C / °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
1.50 / 674.1	204.3	24.8 / 76.6	110.3	46.0%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 15 – 4-ft FDHC 100% MTFR Test Calibration Results

Target Concentration	200 mg/L	Target Feed Rate		523,980 mg/min	
Sample ID	**Sample Time (min)**	**Sample Mass (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	180.656	20	541,968	212
Feed Rate 2	3:00	180.055	20	540,165	212
Feed Rate 3	6:01	178.465	20	535,395	210
Feed Rate 4	9:01	175.592	20	526,776	206
Feed Rate 5	12:02	171.389	20	514,167	201
Feed Rate 6	15:02	167.750	20	503,250	197
			Mean	526,954	**206**

Table 16 – 4-ft FDHC 100% MTFR Background and Effluent Measurements

Sample ID	Time (min)	Concentration (mg/L)		
Background 1	2:00	4		
Background 2	3:00	2		
Background 3	5:31	2		
Background 4	8:01	2		
Background 5	9:01	2		
Background 6	11:32	6		
Background 7	14:02	12		
Background 8	15:02	15		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	2:00	99	4	95
Effluent 2	2:30	107	3	104
Effluent 3	3:00	112	2	110
Effluent 4	5:01	111	2	109
Effluent 5	5:31	119	2	117
Effluent 6	6:01	116	2	114
Effluent 7	8:01	109	2	107
Effluent 8	8:31	114	2	112
Effluent 9	9:01	115	2	113
Effluent 10	11:02	119	4	115
Effluent 11	11:32	114	6	108
Effluent 12	12:02	123	9	114
Effluent 13	14:02	122	12	110
Effluent 14	14:32	132	13.5	119
Effluent 15	15:02	123	15	108
	Mean	**115.7**	**5.4**	**110.3**

Table 17 – 4-ft FDHC 100% MTFR Trial QA/QC Results

Flow Rate			
Target (cfs / gpm)	Mean (cfs / gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
1.50 / 675.2	1.50 / 674.1	0.007	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
523,980	526,954	0.03	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	204.3	0.03	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	15	5.6	<20

125% MTFR Results

The 4-ft FDHC 125% MTFR test was conducted in accordance with the NJDEP HDS protocol at a target flow rate of 1.88 cfs (842 gpm). The 125% MTFR test results are shown in **Table 18**. Calibration results are shown in **Table 19**. Background and effluent results are shown in **Table 20.**

The 4-ft FDHC removed 43.5% of the test sediment at a flow rate of 1.88 cfs. **Table 21** shows that the QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol.

Table 18 – Summary of 4-ft FDHC 125% MTFR Test

Trial Date	Target Flow (cfs / gpm)	Detention Time (sec)	Target Sediment Concentration (mg/L)	Target Feed Rate (mg/min)	Test Duration (Min)
11/16/2015	1.88 / 842.0	23	200	634,499	13:59
Measured Values					
Mean Flow Rate (cfs / gpm)	**Mean Influent Concentration[1] (mg/L)**	**Max. Water Temperature °C / °F**	**Mean Adjusted Effluent Concentration (mg/L)**	**Average Removal Efficiency**	**QA/QC Compliance**
1.88 / 842.3	201.8	24.8 / 76.7	114.0	43.5%	YES

[1] The mean influent concentration reported is calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test divided by the total flow during the injection of test sediment.

Table 19 – 4-ft FDHC 125% MTFR Test Calibration Results

Target Concentration	200 mg/L	Target Feed Rate		634,499 mg/min	
Sample ID	**Sample Time (min)**	**Sample Mass (g)**	**Sample Duration (sec)**	**Feed Rate (mg/min)**	**Calculated Influent Concentration (mg/L)**
Feed Rate 1	0:00	230.390	20	691,170	217
Feed Rate 2	2:40	221.852	20	665,556	209
Feed Rate 3	5:21	224.366	20	673,098	211
Feed Rate 4	8:01	218.425	20	655,275	206
Feed Rate 5	10:42	210.833	20	632,499	198
Feed Rate 6	13:22	204.864	20	614,592	193
			Mean	655,365	**206**

Table 20 – 4-ft FDHC 125% MTFR Background and Effluent Measurements

Sample ID	Time (min)	Concentration (mg/L)		
Background 1	1:40	2		
Background 2	2:40	2		
Background 3	4:51	2		
Background 4	7:01	2		
Background 5	8:01	2		
Background 6	10:12	5		
Background 7	12:22	11		
Background 8	13:22	11		
Sample ID	**Time (min)**	**Concentration (mg/L)**	**Associated Background Concentration (mg/L)**	**Adjusted Concentration (mg/L)**
Effluent 1	1:40	110	2	108
Effluent 2	2:10	121	2	119
Effluent 3	2:40	108	2	106
Effluent 4	4:21	128	2	126
Effluent 5	4:51	119	2	117
Effluent 6	5:21	119	2	117
Effluent 7	7:01	114	2	112
Effluent 8	7:31	115	2	113
Effluent 9	8:01	115	2	113
Effluent 10	9:42	119	3.5	116
Effluent 11	10:12	119	5	114
Effluent 12	10:42	114	8	106
Effluent 13	12:22	122	11	111
Effluent 14	12:52	124	11	113
Effluent 15	13:22	130	11	119
	Mean	**118.5**	**4.5**	**114.0**

Table 21 – 4-ft FDHC 125% MTFR Trial QA/QC Results

Flow Rate			
Target (cfs / gpm)	Mean (cfs / gpm)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
1.88 / 842.0	1.88 / 842.3	0.005	<0.03
Feed Rate			
Target (mg/min)	Mean (mg/min)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
634,499	655,365	0.04	<0.1
Influent Concentration			
Target (mg/L)	Mean (mg/L)	Coef. Of Variance	Acceptable Parameters Coef. Of Variance
200	201.8	0.04	<0.1
Background Concentration			
Low (mg/L)	High (mg/L)	Mean (mg/L)	Acceptable Threshold (mg/L)
2	11	4.6	<20

Excluded Data/Results

Section 5.D, *Verification Report Requirements: Supporting Documentation* of the NJDEP Process document requires that all data from performance evaluation test runs excluded from the computation of the removal rate or verification analysis be disclosed. No test runs were aborted during the testing process, and no data from tests that did not meet protocol requirements have been excluded from the results presented in the previous section of this report.

One duplicate sample was collected for each effluent water quality sample. These samples were sent to an independent analytical laboratory for particle size distribution analysis. As effluent particle size analysis is not required by the NJDEP protocol, the data are not presented in this report.

The protocol requires that three samples of removal efficiency test sediment be collected and analyzed for particle size distribution, and that the average particle size of the three samples be reported. During the collection of the three sediment samples, a fourth sample was taken in case of spoilage or loss of one of the samples. This fourth sample was analyzed for particle size distribution and met the PSD specified by the protocol. The fourth sample was not included in the reported average particle size distribution, as the protocol specifically states that three samples shall be analyzed for particle size distribution.

Annualized Weighted TSS Removal Efficiency

The NJDEP-specified annual weighted TSS removal efficiency calculation is shown in **Table 22** using the results from the removal efficiency testing.

Testing in accordance with the provisions detailed in the NJDEP HDS Protocol demonstrate that the 4-ft FDHC achieved a 52.93% annualized weighted TSS removal at an MTFR of 1.50 cfs (53.6 gpm/sf). This testing demonstrates that the 4-ft FDHC exceeds the NJDEP requirement that HDS devices demonstrate at least 50% weighted annualized TSS removal efficiency at the MTFR.

Table 22 – Annualized Weighted TSS Removal of the 4-ft FDHC

% MTFR	Mean Flow Rate Tested (cfs)	Actual % MTFR	Measured Removal Efficiency	Annual Weighting Factor	Weighted Removal Efficiency
25	0.38	25.3	61.1%	0.25	15.28%
50	0.75	50.0	53.8%	0.3	16.14%
75	1.13	75.3	51.3%	0.2	10.26%
100	1.50	100.0	46.0%	0.15	6.90%
125	1.88	125.3	43.5%	0.1	4.35%
Weighted Annualized TSS Removal Efficiency					**52.93%**

4.3 Test Sediment PSD Analysis - Scour Testing

The scour test sediment, as described in Section 2.3 *Test Sediment*, was high purity (99.8% SiO_2) silica blended by an independent commercial silica supplier to meet the particle size distribution specified by the NJDEP HDS protocol. Three 250 mL subsamples were taken from the sump and analyzed for particle size analysis at the Hydro International lab under the supervision of the independent observer.

The results showed that the average test sediment was found to meet the particle size distribution specified by the protocol (**Table 23**), with no measured value being greater than two percentage points greater than the target percent finer value. A comparison of the PSD specified by the protocol and average PSD of the test sediment is shown in **Figure 10**.

Table 23 – Scour Test Sediment Particle Size Distribution Comparison

Particle Size (µm)	% Finer					% Difference from Spec
	NJDEP Spec	Sample 1	Sample 2	Sample 3	Average	
1000	100	100.0	100.0	100.0	100.0	0.0
500	90	95.1	95.0	95.2	95.1	-5.1
250	55	64.0	64.6	62.8	63.8	-8.8
150	40	49.8	50.0	47.8	49.2	-9.2
100	25	23.4	23.6	22.0	23.0	2.0
75	10	10.6	11.0	10.0	10.5	-0.5
50	0	1.3	1.6	1.3	1.4	-1.4

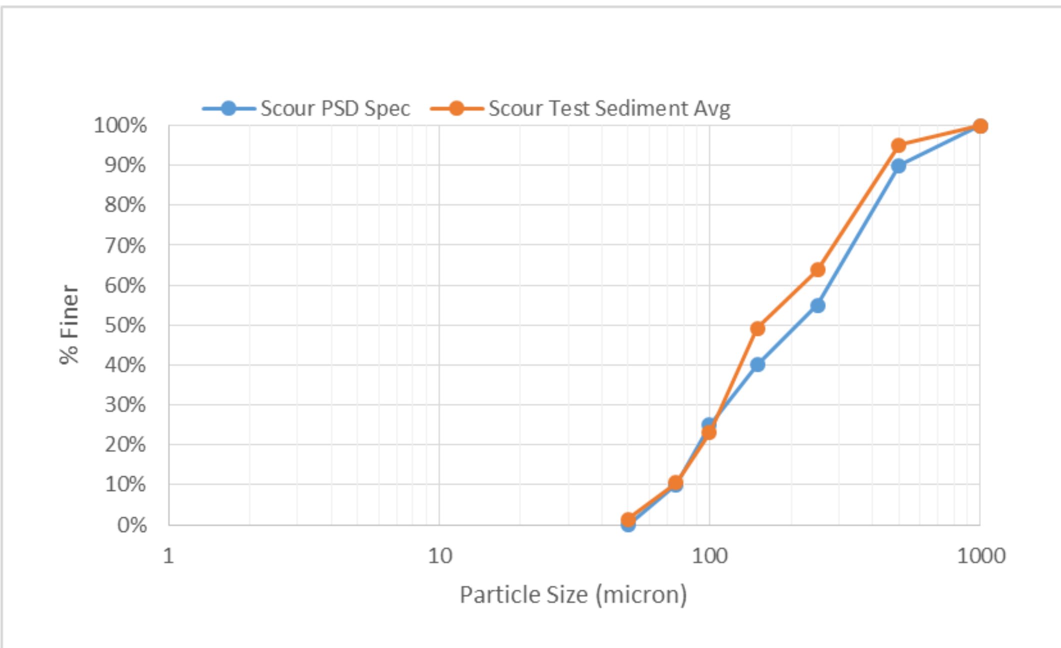


Figure 10 Scour Test Sediment PSD vs Protocol Specification

4.4 Scour Testing for Online Installation

The FDHC underwent scour testing in line with Section 4 of the NJDEP HDS protocol at a flow rate greater than 200% of its MTFR in order to verify its suitability for online use. For the 4-ft FDHC with an MTFR of 1.50 cfs (673 gpm) the average scour test flow rate had to be at least 3.0 cfs (1,344 gpm). The average flow rate for the scour test was 3.24 cfs, which represents 216% of the MTFR. The maximum water temperature during testing was 76.8°F. The flow rate COV was 0.007. Background concentrations measured 2 mg/L for all samples, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Flow and background concentration measurements are shown in **Table 24**.

Table 24 – Flow and Background Concentration Results for 4-ft FDHC Scour Testing

Trial Date		11/18/2015	Average Flow Rate =	3.24cfs
Mean Temperature		**24.5°C / 76.1°F**	**Flow Rate COV**	**0.007**
Sample ID	**Time (min)**	**Concentration (mg/L)**		
Background 1	2:00	2		
Background 2	6:00	2		
Background 3	10:00	2		
Background 4	14:00	2		
Background 5	18:00	2		
Background 6	22:00	2		
Background 7	26:00	2		
Background 8	30:00	2		

Unadjusted effluent concentrations ranged from 2 mg/L to 4 mg/L with a mean of 2.1 mg/L. When adjusted for background concentrations, the effluent concentrations range from 0 to 2 mg/L. The mean adjusted effluent concentration was 0.1 mg/L (**Table 25**).

Table 25 – Effluent Concentration Results for 4-ft FDHC Scour Test at 216% MTFR

Sample ID	Time (min)	Effluent Concentration with Background Concentrations (mg/L)	Background Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
Effluent 1	2:00	2	2	0
Effluent 2	4:00	2	2	0
Effluent 3	6:00	2	2	0
Effluent 4	8:00	2	2	0
Effluent 5	10:00	2	2	0
Effluent 6	12:00	2	2	0
Effluent 7	14:00	2	2	0
Effluent 8	16:00	2	2	0
Effluent 9	18:00	2	2	0
Effluent 10	20:00	2	2	0
Effluent 11	22:00	2	2	0
Effluent 12	24:00	2	2	0
Effluent 13	26:00	2	2	0
Effluent 14	28:00	4	2	2
Effluent 15	30:00	2	2	0
	Mean	**2.1**	**2**	**0.1**

Excluded Data/Results

The protocol requires the disclosure and discussion of any data collected as a part of the testing process that is excluded from the reported results. No test runs were aborted during the scour testing process, and no data from tests that did not meet protocol requirements have been excluded from the results presented in the scour testing section of this report.

5. Design Limitations

The FDHC is an engineered system for which Hydro International's engineers work with site designers to generate a detailed engineering submittal package for each installation. As such, design limitations are typically identified and managed during the design process. Design parameters and limitations are discussed in general terms below.

Required Soil Characteristics

The FDHC is a flow-through system contained within a water tight manhole. Therefore the FDHC can be installed and function as intended in all soil types.

Slope of Drainage Pipe

Hydro International recommends contacting our design engineers when the FDHC is going to be installed on a drainage line with a slope greater than 10%. With steeply sloping pipe, site specific parameters such as pipe size, online vs. offline arrangement of the FDHC and the frequency of peak flow are taken into consideration by the Hydro International design team.

Maximum Flow Rate

The maximum treatment flow rate (MTFR) of the FDHC is dependent upon model size. The recommended maximum peak flow rate is dependent on FDHC model size and other design and performance specifications. Hydro International recommends contacting their engineering staff with questions about managing high peak flow rates.

Maintenance Requirements

The FDHC should be inspected and maintained in line with the recommendations and guidelines set forth in the Operation and Maintenance Manual at: (http://www.hydro-int.com/UserFiles/downloads/FD_O%2BM_F1512.pdf). The sediment accumulation rate in the FDHC is dependent on site-specific characteristics such as site usage and topography. A more detailed discussion of inspection and maintenance requirements is discussed later in Section 6.

Driving head

Testing conducted according to ASTM Standard Test Methods C1745 / C1745M – 11: Standard Test Method for Measurement of Hydraulic Characteristics of Hydrodynamic Stormwater Separators and Underground Settling Devices showed that the headloss across the FDHC is a function of flow rate and pipe velocities. Generally, the FDHC headloss is estimated using Equation 3.

Equation 3 – Flow dependent headloss of the FDHC

Given H_L = FDHC headloss
H_u = measured pressure head or water elevation in the inlet or upstream pipe
H_d = measured pressure head or water elevation in the outlet or downstream pipe
G = gravitational constant, 32.2 ft/sec^2
V_u, V_d = calculated average flow velocities in the upstream and downstream pipes, respectively

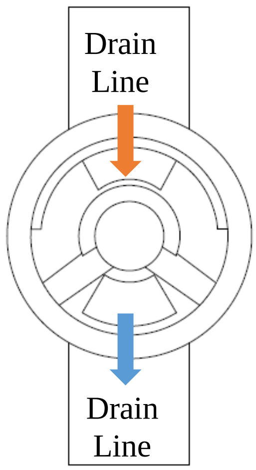
$$H_L = \left(h_u + \frac{V_u^2}{2g}\right) - \left(h_d + \frac{V_d^2}{2g}\right)$$

Installation limitations

Pick weights and installation procedures vary slightly with model size. Hydro International provides contractors with project-specific unit pick weights and installation instructions prior to delivery.

Configurations

The FDHC was designed for online applications in which the inlet and outlet are tied directly into the main drainage line, however the device can also be installed offline using external junction manholes (**Figure 11a-b**).



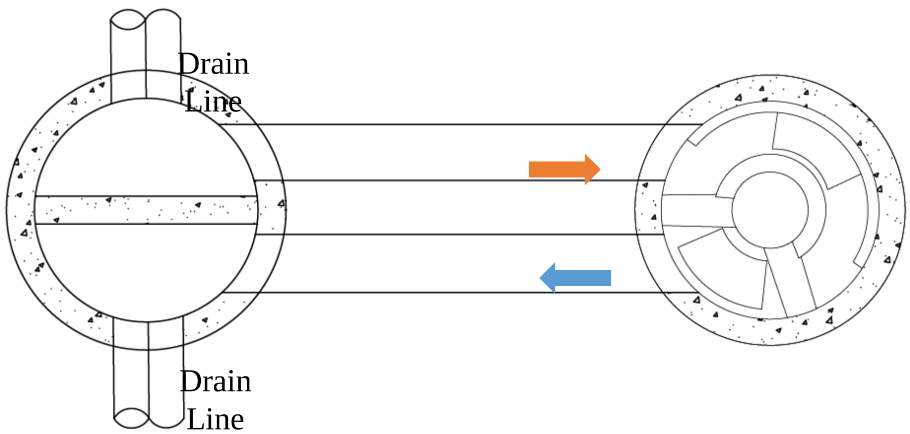


Figure 11 a) FDHC Online Application; b) FDHC Offline Application

In some cases, multiple inlet pipes can be accommodated depending on pipe size and pipe angles as long as at least six inches of concrete remains between inlet pipe knockouts and pipe angles are within 240° of the outlet centerline (**Figure 12**). Contact Hydro International for design assistance with multiple inlet pipes.

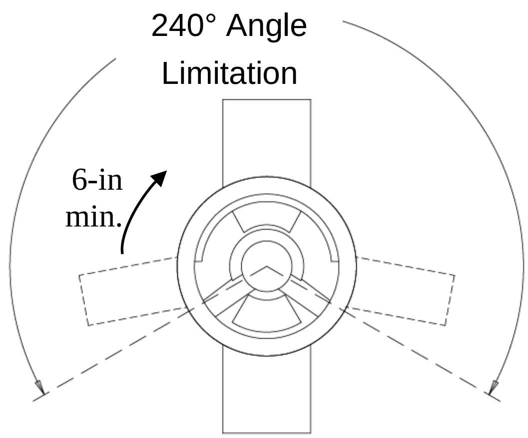


Figure 12 FDHC Design Accommodates Various Inlet Pipe Configurations

Load Limitations

Standard FDHC units are designed for HS-20 loading. Contact Hydro International engineering staff when heavier load ratings are required.

Pretreatment Requirements

The FDHC has no pre-treatment requirements.

Limitations on Tail water

As the FDHC includes an internal bypass, Hydro International recommends working with their engineering team if tail water is present to increase the available driving head to ensure that the full water quality treatment flow rate is treated prior to internal bypass.

Depth to seasonal high water table

Although the functionality of the FDHC is not impacted by high groundwater, Hydro International recommends consulting their engineering staff to determine whether the addition of anti-flotation collars to the base of the FDHC chamber are necessary to counterbalance buoyant forces.

Pipe Size

Each FDHC model has a maximum recommended inlet and outlet pipe size. When the diameter of the main storm drain line exceeds the maximum FDHC pipe size, Hydro International recommends contacting their engineering team. In some circumstances larger pipe sizes can be safely accommodated; otherwise Hydro International recommends the FDHC be designed in an offline configuration. The maximum recommended inlet and outlet pipe diameter for each FDHC model are shown in **Table A-2** of the Verification Appendix.

6. Maintenance Plans

The FDHC treats stormwater by removing pollutants from stormwater runoff and capturing them in the pollutant storage sump. Periodic removal of these captured pollutants is essential to the continuous, long-term functioning of the FDHC. When sediment and oil storage capacities are reached, the FDHC's ability to capture and store removed sediment and oil will be compromised.

Inspection and maintenance of the FDHC are simple procedures conducted from the surface. Neither inspection nor maintenance require purchasing spare parts or tools from Hydro International. The FDHC has one centrally located 30-in manhole lid to provide inspection and maintenance access to both the internal bypass chamber and treatment chamber.

Inspection

The required frequency of cleanout depends on site use and other site specific characteristics and should therefore be determined by inspecting the unit after installation. During the first year of operation, the unit should be inspected at least every six months to determine the rate of sediment and floatables accumulation. More frequent inspections are recommended at sites that would generate heavy solids loads, like parking lots with winter sanding or unpaved maintenance lots. A dipstick can be used to measured accumulated oil; a sediment probe can be used to determine the level of accumulated solids stored in the sump.

Hydro International recommends that the units are cleaned when sediment volumes reach 50% sump capacity. The standard sediment storage depth in the FDHC is 18 inches. Because FDHC model sizes vary in diameter, pollutant storage volumes vary with model size as shown in **Table 26**. When sediment and oil depths are measured during inspection, they should be recorded on the Operation & Maintenance manual log and compared to the as-built drawings of the FDHC to assess whether accumulated sediment has reach 9 inches in depth.

Table 26 – Pollutant Storage Capacities of the FDHC

Model	Oil Storage Volume (gal)	Sediment Volume at 50% Sump Capacity (yd^3)	Sediment Depth at 50% Sump Capacity (in)	Sump Volume (yd^3)	Sump Depth (in)
3-ft FDHC	125	0.20	9	0.4	18
4-ft FDHC	191	0.35	9	0.7	18
5-ft FDHC	300	0.55	9	1.1	18
6-ft FDHC	496	0.8	9	1.6	18
7-ft FDHC	720	1.05	9	2.1	18
8-ft FDHC	1,002	1.4	9	2.8	18

Maintenance

The interval of required clean-out should be determined by post-installation inspection of pollutant accumulation rates. If post-installation inspection cannot be conducted for some reason, Hydro International recommends the FDHC be cleaned out at least once per year. There is no need for man entry into the FDHC during maintenance. However, if man entry does occur then proper confined space entry procedures must be followed.

Floatable trash and debris can be removed by lifting the floatable access lid and using a netted skimming pole or a vactor truck to skim trash from the surface of the standing water. Accumulated oil must be vactored from the surface using a vactor truck or sump vac. Accumulated sediment can be removed by lifting the central access lid and dropping a vactor hose down the center shaft to the sump. The entire sump liquid volume does not necessarily need to be removed from the FDHC during maintenance.

When all pollutants have been removed from the FDHC, the manhole lids should be put securely back in place. Removed pollutants should be disposed of in accordance with local regulations and ordinances.

7. Statements

The following signed statements from the manufacturer, third-party observer 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…®

December 21, 2015

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: Verification of First Defense® HC to NJDEP HDS Laboratory Testing Protocol

Dear Dr. Magee:

Hydro International's First Defense® HC (FDHC) vortex separator for stormwater treatment recently underwent verification testing according to the NJDEP HDS Laboratory Testing Protocol. As required by the "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology", 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. The 4-ft FDHC removal efficiency and scour tests conducted at Hydro International's laboratory facility in Portland, Maine were done so under the direct supervision of FB Environmental Associates. All water quality samples were analyzed by the independent analytical lab, Maine Environmental Laboratory. The removal efficiency particle size distribution was analyzed by the independent analytical laboratory, GeoTesting Express. The scour test particle size distribution was analyzed at Hydro International's facility under the supervision of FB Environmental Associates. Additionally, 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 of the FDHC, please do not hesitate to contact us.

Sincerely,

Lisa Lemont, CPSWQ
Business Development 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

STATEMENT OF THIRD PARTY OBSERVER

To: **Lisa Lemont, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: **Third Party Review under** ***Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*** **(NJDEP, January 25 2013)**[1]

Date: December 31, 2015

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

Statement of Third Party Observer

FB Environmental has served as the third-party observer for tests performed by Hydro International in October through December 2015. The tests assessed the First Defense HC Stormwater Treatment Device as a 50% Total Suspended Solids (TSS) removal device under the New Jersey Department of Environmental Protection certification. Tests were performed by Hydro International staff at their laboratory located at 94 Hutchinson Drive in Portland, Maine, to meet the standards described in *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP, January 25 2013)[1]. On May 10, 2014, we also submitted a statement of qualifications, as required by NJCAT MTD process.

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 *Verification Testing Report for the First Defense® HC Stormwater Treatment Device* by Hydro International, dated December 29, 2015, and state that they conform to what we saw during our supervision as third-party observer.

December 31, 2015

Signed: Date:

[1] Available at http://www.nj.gov/dep/stormwater/treatment.html

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Statement of Disclosure

STATEMENT OF DISCLOSURE – THIRD PARTY OBSERVER

To: **Lisa Lemont, Hydro International, Portland, Maine**

From: Forrest Bell, FB Environmental Associates

Subject: Third Party Observer Statement of Disclosure under *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP, January 25 2013)[1]

Date: December 31, 2015

cc: Andrew Anastasio, 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 *Verification Testing Report for the First Defense ® HC Stormwater Treatment Device* by Hydro International, dated December 29, 2015.

Disclosure Record

FB Environmental has provided the service of third party observer for tests performed by Hydro International in October through December of 2015. The tests assessed the First Defense HC Stormwater Treatment Device as a 50% Total Suspended Solids (TSS) removal device under the New Jersey Department of Environmental Protection certification as outlined in the *Verification Testing Report for the First Defense ® HC Stormwater Treatment Device* by Hydro International, dated December 29, 2015. Beyond this, FB Environmental and Hydro International have no relationships that would constitute a conflict of interest, as outlined in *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology* (NJDEP 2013). 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.

December 31, 2015

Signed: Date:

[1] Available at http://www.nj.gov/dep/stormwater/treatment.html

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

January 9, 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 the First Defense® HC (FDHC) Stormwater Treatment Device by Hydro International and observed by FB Environmental Associates, the test protocol requirements contained in the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP HDS Protocol) were met or exceeded. Specifically:

Test Sediment Feed

The mean PSD of Hydro Internationals test sediments comply with the PSD criteria established by the NJDEP HDS protocol. The Hydro International removal efficiency test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification. The test sediment was shown to be slightly finer than the sediment blend specified by the protocol. The Hydro International scour test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification and shown to be much finer than specified by the protocol.

Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the 4-ft. laboratory unit in order to establish the ability of the FDHC to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. Prior to the start of testing Hydro International reviewed existing data and decided to utilize a target MTFR of 675 gpm (1.50 cfs). This target was chosen based on the ultimate goal of demonstrating greater than 50% annualized weighted solids removal as defined in the NJDEP HDS Protocol. The flow rates, feed rates and influent concentration all met the NJDEP HDS test protocol's coefficient of variance requirements and the background concentration for all five test runs never exceeded 20 mg/L.

Scour Testing

In order to demonstrate the ability of the FDHC to be used as an online treatment device scour testing was conducted at greater than 200% of MTFR in accordance with the NJDEP HDS Protocol. The average flow rate during the online scour test was 3.24 cfs, which represents 216% of the MTFR (MTFR = 1.50 cfs). Background concentrations were 2 mg/L throughout the scour testing, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Unadjusted effluent concentrations ranged from 2 mg/L to 4 mg/L with a mean of 2.1 mg/L. When adjusted for background concentrations, the effluent concentrations range from 0 to 2 mg/L with a mean of 0.1 mg/L. These results confirm that the 4-ft. FDHC did not scour at 216% MTFR and meets the criteria for online use.

Maintenance Frequency

The predicted maintenance frequency for all models is 44 months.

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 2014. *Quality Assurance Project Plan for FDHC® NJDEP Testing.* Prepared by H.I.L. Technology, Inc. dba Hydro International. October, 2015.

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 Hydrodynamic Sedimentation Manufactured Treatment Device.* Trenton, NJ. January 25, 2013.

VERIFICATION APPENDIX

Introduction

- Manufacturer – Hydro International, 94 Hutchins Drive, Portland, ME 04102. *General Phone: (207)756-6200*. *Website:* www.hydro-int.com/us.

- MTD – First Defense® HC Stormwater Treatment Device. Verified First Defense® HC Models are shown in **Table A-1.**

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- TSS Removal Rate – 50%

- On-line installation

Detailed Specification

- NJDEP sizing tables attached as **Table A-1** and **Table A-2**.

- New Jersey requires that the peak flow rate of the NJWQ Design Storm event of 1.25 inch in 2 hours shall be used to determine the appropriate size for the MTD.

- Pick weights and installation procedures vary slightly with model size. Hydro International provides contractors with project-specific unit pick weights and installation instructions prior to delivery.

- Maximum recommended sediment depth prior to cleanout is 9 inches for all model sizes.

- For a reference maintenance plan, download the First Defense® HC Operation and Maintenance Manual at: http://www.hydro-int.com/UserFiles/downloads/FD_O%2BM_F1512.pdf

- Under N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow a hydrodynamic separator such as the First Defense® HC to be used in series with another hydrodynamic separator to achieve an enhanced total suspended solids (TSS) removal rate.

Table A-1 MTFRs and Required Sediment Removal Intervals for FDHC Models

First Defense® HC Model	Manhole Diameter (ft)	NJDEP 50% TSS Maximum Treatment Flow Rate (cfs)	Treatment Area (ft^2)	Hydraulic Loading Rate (gpm/ft^2)	50% Max Sediment Storage Volume (ft^3)	Required Sediment Removal Interval[1] (Months)
3-ft	3	0.85	7.1	53.58	5.30	44
4-ft	4	1.50	12.6	53.58	9.42	44
5-ft	5	2.35	19.6	53.58	14.7	44
6-ft	6	3.38	28.3	53.58	21.2	44
7-ft	7	4.60	38.5	53.58	28.9	44
8-ft	8	6.00	50.2	53.58	37.7	44

[1] Required sediment removal interval was calculated using the equation specified in Appendix B Part B of the NJDEP Laboratory Protocol for HDS MTDs:

$$\text{Sediment Removal Interval (months)} = \frac{\text{(50\% HDS MTD Max Sediment Storage Volume * 3.57)}}{\text{(MTFR * TSS Removal Efficiency)}}$$

Table A-2 Standard Dimensions for FDHC Models (Revised January 2017)

FDHC Model and Manhole Diameter (ft)	Maximum Treatment Flow Rate (cfs)	50% Max Sediment Storage Volume (ft^3)	Chamber Depth (ft)	Treatment Chamber Depth [1] (ft)	Sediment Sump Depth (ft)	Aspect Ratio Treatment Depth: Diameter	Maximum Pipe Diameter (in)
3-ft	0.85	5.30	3.75	3.00	1.5	1.00	18
4-ft	1.50	9.42	5.00	4.25	1.5	1.06	24
5-ft	2.35	14.7	5.25	4.50	1.5	0.90	24
6-ft	3.38	21.2	6.25	5.50	1.5	0.92	32
7-ft	4.60	28.9	7.25	6.50	1.5	0.93	42
8-ft	6.00	37.7	8.00	7.25	1.5	0.91	48

[1] Treatment Chamber Depth is the chamber depth minus ½ the sediment sump depth. Larger models (>250% MTFR of the tested unit) must be geometrically proportionate to the tested unit (4' model). A variance of 15% is allowable. For units <250% MTFR (5 and 6-ft models) the depth must be equal or greater than the depth of the unit treated.