NJCAT TECHNOLOGY VERIFICATION

First Defense® Optimum
Vortex Separator

Hydro International

July 2021

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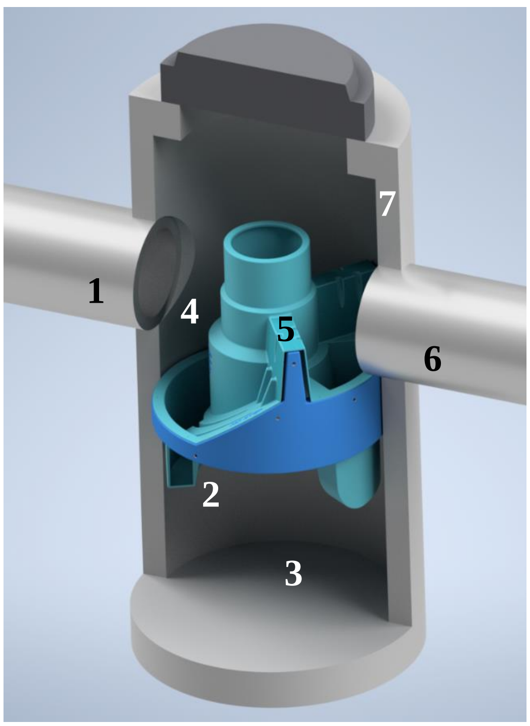
1. Description of Technology

The First Defense® Optimum vortex separator (FD Optimum) is designed and supplied by Hydro International **(Figure 1)**. The FD Optimum is installed as part of typical drainage network systems to capture particulate pollutants that have entered the system from surface runoff. The FD Optimum has patented flow-modifying internal components that create a swirling flow path within the treatment chamber. This rotational motion supplements gravitational settling forces with additional vortex forces for enhanced settling performance. The internal components include an internal bypass weir to divert flows over the treatment chamber to prevent captured particles from being resuspended and washed out.

The FD Optimum chamber is a precast concrete manhole. The internal components are rotationally molded plastic. Stormwater enters the FD Optimum through an inlet pipe. 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 FD Optimum via an outlet pipe.

The FD Optimum differs from the First Defense® High Capacity (FDHC) Stormwater Treatment Device verified by NJCAT in February 2016 by optimizing the orifice sizes within the system.



1. Inlet Pipe
2. Vortex Treatment Chamber
3. Sediment Storage Sump
4. Internal Bypass Chamber
5. Internal Bypass Weir
6. Outlet Pipe
7. Manhole

Figure 1 Rendering of the FD Optimum Showing System Components

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 (NJDEP 2013a*) (hereafter referred to as "NJDEP Approval Process"). The NJDEP Approval Process requires that TSS treatment devices operating on hydrodynamic principles be tested according to the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Treatment Device (NJDEP 2013b)* (hereafter 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 Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology *(NJDEP 2013).* The QAPP was submitted and approved by NJCAT in January 2020 prior to commencement of testing.

Testing was conducted with a full-scale, 3-ft FD Optimum in April-May 2021 by Hydro International ("Hydro") at the company's full-scale hydraulic testing facility in Portland, Maine. Since testing was carried out in-house, Hydro contracted with FB Environmental Associates of Portland, Maine to provide NJDEP Protocol required third party oversight. FB Environmental Associates representatives were present during all testing procedures. The test program was conducted in accordance with the NJDEP Protocol in two phases: removal efficiency testing and scour testing.

2.1 Test Setup

A schematic drawing of the laboratory setup is shown in **Figure 2** and key dimensions of the test vessel are shown in **Figure 3**. Operating as a recirculating closed loop system, water from a 10,000-gallon supply tank was pumped to the system through an 8-inch line via a Flygt submersible pump. The flow rate of the pump was controlled by a GE Fuji Electric AF300 P11 Adjustable Frequency Drive and measured by an EMCO Flow Systems 4411e Electromagnetic Flow Transmitter. The water temperature within the tank was regulated by a Hayward 350FD pool heater.

A three-way valve was located between the Flygt pump and the FD Optimum which would allow flow to bypass the FD Optimum if fully opened. This valve was installed as part of the piping network to direct flow to other manufactured stormwater and wastewater treatment systems installed at the test facility along the same piping network. This valve was fully closed throughout the entire period when the FD Optimum testing was conducted. A background sampling port was installed about 20 feet upstream of the FD Optimum. The 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 bags in order to remove the majority of fine sediment that remained in the flow stream. The filter box was located in a separate Discharge Tank in order to keep the background concentration from surpassing the maximum allowable limit over the duration of the removal efficiency tests.

During performance testing, test sediment was injected through an Auger Feeder Model VF-2 volumetric screw feeder at a steady state upstream of the FD Optimum. The auger was calibrated prior to each test.

Water temperature was measured in the supply tank with a LASCAR EL-USB-TP-LCD sensor and logger. The sensor was placed near the 8-inch pump to provide a representative measurement of the water entering the test system. Maximum temperature remained below 80°F for the duration of each test run. Temperature was recorded every 30 seconds. The original thermocouple calibration was confirmed by the independent observer as part of the observation process.

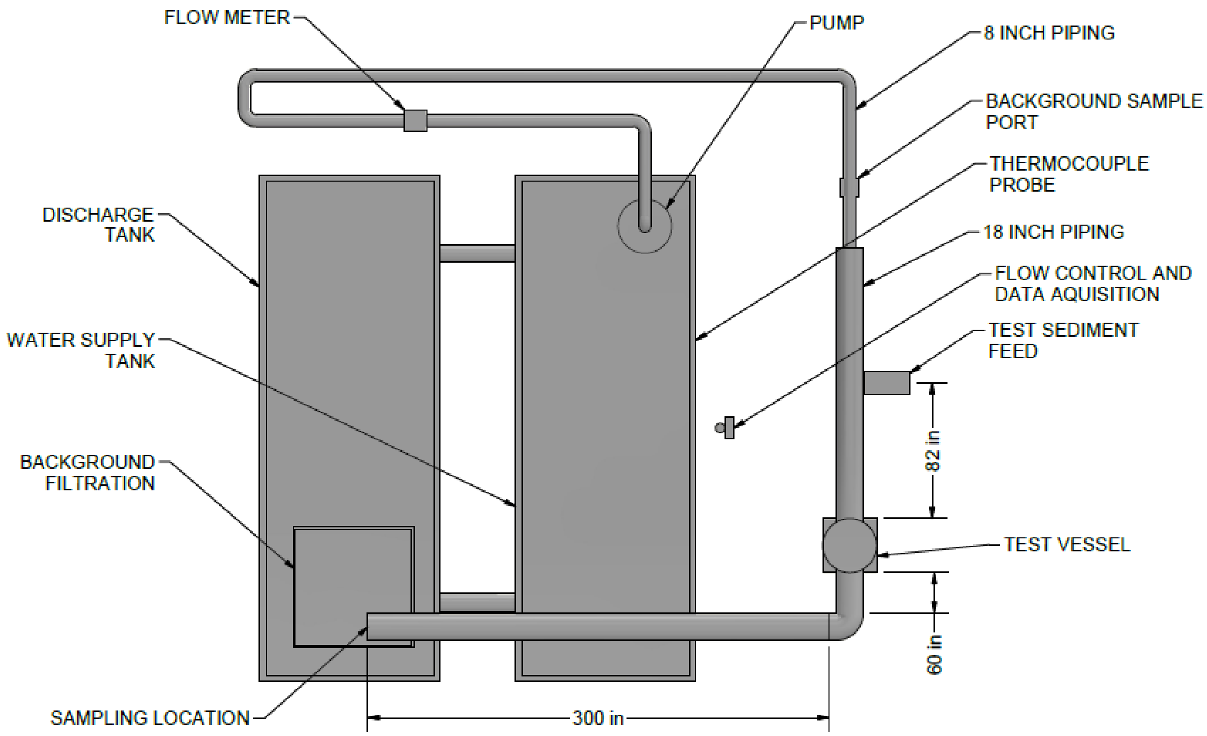


Figure 2 Laboratory Testing Arrangement Diagram

Test Unit Description

The laboratory arrangement was designed for a FD Optimum test unit comprised of full-scale, commercially available 3-ft FD Optimum internal components installed in a 3-ft round plastic manhole chamber consistent in all key dimensions with the precast chambers used for commercial installations (**Figure 4**). Both the inlet and outlet pipe diameters of the test model were nominally 18 inches, which was the maximum pipe size for a 3-ft FD Optimum. Both the inlet and outlet pipes were set at 1% slope.

The plastic manhole chamber was equipped with a detachable sediment storage zone (**Figure 3**) used for system maintenance between tests. This sediment storage zone was 18 inches deep and is located 26.5 inches below the pipe inverts. Mounting flanges supported a false floor at two different positions. The upper position allowed for the simulation of a 50% full condition for use during TSS removal efficiency testing. The lower position allowed for 4 inches of sediment to be pre-loaded before scour testing.

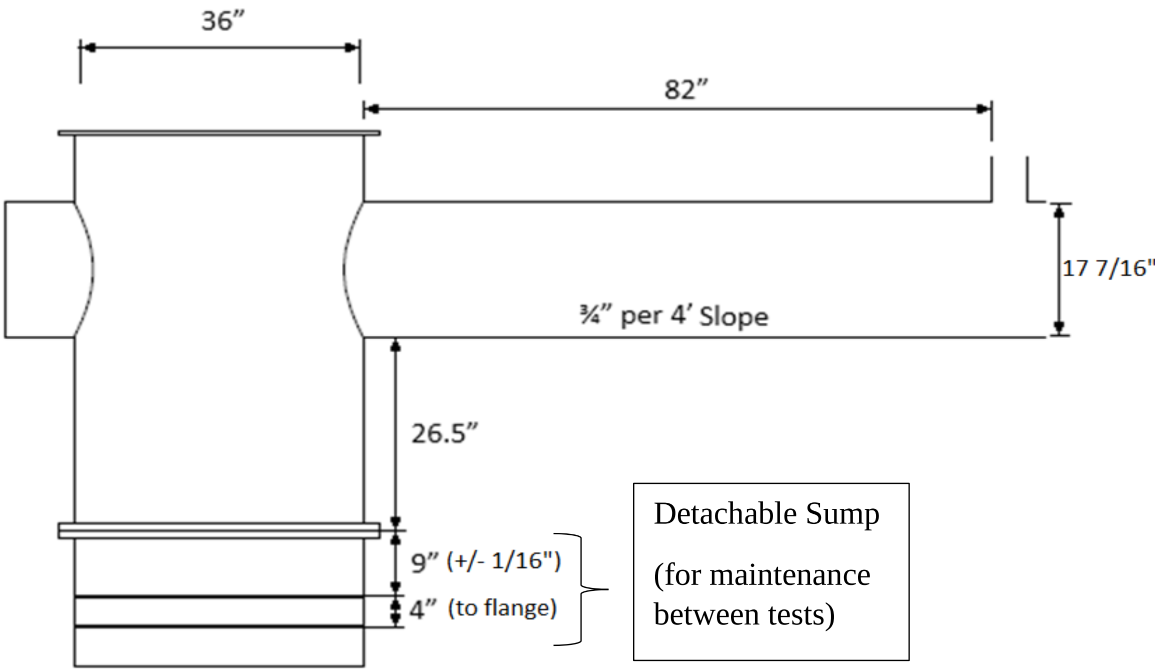


Figure 3 Key Dimensions of Test Vessel

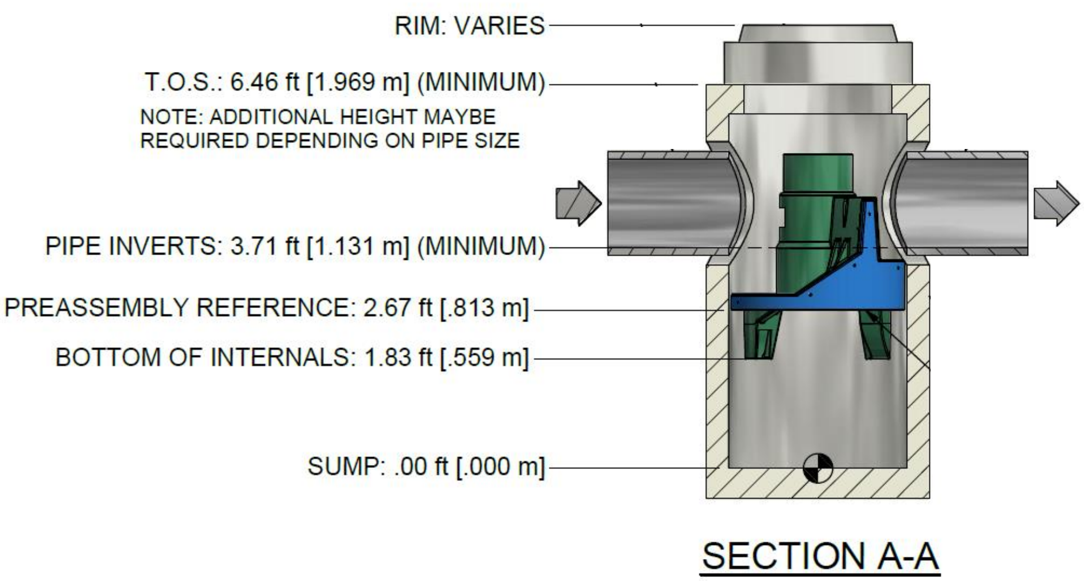


Figure 4 Key Dimensions of 3-ft FD Optimum

2.2 Test Sediment

The test sediment was a blend of commercially available silica particulate grades. The sediment was blended by Hydro and the particle size distribution was independently confirmed by GeoTesting Express in Acton, Massachusetts certifying that the supplied silica meets the specification within tolerance using ASTM D-422 as described in Section 5A of the Protocol. Results of particle size gradation testing are shown in **Table 1a** and **Figure 5a** below. The D_{50} of this blend is 56 microns.

Table 1a Particle Size Distribution Results of Removal Efficiency Sediment Samples

Particle Size (µm)	% Finer				Test Sediment Average	Diff. from Protocol
	Protocol	Sample 1	Sample 2	Sample 3		
1000	100	100	100	100	100	0
500	95	99	99	99	99	4
250	90	94	94	94	94	4
150	75	85	85	86	85	10
100	60	71	70	70	70	10
75	50	60	59	59	59	9
50	45	48	47	47	47	2
20	35	35	37	35	36	1
8	20	20	19	20	20	0
5	10	15	14	14	14	4
2	5	7	6	7	7	2
D_{50} (µm)	≤75	56	57	56	56	

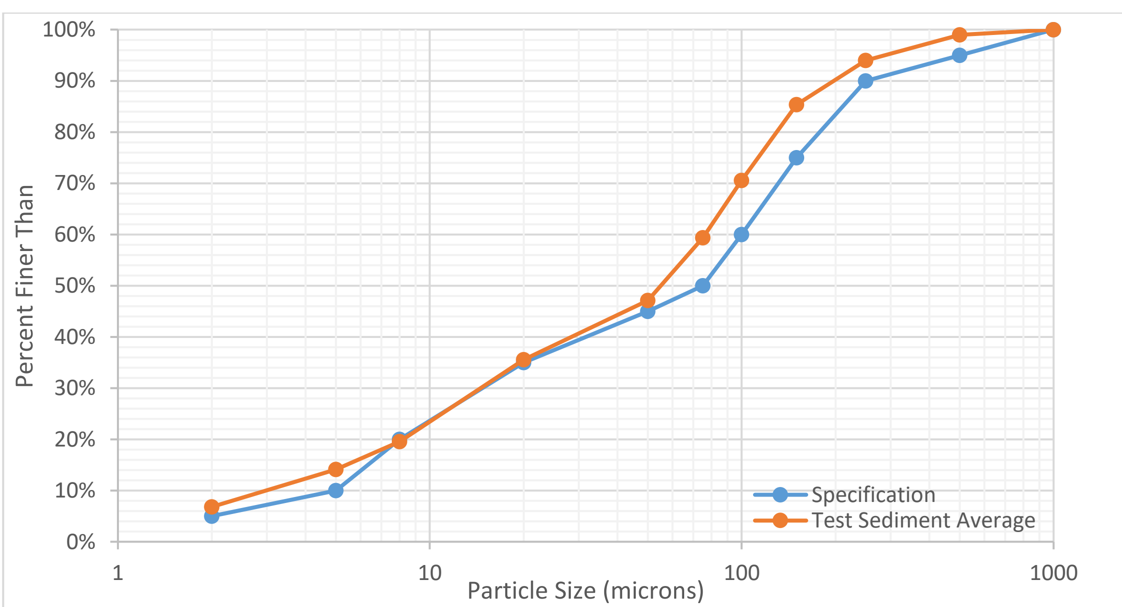


Figure 5a Average Removal Efficiency Sediment PSD Compared to Specification

The scour sediment was a blend of commercially available silica sand grades. The sediment was blended by Hydro and the particle size distribution was independently confirmed by GeoTesting Express in Acton, Massachusetts certifying that the supplied silica meets the specification within tolerance using ASTM D-422 as described in Section 5A of the Protocol. Results of particle size gradation testing are shown in **Table 1b** and **Figure 5b** below.

Table 1b Particle Size Distribution Results of Scour Sediment Samples

Particle Size (µm)	% Finer				Test Sediment Average	Diff. from Protocol
	Protocol	Sample 1	Sample 2	Sample 3		
1000	100	100	100	100	100	0
500	90	92	93	92	92	2
250	55	79	80	78	79	24
150	40	55	57	55	56	16
100	25	31	30	30	30	5
75	10	18	16	17	17	7
50	0	4	4	5	4	4

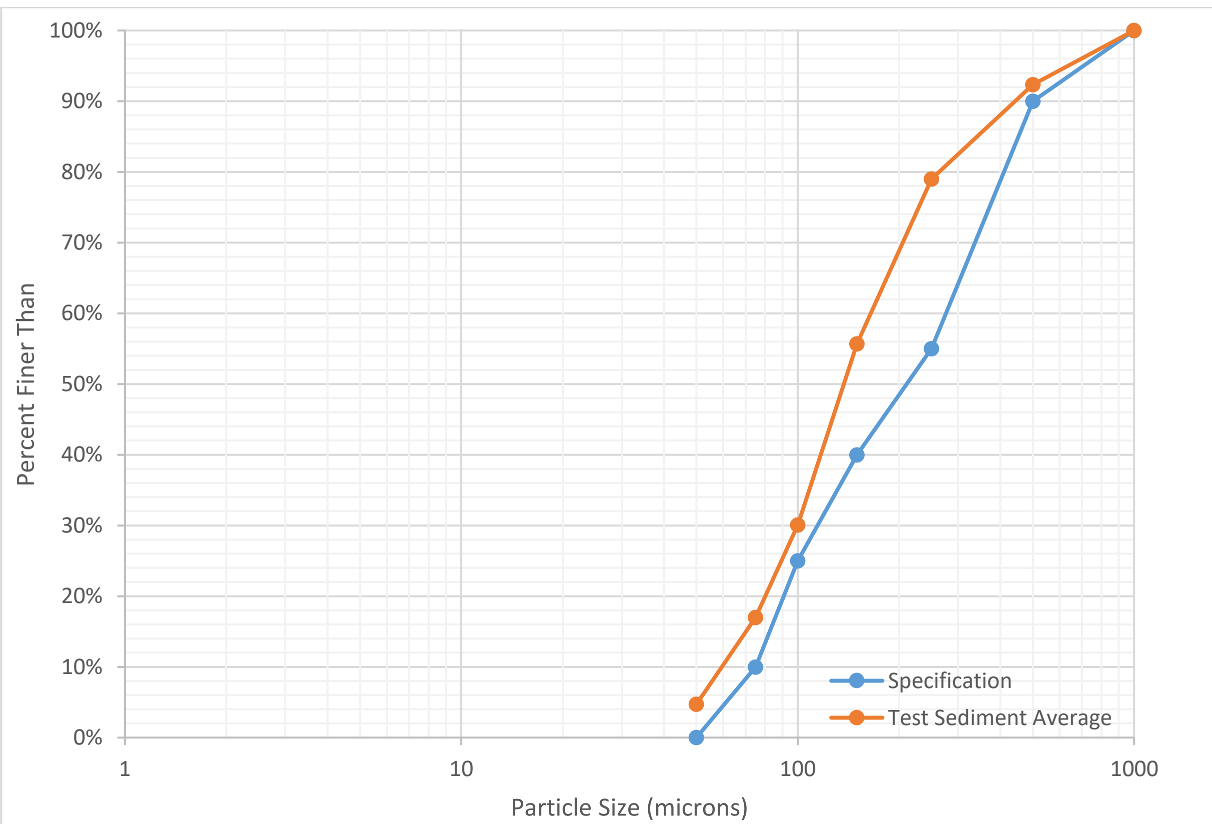


Figure 5b Average Scour Sediment PSD Compared to Specification

2.3 Removal Efficiency Testing

The FD Optimum performance was determined by testing its sediment removal efficiency. In accordance with the NJDEP Hydrodynamic Protocol Section 5, this was tested in the laboratory by seeding the system with a known test sediment gradation and concentration and determining what proportion of the material was retained within the device. The removal efficiency testing occurred by testing five flow rates from 25 to 125% of the maximum treatment flow rate (MTFR) in 25% increments as specified in the protocol.

The output of the EMCO Electromagnetic Flow Transmitter was logged every 30 seconds with a USB data logger. The coefficient of variance (COV) was not to exceed 0.03.

Background samples were taken at the background sample port located upstream of the FD Optimum unit. Influent background samples were taken in correspondence with the odd numbered effluent samples (first, third, fifth, etc.). The collection time was recorded for each background and effluent sample. The background data was used to adjust the effluent samples.

The test sediment feed rate and total mass of test sediment introduced during each test run was a known quantity. The target influent concentration was 200 mg/L. Total mass introduced was determined by weighing the mass of sediment placed in the auger hopper at the start of the test and then emptying the hopper at the end of the test to weigh the sediment remaining. All masses were taken with an Ohaus D25WR laboratory balance. The average influent concentration was then calculated based on the total mass and volume according to **Equation 1**.

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

Equation 1 Calculation for Average Influent Concentration

Sediment feed calibration samples were taken from the injection point at the start of testing and after every third effluent sample. Samples were taken by interrupting the dry sediment feed from the auger and weighing with a Denver Instrument TR203 laboratory balance. The duration of sampling varied from 20 seconds to one minute and ensured that at least 100 mL of sediment was collected while causing minimal disturbance to the feed. The mass extracted for calibration was subtracted from the total sediment mass removed. The concentration COV was not to exceed 0.10.

Once a constant feed of test sediment and flow rate was established, the first effluent sample was collected after three volume exchanges within the FD Optimum had passed. The effluent samples were collected from the test vessel discharge pipe and time stamped in 1-liter bottles using the grab sample method as described in Section 5D of the Protocol.

The time interval between sequential samples was evenly spaced during the test sediment feed period to achieve fifteen effluent samples. However, when the test sediment feed was interrupted for measurement, the next effluent sample collected was after three volume exchanges within the FD Optimum. An example sampling schedule (for 100% MTFR) is given in **Table 2**.

Table 2 Sampling Time for TSS Removal Efficiency Testing (100% MTFR)

Elapsed Time	Dry Feed Sample	Effluent Sample	Background Sample
00:00	1		
01:54		1	1
02:24		2	
02:54	2	3	2
04:48		4	
05:18		5	3
05:48	3	6	
07:42		7	4
08:12		8	
08:42	4	9	5
10:36		10	
11:06		11	6
11:36	5	12	
13:30		13	7
14:00		14	
14:30	6	15	8

All samples were collected in one-liter wide mouth bottles. At the conclusion of each flow rate test, the collected effluent and background water quality samples were placed into delivery containers and transported to the analytical laboratory by the independent observer. All samples were analyzed by Maine Environmental Laboratory, Yarmouth, ME in accordance with ASTM D3977-97 (re-approval 2019) “Standard Test Methods for Determining Sediment Concentrations in Water Samples”. Removal efficiency was calculated per **Equation 2**. Captured sediment was removed from the sump and inlet pipe between each flow rate test.

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

* Adjusted for background concentration

Equation 2 Equation for Calculating Removal Efficiency

2.4 Scour Testing

To simulate a 50% full sump condition, the FD Optimum sump false bottom was set to a height of 5 inches and then topped with 4 inches of scour test sediment. The sediment was levelled, then the FD Optimum was filled with clean water up to the outlet pipe invert at a slow rate as to not disturb the sediment prior to the beginning of testing. Scour testing began on the following day after the sediment was added which was less than the required 96 hours maximum allowance. All setup and measurements, testing and sample collection 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 every 30 seconds. 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 total of 15 effluent samples were taken over the duration of the test.

Eight background samples were collected at evenly spaced intervals throughout the duration of the target maximum flow rate testing corresponding to the odd numbered effluent samples. The background samples were drawn from the background sample port located upstream of the FD Optimum.

All samples were collected in one-liter wide mouth bottles. At the conclusion of the test, the collected effluent and background water quality samples were placed into delivery containers and transported to the analytical laboratory by the independent observer. All samples were analyzed by Maine Environmental Laboratory in accordance with ASTM D3977-97 (re-approval 2019) "Standard Test Methods for Determining Sediment Concentrations in Water Samples".

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.

2.5 Quality Objectives and Criteria

Samples sent for external analysis were shipped or delivered to the laboratory immediately following each flow rate test. Auger sample weights analyzed in-house were observed by the independent observer 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. Samples were then placed in containers and transported to the analytical laboratory by the independent observer.

Data was recorded and maintained in accordance with standard laboratory procedures used at Hydro. Hard copies of all original data sets are maintained on site.

The following quality criteria had to be met in order for the data from a run to be included in the report:

- Background TSS concentrations ≤ 20 mg/L
- Temperature of test water ≤ 80 degrees Fahrenheit
- Variation in calculated influent concentration ≤ 10% of target concentration

- Coefficient of variation of dry calibration samples ≤ 0.10
- Variation in flow rate ≤ 10% of target flow rate
- Coefficient of variation of flow rates ≤ 0.03

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the FD Optimum, the following are the performance claims made by Hydro.

Total Suspended Solids (TSS) Removal Efficiency

The TSS removal rate of the FD Optimum is dependent upon flow rate, particle density and particle size. For the particle size distribution and weighted calculation method required by the NJDEP Protocol, the 3-ft FD Optimum at a MTFR of 1.02 cfs will demonstrate at least 50% TSS removal efficiency.

Effective Sedimentation Treatment Area (ESTA)

The effective sedimentation treatment area (ESTA) of the 3-ft FD Optimum is 7.1 sq. ft.

Maximum Treatment Flow Rate (MTFR)

The MTFR for the 3-ft FD Optimum was demonstrated to be 458 gpm (1.02 cfs) which corresponds to a hydraulic loading rate of 64.5 gpm/sq. ft.

Sediment Storage Depth and Volume

The maximum sediment storage depth of the FD Optimum is 18 inches. Available sump volume varies with each FD Optimum model as diameter increases. The available sump volume for a 3-ft FD Optimum model is 0.39 cubic yards. The maximum sediment storage depth is 9 inches, which corresponds to a 50% full sump capacity (or 0.20 cubic yards) for this model (**see Appendix Table A-2**)

Online Installation

Based on the Scour Test results described in Section 4.2, the FD Optimum qualifies for online installation.

Wet Volume and Detention Time

The detention time of the FD Optimum depends on flow rate and model size as detention time is calculated by dividing the treatment volume by the flow rate. The inlet and outlet water levels measured during the hydraulic characterization of the system were used to calculate the treatment volume. The 28.5 sq.ft. volume calculated for a flow rate of 1.4 cfs was used to set the sampling schedule for all tested flow rates. For the tested 3-ft FD Optimum at the MTFR of 1.02 cfs, the detention time is 28 seconds.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013) 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 Results

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the 3-ft FD Optimum unit in order to establish the ability of the FD Optimum to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. The target MTFR was 458 gpm (1.02 cfs). The 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 did not exceed 0.10 for any flow rate test.

The mean influent concentration was calculated using **Equation 1** from *Section 5D Effluent Sampling Test Methods*. 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 °F.

Maine Environmental Lab references an LOQ of 2.5 mg/L when reporting their analysis. This was indicated in the footnotes if analysis reported a value lower than the LOQ of 2.5 mg/L and a value of half the LOQ (1.25 mg/L) was used in its place.

25% MTFR Results

The 25% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.26 cfs. A summary of test readings, measurements and calculations are shown in **Table 3**. Feed rate calibration results are shown in **Table 4**. Background and effluent sediment concentrations are shown in **Table 5**.

The 3-ft FD Optimum removed 61.5% of the test sediment at a flow rate of 0.26 cfs. **Table 6** shows that the QA/QC results for flow rate, feed rate, background sediment concentration and temperature were within the allowable limits specified by the protocol.

Table 3 Summary of 3-ft FD Optimum 25% MTFR Test Results

Trial Date	Target Flow Rate (cfs)/(gpm)	Detention Time (sec)	Start Mass (lbs)	End Mass (lbs)	Influent Concentration[1] (mg/L)	Max. Water Temperature (°F)	Adj. Effluent Concentration (mg/L)	Removal Efficiency
4/21/21	0.26 / 117	110	70.000	62.495	202.3	75.3	77.9	61.5%

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

Table 4 – 3-ft FD Optimum 25% MTFR Feed Rate Calibration Results

Sample ID	Sample Time (mm:ss)	Sample Mass (g)	Sample Duration (sec)	Feed Rate (mg/min)	Influent Concentration (mg/L)
1	00:00	85.379	60	85,379	195
2	07:30	87.737	60	87,737	201
3	15:00	88.309	60	88,309	202
4	22:30	89.264	60	89,264	204
5	30:00	90.121	60	90,121	206
6	37:30	92.134	60	92,134	211
			Mean	**88,284**	**203**

Table 5 – 3-ft FD Optimum 25% MTFR TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
06:30	80	3.7	76.3
7:00	86	6.9	79.2
07:30	85	10.0	75.0
14:00	80	6.7	73.4
14:30	81	3.3	77.7
15:00	87	4.3	82.8
21:30	81	5.2	75.8
22:00	83	6.1	77.0
22:30	86	6.9	79.1
29:00	86	6.3	79.7
29:30	81	5.7	75.3
30:00	81	9.4	71.7
36:30	99	13.0	86.0
37:00	87	9.7	77.4
37:30	89	6.3	82.7
Mean	**84.8**	**6.9**	**77.9**

[1]Shaded background concentrations are interpolated.

Table 6 – 3-ft FD Optimum 25% MTFR Test QA/QC Results

Parameter	Unit	Measured Value	Acceptable Range	Coefficient of Variance	Acceptable Range
Flow Rate	gpm	115	105 - 129	0.021	<0.03
Feed Rate	mg/L	202.3	180 - 220	0.026	<0.10
Max. BG Conc.	mg/L	13.0	≤20	-	-
Water Temperature	°F	75.3	≤80	-	-

50% MTFR Results

The 50% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.51 cfs. A summary of test readings, measurements and calculations are shown in **Table 7**. Feed rate calibration results are shown in **Table 8**. Background and effluent sediment concentrations are shown in **Table 9**.

The 3-ft FD Optimum removed 53.8% of the test sediment at a flow rate of 0.51 cfs. **Table 10** shows that the QA/QC results for flow rate, feed rate, background sediment concentration and temperature were within the allowable limits specified by the protocol.

Table 7 Summary of 3-ft FD Optimum 50% MTFR Test Results

Trial Date	Target Flow Rate (cfs)/(gpm)	Detention Time (sec)	Start Mass (lbs)	End Mass (lbs)	Influent Concentration[1] (mg/L)	Max. Water Temperature (°F)	Adj. Effluent Concentration (mg/L)	Removal Efficiency
4/26/21	0.51 / 229	56	75.000	65.635	198.4	76.9	91.6	53.8%

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

Table 8 – 3-ft FD Optimum 50% MTFR Feed Rate Calibration Results

Sample ID	Sample Time (mm:ss)	Sample Mass (g)	Sample Duration (sec)	Feed Rate (mg/min)	Influent Concentration (mg/L)
1	00:00	168.127	60	168,127	196
2	04:48	168.736	60	168,736	197
3	09:36	170.858	60	170,858	200
4	14:24	168.958	60	168,958	197
5	19:12	172.563	60	172,563	202
6	24:00	171.990	60	171,990	201
			Mean	**170,205**	**199**

Table 9 – 3-ft FD Optimum 50% MTFR TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
03:48	90	1.3[2]	88.8
04:18	91	3.3	87.7
04:48	91	5.3	85.7
08:36	94	3.9	90.1
09:06	92	2.5	89.5
09:36	99	2.8	96.3
13:24	86	3.0	83.0
13:54	94	2.2	91.9
14:24	98	1.3[2]	96.7
18:12	94	3.1	91.0
18:42	104[2]	4.8	99.2
19:12	98	5.1	92.9
23:00	103	5.4	97.6
23:30	93	6.2	86.8
24:00	104	7.0	97.0
Mean	**95.4**	**3.8**	**91.6**

[1]Shaded background concentrations are interpolated. [2]LOQ was 2.5 mg/L; half LOQ was used.
[2]Material lost during sample analysis. Substituting maximum effluent concentration.

Table 10 – 3-ft FD Optimum 50% MTFR Test QA/QC Results

Parameter	Unit	Measured Value	Acceptable Range	Coefficient of Variance	Acceptable Range
Flow Rate	gpm	226	206 - 252	0.010	<0.03
Feed Rate	mg/L	198.4	180 - 220	0.011	<0.10
Max BG Conc.	mg/L	7.0	≤20	-	-
Water Temperature	°F	76.9	≤80	-	-

75% MTFR Results

The 75% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.77 cfs. A summary of test readings, measurements and calculations are shown in **Table 11**. Feed rate calibration results are shown in **Table 12**. Background and effluent sediment concentrations are shown in **Table 13**.

The 3-ft FD Optimum removed 46.1% of the test sediment at a flow rate of 0.77 cfs. **Table 14** shows that the QA/QC results for flow rate, feed rate, background sediment concentration and temperature were within the allowable limits specified by the protocol.

Table 11 Summary of 3-ft FD Optimum 75% MTFR Test Results

Trial Date	Target Flow Rate (cfs)/(gpm)	Detention Time (sec)	Start Mass (lbs)	End Mass (lbs)	Influent Concentration[1] (mg/L)	Max. Water Temperature (°F)	Adj. Effluent Concentration (mg/L)	Removal Efficiency
4/27/21	0.77 / 346	38	75.000	64.865	201.9	78.2	104.7	48.1%

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

Table 12 – 3-ft FD Optimum 75% MTFR Feed Rate Calibration Results

Sample ID	Sample Time (mm:ss)	Sample Mass (g)	Sample Duration (sec)	Feed Rate (mg/min)	Influent Concentration (mg/L)
1	00:00	129.358	30	258,716	199
2	03:24	131.374	30	262,748	202
3	06:48	132.438	30	264,876	204
4	10:12	132.633	30	265,266	204
5	13:36	133.474	30	266,948	205
6	17:00	133.259	30	266,518	205
			Mean	**264,179**	**203**

Table 13 – 3-ft FD Optimum 75% MTFR TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
02:24	103	2.8	100.2
02:54	105	3.1	102.0
03:24	117	3.3	113.7
05:48	106	3.0	103.1
06:18	118	2.6	115.4
06:48	108	3.6	104.5
09:12	105	4.5	100.5
09:42	110	5.0	105.1
10:12	106	5.4	100.6
12:36	96	5.2	90.9
13:06	107	4.9	102.1
13:36	112	5.1	106.9
16:00	123	5.3	117.7
16:30	108	5.9	102.2
17:00	112	6.4	105.6
Mean	**109.1**	**4.4**	**104.7**

[1]Shaded background concentrations are interpolated.

Table 14 – 3-ft FD Optimum 75% MTFR Test QA/QC Results

Parameter	Unit	Measured Value	Acceptable Range	Coefficient of Variance	Acceptable Range
Flow Rate	gpm	343	311 - 381	0.008	<0.03
Feed Rate	mg/L	202	180 - 220	0.012	<0.10
Max BG Conc.	mg/L	6.4	≤20	-	-
Water Temperature	°F	78.2	≤80	-	-

100% MTFR Results

The 100% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 1.02 cfs. A summary of test readings, measurements and calculations are shown in **Table 15**. Feed rate calibration results are shown in **Table 16**. Background and effluent sediment concentrations are shown in **Table 17**.

The 3-ft FD Optimum removed 45.3% of the test sediment at a flow rate of 1.02 cfs. **Table 18** shows that the QA/QC results for flow rate, feed rate, background sediment concentration and temperature were within the allowable limits specified by the protocol.

Table 15 Summary of 3-ft FD Optimum 100% MTFR Test Results

Trial Date	Target Flow Rate (cfs)/(gpm)	Detention Time (sec)	Start Mass (lbs)	End Mass (lbs)	Influent Concentration[1] (mg/L)	Max. Water Temperature (°F)	Adj. Effluent Concentration (mg/L)	Removal Efficiency
4/28/21	1.02 / 458	28	75.000	63.729	197.6	74.6	108.3	45.2%

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

Table 16 – 3-ft FD Optimum 100% MTFR Feed Rate Calibration Results

Sample ID	Sample Time (mm:ss)	Sample Mass (g)	Sample Duration (sec)	Feed Rate (mg/min)	Influent Concentration (mg/L)
1	00:00	174.126	30	348,252	202
2	02:54	175.003	30	350,006	203
3	05:48	170.673	30	341,346	198
4	08:42	169.556	30	339,112	197
5	11:36	170.872	30	341,744	198
6	14:30	168.548	30	337,096	196
			Mean	**342,926**	**199**

Table 17 – 3-ft FD Optimum 100% MTFR TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
01:54	109	2.7	106.3
02:24	115	2.8	112.2
02:54	119	2.9	116.1
04:48	118	2.9	115.1
05:18	107	2.9	104.1
05:48	119	3.5	115.5
07:42	104	4.2	99.8
08:12	117	4.4	112.6
08:42	106	4.7	101.3
10:36	108	4.7	103.4
11:06	112	4.6	107.4
11:36	119	5.6	113.4
13:30	106	6.6	99.4
14:00	111	7.0	104.1
14:30	122	7.3	114.7
Mean	**112.8**	**4.5**	**108.3**

[1]Shaded background concentrations are interpolated.

Table 18 – 3-ft FD Optimum 100% MTFR Test QA/QC Results

Parameter	Unit	Measured Value	Acceptable Range	Coefficient of Variance	Acceptable Range
Flow Rate	gpm	455	412 - 504	0.008	<0.03
Feed Rate	mg/L	197.8	180 - 220	0.015	<0.10
Max BG Conc.	mg/L	7.3	≤20	-	-
Water Temperature	°F	74.6	≤80	-	-

125% MTFR Results

The 125% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 1.28 cfs. A summary of test readings, measurements and calculations are shown in **Table 19**. Feed rate calibration results are shown in **Table 20**. Background and effluent sediment concentrations are shown in **Table 21**.

The 3-ft FD Optimum removed 38.3% of the test sediment at a flow rate of 1.28 cfs. **Table 22** shows that the QA/QC results for flow rate, feed rate, background sediment concentration and temperature were within the allowable limits specified by the protocol.

Table 19 Summary of 3-ft FD Optimum 125% MTFR Test Results

Trial Date	Target Flow Rate (cfs)/(gpm)	Detention Time (sec)	Start Mass (lbs)	End Mass (lbs)	Influent Concentration[1] (mg/L)	Max. Water Temperature (°F)	Adj. Effluent Concentration (mg/L)	Removal Efficiency
5/3/21	1.28 / 575	23	75.000	63.085	195.7	74.1	120.3	38.5%

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

Table 20 – 3-ft FD Optimum 125% MTFR Feed Rate Calibration Results

Sample ID	Sample Time (mm:ss)	Sample Mass (g)	Sample Duration (sec)	Feed Rate (mg/min)	Influent Concentration (mg/L)
1	00:00	142.209	20	426,627	197
2	02:29	146.255	20	438,765	203
3	04:58	142.995	20	428,985	199
4	07:27	141.493	20	424,479	196
5	09:56	142.116	20	426,348	197
6	12:25	141.964	20	425,892	197
			Mean	**428,516**	**198**

Table 21 – 3-ft FD Optimum 125% MTFR TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
01:29	112	7.2	104.8
01:59	129	5.9	123.1
02:29	121	4.6	116.4
03:58	131	5.3	125.7
04:28	130	6.0	124.0
04:58	119	6.1	113.0
06:27	115	6.1	108.9
06:57	136	6.1	129.9
07:27	134	6.1	127.9
08:56	128	9.1	119.0
09:26	119	12.0	107.0
09:56	143	11.0	132.0
11:25	130	10.0	120.0
11:55	129	9.2	119.9
12:25	141	8.3	132.7
Mean	**127.8**	**7.5**	**120.3**

[1]Shaded background concentrations are interpolated.

Table 22 – 3-ft FD Optimum 125% MTFR Test QA/QC Results

Parameter	Unit	Measured Value	Acceptable Range	Coefficient of Variance	Acceptable Range
Flow Rate	gpm	571	518 - 633	0.007	<0.03
Feed Rate	mg/L	196	180 - 220	0.012	<0.10
Max BG Conc.	mg/L	12.0	≤20	-	-
Water Temperature	°F	74.1	≤80	-	-

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. Two test runs were excluded from the results for failure to meet the quality standards. The first 50% MTFR test had a background concentration exceeding 20 mg/L, and the wrong sampling schedule was used for the first 125% MTFR test resulting in an aborted test.

Annualized Weighted TSS Removal Efficiency

The NJDEP-specified annual weighted TSS removal efficiency calculation is shown in **Table 23** using the results from the removal efficiency testing.

Testing in accordance with the provisions detailed in the NJDEP HDS Protocol demonstrate that the 3-ft FD Optimum achieved a 51.8% annualized weighted TSS removal at an MTFR of 1.02 cfs (64.5 gpm/sf). This testing demonstrates that the 3-ft FD Optimum exceeds the NJDEP requirement that HDS devices demonstrate at least 50% weighted annualized TSS removal efficiency at the MTFR.

Table 23 Annualized Weighted TSS Removal of the 3-ft FD Optimum

% MTFR	Flow Rate (cfs)	Removal Efficiency	Weighting Factor	Weighted Efficiency-%
25	0.26	61.5%	0.25	15.4
50	0.51	53.8%	0.3	16.1
75	0.77	48.1%	0.2	9.6
100	1.02	45.2%	0.15	6.8
125	1.28	38.5%	0.1	3.9
Weighted Annualized TSS Removal Efficiency				**51.8**

4.2 Scour Testing Results

The FD Optimum underwent scour testing according to the requirements of Section 4 of the NJDEP Protocol at a flow rate greater than 200% of its MTFR in order to verify its suitability for online use. For the 3-ft FD Optimum with an MTFR of 1.02 cfs (458 gpm) the average scour test flow rate had to be at least 2.04 cfs (916 gpm). The average flow rate for the scour test was 2.3 cfs which represents 225% of the MTFR. The maximum water temperature during testing was 74.3°F. The flow rate COV was 0.007. The maximum background concentration measured was 0.7 mg/L which complies with the 20 mg/L maximum background concentration specified by the test protocol. Effluent and background sample measurements are shown in **Table 24**. The mean adjusted effluent concentration of 1.1 mg/L was below the 20 mg/L concentration specified by the test protocol.

Table 24 3-ft FD Optimum Scour Test TSS Concentration Results

Time (mm:ss)	Effluent Concentration (mg/L)	Background Concentration[1] (mg/L)	Adjusted Effluent Concentration (mg/L)
02:00	3.8	2.9	0.9
04:00	3.3	2.9	0.4
06:00	4.3	2.9	1.4
08:00	2.9	3.0	0.0
10:00	4.5	3.0	1.5
12:00	3.8	3.0	0.8
14:00	3.1	3.0	0.1
16:00	4.2	3.4	0.8
18:00	3.3	3.8	0.0
20:00	3.3	3.2	0.1
22:00	3.2	2.6	0.6
24:00	3.2	2.0	1.3
26:00	5.2	1.3[2]	3.9
28:00	2.9	1.3	1.6
30:00	4.0	1.3[2]	2.7
Mean	**3.7**	**2.6**	**1.1**

[1]Shaded background concentrations are interpolated. [2]LOQ was 2.5 mg/L; half LOQ was used.

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 FD Optimum 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 FD Optimum is a flow-through system contained within a watertight manhole. Therefore, the FD Optimum can be installed and function as intended in all soil types.

Slope

Hydro International recommends contacting our design engineers when the FD Optimum 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 FD Optimum and the frequency of peak flow are taken into consideration by the Hydro International team.

Maximum Treatment Flow Rate (MTFR)

The MTFR of the FD Optimum is dependent upon model size. The recommended maximum treatment flow rate is dependent on FD Optimum 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 FD Optimum should be inspected and maintained according to recommendations and guidelines set forth in the Operation and Maintenance manual at: (https://www.hydro-int.com/en/resources/first-defense-operations-maintenance-manual). A detailed discussion of inspection and maintenance requirements is discussed later in Section 6.

Operating Head

Water levels were measured in the First Defense Optimum using the vessel outlet invert as a datum. Measurements were taken to the nearest 1/16-inch using pressure taps and an engineer's scale. The average of three readings were used. Measured water levels are reported in **Table 25**. Total energy loss is calculated in **Table 26**.

Table 25 Measured Static Water Levels

	Static Head (inches)			
Flow (cfs)	**Inlet Pipe**	**Vessel Inlet**	**Vessel Outlet**	**Outlet Pipe**
0.00	0.63	0.00	0.00	-0.58
0.10	3.48	3.79	2.08	0.44
0.20	7.67	7.73	2.92	0.94
0.30	10.44	10.44	3.46	1.25
0.40	11.06	11.02	4.21	1.60
0.50	11.48	11.44	5.19	1.88
0.60	11.81	11.79	5.50	2.13
0.70	12.13	12.13	6.06	2.38
0.80	12.44	12.42	6.42	2.48
0.90	12.71	12.71	6.71	2.56
1.00	12.96	12.94	7.04	2.65
1.20	13.48	13.40	7.69	2.98
1.40	13.88	13.77	8.29	3.19
1.60	14.23	14.21	8.63	3.38
1.80	14.73	14.67	9.04	3.54
2.00	15.13	15.06	9.38	3.71
2.20	15.42	15.31	9.90	3.90
2.40	15.77	15.67	10.42	4.13

Table 26 Calculated Energy Losses

	DOF in Pipe (ft)		Velocity in Pipe (ft/s)		Velocity Head (ft)		Total head (ft)		Tot. Loss
Flow (cfs)	Inlet Pipe	Outlet Pipe	Inlet Pipe	Outlet Pipe	Inlet Pipe	Outlet Pipe	Inlet pipe	Outlet pipe	(ft)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	-0.05	0.10
0.10	0.24	0.09	0.55	2.31	0.00	0.08	0.29	0.12	0.18
0.20	0.59	0.13	0.31	2.68	0.00	0.11	0.64	0.19	0.45
0.30	0.82	0.15	0.30	3.26	0.00	0.17	0.87	0.27	0.60
0.40	0.87	0.18	0.38	3.33	0.00	0.17	0.92	0.31	0.62
0.50	0.90	0.20	0.45	3.57	0.00	0.20	0.96	0.35	0.61
0.60	0.93	0.23	0.52	3.50	0.00	0.19	0.99	0.37	0.62
0.70	0.96	0.25	0.59	3.62	0.01	0.20	1.02	0.40	0.61
0.80	0.98	0.26	0.65	3.91	0.01	0.24	1.04	0.44	0.60
0.90	1.01	0.26	0.71	4.39	0.01	0.30	1.07	0.51	0.55
1.00	1.03	0.27	0.77	4.62	0.01	0.33	1.09	0.55	0.54
1.20	1.07	0.30	0.89	4.77	0.01	0.35	1.14	0.60	0.53
1.40	1.10	0.31	1.00	5.31	0.02	0.44	1.17	0.70	0.47
1.60	1.13	0.33	1.12	5.55	0.02	0.48	1.21	0.76	0.45
1.80	1.18	0.34	1.21	5.59	0.02	0.49	1.25	0.78	0.47
2.00	1.21	0.36	1.31	6.13	0.03	0.58	1.29	0.89	0.39
2.20	1.23	0.37	1.42	6.50	0.03	0.66	1.32	0.98	0.34
2.40	1.26	0.39	1.52	6.57	0.04	0.67	1.35	1.01	0.34

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 FD Optimum was designed for online applications in which the inlet and outlet are tied directly into the main drainage line.

Structural Load Limitations

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

Pretreatment Requirements

The FD Optimum has no pre-treatment requirements.

Limitations on Tailwater

Hydro International recommends working with their engineering team if tailwater is present to increase the available driving head to ensure that the full water quality treatment flow rate is treated consistent with NJDEP protocol requirements.

Depth to seasonal high water table

Although the functionality of the FD Optimum 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 FD Optimum chamber are necessary to counterbalance buoyant forces.

Pipe Size

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

6. Maintenance

Inspection and maintenance of the FD Optimum are simple procedures conducted from the surface. An Operation and Maintenance Manual can be found at:
https://www.hydro-int.com/en/resources/first-defense-operations-maintenance-manual

Neither inspection nor maintenance require purchasing spare parts or tools from Hydro International. The FD Optimum has one centrally located 30-in manhole lid to provide inspection and maintenance access to both the internal bypass chamber and vortex 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 measure 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 FD Optimum is 18 inches. Because FD Optimum model sizes vary in diameter, pollutant storage volumes vary with model size as shown in **Table 25**. 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 FD Optimum to assess whether accumulated sediment has reached 9 inches in depth.

Table 27 Pollutant Storage Capacities of the FD Optimum

Model	Sediment Volume at 50% Sump Capacity (yd^3)	Sediment Depth at 50% Sump Capacity (in)	Sump Volume (yd^3)	Sump Depth (in)
3-ft	0.20	9	0.39	18
4-ft	0.35	9	0.70	18
5-ft	0.55	9	1.1	18
6-ft	0.80	9	1.6	18
7-ft	1.1	9	2.1	18
8-ft	1.4	9	2.8	18
10-ft	2.2	9	4.4	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 FD Optimum be cleaned out at least once per year. There is no need for man entry into the FD Optimum 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 removed 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 FD Optimum during maintenance. When all pollutants have been removed from the FD Optimum, the manhole lids should be put securely back in place.

Sediment, floatables, and gross debris 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. 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 Associates) 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.

Turning Water Around...®

May 20th, 2021

Dr. Richard Magee, Sc.D., P.E., BCEE
Executive 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

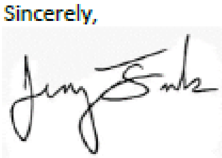
Dear Dr. Magee:

Hydro International has completed verification testing for the First Defense High Capacity Optimum in accordance with the *"New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation 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 three foot diameter First Defense High Capacity Optimum unit was tested at Hydro International's laboratory in Portland, Maine for efficacy and scour resistance. 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,



Jeremy Fink, PE
Pr. Product Development Engineer

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

STATEMENT OF WITNESS | THIRD PARTY OBSERVER

TO: Jeremy Fink, Hydro International
FROM: Forrest Bell, FB Environmental Associates (FBE)
SUBJECT: Third Party Witness of Hydro International First Defense® Optimum Vortex Separator
DATE: May 25, 2021
CC: Margaret Mills, FB Environmental Associates (FBE)

Statement of Third Party Observer

FB Environmental served as the third-party observer for tests performed on the First Defense® Optimum Vortex Separator by Hydro International in April through May of 2021 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 (January, 2013).* 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 all testing procedures.

We have also reviewed the data, calculations, and conclusions associated with the removal efficiency testing in the *NJCAT Technology Verification: First Defense® Optimum Vortex Separator* report by Hydro International, dated May 2021 with the May 24, 2021 edits incorporated. We state that they conform to what we saw during our supervision as a third-party observer.

Forrest Bell

________________________________ _5/25/2021__________________________

Forrest Bell ~ FB Environmental Associates Date

STATEMENT OF DISCLOSURE | THIRD PARTY OBSERVER

TO: Jeremy Fink, Hydro International
FROM: Forrest Bell, FB Environmental Associates (FBE)
SUBJECT: Third Party Observer Statement of Disclosure under New Jersey Department of Environmental Protection Process for Approval of Use for Manufactured Treatment Devices
DATE: May 25, 2021
CC: Margaret Mills, FB Environmental Associates (FBE)

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: First Defense® Optimum Vortex Separator* report by Hydro International, dated May 2021 with the May 24, 2021 edits incorporated.

Disclosure Record

FB Environmental has provided the service of third-party observer for tests performed by Hydro International in April through May of 2021. The tests assessed the removal efficiency of the First Defense® Optimum vortex separator to prepare for its designated use of capturing particulate pollutants entering the system as part of surface runoff. 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.

5/25/2021

Forrest Bell ~ FB Environmental Associates

Date

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

June 5, 2021

Gabriel Mahon, Chief
NJDEP
Bureau of Non-Point Pollution Control
Division of Water Quality
401 E. State Street
Mail Code 401-02B, PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Mahon,

Based on my review, evaluation and assessment of the testing conducted on the First Defense® Optimum vortex separator (FD Optimum) by Hydro International and observed by FB Environmental Associates of Portland, Maine, 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, (January 25, 2013)"* (NJDEP HDS Protocol) were met or exceeded. Specifically:

Test Sediment Feed

The mean PSD of Hydro International's 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 significantly finer (d_{50} of 56μm vs 75μm) than the sediment blend specified by the protocol. The Hydro International scour test sediment PSD analysis was plotted against the NJDEP scour sediment test PSD specification and shown to be also much finer than specified by the protocol.

Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on a full-scale 3-ft FD Optimum model in order to establish the ability of the FD Optimum 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 458 gpm (1.02 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. The annualized weighted sediment removal of the 3-ft FD Optimum was 51.8%.

Scour Testing

In order to demonstrate the ability of the FD Optimum to be used as an online treatment device, scour testing was conducted at greater than 200% of the MTFR in accordance with the NJDEP HDS Protocol. The average flow rate during the online scour test was 2.3 cfs, which represents 225% of the MTFR (MTFR = 1.02 cfs). Background sediment concentration measured was 1.3 to 3.8 mg/L (LOQ = 2.5 mg/L) throughout the scour testing, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Unadjusted effluent sediment concentrations ranged from 2.9 mg/L to 5.2 mg/L with a mean of 3.7 mg/L. When adjusted for background concentrations, the effluent concentrations range from 0.0 to 3.9 mg/L with a mean of 1.1 mg/L. These results confirm that the 3-ft. FD Optimum did not scour at 225% MTFR and meets the criterion for online use.

Maintenance Frequency

The predicted maintenance frequency for all models is 37 months.

Sincerely,

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

8. References

ASTM D422-63 (2007). *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D3977-97 (2013). *Standard Test Methods for Determining Concentrations in Water Samples*.

NJDEP 2013. *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 2013a. *New Jersey Department of Environmental Protection Laboratory Process for Approval of Use for Manufactured Treatment Devices.* 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 – Typical FD Optimum Design Specifications are shown in **Table A-1**.

- TSS Removal Rate – 50%

- Online or offline installation

Detailed Specification

- FD Optimum maximum treatment flow rates (MTFRs), sediment storage amounts and sediment removal intervals per NJDEP sizing requirements are attached as **Table A-1**.
- Standard FD Optimum dimensions are attached as **Table A-2**.
- Pick weights and installation procedures vary 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 Operation & Maintenance Manual at: https://www.hydro-int.com/en/resources/first-defense-operations-maintenance-manual

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

Table A-1 MTFRs and Sediment Removal Intervals for FD Optimum Models

FD Optimum 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	1.02	7.1	64.5	5.3	37
4-ft	4	1.81	12.6	64.5	9.4	37
5-ft	5	2.83	19.6	64.5	14.7	37
6-ft	6	4.07	28.3	64.5	21.2	37
7-ft	7	5.53	38.5	64.5	28.9	37
8-ft	8	7.23	50.3	64.5	37.7	37
10-ft	10	11.33	78.5	64.5	58.9	37

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

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

Table A-2 Standard Dimensions for FD Optimum Models

FD Optimum Model and Diameter	Maximum Treatment Flow Rate (cfs)	50% Max Sediment Storage Volume (ft^3)	Chamber Depth (ft)	Treated Chamber Depth[1] (ft)	Sediment Sump Depth (ft)	Aspect Ratio Treatment Depth: Diameter	Maximum Pipe Diameter (inch)
3-ft	1.02	5.3	3.71	2.96	1.5	0.99	18
4-ft	1.81	9.4	5.00	4.25	1.5	1.06	24
5-ft	2.83	14.7	5.25	4.50	1.5	0.90	24
6-ft	4.07	21.2	6.25	5.50	1.5	0.92	32
7-ft	5.53	28.9	7.25	6.50	1.5	0.93	42
8-ft	7.23	37.7	8.00	7.25	1.5	0.91	48
10-ft	11.33	58.9	10.25	9.50	1.5	0.95	60

[1]Treated 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 (3-ft model). A variance of 15% is allowable. For units <250% MTFR (4-ft model) the depth must be equal or greater than the depth of the unit tested.