NJCAT TECHNOLOGY VERIFICATION

Aqua-Filter™ Stormwater Filtration System with Perlite Media

AquaShield™, Inc.

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1. Description of Technology

The Aqua-Filter™ is a post-construction, custom engineered, two component modular structure that utilizes a treatment-train approach for stormwater quality treatment. The patented configuration of the Aqua-Filter™ always includes an upstream pretreatment hydrodynamic separator (HDS) chamber followed downstream by a filtration chamber. A drawing of the AF-2.1 test unit is provided in **Figure 1**. This verification applies only to Aqua-Filter™ systems that utilize a rectangular filter media bed within a horizontal filtration chamber.

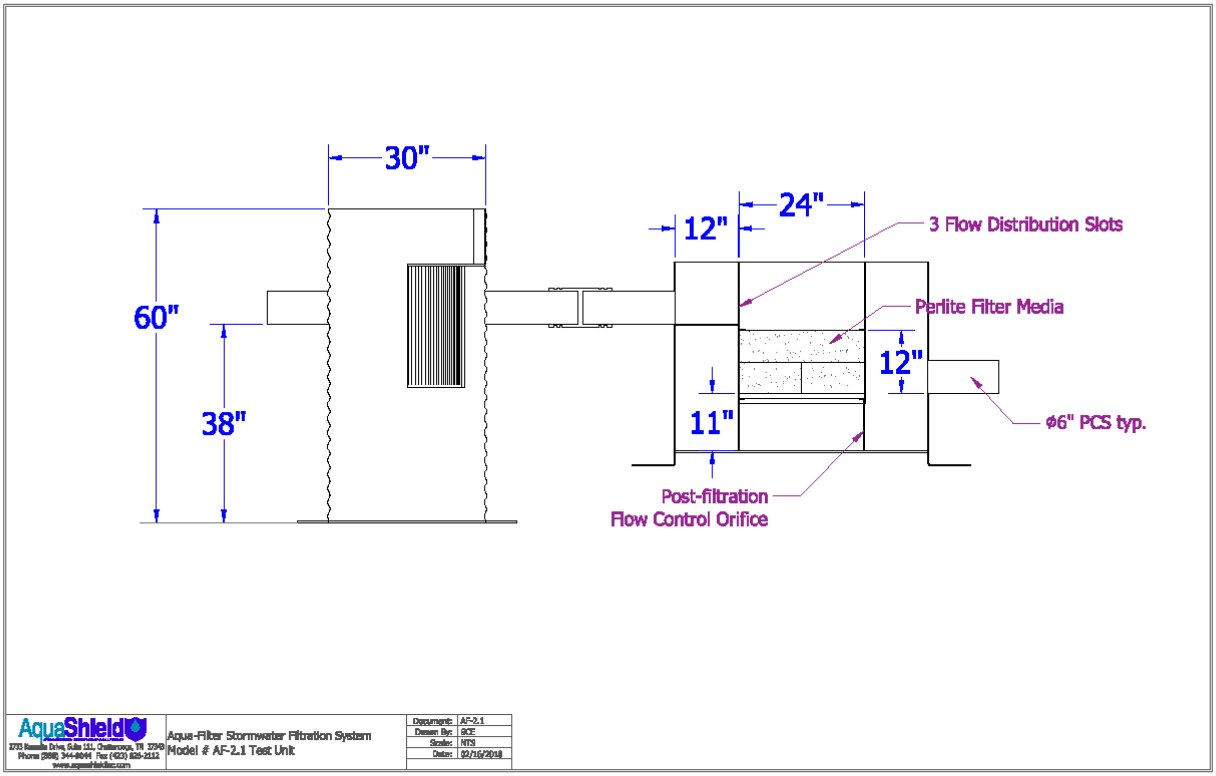

Figure 1 Aqua-Filter™ Model AF-2.1

Aqua-Filter™ technology is a rapid or high flow rate device that has no moving parts and operates on gravity flow or movement of the stormwater runoff entering the structure. Pretreatment is provided by the HDS which uses vortex enhanced sedimentation technology designed to remove coarse sediment, floating debris, and free-floating oil. Operation begins when stormwater enters the pretreatment HDS by means of its tangential inlet pipe which induces a circular (swirl or vortex) flow pattern. The swirl chamber retains water between storm events that allows for both dynamic and quiescent settling of solids. The dynamic settling occurs during each storm event while the quiescent settling takes place between successive storms. A combination of gravitational and hydrodynamic drag forces results in solids dropping out of the flow. Particles settle at the base of the HDS chamber while the treated flow exits the pretreatment HDS behind the arched inner baffle. The top of the baffle is sealed across the treatment channel to eliminate floatable pollutants from escaping the system. A vent pipe is extended up the riser to expose the backside of the baffle to atmospheric conditions, preventing a siphon from forming at the bottom of the baffle.

Once pretreated stormwater leaves the HDS chamber, runoff enters the filtration chamber which is designed to refine and polish the stormwater quality prior to discharge. The peak filtration flow rate is based on the calculated water quality flow rate (WQ_f) requirements desired for the site. As the pretreated runoff enters the filtration chamber, the water flows across a conveyance shelf in order to facilitate the distribution of water to the entire surface of the filter bed. The elevation of this conveyance shelf is coincident with the invert elevation of the influent pipe of the filtration chamber. This shelf also serves to accommodate the minimum 12 inch drop in invert elevations between the inlet and outlet pipes of the filtration chamber. After water passes across the conveyance shelf, the water then enters the filter bed and permeates downward through the filter media. Gravity drives the flow of water downward through the filtration media.

Sediment is trapped within the interstitial spaces throughout the porous media as the stormwater percolates through the filters. The filter media is contained in individual polyproplyene mesh containers which are secured and layered in rows patterned to minimize short-circuiting. Perlite is the most common filter media used in the Aqua-Filter™ systems and was used for this NJCAT verification testing program. AquaShield™ has developed other proprietary filter media blends that are used to target other contaminants of concern.

Once the filtered (treated) water passes through the filter media and post-filtration flow control, it passes through a service area which provides access to the filtration chamber for inspection and maintenance purposes. The treated water then exits the filtration chamber via the effluent pipe stubout.

2. Laboratory Testing

Laboratory testing was performed to independently verify that the Aqua-Filter™ is eligible for certification by the New Jersey Department of Environmental Protection (NJDEP) as an 80% Total Suspended Solids (TSS) removal device. Note that the HDS used in the Aqua-Filter™ system is *not* identical to the Aqua-Swirl® hydrodynamic separator that holds Laboratory Certification issued by NJDEP in a letter dated December 1, 2016. It is important to keep in mind that the Aqua-Swirl® system is certified for 50% TSS removal as a standalone technology for pretreatment, whereas the HDS used in the Aqua-Filter™ system is not held to the same criteria given the Aqua-Filter™ treatment train design.

The Aqua-Filter™ was tested in accordance with the "*New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device*" (NJDEP 2013). Testing was conducted in Chattanooga, Tennessee at the hydraulics laboratory of AquaShield™, Inc. under the supervision of Southern Environmental Technologies, Inc. of Sewanee, Tennessee. The independent observer was approved by NJCAT as cited in the Quality Assurance Project Plan (QAPP).

The test sediment used for both the removal efficiency testing and the sediment mass loading capacity testing was independently prepared by Good Harbour Laboratories, Ltd., at their Mississauga, Ontario facility. The particle size distribution (PSD) analysis was performed in accordance with ASTM D 422-63 (2007) by Maxxam Analytics in Mississauga, Ontario. All test sediment was collected, labeled and security sealed by Good Harbour Laboratories prior to shipment to the AquaShield™ test facility. The independent observer confirmed that the security seals were intact prior to opening the test sediment shipment containers at the AquaShield™ test facility.

2.1 Test Unit

The full scale, commercially available Aqua-Filter™ Model AF-2.1 test unit is a two-component treatment train device. The upstream pretreatment component is a 2.5-foot diameter vortex type hydrodynamic separator (HDS) chamber constructed of polymer coated steel (PCS). The downstream component is a filtration chamber also constructed of PCS material containing 12 ft^2 of perlite filter media in one "row" of filter containers. Both fiberglass grating on top of the media bed and post-filtration flow controls are used to ensure even distribution of water across the filter media bed.

The upstream pretreatment HDS uses 6-inch influent and effluent piping stubouts. The downstream filtration component of the AF-2.1 also uses 6-inch influent and effluent piping stubouts. The effective sedimentation area of the pretreatment HDS is 4.9 ft^2 while the effective filtration treatment area of the filtration chamber is 12.0 ft^2. The sedimentation area below the filter bed is also 12.0 ft^2. The two chambers of the test unit are identical to a commercially available unit with the exception that it does not have a cover in order to facilitate this laboratory testing program.

The filtration chamber test unit utilized perlite filter media contained in a series of polypropylene mesh containers ("bags") and configured in such a manner as to minimize short circuiting between the containers. Water passes through the filter media under gravity flow in a downflow configuration. The AF-2.1 and larger Aqua-Filter™ models utilize rectangular shaped filter containers with a 90 degree offset for the two filter bed layers. Each filter container measures 24 inches long (2.0 feet), 12 inches wide (1.0 foot) and 6.0 inches thick (0.5 feet), or 2.0 ft^2 per container. Two layers of 6-inch thick filter containers are used for Aqua-Filter™ systems which results in a total of 12 inches of media thickness. That is, each of the two filter bed layers contains six filter containers providing for a total of 12 filter containers for a one row Aqua-Filter™ system.

Key dimensions of the test unit were measured by the independent observer prior to the beginning of the testing program to ensure that the test unit and test loop setup dimensions matched those shown in **Figures 1** and **2**.

2.2 Test Setup

The test loop is illustrated in **Figure 2** as a recirculation system. Both 2,700 and 2,300-gallon water supply tanks were used in series. A Berkeley Model B5ZPBH centrifugal pump draws water from the 2,300-gallon water supply tank via a 6-inch diameter Schedule 40 PVC pipe. Inflow to the test unit was measured by a Badger M-2000 flow meter that was pre-calibrated and certified by the manufacturer as such. The accuracy of the flow measurement is ±2.0%. The test flow rate was averaged based on recorded flow rate. The maximum allowable coefficient of variance (COV) for flow documentation is 0.03. Flow data was recorded every 60 seconds throughout the duration of the test using a Lascar EL-USB-4 Data Logger.

Background filtration is located downstream of the pump and upstream of the background sample location. A 1-micron filter assembly manufactured by Filtra Systems, Model # FSSB-080808CSVR2, Option B was used for the testing program.

Influent PVC piping to the test unit from the background filter assembly is routed to an elevated platform where the background sample port and influent test sediment feeder are positioned. The 6 inch diameter influent pipe is expanded to 12 inches in diameter downstream of the background sample port. The 12-inch diameter piping run was set at approximately 1.0% downward slope to the test unit. The 12-inch diameter influent pipe includes an open sediment feed port (tee) for injecting sediment through the crown of the pipe 5 feet upstream of the test unit. Test sediment injection used an IPM Systems Auger® volumetric screw feeder Model VF-2 with an attached vibrator mounted on the hopper. The sediment feeder assembly was positioned adjacent to and above the 12-inch diameter pipe to accommodate sediment feed sampling and injection. Both the background sample location and the auger feeder are situated on the raised platform to allow for the influent piping to enter the AF-2.1 at the design elevation.

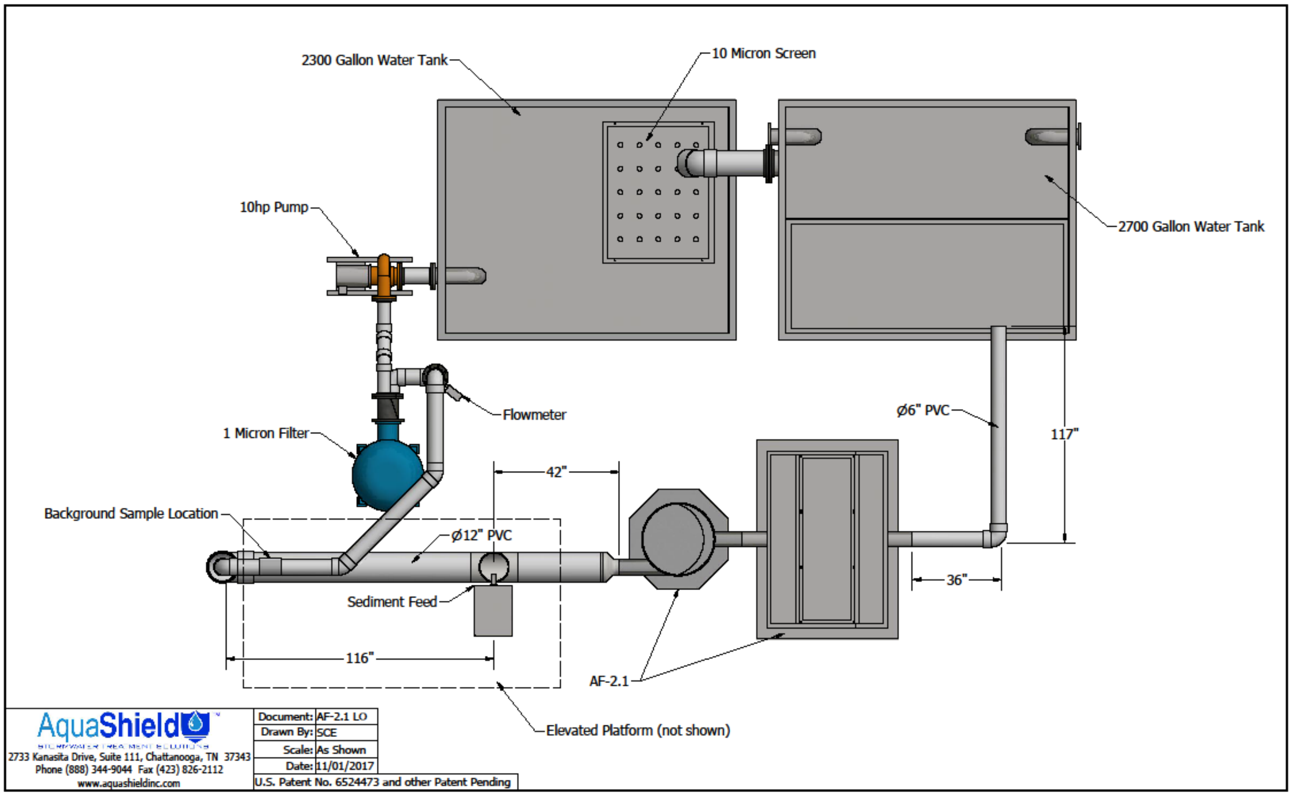

Figure 2 Illustration of AF-2.1 Test Loop Setup

The 12-inch diameter PVC piping run was reduced again to 6 inches in diameter downstream of the sediment feeder and upstream of the test unit via an eccentric reducer coincident with the HDS inlet stubout pipe. Piping connections are made using Fernco couplers for the 6-inch diameter influent HDS stubout, the 6-inch diameter HDS effluent stubout, and both the 6-inch diameter influent and effluent stubouts of the filtration chamber.

A downward slope of approximately 1.0% was set for the test unit's 6-inch diameter PVC effluent piping run leading to the effluent sample location at the edge of the 2,700-gallon water supply tank. The effluent piping run extends 36 inches (3.0 feet) from the stubout pipe of the filtration chamber where a 90-degree elbow leads to a 117-inch (9.75 feet) piping run to the 2,700-gallon water tank resulting in a total of 153 inches (12.75 feet) of effluent piping. Water free falls from the effluent pipe into the 2,700-gallon water tank. Effluent samples were collected from the discharge by the grab sampling method as cited in Section 5G of the protocol (sweeping motion).

2.3 Test Sediment

All test sediment used for both the removal efficiency testing and the sediment mass loading capacity testing was blended by Good Harbour Laboratories (GHL) of Mississauga, Ontario using high purity silica obtained from various suppliers in North America. All blending activities took place at the GHL facility. Three random sediment samples were collected from sediment blends and delivered to Maxxam Analytics in Mississauga for particle size distribution (PSD) analysis using ASTM D 422-63. The PSD of each of the 3 samples were averaged and reported as the overall PSD (**Table 1 and Figure 3**). It was determined that the test sediment blend met the protocol specification. Test sediment was placed in shipping containers, security sealed by GHL and transported to the AquaShield™ laboratory test facility in Chattanooga, Tennessee. All container seals were intact upon receipt and were removed by the independent observer at the initiation of testing. The sediment containers were security sealed by the observer at the conclusion of all testing activities.

Table 1 Particle Size Distribution of Test Sediment

Particle Size (Microns)	Test Sediment Particle Size (% Less Than)[1]				NJDEP Specification[2]	QA/QC
	Sample 1	Sample 2	Sample 3	Average		
1,000	100	100	100	100	100	PASS
500	94	94	94	94	95	PASS
250	89	89	89	89	90	PASS
150	82	81	81	81	75	PASS
100	62	61	61	61	60	PASS
75	54	52	52	53	50	PASS
50	46	45	44	45	45	PASS
20	38	37	36	37	35	PASS
8	20	19	20	20	20	PASS
5	14	13	12	13	10	PASS
2	6	8	5	6	5	PASS
d_{50}	62 µm	67 µm	68 µm	66 µm	≤ 75 µm	PASS

[1] Where required, particle size data has been interpolated to allow for comparison to the required particle size specification.

[2] A measured value may be lower than a target minimum % less than value by up to two percentage points provided that the measured d_{50} value does not exceed 75 microns.

2.4 Removal Efficiency Testing

Removal efficiency testing was performed in accordance with Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. The Aqua-Filter™ was tested at a maximum treatment flow rate (MTFR) of 95.2 gpm (0.212 cfs, or 7.93 gpm/ft^2 of filtration area). The test sediment mass was fed into the flow stream at a known rate using a screw auger. Sediment was introduced at a rate within 10% of the targeted concentration of 200 mg/L influent concentration throughout the duration of the removal efficiency testing program. Water temperature did not exceed 80°F during the testing program and was recorded at 60 second intervals.

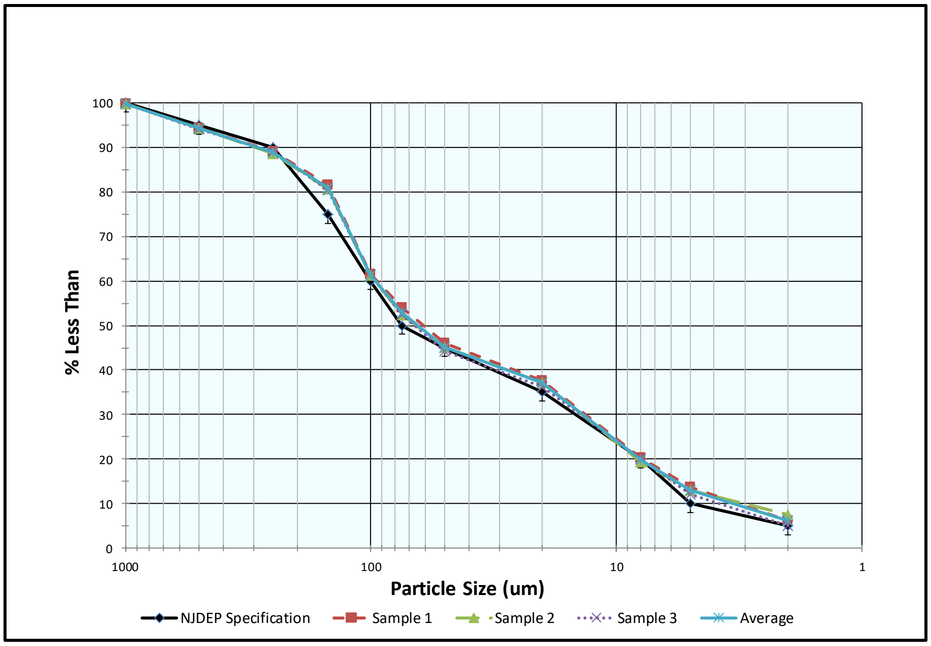

Figure 3 Comparison of Test Sediment PSD to NJDEP PSD Specification

Test runs 1 through 10 apply to TSS removal efficiency testing while test runs 11 through 36 are associated with the sediment mass loading capacity testing. **Table 2** depicts the sediment removal efficiency sampling frequency for sediment feed, background and effluent samples for runs 1 through 10. **Table 2** also includes sampling frequency for runs 11 through 36 at the MTFR for the sediment mass loading capacity testing. See Section 2.5 for an explanation of test runs with respect to MTFR.

Three sediment feed samples were collected per run including one sample at the start of dosing, one in the middle of the run and one toward the end of dosing to allow for 3 residence times to pass prior to when drawdown began. Sediment feed rate samples were collected from the injection point using clean, laboratory-supplied 1-liter plastic bottles. Sediment feed samples were collected over a 60 second period and timed to the nearest second. A factory-calibrated stop watch was used for timing all sediment feed sampling intervals. These samples were weighed to the nearest milligram using a calibrated Tree® Model HRB-413 electronic balance. This data was used to calculate influent TSS concentration and to confirm that the sediment feed rate COV stayed below the limit of 0.10 as required by the protocol.

Table 2 Sampling Frequency for Removal Efficiency Runs 1 through 10 and Sediment Mass Retention Capacity Runs 11 through 36

Scheduled time (min:sec)	Sample			
	Feed Rate*	Effluent TSS	Background TSS	Drawdown TSS
0:00	Start sediment feed			
	1			
6:00		1	1	
12:00	2	2		
18:00		3	2	
24:00	3	4		
30:00		5	3	
31:00	End flow			
39:00				1
48:00				2

* Feed rate = 60 seconds

The average influent TSS concentration used for calculating removal efficiency was calculated using **Equation 1** below.

$$Average\ Influent\ Concentration\ \left(\frac{mg}{L}\right) = \frac{Total\ mass\ added}{\begin{array}{c}Total\ volume\ of\ water\ flowing\\ through\ the\ MTD\ during\ addition\\ of\ test\ sediment\end{array}}$$

Equation 1 Calculation for Average Influent Sediment Concentration

Background samples were collected at the valved sample port using clean, laboratory-supplied 1-liter plastic bottles. Influent background samples were collected at the same time as odd numbered effluent grab samples (first, third, fifth). Background samples were time stamped and confirmed by the observer that each background sample was properly recorded.

During each test run the flow meter data logger recorded flow rates once per minute. Once constant flow rate and test sediment feed were established, three MTD detention times passed before the first of five effluent samples were collected. All effluent samples were collected in clean, laboratory-supplied 1-liter plastic bottles using a sweeping grab sampling motion through the effluent stream as described in Section 5G of the protocol. Samples were then time stamped and confirmed by the observer that each effluent sample was properly recorded.

Two drawdown samples were collected for all test runs at nine minute intervals following the end of the test flow period. Test runs and drawdown flow were considered complete when the effluent drawdown flow decreased to a trickle thus allowing the next test to commence.

Due to the physical nature of the test set up it was not practical to completely isolate and capture the draw down volume for every test run; thus, the total drawdown volume was calculated based on filter bag measured void volume for each test run. Draw down volume was calculated as the volume of water contained in the HDS above static water level and the volume of water contained in the filter chamber above outlet invert.

A chain of custody form was completed for each test run and samples were transported to the independent laboratory for TSS analysis in security sealed coolers. All background, effluent and drawdown samples were analyzed by AIRL, Inc. of Cleveland, Tennessee in accordance with ASTM D 3977-97 (re-approval 2007) “Standard Test Methods for Determining Sediment Concentrations in Water Samples.”

The TSS removal efficiency for each tested flow rate was calculated following **Equation 2** as follows:

$$Removal\ Efficiency\ (\%) = \frac{\begin{pmatrix} Average\ Influent \\ TSS\ Concentration\ X \\ Total\ Volume \\ of\ Test\ Water \end{pmatrix} - \begin{pmatrix} Adjusted\ Effluent \\ TSS\ Concentration\ X \\ Total\ Volume \\ of\ Effluent\ Water \end{pmatrix} - \begin{pmatrix} Average \\ Drawdown\ Flow \\ TSS\ Concentration\ X \\ Total\ Volume \\ of\ Drawdown\ Water \end{pmatrix}}{\begin{matrix} Average\ Influent\ TSS\ Concentration\ X \\ Total\ Volume\ of\ Test\ Water \end{matrix}} \times 100$$

Equation 2 Equation for Calculating Removal Efficiency

2.5 Sediment Mass Loading Capacity Testing

Sediment Mass Loading Capacity Testing is represented in this AF-2.1 testing program by runs 11 through 36. Per the protocol these runs are an extension of the removal efficiency testing and are used to determine the maximum mass of test sediment that can be captured by the MTD prior to either an unacceptable loss of hydraulic capacity at design driving head, unacceptable head loss at MTFR, or an unacceptable reduction in pollutant removal efficiency at MTFR, each occurring as a result of filter media occlusion.

Although the protocol allows for the influent concentration to be increased to 400 mg/L for the mass loading capacity testing, runs 11 through 36 were conducted at the targeted 200 mg/L concentration. While the Aqua-Filter^{TM} is a head driven system and it never reached maximum head during testing, the cumulative average TSS removal efficiency did drop below 80.0% at run 36 and the testing program was concluded.

2.6 Scour Testing

No scour testing was performed for this testing program since Aqua-Filter™ systems are designed to be installed only in offline configurations. The efficiency measurements produced will be applicable to offline configurations that are designed to divert flows in excess of the MTFR from both the HDS and filtration chambers of the Aqua-Filter™ treatment train system.

3. Performance Claims

In keeping with the NJCAT verification process, Aqua-Filter™ performance claims are cited below.

Total Suspended Solids Removal Rate

For the particle size distribution specified by the NJDEP Filtration MTD protocol, the Aqua-Filter™ Model AF-2.1 at an MTFR of 7.93 gpm/ft^2 of filter surface area will demonstrate 80.0% TSS removal efficiency.

Maximum Treatment Flow Rate

The MTFR for the Aqua-Filter™ Model AF-2.1 was demonstrated to be 95.2 gpm (0.212 cfs) which corresponds to a surface area loading rate of 7.93 gpm/ft^2 (0.0177 cfs/ft^2) of filter surface area.

Wet Volume and Detention Time

The wet volume and detention time of the Aqua-Filter™ depends on flow rate and model size. Specifically, detention time is limited to the wet volume of the HDS chamber since there is no appreciable detention that occurs within the filtration chamber. Detention time for the Aqua-Filter™ is calculated by dividing the treatment volume by the flow rate. The treatment volume is defined as the surface area of the HDS chamber multiplied by the depth between the pipe inverts (which are at the same elevation) and the floor of the HDS. The tested Aqua-Filter™ AF-2.1 model at the MTFR has a detention time of 73 seconds.

Effective Sedimentation Area

The effective sedimentation areas of the Aqua-Filter™ models vary with model size. There is no effective sedimentation area within the filtration chamber. However, to be conservative, an area equal to the effective filtration treatment area (EFTA) has been included for scaling purposes. The tested Aqua-Filter™ Model AF-2.1 has an effective sedimentation area of 16.01 ft^2 corresponding to the inlet side of the arched baffle within the HDS pretreatment chamber (4.01 ft^2) plus 12.0 ft^2 in the filtration chamber.

Sediment Mass Load Capacity

The tested Aqua-Filter™ Model AF-2.1 exhibited a sediment mass loading capacity of 126.0 pounds (57.15 kg) for runs 1 through 35.

Maximum Allowable Inflow Drainage Area

To ensure the drainage area and expected annual sediment load does not exceed the intended bypass flows, the sediment mass capture capacity of 126.0 pounds (57.15 kg) of sediment is used to limit the treatable drainage area of the Aqua-Filter™ system. Given the protocol requirements for "Maximum Allowable Inflow Drainage Area," the Aqua-Filter™ Model AF-2.1 demonstrates that it can effectively treat 0.21 acres on an annual basis.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013a) for obtaining verification of an MTD from NJCAT requires that copies of the laboratory test reports, including all collected and measured data, all data from performance test runs, all pertinent calculations, etc. be included in this section. It is the understanding of AquaShield™ that 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 necessary to include all such supporting documentation in verification reports. Supporting documentation is being held by the independent observer and NJCAT.

4.1 Removal Efficiency

In accordance with the NJDEP Filtration MTD Protocol, sediment removal efficiency testing was conducted on the Aqua-Filter™ Model AF-2.1 unit in order to establish the ability of the system to remove the specified test sediment at the target MTFR with the goal to demonstrate at least 80% sediment removal as defined in the protocol. The MTFR established through this testing program to establish the removal efficiency (10 runs) is 95.2 gpm (0.212 cfs).

Test runs 1 through 10 represent sediment Removal Efficiency Testing while test runs 11 through 36 represent Sediment Mass Loading Capacity Testing. The cumulative average TSS removal rate fell below 80% after run 35.

None of the sediment feed samples exceeded 1 minute for any of the tests. The inlet feed concentration COV did not exceed 0.10 for any test flow rate. The average influent sediment concentration was calculated using Equation 1 from Section 2.4 herein. Average effluent sediment concentrations were adjusted by subtracting the measured background concentrations. No background TSS concentrations exceeded the 20 mg/L maximum allowed by the protocol. Also note that background sample concentrations listed as 2 mg/L represent one half of the method detection limit of 4 mg/L (reported by the laboratory as < 4 mg/L).

The flow meter and data logger took a reading every 60 seconds. Flow rate data for sediment removal efficiency and sediment mass loading capacity testing is summarized in **Table 3** including compliance to the protocol.

Water temperature did not exceed 80°F during any of the test runs. Maximum temperatures for removal efficiency and sediment mass loading capacity testing are summarized in **Table 4**.

Influent sediment concentrations for removal efficiency and sediment mass loading capacity testing are summarized in **Table 5**.

Background sediment concentrations for removal efficiency and sediment mass loading capacity testing are summarized in **Table 6**.

Adjusted effluent sediment concentrations for removal efficiency and sediment mass loading capacity testing are summarized in **Table 7**.

Removal Efficiency results are presented in **Table 8**. Data from the 10 removal efficiency test runs indicate 83.97 % TSS removal efficiency at the MTFR of 7.93 gpm/ft^2 of filter surface area.

Table 3 Summary of Flow Rates for Removal Efficiency and Sediment Mass Loading Capacity Testing

Run #	Average Flow Rate (gpm)	COV	Compliance (COV < 0.03)
1	94.8	0.005	Yes
2	94.4	0.006	Yes
3	94.9	0.007	Yes
4	95.4	0.006	Yes
5	94.9	0.010	Yes
6	95.2	0.014	Yes
7	96.4	0.004	Yes
8	93.7	0.009	Yes
9	96.2	0.006	Yes
10	95.7	0.016	Yes
Average	**95.2**		
11	96.5	0.006	Yes
12	95.0	0.005	Yes
13	94.4	0.008	Yes
14	94.9	0.009	Yes
15	94.3	0.009	Yes
16	95.3	0.010	Yes
17	94.7	0.004	Yes
18	94.5	0.004	Yes
19	94.9	0.005	Yes
20	95.0	0.007	Yes
21	91.0	0.006	Yes
22	90.8	0.005	Yes

23	93.1	0.005	Yes
24	93.4	0.008	Yes
25	95.0	0.005	Yes
26	92.3	0.006	Yes
27	91.6	0.006	Yes
28	92.6	0.011	Yes
29	93.7	0.005	Yes
30	94.5	0.004	Yes
31	93.3	0.006	Yes
32	93.2	0.008	Yes
33	90.7	0.006	Yes
34	91.1	0.006	Yes
35	90.6	0.007	Yes
36	91.0	0.006	Yes

Table 4 Temperature Data for Removal Efficiency and Sediment Mass Loading Capacity Testing

Run #	Maximum Temperature (°F)	Compliance (Max ≤ 80°F)
1	62.0	Yes
2	62.5	Yes
3	62.0	Yes
4	62.5	Yes
5	63.0	Yes
6	63.5	Yes
7	62.5	Yes
8	63.0	Yes
9	61.5	Yes
10	61.5	Yes
11	60.0	Yes
12	60.5	Yes

13	60.0	Yes
14	60.5	Yes
15	60.5	Yes
16	59.5	Yes
17	56.0	Yes
18	56.0	Yes
19	56.5	Yes
20	56.0	Yes
21	60.5	Yes
22	60.5	Yes
23	61.0	Yes
24	61.0	Yes
25	59.5	Yes
26	61.0	Yes
27	58.5	Yes
28	58.0	Yes
29	59.5	Yes
30	59.0	Yes
31	59.0	Yes
32	59.0	Yes
33	61.5	Yes
34	62.5	Yes
35	64.0	Yes
36	64.0	Yes

Table 5 Summary of Influent Sediment Concentrations for Removal Efficiency and Sediment Mass Loading Capacity Testing

Run #	Influent Concentration (mg/L)[1]	Mass Loading Rate (g/min) / Influent Concentration (mg/L)			Mean (g/min / mg/L)	COV	Compliance (COV ≤0.10)
1	199.2	79.684/222.4	71.254/198.8	73.421/204.9	74.786/208.7	0.059	Yes
2	198.7	72.947/204.4	71.542/200.5	71.050/199.1	71.846/201.3	0.014	Yes
3	207.6	76.765/214.0	76.078/212.1	74.802/208.5	75.882/211.5	0.013	Yes
4	206.9	74.579/206.8	73.827/204.7	76.698/212.7	75.035/208.1	0.020	Yes
5	206.4	71.473/199.2	72.769/202.9	73.820/205.8	72.687/202.6	0.016	Yes
6	201.7	71.837/199.6	69.869/194.2	72.736/202.1	71.481/198.6	0.021	Yes
7	192.5	76.030/208.6	68.750/188.7	68.555/188.1	71.112/195.2	0.060	Yes
8	196.5	68.938/194.6	68.793/194.2	68.079/192.2	68.603/193.7	0.007	Yes
9	200.3	75.724/208.2	75.717/208.2	76.698/210.9	76.046/209.1	0.007	Yes
10	210.1	76.716/212.1	75.684/209.2	77.953/215.5	76.784/212.3	0.015	Yes
11	207.6	79.630/218.3	79.324/217.5	79.230/217.2	79.395/217.7	0.002	Yes
12	212.2	75.642/210.6	72.341/201.5	77.991/217.2	75.325/209.8	0.038	Yes
13	213.8	76.223/213.6	71.644/200.8	76.026/213.1	74.631/209.1	0.035	Yes
14	193.1	73.341/204.5	70.161/195.6	71.576/199.5	71.693/199.9	0.022	Yes
15	192.8	71.950/201.8	69.240/194.2	67.053/188.1	69.414/194.7	0.035	Yes
16	209.5	76.982/213.7	72.622/201.6	74.984/208.2	74.863/207.8	0.029	Yes
17	208.6	74.300/207.6	73.063/204.1	76.084/212.5	74.482/208.1	0.020	Yes
18	204.8	71.521/200.2	76.888/215.2	71.587/200.4	73.332/205.3	0.042	Yes
19	208.2	73.469/204.8	75.491/210.4	75.419/210.2	74.793/208.5	0.015	Yes
20	207.9	73.289/204.1	75.137/209.2	72.823/202.8	73.750/205.4	0.017	Yes
21	216.6	77.079/224.1	74.625/216.9	75.527/219.6	75.744/220.2	0.016	Yes
22	204.6	72.950/212.5	69.133/201.4	68.211/198.7	70.098/204.2	0.036	Yes
23	203.4	71.897/204.3	73.674/209.3	71.943/204.4	72.505/206.0	0.014	Yes
24	202.6	71.761/203.3	75.882/214.9	72.124/204.3	73.256/207.5	0.031	Yes
25	205.1	74.170/206.5	75.237/209.5	79.091/220.2	76.166/212.1	0.034	Yes
26	211.8	70.823/203.0	74.871/214.6	76.061/218.0	73.918/211.9	0.037	Yes
27	209.0	73.412/212.0	72.218/208.6	72.610/209.7	72.747/210.1	0.008	Yes
28	206.4	73.801/210.8	74.424/212.6	74.931/214.1	74.385/212.5	0.008	Yes

29	207.9	74.074/209.1	77.161/217.9	77.710/219.4	76.315/215.5	0.026	Yes
30	204.3	77.456/216.8	72.721/203.6	74.045/207.3	74.741/209.2	0.033	Yes
31	206.2	75.993/215.5	76.855/217.9	78.112/221.5	76.987/218.3	0.014	Yes
32	205.4	74.792/212.3	71.548/203.1	74.434/211.3	73.591/208.9	0.024	Yes
33	213.2	74.044/216.0	74.477/217.2	73.060/213.1	73.860215.4	0.010	Yes
34	203.9	71.412/207.4	69.527/201.9	70.593/205.0	70.511/204.8	0.013	Yes
35	207.5	70.135/204.8	68.204/199.2	71.807/209.7	70.049/204.5	0.026	Yes
36	204.5	67.902/197.4	69.239/201.3	70.486204.9	69.209/201.2	0.019	Yes

[1]Influent concentration per Equation 1.

Table 6 Summary of Background Sediment Concentrations for Removal Efficiency and Sediment Mass Loading Capacity Testing

Run #	Background Sediment Concentration (mg/L)*			Compliance (≤ 20 mg/L)
	Sample 1	Sample 2	Sample 3	
1	2	2	2	Yes
2	2	2	2	Yes
3	2	2	2	Yes
4	2	2	2	Yes
5	2	2	2	Yes
6	2	2	2	Yes
7	2	2	2	Yes
8	2	2	2	Yes
9	2	2	2	Yes
10	2	2	2	Yes
11	2	2	2	Yes
12	2	2	2	Yes
13	2	2	2	Yes
14	2	4	4	Yes
15	2	2	2	Yes
16	2	2	2	Yes
17	2	2	2	Yes
18	2	2	2	Yes
19	2	2	2	Yes
20	2	2	2	Yes
21	2	2	2	Yes
22	2	2	2	Yes
23	2	2	2	Yes
24	2	4	4	Yes
25	2	2	2	Yes
26	2	2	2	Yes
27	2	2	2	Yes
28	2	4	8	Yes

29	2	2	2	Yes
30	2	2	2	Yes
31	2	2	2	Yes
32	2	4	7	Yes
33	2	2	2	Yes
34	2	2	2	Yes
35	2	2	2	Yes
36	2	2	2	Yes

* Values listed as 2 mg/L represent one-half of the method detection limit of 4 mg/L. Concentrations less than 4 mg/L were reported by the laboratory as < 4 mg/L.

Table 7 Adjusted Effluent Concentrations for Removal Efficiency and Sediment Mass Loading Capacity Testing

Run #	**TSS Concentration (mg/L)**						
	Effluent #	**1**	**2**	**3**	**4**	**5**	**Average**
1	Background	2	2	2	2	2	2
	Effluent	34	38	34	37	35	35.6
	Adjusted Average Sediment Concentration						**33.6**
2	Background	2	2	2	2	2	2
	Effluent	32	39	36	39	37	36.6
	Adjusted Average Sediment Concentration						**34.6**
3	Background	2	2	2	2	2	2
	Effluent	31	37	35	39	35	35.4
	Adjusted Average Sediment Concentration						**33.4**
4	Background	2	2	2	2	2	2
	Effluent	28	27	31	34	28	29.6
	Adjusted Average Sediment Concentration						**27.6**
5	Background	2	2	2	2	2	2
	Effluent	31	35	24	36	34	32.0
	Adjusted Average Sediment Concentration						**30.0**
6	Background	2	2	2	2	2	2
	Effluent	33	36	37	39	34	35.8
	Adjusted Average Sediment Concentration						**33.8**

7	Background	2	2	2	2	2	2
	Effluent	35	33	32	36	30	33.2
	Adjusted Average Sediment Concentration						**31.2**
8	Background	2	2	2	2	2	2
	Effluent	26	30	32	32	37	31.4
	Adjusted Average Sediment Concentration						**29.4**
9	Background	2	2	2	2	2	2
	Effluent	32	41	39	45	38	39.0
	Adjusted Average Sediment Concentration						**37.0**
10	Background	2	2	2	2	2	2
	Effluent	40	43	46	42	35	41.2
	Adjusted Average Sediment Concentration						**39.2**
11	Background	2	2	2	2	2	2
	Effluent	42	50	43	50	45	46.0
	Adjusted Average Sediment Concentration						**44.0**
12	Background	2	2	2	2	2	2
	Effluent	42	49	44	48	46	45.8
	Adjusted Average Sediment Concentration						**43.8**
13	Background	2	2	2	2	2	2
	Effluent	40	45	42	47	45	43.8
	Adjusted Average Sediment Concentration						**41.8**
14	Background	2	3	4	4	4	3.4
	Effluent	41	46	41	45	45	43.6
	Adjusted Average Sediment Concentration						**40.2**
15	Background	2	2	2	2	2	2
	Effluent	39	44	42	44	43	42.4
	Adjusted Average Sediment Concentration						**40.4**
16	Background	2	2	2	2	2	2
	Effluent	45	50	48	50	47	48.0
	Adjusted Average Sediment Concentration						**46.0**
17	Background	2	2	2	2	2	2
	Effluent	47	53	49	52	48	49.8

	Adjusted Average Sediment Concentration						**47.8**
18	Background	2	2	2	2	2	2
	Effluent	48	53	49	54	50	50.8
	Adjusted Average Sediment Concentration						**48.8**
19	Background	2	2	2	2	2	2
	Effluent	38	37	39	44	41	39.8
	Adjusted Average Sediment Concentration						**37.8**
20	Background	2	2	2	2	2	2
	Effluent	43	49	48	52	53	49.0
	Adjusted Average Sediment Concentration						**47.0**
21	Background	2	2	2	2	2	2
	Effluent	41	49	44	50	47	46.2
	Adjusted Average Sediment Concentration						**44.2**
22	Background	2	2	2	2	2	2
	Effluent	40	45	42	47	44	43.6
	Adjusted Average Sediment Concentration						**41.6**
23	Background	2	2	2	2	2	2
	Effluent	41	46	43	50	46	45.2
	Adjusted Average Sediment Concentration						**43.2**
24	Background	2	3	4	4	4	3.4
	Effluent	44	55	50	54	50	50.6
	Adjusted Average Sediment Concentration						**47.2**
25	Background	2	2	2	2	2	2
	Effluent	56	56	48	51	46	51.4
	Adjusted Average Sediment Concentration						**49.4**
26	Background	2	2	2	2	2	2
	Effluent	43	50	49	54	49	49.0
	Adjusted Average Sediment Concentration						**47.0**
27	Background	2	2	2	2	2	2
	Effluent	44	50	46	50	48	47.6
	Adjusted Average Sediment Concentration						**45.6**
28	Background	2	3	4	6	8	4.6

	Effluent	45	53	50	55	54	51.4
	Adjusted Average Sediment Concentration						**46.8**
29	Background	2	2	2	2	2	2
	Effluent	55	56	49	55	49	52.8
	Adjusted Average Sediment Concentration						**50.8**
30	Background	2	2	2	2	2	2
	Effluent	51	54	50	53	49	51.4
	Adjusted Average Sediment Concentration						**49.4**
31	Background	2	2	2	2	2	2
	Effluent	42	54	48	53	51	49.6
	Adjusted Average Sediment Concentration						**47.6**
32	Background	2	3	4	5.5	7	4.3
	Effluent	41	55	49	57	54	51.2
	Adjusted Average Sediment Concentration						**46.9**
33	Background	2	2	2	2	2	2
	Effluent	47	52	45	51	46	48.2
	Adjusted Average Sediment Concentration						**46.2**
34	Background	2	2	2	2	2	2
	Effluent	44	48	48	54	50	48.8
	Adjusted Average Sediment Concentration						**46.8**
35	Background	2	2	2	2	2	2
	Effluent	43	49	45	49	44	46.0
	Adjusted Average Sediment Concentration						**44.0**
36	Background	2	2	2	2	2	2
	Effluent	47	48	45	49	46	47.0
	Adjusted Average Sediment Concentration						**45.0**

Table 8. Removal Efficiency Results

Run #	Average Influent TSS (mg/L)	Average Adjusted Effluent TSS (mg/L)	Average Adjusted Drawdown TSS (mg/L)	Influent Volume (L)	Effluent Volume (L)	Drawdown Volume (L)	Mass Loading (kg)	Mass Captured (kg)	Run Removal Efficiency by Mass (%)
1	199.2	33.6	20.5	10,033.6	9,680.9	352.7	2.00	1.67	83.50
2	198.7	34.6	21.5	9,986.8	9,644.6	342.1	1.98	1.64	82.83
3	207.6	33.4	17.0	10,044.2	9,691.5	352.7	2.09	1.76	84.21
4	206.9	27.6	18.0	10,092.4	9,734.3	358.0	2.09	1.81	86.60
5	206.4	30.0	18.0	10,040.8	9,688.1	352.7	2.07	1.78	85.99
6	201.7	33.8	18.5	10,069.9	9,711.9	358.0	2.03	1.70	83.74
7	192.5	31.2	10.5	10,204.5	9,834.4	370.1	1.96	1.65	84.18
8	196.5	29.4	19.5	9,917.2	9,575.1	342.1	1.95	1.66	85.13
9	200.3	37.0	24.5	10,184.8	9,814.7	370.1	2.04	1.67	81.86
10	210.1	39.2	23.0	10,128.9	9,764.1	364.8	2.13	1.74	81.69
						Total Mass	20.34	17.08	--
								Average Removal Efficiency by Mass	**83.97**

The total mass captured for runs 1 through 10 was 37.65 pounds (17.08 kg).

Excluded Data/Results

No data was excluded for the sediment removal efficiency testing.

4.2. Sediment Mass Loading Capacity

The sediment mass loading capacity test (**Table 9)** was a continuation of the removal efficiency test. The MTFR loading rate was 7.93 gpm/ft^2 of effective filter area. Sediment mass loading per run and mass retained per run were calculated using **Equation 3** and **Equation 4** as follows:

$$Mass\ Loading\ (kg) = Influent\ TSS\ \left(\frac{mg}{L}\right)\ x\ Influent\ Volume\ (L)\ x\ 1{,}000$$

Equation 3 Sediment Mass Loading per Run

$$Mass\ Captured\ (kg) = Mass\ Loading\ (kg) - Mass\ Effluent\ (kg) - Mass\ Draindown\ (kg)$$

Equation 4 Mass Captured per Run

Table 9. Summary of Sediment Mass Loading Capacity Testing

Run #	Average Influent TSS (mg/L)	Average Adjusted Effluent TSS (mg/L)	Average Adjusted Drawdown TSS (mg/L)	Influent Volume (L)	Effluent Volume (L)	Drawdown Volume (L)	Mass Loading (kg)	Mass Captured (kg)	Run Removal Efficiency (%)
11	207.6	44.0	24.0	10,213.6	9,848.8	364.8	2.12	1.68	81.86
12	212.2	43.8	25.0	10,051.8	9,704.3	347.4	2.13	1.70	81.69
13	213.8	41.8	19.0	9,985.2	9,637.8	347.4	2.13	1.73	79.25
14	193.1	40.2	21.0	10,044.2	9,691.5	352.7	1.94	1.54	79.81
15	192.8	40.4	23.5	9,977.7	9,630.3	347.4	1.92	1.53	81.22
16	209.5	46.0	26.0	10,077.5	9,724.7	352.7	2.11	1.65	79.38
17	208.6	47.8	23.5	10,018.5	9,676.4	342.1	2.09	1.62	79.69
18	204.8	48.8	25.0	10,000.4	9,658.2	342.1	2.05	1.57	78.20
19	208.2	37.8	17.5	10,035.1	9,693.0	342.1	2.09	1.72	77.51
20	207.9	47.0	24.5	10,060.8	9,708.1	352.7	2.09	1.63	76.59
21	216.6	44.2	21.0	9,631.4	9,321.1	310.3	2.09	1.67	82.30
22	204.6	41.6	23.0	9,613.3	9,303.0	310.3	1.97	1.57	77.99
23	203.4	43.2	24.5	9,856.7	9,519.9	336.8	2.01	1.59	79.90
24	202.6	47.2	21.5	9,887.0	9,550.1	336.8	2.00	1.54	79.70
25	205.1	49.4	25.5	10,054.8	9,702.1	352.7	2.06	1.57	79.10
26	211.8	47.0	27.0	9,769.0	9,437.5	331.5	2.07	1.62	77.00
27	209.0	45.6	24.5	9,696.5	9,375.5	320.9	2.03	1.59	76.21
28	206.4	46.8	20.0	9,796.2	9,459.4	336.8	2.02	1.57	78.26
29	207.9	50.8	23.5	9,917.2	9,569.8	347.4	2.06	1.57	78.33
30	204.3	49.4	24.5	10,001.9	9,654.4	347.4	2.04	1.56	77.72
31	206.2	47.6	25.0	9,880.9	9,538.8	342.1	2.04	1.57	76.21
32	205.4	46.9	21.0	9,856.7	9,519.9	336.8	2.02	1.57	76.47
33	213.2	46.2	21.0	9,596.7	9,286.3	310.3	2.05	1.61	76.96
34	203.9	46.8	22.0	9,639.0	9,318.1	320.9	1.97	1.52	77.72
35	207.5	44.0	20.5	9,587.6	9,272.0	315.6	1.99	1.58	78.54
36	204.5	45.0	23.0	9,631.4	9,310.5	320.9	1.97	1.54	77.16
Total Mass Runs 1-35							71.43	57.15	--
Avg. Removal Eff. by Mass Through Run 35 = 80.01%					**Avg. Removal Eff. by Mass Through Run 36 = 79.96%**				

Testing was discontinued after test run 36 when the cumulative sediment removal efficiency by mass fell below 80.0%.

Excluded Data/Results

No data was excluded for the Sediment Mass Load Capacity testing. One additional run was performed after test run 35 confirming that the average sediment removal efficiency fell below 80.0% beginning with test run 36.

4.3 Operating Head

Head measurements were obtained from measuring scales mounted in both the HDS and filtration chambers. These scales were graded to 1/16 inch. The HDS scale was zeroed at the same invert elevations of the inlet and outlet pipes (top of static water) while the filtration chamber scale was zeroed at the top of the filter media bed. Given that the Aqua-Filter™ system utilizes two components, the operating heads of both the HDS pretreatment chamber and filtration chamber were measured every six minutes and coincident with the collection of effluent samples. The final head measurements in both chambers were used to calculate the drawdown water volume. **Table 10** lists the final head measurements for each of the 36 test runs.

Table 10. Summary of Operating Heads for HDS and Filtration Chamber

Run #	HDS Operating Head (inches)	Filter Operating Head (inches)
1	4.25	3.00
2	4.25	2.75
3	4.25	3.00
4	4.25	3.13
5	4.25	3.00
6	4.25	3.13
7	4.38	3.38
8	4.25	2.75
9	4.38	3.38
10	4.38	3.25
11	4.38	3.25
12	4.25	2.88
13	4.25	2.88
14	4.25	3.00
15	4.25	2.88
16	4.25	3.00

17	4.25	2.75
18	4.25	2.75
19	4.25	3.00
20	4.25	3.00
21	4.25	2.00
22	4.25	2.00
23	4.25	2.63
24	4.25	2.63
25	4.25	3.00
26	4.25	2.50
27	4.25	2.25
28	4.25	2.63
29	4.25	2.88
30	4.25	2.88
31	4.25	2.75
32	4.25	2.63
33	4.25	2.00
34	4.25	2.25
35	4.25	2.13
36	4.25	2.25

5. Design Limitations

The Aqua-Filter™ is an engineered system designed to meet site-specific installation requirements. General terms of design parameters and limitations are cited below.

Operating Head

Aqua-Filter™ technology does not require an external operating (driving) head, beyond that required to achieve flow, to achieve operating conditions.

Media Thickness

Aqua-Filter™ systems utilize a 12-inch drop in the filtration chamber between the elevations of the inlet pipe invert and the outlet pipe invert. This drop provides for a minimum of 12 inches of filter media to prevent the media from being saturated between runoff events. Greater piping invert elevation drops are acceptable and AquaShield™ engineers can assist site designers with custom conveyance configurations.

Soil Characteristics

AquaShield™ specifies that installations utilize stone backfill material. Site-specific native soils can be used as backfill provided that the material substantially conforms to the backfill specification. AquaShield™ engineers can assist contractors with backfill questions when using native soil.

Slope of Drainage Pipe

There is no specific drainage pipe slope limitation. However, site designs should consider that the Aqua-Filter™ system does require a minimum 12-inch drop in the filtration chamber between the elevations of the inlet pipe invert and the outlet pipe invert. AquaShield™ engineers can collaborate with site design engineers to facilitate an appropriate conveyance design.

Maximum Water Quality Treatment Flow Rate

The maximum water quality treatment flow rate varies by Aqua-Filter™ model size and should be taken into consideration for site designs. AquaShield™ engineers can assist site designers with managing peak flow rates.

Maintenance Requirements

Aqua-Filter™ systems should be inspected and maintained following the recommendations and guidelines included in the Inspection & Maintenance Manual at: http://www.aquashieldinc.com/-aqua-filter-resources.html. Section 6 herein includes additional maintenance information.

Installation Limitations

Pick weights vary by Aqua-Filter™ model size to include both the HDS chamber and the filtration chamber. AquaShield™ can provide contractors with model-specific pick weights prior to delivery.

Configurations

The HDS technology of the Aqua-Filter™ system is based on the tangential inlet to set up the vortex separation. The off-line configuration of the Aqua-Filter™ system can accommodate clockwise and counter clockwise flow processes. In addition, Aqua-Filter™ installations can utilize a range of inlet to outlet pipe angles. AquaShield™ engineers can assist site designers with custom configurations.

Loading

Aqua-Filter™ systems are designed for HS-25 or greater loading. Contact AquaShield™ engineering staff when heavier loading conditions are anticipated.

Pretreatment Requirements

The Aqua-Filter™ system already incorporates the pretreatment HDS chamber; thus, no additional pretreatment practice is necessary.

Depth to Seasonal High-Water Table

Aqua-Filter™ performance is independent of high groundwater conditions. AquaShield™ routinely performs buoyancy calculations for all system installations to ensure long term functionality. Anti-floatation controls can be added for system installations when necessary.

Pipe Size

Each Aqua-Filter™ system has a maximum recommended inlet and outlet pipe size. AquaShield™ engineering staff can assist with pipe sizing.

6. Maintenance Plan

The Aqua-Filter™ Inspection and Maintenance Manual is available at: http://www.aquashieldinc.com/-aqua-filter-resources.html.

The Aqua-Filter™ is designed to remove suspended sediment, debris, floatables and free-floating oil from stormwater runoff using a treatment train approach that includes a single pretreatment HDS chamber followed by a filtration chamber. Periodic removal of these captured materials is essential to ensure long term functionality. Aqua-Filter™ performance may be diminished when sediment and/or oil storage capacities are reached. An Aqua-Filter™ Inspection and Maintenance manual is provided for each site delivery to track and document system operations.

Both inspection and maintenance activities of the HDS chamber are simply performed and are accomplished from the surface. While the filtration chamber can typically be inspected from the surface, confined space entry is recommended for more detailed inspections where warranted. Confined space entry is recommended for maintenance events that include filter media removal and replacement. There are no moving parts and no product-specific tools are needed from AquaShield™. Replacement filter media (with containers) is available from AquaShield™. It is not necessary for AquaShield™ personnel to be on-site during inspection or maintenance events.

A typical maintenance event for the cleaning of the HDS chamber can be accomplished with a vacuum truck. The HDS chamber can utilize one or two manholes depending on size to facilitate inspection and maintenance events. Maintenance events for the filtration chamber should use confined space entry techniques. A built-in ingress/egress ladder is provided for Aqua-Filter™ models AF-2.1 and larger. The number of access manholes increase as filtration chamber sizes increase, such as one manhole being used for every three rows of filter media.

Inspection

Upon installation and during construction, AquaShield™ recommends that an Aqua-Filter™ system (HDS chamber plus filtration chamber) be inspected every three months and the system be cleaned as needed. Essential elements of an Aqua-Filter™ inspection include observing floating materials and measuring the accumulated sediment at the base of the HDS chamber. The integrity of the filter media and containers should also be inspected at the same time. AquaShield™ recommends that external bypass structures be inspected when performing inspections. AquaShield™ also recommends that systems be inspected and cleaned at the end of construction. During the first-year post-construction, the Aqua-Filter™ should again be inspected every three months and cleaned as needed depending on site conditions. The ultimate inspection frequency will be determined by site-specific runoff conditions. Yet, AquaShield^{TM} recommends a minimum inspection frequency of once per year post-construction.

AquaShield^{TM} recommends that the HDS chamber be cleaned once per year when the filter chamber media is replaced.

Maintenance

Clean-out frequency will ultimately be determined by post-installation and post-construction runoff conditions. As a rule, AquaShield^{TM} recommends that Aqua-Filter^{TM} systems be maintained at a minimum of once per year. There is no need to enter an HDS chamber for inspections or maintenance activities. If entry is necessary, confined space entry procedures should be employed. AquaShield^{TM} further recommends that confined space entry techniques be used for maintenance of the filtration chamber.

Cleaning of the HDS is performed by a vacuum truck but it may be warranted to remove gross debris and floatable objects by an alternate suitable means (e.g., skimming pole with net). Any accumulated oil can be vacuumed from the surface. Accumulated sediment at the base of the HDS chamber can also be removed via vacuum through the manhole(s) opening from the surface. There are no hidden or blind access chambers in the HDS which allows for a complete cleaning of the unit.

Replacement of filter media and containers should be performed when evidence of media occlusion is noted via visual impairment, decreased performance and or diminished functionality. Brown to black colored perlite is a typical indicator that media replacement is warranted.

The manhole lid(s) should be put back into place at the conclusion of inspection and maintenance activities. AquaShield^{TM} advises that all removed pollutants be disposed in accordance with all applicable 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. Additionally, this report has been subjected to public review and all comments and concerns have been satisfactorily addressed.

AquaShield™
STORMWATER TREATMENT SOLUTIONS

April 9, 2018

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

Re: Verification of Aqua-Filter™ Stormwater Filtration System to NJDEP Filtration Laboratory Testing Protocol

The AquaShield™, Inc. Aqua-Filter™ Stormwater Filtration System (Aqua-Filter™) uses a treatment train approach that includes a pretreatment hydrodynamic separator (HDS) chamber followed by a filtration chamber. An Aqua-Filter™ Model AF-2.1 recently completed verification testing in compliance with the NJDEP Filtration Laboratory Testing Protocol. As specified by the "Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology," this letter serves as the AquaShield™ statement that all procedures and requirements identified in the above-cited protocol and process document were met or exceeded. The AF-2.1 sediment removal efficiency and sediment mass loading capacity testing conducted at the AquaShield™ laboratory facility in Chattanooga, Tennessee were conducted under the direct and independent supervision of Ms. Maureen Handler of Southern Environmental Technologies of Sewanee, Tennessee. All water quality samples were analyzed by the independent analytical laboratory, AIRL, Inc. of Cleveland, Tennessee. The test sediment particle size distribution was prepared by Good Harbour Laboratories of Mississauga, Ontario and analyzed by Maxxam Analytics of Mississauga. Preparation of the verification report and the supporting documentation fulfill the submission requirements of the process document and protocol.

Sincerely,

AquaShield™, Inc.

Mark B. Miller

Mark B. Miller
Research Scientist

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www.southernenvironmental.us

April 06, 2018

Dr. Richard Magee
Executive Director
New Jersey Corporation for Advanced Technology

RE: Third party observation of testing of the Aqua-Filter AF-2.1 according to the New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 25, 2013)

Dear Dr. Magee,

The purpose of this letter is to confirm that I personally witnessed all of the AF-2.1 testing conducted at the AquaShield facility in Chattanooga, Tennessee from February 26 to April 4, 2018. I can attest that the testing was done in accordance with the above referenced protocol, as required by the Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology, for use in accordance with the Stormwater Management Rules N.J.A.C. 7:8 (January 25, 2013).

Prior to testing, I witnessed the unsealing of the test sediment that had been mixed and supplied to AquaShield by Good Harbour Laboratories of Mississauga, Ontario.

During the testing, I witnessed the sampling during every run and verified all mass measurements. I also verified all sample bottle labels and confirmed the chains of custody for all analyzed samples. I have retained copies of the field notes and this supporting information is available to you upon request.

Sincerely

Maureen Handler

Maureen Handler
Environmental Scientist

CC: Mark Miller & Stuart Ellis, AquaShield, Inc.

Southern Environmental Technologies, Inc.

900 Old Sewanee Road, Sewanee, TN 37375

Phone: 423-605-5569 Fax: 423-710-3094

www.southernenvironmental.us

April 06, 2018

Dr. Richard Magee
Executive Director
New Jersey Corporation for Advanced Technology

RE: Performance Verification of the Aqua-Filter AF-2.1

Dear Dr. Magee,

I have been contracted, as a representative of Southern Environmental Technologies, Inc., by AquaShield, Inc., to witness the performance testing of their Aqua-Filter AF-2.1, in accordance with the New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 25, 2013).

Southern Environmental Technologies, Inc. (SET) is an independent Environmental and Civil Engineering Field Services Company located in Sewanee, Tennessee.

I, the undersigned, on behalf of SET, confirm:

- that I do not have any conflict of interest in connection to the contracted testing. Potential conflict of interest may arise, in particular, as a result of economic interests, political or national affinities, family or emotional ties, or any other relevant connection or shared interest;

- that I will inform NJCAT, without delay, of any situation constituting a conflict of interest or potentially giving rise to a conflict of interest;

- that I have not granted, sought, attempted to obtain or accepted and will not grant, seek, attempt to obtain, or accept any advantage, financial or in kind, to or from any party whatsoever, constituting an illegal or corrupt practice, either directly or indirectly, as an incentive or reward relating to the award of the contract.

Aqua-Filter AF-2.1 Testing
AquaShield, Inc.

Page 2
April 6, 2018

Sincerely,

Date

Maureen Handler

____

_April 6, 2018_____________

Maureen Handler
Environmental Scientist
President
Southern Environmental Technologies, Inc.

CC: Mark Miller & Stuart Ellis, AquaShield, Inc.

Center for Environmental Systems

Stevens Institute of Technology

One Castle Point,

Hoboken, NJ 07030-0000

April 25, 2018

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

Dear Mr. Murphy,

Based on my review, evaluation and assessment of the testing conducted on a full-scale, commercially available AquaShield Aqua-Filter™ Model AF-2.1, Stormwater Filtration System with Perlite Media, and observed by Maureen Handler, President, Southern Environmental Technologies, Inc., Sewanee, Tennessee, the test protocol requirements contained in the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filtration Protocol, January 2013) were met or exceeded. Specifically:

Test Sediment Feed

The mean PSD of the AquaShield test sediments comply with the PSD criteria established by the NJDEP HDS protocol. The AquaShield removal efficiency test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification. The test sediment was shown to be finer than the sediment blend specified by the protocol (<75µm); the test sediment d_{50} was approximately 66 microns.

Removal Efficiency (RE) Testing

Thirty-six (36) removal efficiency testing runs were completed in accordance with the NJDEP test protocol. Twenty-six (26) of the 36 test runs were conducted during mass loading and 10 during RE testing. The flow rate and influent sediment concentration were 95.2 gpm and 200 mg/L. The system did not occlude or reach maximum driving head during the test process, but the average removal efficiency (on a mass basis) dropped below 80% after test run 35 so testing was suspended and deemed complete as per the QAPP and protocol. The Aqua-Filter™ demonstrated an average sediment removal efficiency on a mass basis of 80% over the course of the 35 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted as a continuation of RE testing. Mass loading test runs were conducted using identical testing procedures and targets as those used in the RE runs. Testing concluded after test run 36, when the cumulative sediment removal efficiency by mass fell below 80.0%.

The total influent mass loaded through run 35 was 157.5 lb. (71.43 kg) and the total mass captured by the Aqua-Filter™ was 126.0 lb. (57.15 kg). This is equivalent to a sediment mass loading capacity of 10.5 lb./ft^2 of effective filtration treatment area.

No maintenance was performed on the test system during the entire testing program.

Scour Testing

The Aqua-Filter™ is designed for off-line installation. Consequently, scour testing is not required.

Sincerely,

Richard S Magee

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

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.*

AquaShield™, Inc. *Verification Testing of the Aqua-Filter™ Model AF-2.1 with Perlite Media in Accordance with the NJDEP Laboratory Testing Protocol 2013, Quality Assurance Project Plan*. February 21, 2018.

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

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

VERIFICATION APPENDIX

Introduction

- Manufacturer: AquaShield™, Inc., 2733 Kanasita Drive, Suite 111, Chattanooga, Tennessee 37343. *General Phone: (423) 870-8888*. Website: www.aquashieldinc.com.

- MTD: Aqua-Filter™ Stormwater Filtration System (Aqua-Filter™). Verified Aqua-Filter™ models are shown in **Table A-1.**

- TSS Removal Rate: 80%

- Off-line installation

Detailed Specification

- **Table A-1** includes Aqua-Filter™ MTFRs and maximum allowable drainage areas for the verified models. **Table A-2** lists the HDS dimensions including the sedimentation areas and the wet volumes. **Table A-3** includes Aqua-Filter™ model scaling ratios while **Table A-4** lists storage capacities compared to the maximum allowable drainage areas.

- Head constraints for the Aqua-Filter™ will vary based on site-specific conditions. The Aqua-Filter™ filtration chamber requires a minimum inlet invert to outlet invert drop of 12 inches.

- Drain down flow through the Aqua-Filter™ is regulated by post-filtration flow control orifices. Drain down in a clean filter is approximately 50 minutes.

- Pick weights and installation procedures vary with model size. AquaShield™ provides contractors with project-specific unit pick weights and installation instructions as warranted prior to delivery.

- Inspection and Maintenance Manual provided for each project installation and is available to download at: http://www.aquashieldinc.com/-aqua-filter-resources.html.

- According to N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow the Aqua-Filter™ system to be used in series with a settling chamber (such as a hydrodynamic separator) or a media filter (such as a sand filter) to achieve an enhanced TSS removal rate.

Table A-1. Aqua-Filter™ Model MTFRs and Maximum Allowable Drainage Area

Aqua-Filter™ Model	Number of Filter Bags	Effective Filtration Treatment Area (ft^2)	MTFR (cfs)[1]	Maximum Allowable Drainage Area (acres)[2]
AF-2.1	12	12	0.21	0.21
AF-3.2	24	24	0.42	0.42
AF-4.3	36	36	0.64	0.63
AF-5.4	48	48	0.85	0.84
AF-6.5	60	60	1.06	1.05
AF-7.6	72	72	1.27	1.26
AF-7.7	84	84	1.49	1.47
AF-8.8	96	96	1.70	1.68
AF-8.9	108	108	1.91	1.89
AF-8.10	120	120	2.12	2.10
AF-8.11	132	132	2.34	2.31
AF-9.12	144	144	2.55	2.52
AF-9.13	156	156	2.76	2.73
AF-10.14	168	168	2.97	2.94
AF-10.15	180	180	3.19	3.15
AF-10.16	192	192	3.40	3.36
AF-11.17	204	204	3.61	3.57
AF-11.18	216	216	3.82	3.78
AF-12.10 Twin	240	240	4.25	4.20
AF-12.11 Twin	264	264	4.67	4.62
AF-13.12 Twin	288	288	5.10	5.04
AF-13.13 Twin	312	312	5.52	5.46

1. Calculated based on 0.0177 cfs/ft^2 of effective filtration treatment area.
2. From Table A-4.

Table A-2. Standard HDS Dimensions of Aqua-Filter™ Models

Aqua-Filter™ Model	HDS Diameter (ft)	HDS Depth (ft)	HDS Surface Area (ft^2)	HDS Effective Sedimentation Area (ft^2)[1]	HDS Wet Volume (ft^3)[2]
AF-2.1	2.5	3.2	4.9	4.01	15.7
AF-3.2	3.5	4.4	9.6	8.26	42.2
AF-4.3	4.5	5.5	15.9	13.67	87.5
AF-5.4	5.0	5.5	19.6	17.27	107.8
AF-6.5	6.0	5.5	28.3	25.18	155.7
AF-7.6	7.0	5.5	38.5	34.59	211.8
AF-7.7	7.0	5.5	38.5	34.59	211.8
AF-8.8	8.0	5.5	50.3	45.48	276.7
AF-8.9	8.0	5.5	50.3	45.48	276.7
AF-8.10	8.0	5.5	50.3	45.48	276.7
AF-8.11	8.0	5.5	50.3	45.48	276.7
AF-9.12	9.0	5.5	63.6	57.86	349.8
AF-9.13	9.0	5.5	63.6	57.86	349.8
AF-10.14	10.0	5.5	78.5	71.73	431.8
AF-10.15	10.0	5.5	78.5	71.73	431.8
AF-10.16	10.0	5.5	78.5	71.73	431.8
AF-11.17	11.0	5.5	95.0	87.09	522.5
AF-11.18	11.0	5.5	95.0	87.09	522.5
AF-12.10 Twin	12.0	5.5	113.1	103.93	622.1
AF-12.11 Twin	12.0	5.5	113.1	103.93	622.1
AF-13.12 Twin	13.0	5.5	132.7	122.26	729.9
AF-13.13 Twin	13.0	5.5	132.7	122.26	729.9

1. The effective sedimentation area corresponds to the inlet side of the arched baffle within the pretreatment HDS chamber.
2. The HDS wet volume includes the entire volume inside the HDS manhole corresponding to the HDS diameter.

Table A-3. Aqua-Filter™ Model Scaling Ratios

Aqua-Filter™ Model	MTFR (cfs)	Effective Filtration Treatment Area (EFTA) (ft^2)	Effective Sedimentation Area (ESA) (ft^2)[1]	Wet Volume (WV) (ft^3)	Ratio MTFR to EFTA	Ratio ESA to EFTA	Ratio WV to EFTA
AF-2.1	0.21	12	16.01	26.7	0.0177	1.33	2.2
AF-3.2	0.42	24	32.26	64.2	0.0177	1.34	2.7
AF-4.3	0.64	36	49.67	120.5	0.0177	1.38	3.3
AF-5.4	0.85	48	65.27	151.8	0.0177	1.36	3.2
AF-6.5	1.06	60	85.18	210.7	0.0177	1.42	3.5
AF-7.6	1.27	72	106.59	277.8	0.0177	1.48	3.9
AF-7.7	1.49	84	118.59	288.8	0.0177	1.41	3.4
AF-8.8	1.70	96	141.48	364.7	0.0177	1.47	3.8
AF-8.9	1.91	108	153.48	375.7	0.0177	1.42	3.5
AF-8.10	2.12	120	165.48	386.7	0.0177	1.38	3.2
AF-8.11	2.34	132	177.48	397.7	0.0177	1.34	3.0
AF-9.12	2.55	144	201.86	481.8	0.0177	1.40	3.3
AF-9.13	2.76	156	213.86	492.8	0.0177	1.37	3.2
AF-10.14	2.97	168	239.73	585.8	0.0177	1.43	3.5
AF-10.15	3.19	180	251.73	596.8	0.0177	1.40	3.3
AF-10.16	3.40	192	263.73	607.8	0.0177	1.37	3.2
AF-11.17	3.61	204	291.09	709.5	0.0177	1.43	3.5
AF-11.18	3.82	216	303.09	720.5	0.0177	1.40	3.3
AF-12.10 Twin	4.25	240	343.93	842.1	0.0177	1.43	3.5
AF-12.11 Twin	4.67	264	367.93	864.1	0.0177	1.39	3.3
AF-13.12 Twin	5.10	288	410.26	993.9	0.0177	1.42	3.5
AF-13.13 Twin	5.52	312	434.26	1,015.9	0.0177	1.39	3.3

Table A-4. Aqua-Filter™ Maximum Allowable Drainage Area (acres)

Aqua-Filter™ Model	MTFR (cfs)	Storage Capacity/ft^2 of Filtration Area (lbs/ft^2)[1]	EFTA (ft^2)	Storage Capacity (lbs)	Maximum Allowable Drainage Area (acres)[2]
AF-2.1	0.21	10.5	12	126	0.21
AF-3.2	0.42	10.5	24	252	0.42
AF-4.3	0.64	10.5	36	378	0.63
AF-5.4	0.85	10.5	48	504	0.84
AF-6.5	1.06	10.5	60	630	1.05
AF-7.6	1.27	10.5	72	756	1.26
AF-7.7	1.49	10.5	84	882	1.47
AF-8.8	1.70	10.5	96	1,008	1.68
AF-8.9	1.91	10.5	108	1,134	1.89
AF-8.10	2.12	10.5	120	1,260	2.10
AF-8.11	2.34	10.5	132	1,386	2.31
AF-9.12	2.55	10.5	144	1,512	2.52
AF-9.13	2.76	10.5	156	1,638	2.73
AF-10.14	2.97	10.5	168	1,764	2.94
AF-10.15	3.19	10.5	180	1,890	3.15
AF-10.16	3.40	10.5	192	2,016	3.36
AF-11.17	3.61	10.5	204	2,142	3.57
AF-11.18	3.82	10.5	216	2,268	3.78
AF-12.10 Twin	4.25	10.5	240	2,520	4.20
AF-12.11 Twin	4.67	10.5	264	2,772	4.62
AF-13.12 Twin	5.10	10.5	288	3,024	5.04
AF-13.13 Twin	5.52	10.5	312	3,276	5.46

1. Based on test results of 126.0 lbs. of sediment captured before mass capture efficiency dropped below 80%.
2. Maximum Allowable Drainage Area (acres) = Weight of TSS captured before capture efficiency drops below 80%/600 lbs. per acre of drainage area annually.