New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device

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Contents

1. Overview

This document is the laboratory testing procedures required for stormwater filtration manufactured treatment devices (MTD) seeking verification in the State of New Jersey, as required by the Stormwater Management Rules, N.J.A.C. 7:8. This document shall be adhered to by manufacturers, New Jersey Corporation for Advanced Technology (NJCAT) and entities preforming or overseeing the testing of a filtration MTD to meet that verification requirement.

2. Definitions

Detention Time
The period of time during TSS Removal Efficiency Testing that is calculated by dividing the operational wet volume of the filtration MTD at maximum treatment flow rate (MTFR) by the target flow rate during the test run.

Test Sediment
Material that is hard, firm, and inorganic with a specific gravity of 2.65, which is uniformly distributed and complies with the composition and particle size distribution criteria detailed in Table 1, Section 5.

3. Laboratory Testing Criteria

A. Laboratory Qualifications

Information regarding laboratory testing qualifications can be found at: http://www.njcat.org/ in the document entitled "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."

B. Analysis of TSS Samples

Analysis of all Total Suspended Solids (TSS) samples shall be done in accordance with ASTM: D3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples." TSS is defined as any particulate test sediment that is transported to the filtration MTD during flow conditions.

C. Temperature

The temperature of the water for all testing shall not exceed 80 degrees Fahrenheit.

D. Background TSS Levels

Background levels of TSS shall be no more than 10% of the target influent concentration in all tests. Background TSS is defined as the TSS present in the source water used for testing. The maximum allowable background concentration is 20 mg/L. The use of flocculants is not an acceptable means to reduce background TSS levels.

E. MTD Size and Availability

A full scale, commercially available filtration MTD shall be tested in the laboratory in the same configuration and with the same components as typically used in actual installations. See Section 5 for information regarding the scaling of filtration MTDs. A single full scale commercially available cartridge or filtration module may be tested in the laboratory so long as the ratio of effective sedimentation area to effective filtration treatment area is equal to or less than the ratio utilized in commercially available units. The effective sedimentation area is defined as the area within a filtration MTD where sedimentation occurs, and the effective filtration treatment area is defined as the surface area of the filtration media layer within a filtration MTD. In addition, the ratio of wet volume to effective filtration treatment area must also be equal to or less than the ratio utilized in commercially available units. The wet volume is defined as the sump and wet influent piping of a filtration MTD. The test configuration will determine the critical application parameters of the filtration MTD, which shall include the following:

1. Ratio of Effective Filtration Treatment Area to Effective Sedimentation Area;
2. The ratio of wet volume to effective filtration treatment area
3. Flow rate per unit surface area of filtration media (gpm/ft^2) at the MTFR, which is defined as the highest flow rate that can be conveyed through the MTD while both achieving a performance claim based on the TSS Removal Efficiency Testing procedures described in Section 5 of this protocol and allowing for sufficient operational longevity so as not to cause an excessive maintenance frequency;
4. Flow rate (gpm) per standard or draindown cartridge or module at MTFR, if applicable;
5. Minimum and maximum driving head;
6. Depth of media; and
7. Media composition and gradation.

4. Scour Testing For On-line Approval

In the event that a manufacturer would like to pursue verification for an on-line system, a scour test is required to ensure that previously captured sediment will not be released or discharged. On-line systems are those in which all conveyed flows are routed through the filtration MTD without the use of an external bypass or other upstream diversion. Scour testing shall be conducted at the maximum flow rate that the manufacturer intends to convey through the filtration MTD. Scour test results will determine the maximum allowable flow rate conveyed through the drainage system for on-line use. Therefore, if the maximum flow rate through the drainage system where the filtration MTD is place on-line exceeds that maximum allowable flow rate, the filtration MTD cannot be placed on line. Only flows passing through the internal components of the filtration MTD shall be utilized for scour testing.

A. Scour Testing Procedure

This test shall be performed utilizing a full-scale, commercially available filtration MTD. The sedimentation chamber(s) shall be pre-loaded to 50% of the manufacturer's recommended maximum sediment storage volume. The pre-load shall be consistent with the particle size distribution (PSD) described in Table 1. Three samples of the test sediment shall be obtained for PSD analysis and the results reported accordingly. The average of the three test sediment samples shall be used to assess compliance with the target PSD.

If applicable, a false floor may be installed in the sedimentation chamber of the filtration MTD at a level below the 50% maximum sediment storage volume and then covered with sufficient test sediment to

achieve 50% of the maximum sediment storage volume. In doing so, the level of the false floor shall be at least four inches below the 50% maximum sediment storage volume. Following pre-loading of sediment and prior to commencing the scour test, the test sediment layer shall be leveled. Commencement of the scour test shall start within 96 hours of pre-loading the filtration MTD.

When applicable, the filtration MTD shall be filled with clear water to its normal, dry weather operating depth. Clear water is defined as water with a background TSS concentration of less than 20 mg/L.

Following pre-loading and the addition of clear water, the scour test shall commence by conveying clear water through the MTD at increasing flow rates up to the target maximum conveyance rate. The flow rate shall be increased to the target flow rate within five minutes of commencement of the test. The flow rate shall then remain constant at the target maximum flow rate for the remainder of the test duration. Effluent samples shall be collected and time stamped every two minutes after achieving the maximum target flow rate. A minimum of 15 effluent samples shall be collected over the duration of the test. The flow rate shall be recorded continuously so that the effluent samples can be compared to corresponding flow rate. Samples shall only be taken from the effluent of the MTD and shall not include any externally bypassed flow.

A minimum of eight background samples of the clear water shall be collected at evenly spaced intervals throughout the duration of the scour test (occurring at the target maximum flow rate). All samples (background and effluent) shall be analyzed for TSS in accordance with ASTM D3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples." The maximum allowable background concentration in the clear water shall not exceed 20 mg/L.

B. Sampling Procedures

Effluent sampling shall be conducted using one of the methods cited in Section 5G entitled "Effluent Sampling Test Methods", including the Effluent Grab Sampling, Isokinetic or Automatic Effluent Sampling Methods.

C. Scour Testing Results

All effluent sample results from a scour test shall be adjusted for background concentration [adjusted effluent concentration = recorded effluent concentration– background concentration (maximum allowable background TSS concentration is 20 mg/L)]. All background sample results shall be graphed with respect to time of collection so that the proper background TSS concentration at the time of effluent sample collection can be used for determining the adjusted effluent concentration. All adjusted effluent concentrations from a scour test shall be included in the calculation of the average effluent TSS concentration. As stated above, there shall be a minimum of 15 effluent sample results used to determine the average effluent TSS concentration.

If the average effluent TSS concentration measured during scour testing is no more than 20 mg/L above the average background concentration, the MTD qualifies for on-line installation as long as the maximum conveyance rate of the drainage system does not exceed the maximum conveyance rate used for scour testing. However, if the average effluent TSS concentration is greater than 20 mg/L above the average background TSS concentration or the conveyance rate of the drainage system exceeds the tested conveyance rate, the MTD does not qualify for on-line installation for drainage conveyance rates above the tested flow rate and shall be installed off-line. An off-line system is defined as one in which only the

MTFR is routed into the filtration MTD and all flows in excess of the MTFR are diverted around the MTD via an upstream bypass or diversion.

5. Total Suspended Solids Removal Efficiency and Sediment Mass Loading Capacity Testing

The objectives of laboratory testing of a filtration MTD are to establish a baseline for treatment performance (removal efficiency) and anticipated life cycle of the filtration MTD (Sediment Mass Loading Capacity). To ensure accurate results MTDs shall be tested in a new or restored condition, which includes maintaining the filtration MTD's sump, media, etc. to a level similar to the new condition. Removal efficiency is based on the ability of the filtration MTD to reduce the influent TSS concentration. TSS Removal Efficiency shall be established by the Effluent Sampling Test Method as described below. The testing will be conducted at MTFR (minimum of 10 test runs) until the maximum design driving head is reached. Then the influent flow rate shall be reduced to 90% of MTFR and testing shall resume until maximum design driving head is reached.

The Sediment Mass Loading Capacity is defined as the maximum mass of test sediment that can be captured by the filtration 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. Sediment Mass Loading Capacity testing is conducted as a continuation of the TSS removal efficiency testing. It is used to determine the maximum mass of test sediment that can be captured by the filtration MTD at 90% MTFR prior to an increase of head above maximum design driving head. For filtration MTDs that do not operate under a driving head, the testing is conducted at MTFR (minimum of 10 test runs) until bypass occurs or a 10% reduction in effluent flow rate from MTFR occurs. All tests shall incorporate the following minimum criteria or apparatus (A through G).

From the data collected from the controlled laboratory testing, the following graphs shall be produced to show the life cycle (performance loss) of the filtration MTD:

- Sediment mass loading vs. flow rate at specified driving head;
- Sediment mass loading vs. head loss at MTFR; and
- Sediment mass loading vs. removal efficiency at MTFR.

A. Influent Flow Rate

The influent flow rate shall be at MTFR during all test runs until the maximum design driving head is reached as a result of media occlusion. Upon reaching the maximum design driving head, the influent flow rate shall be reduced to 90% of the MTFR. For filtration MTDs that do not operate under a design driving head, the influent flow rate shall remain at MTFR.

B. Test Sediment

The Test Sediment standard shall be the Particle Size Distribution (PSD) as described in Table 1 below.

The PSD of the actual test (feed) sediment shall be determined using ASTM D 422-63 (Re-approved 2007) "Standard Test Method for Particle-Size Analysis of Soils." Three samples of the test sediment shall be obtained for PSD analysis and the results reported accordingly. The average of the three samples shall be used to assess compliance with the target PSD.

Table 1: Test Sediment Particle Size Distribution[1]	
Particle Size (Microns)	**Target Minimum % Less Than[2]**
1,000	100
500	95
250	90
150	75
100	60
75	50
50	45
20	35
8	20
5	10
2	5

1. The material shall be hard, firm, and inorganic with a specific gravity of 2.65. The various particle sizes shall be uniformly distributed throughout the material prior to use.
2. A measured value may be lower than a target minimum % less than value by up to two percentage points, A measured value may be lower than a target minimum % less than value by up to two percentage points (e.g., at least 3% of the particles must be less than 2 microns in size [target is 5%]), provided the measured d50 value does not exceed 75 microns..

C. Background Sampling

- Background TSS samples shall be obtained at a pre-determined location upstream from the introduction of the test sediment;
- Influent background samples shall be taken in correspondence with the odd numbered effluent samples (first, third, fifth, etc.);
- The time each sample is collected shall be recorded. The background data shall be plotted on a curve for use in adjusting the effluent samples for background concentration;
- Background concentrations shall not exceed 20 mg/L.

D. Test Sediment Feed

The test sediment feed shall include a method to introduce the test sediment within the following parameters:

1. The test sediment feed rate and total mass of test sediment introduced during each test run shall be a precisely known quantity;
2. A test run comprises the time interval during which the addition of a known quantity of Test Sediment is added to the filtration MTD at a predetermined target concentration. The test run shall be a minimum of 30 minutes;
3. A minimum of ten (10) test runs at MTFR shall be conducted at an influent TSS concentration of 200 mg/L. Additional test run(s) may be conducted to determine the sediment mass load capacity using an influent TSS concentration of 200 mg/L or 400 mg/L. The test runs will

continue until the maximum design driving head is reached. Then the influent flow rate will be reduced to 90% of MTFR and test runs will continue until the maximum design driving head is reached. Once this occurs the filter is considered to be occluded and testing may stop. Filtration MTDs that do not require a driving head for operation/treatment shall continue testing at MTFR until bypass occurs, or a reduction in effluent flow rate of 10% MTFR occurs and the sediment mass loading capacity is determined;

4. The test sediment feed rate shall be introduced at a rate within 10% of the targeted value of 200 mg/L (180 – 220 mg/L) or 400 mg/L (360 – 440 mg/L) influent concentration;
5. Test sediment shall be injected using an auger, vibratory hopper, well-mixed slurry injection system or other suitable means of sediment addition that provides a consistent, calibrated concentration of solids. Three test sediment feed samples shall be collected from the injection point, to include one sample at the start of dosing, one sample in the middle of the test run, and one sample just prior to the conclusion of the dosing. Each sample shall be collected in a clean container over an interval timed to the nearest second and shall be a minimum 0.1 liter or collection interval shall not exceed one minute, whichever comes first. In general the sample collection time should be as short as possible. Samples shall be weighed to the nearest milligram and the concentration coefficient of variance (COV, defined by standard deviation divided by mean) shall not exceed 0.10. Note that the mass extracted for calibration samples should be subtracted from the total mass introduced to the system when calculating removal efficiency.
6. As an alternative to the injection calibration test above, corresponding influent and effluent sample pairs can be collected to validate the target influent TSS concentration. For a paired sample, the effluent sample shall be collected one detention time after the influent sample is collected.

E. Flow Measurements

- A flow meter or equivalent device shall be located either upstream or downstream of the filtration MTD;
- Flow meters used in this protocol shall be calibrated as required by the instrument manufacturer. Copies of flow meter calibrations shall be included in the final report. The flow meter data logger shall record flows at a minimum of once per minute.
- The flow rate can also be measured by time to fill a known volume ("timed bucket method") or weight of volume.

F. Head Measurements

Either a data logging depth gauge or standpipe shall be used during all test runs. If using a data logging depth gauge, the water level shall be recorded at a minimum frequency of at least every 10 seconds for the entire run including startup and drain down of the vault. If using a standpipe, the water level shall be recorded at a minimum of five minute intervals, as well as the start and end of each test run, and when samples are collected. The minimum tolerance of the depth gauge or standpipe shall be to within +/- 0.125 inches.

G. Effluent Sampling Test Methods

Effluent sampling shall be performed through the use of one of the following methods, depending on flow rate: the Effluent Grab Sampling Method, Isokinetic Sampling Method or the Automatic Effluent Sampling Method. For flows less than 0.5 cfs (225 gpm), the Effluent Grab Sampling Method must be utilized. For flow greater than 0.5 cfs, either the Isokinetic Sampling Method or the Automatic Effluent Sampling Method may be employed.

Effluent Grab Sampling Method

This method allows for conducting manual sample collection procedures. The effluent sample location shall be either end of pipe or in-line, and should consider the distance from the filtration MTD, sample container size to minimize the potential for spilling, and sediment capture method (e.g., sweeping motion or isokinetic).

1. After initiating and stabilizing the flow rate at MTFR as well as the sediment feed, effluent sampling shall not begin until the filtration MTD has been in operation for a minimum of three detention times. For systems with no wet sump, as long as all influent is dosed to the target sediment concentration, the requirement of three detention times is eliminated.
2. The average influent TSS concentration shall be calculated using the total mass of the test sediment added during dosing divided by the volume of water that flowed through the filtration MTD during dosing as follows:

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

   The volume of water that flows through the filtration MTD shall be calculated by multiplying the average flow rate by the time of sediment injection only.
3. If the test sediment feed is interrupted for measurement, the next effluent sample shall be collected following a minimum of three detention times.
4. The minimum sample size collected shall be 500 milliliters (ml).
5. A minimum of five evenly spaced effluent samples shall be collected downstream of the filtration MTD during each test run. The time interval between samples shall not exceed 15 minutes. Any internally bypassed water shall be included in the sample.
6. For filtration MTDs that have backwash or post-operation drawdown flows, the effluent shall be volumetrically quantified and sampled. Two evenly spaced samples shall be collected of the backwash or drawdown effluent to determine the TSS concentration and included in the removal efficiency calculations (see below in item 8).
7. All effluent samples shall be analyzed to determine TSS concentration in accordance with ASTM D3977-97 (re-approval 2007) "Standard Test Methods for Determining Sediment Concentrations in Water Samples."
8. Removal efficiency shall be calculated as follows:

$$\text{Removal Efficiency (\%)} = \frac{\left(\begin{array}{c}\text{Average Influent}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Test Water}\end{array}\right) - \left(\begin{array}{c}\text{Adjusted Effluent}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Test Water}\end{array}\right) - \left(\begin{array}{c}\text{Average}\\ \text{Drawdown Flow}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Drawdown Water}\end{array}\right)}{\begin{array}{c}\text{Average Influent TSS Concentration x}\\ \text{Total Volume of Test Water}\end{array}} \text{ x } 100$$

Notes:

Test Water:	Volume of water flowing through filtration MTD during addition of test sediment. Adjusted Effluent TSS Concentration is adjusted for background TSS concentration.
Influent Mass:	Average Influent TSS Concentration x Total Volume of water flowing through the filtration MTD during the addition of test sediment or Total Mass Added.
Effluent Mass:	Adjusted (for background TSS concentration) Effluent TSS Concentration x Total Volume of water flowing through the filtration MTD during the addition of test sediment.

Drawdown Mass: Average Drawdown TSS Concentration x Total Volume of water flowing from the filtration MTD during drawdown.

Isokinetic Sampling Method
The use of isokinetic sampling procedures may be applicable for this method depending on water depth in the effluent piping. This procedure shall include a minimum of three evenly spaced, vertically and centrally aligned sampling tubes. Flows from the tubes shall be composited. With isokinetic sampling, the sampling tube's intake flow velocity is equal to the pipe flow velocity at the sample tube's location. For flows greater than 0.5 cfs (225 gpm), three intake points shall be used in the pipe. For flows less than 0.5 cfs, only the Effluent Grab Sampling Method is acceptable. Additionally, each of the applicable test conditions described in the effluent grab sampling method shall be met.

Automatic Effluent Sampling Method
This method allows for the use of automated sampling equipment positioned downstream of the filtration MTD. This procedure requires three automatic samplers each having its own inlet tube. The three inlet tubes shall be evenly spaced, vertically aligned and centrally located. The intake elevations shall be at approximately 25, 50 and 75% of the flow depth at MTFR. The samples collected from each sample time interval may be composited for analysis.

The sampling equipment shall be positioned at a distance of no more than three feet from the outlet of the filtration MTD. Each sample container within the auto-sampler shall be at least 0.5 liter in size. The auto-sampler equipment shall be calibrated and properly cleaned in compliance with the manufacturer's recommendations. For flows less than 0.5 cfs, only the Effluent Grab Sampling Method is acceptable. Additionally, each of the applicable test conditions described in the effluent grab sampling method shall be met.

6. Scaling of Filtration MTDs

The TSS removal rate determined for the tested full scale, commercially available filtration MTD may be applied to other model sizes of that filtration MTD provided that appropriate scaling principles are applied. Scaling the tested filtration MTD to determine other model sizes and performance without completing additional testing is acceptable provided that:

A. Depth of media, composition of media, and gradation of media remain constant;

B. The ratio of the MTFR to effective filtration treatment area (filter surface area) is the same or less than the tested filtration MTD; **and**

C. The ratio of effective sedimentation area to effective filtration treatment area is the same or greater than the tested filtration MTD; and

D. The ratio of wet volume to effective filtration treatment area is the same or greater than the tested filtration MTD.

If requirements (B) and (C) are not met, then a second full scale, commercially available filtration MTD with an MTFR difference of at least 250% is required to be tested to validate the alternative scaling methodology. Testing of the similar model shall follow the same TSS Removal Efficiency Testing and Sediment Mass Loading Capacity procedures as described in Section 5. The scaling methodology shall be deemed valid if the TSS removal efficiency of the similar filtration MTD is within five percentage points of the TSS removal efficiency of the first tested filtration MTD.

7. Units of Measure

All dimensions shall be consistent with standard units utilized in stormwater management design.

- **Area**: square feet
- **Concentration**: milligrams/liter
- **Flow Rate**: cubic feet per second, gallons per minute
- **Hydraulic Loading Rate**: gallons per minute per square foot
- **Length/Distance**: inches, feet
- **Velocity**: feet per second
- **Volume**: cubic feet, milliliter, liter, gallons

Appendix - Requirements for Filtration MTDs

A. TSS Removal Efficiency

TSS removal efficiency is based on the ability of the filtration MTD to reduce the influent TSS concentration. Since all TSS removal efficiency test runs for filtration MTDs are to be conducted at MTFR the estimated annual TSS removal rating will be a simple average as opposed to a weighted average.

B. Maximum Allowable Inflow Drainage Area

The maximum impervious inflow drainage area per filter cartridge or module shall be computed by the below equation. This equation is based upon the requirement that the minimum interval between required filter maintenance shall be one year. For information on the Verification requirements for Maintenance refer to 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" for details on the submittal process which is available at http://www.njcat.org/.

Maximum Inflow Drainage Area (acres)

$$= \frac{\text{Weight of TSS Before 10\% Loss in MTFR (LBS)}}{\text{600 LBS per Acre of Drainage Area Annually*}}$$