NJCAT TECHNOLOGY VERIFICATION

EcoPure BioFilter^{TM} 3-Cell

Advanced Drainage Systems, Inc.

April 2021

Table of Contents

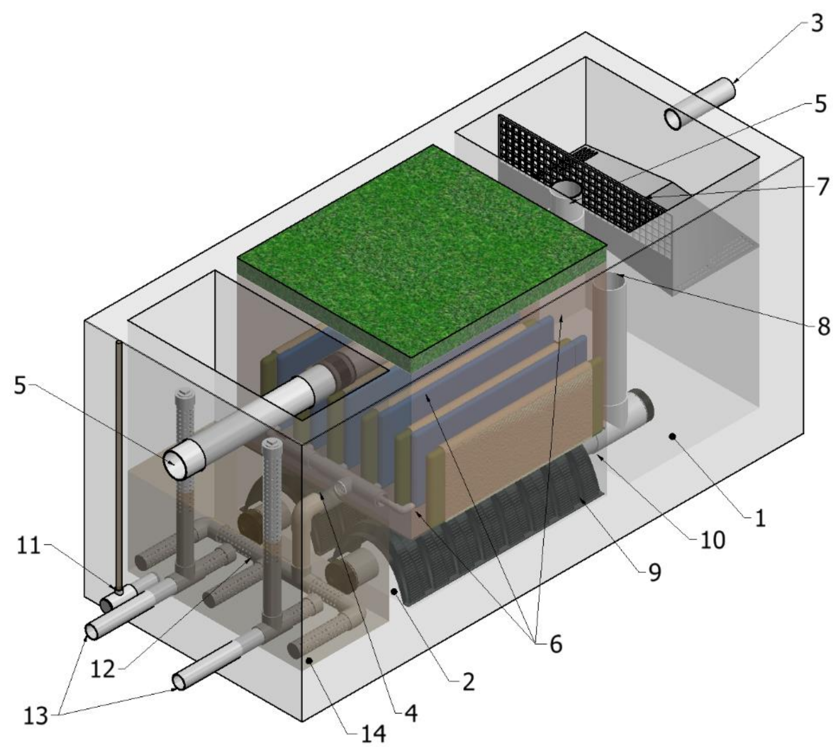
List of Figures

List of Tables

1. Description of Technology

The EcoPure BioFilter™ Three-Cell Filtration System (EcoPure 3-Cell), shown in **Figure 1**, is a stormwater manufactured treatment device (MTD) with engineered biofiltration media designed for removing traditional stormwater pollutants. The EcoPure 3-Cell allows for a high treatment flow rate with a smaller footprint than conventional bioretention and filtration (e.g., sand filter) systems.

The EcoPure 3-Cell removes pollutants from water by four mechanisms: 1) screening, 2) gravitational settling, 3) filtration, and 4) adsorption. The first cell of the EcoPure 3-Cell removes debris/trash and allows for gravity-driven settling of coarse particles of sediment, prior to introduction of water to the second cell, the biofiltration cell, which is designed to remove sediment and particulate-bound pollutants (e.g, nutrients such as phosphorus) through filtration and adsorption, while supporting plantings. The third (polishing) cell of the EcoPure 3-Cell contains a different media with a higher adsorption capacity for metals. Only the zinc, copper, and phosphorus removal capabilities of the EcoPure 3-Cell were performance tested for this verification. However, this testing was performed in the presence of sediment (removal performance of which was previously tested in the EcoPure 2-Cell testing program and was confirmed by in-house measurements during this testing program).



1	Pretreatment Gravitational and Trash-removal Cell
2	Biofiltration Cell
3	Pipe or Surface Influent
4	Cell 2 Effluent Pipe
5	High-flow Bypass
6	Bioretention Cell Internal Manifold
7	Trash Screen
8	Riser Pipes (two symmetrical pipes; only one visible here)
9	Infiltrator® Chambers
10	Gravel Layer
11	Standpipe for Measuring Hydrostatic Head
12	Third Cell Influent Manifold
13	Effluent Pipe (2)
14	Polishing Cell

Figure 1 The EcoPure BioFilter™ 3-Cell

The EcoPure 3-Cell, shown in three dimensions in **Figure 1**, is assembled inside a 4' x 10.5' concrete vault and consists of a pre-filtration gravitational settling and trash-removal cell (**Label 1**), a biofiltration cell (**Label 2**), and a polishing cell for enhanced removal of additional dissolved contaminants (**Label 14**). The structure contains a PVC influent pipe (**Label 3**) (which could be a curb, gutter, grated inlet, or straight-in pipe), and two PVC effluent pipes (**Label 13**), a high-flow bypass pipe (**Label 5**), and an internal manifold (**Label 6**) through which water flows to the polishing cell (**Label 14**). For this testing, the upper biofiltration cell did not include plants. The (third) polishing cell of the Eco-Pure 3-Cell contains a bed of proprietary high-adsorption-capacity media.

The flow path for the EcoPure 3-Cell is shown in **Figure 2a**. Stormwater runoff enters the concrete structure via an influent pipe or surface inlet (**Label 3**) and begins to fill the first cell of the structure (**Label 1**), which is 3' x 4' and contains a stainless steel trash screen (**Label 7**) for removal of large debris and dispersion of the influent water such that the turbulence is reduced. Leaf and trash debris are collected, and the coarse sediment particles in the influent settle out in this first cell. When the water surface elevation in the pretreatment cell reaches the level of the top of the "riser" pipes, the water exits via two 6"-diameter solid-wall riser pipes (**Label 8**; two symmetrical PVC pipes; one is visible in **Figure 1**) and flows into the bottom of the second cell. The first cell also includes a third solid-wall riser pipe at a 16" higher elevation, which serves as the inlet to the internal high-flow bypass (**Label 5**). Water then flows into the second cell (**Label 2**) and through the filtration bioretention media, driven by hydrostatic head. In the second cell, the water fills from the bottom through Infiltrator® chambers (**Label 9**) and a gravel layer (**Label 10**), is distributed through multiple manifold inlets, then flows horizontally and vertically through the bioretention media bed, where pollutants are removed, and then flows downward through multiple manifold outlets, and out through the second-cell effluent pipe (**Label 4**) into the bottom of the 2' x 4' third cell (**Label 14**), below the polishing media bed. The water is then distributed to the polishing bed via a perforated three-pronged pipe manifold (**Label 12)** that allows the water to flow upward through the engineered adsorptive media bed (**Label 14**) for maximum contact and metals removal. The water exits the system via two 4" vertical perforated pipes connected to an effluent pipe (**Label 13**). The standpipe (**Label 11**), used to measure hydrostatic head during testing, is part of the tested unit only. In between storm events, the water in the second and third cells drains down to the level of their respective effluent pipe inverts, and the water in the first cell drains down to the level of the top of the two riser pipes (**Label 8 in Figure 1**).

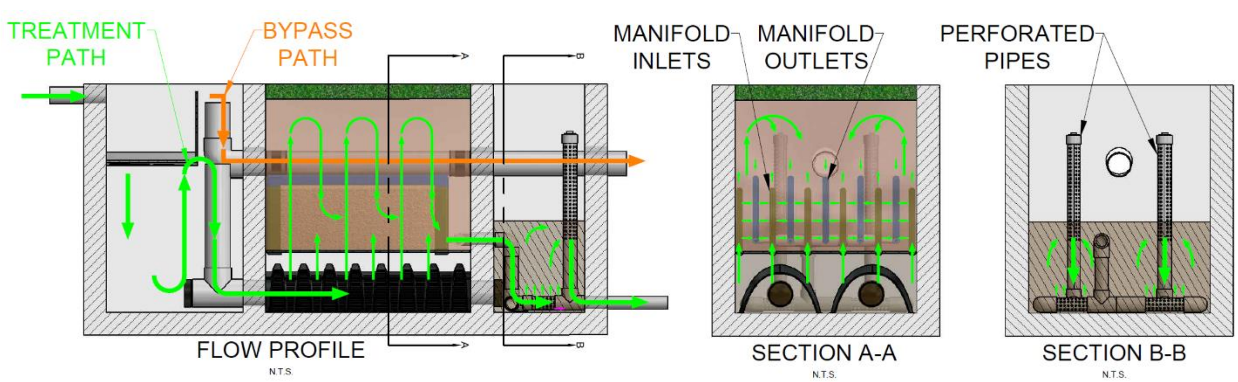


Figure 2a Flow Path of the EcoPure BioFilter™ 3-Cell

Figure 2b provides section dimensions for the tested EcoPure 3-Cell. The 4’ x 10.5’ EcoPure 3-Cell has 60 square feet of effective filtration treatment area (EFTA) in the second cell. The maximum treatment flow rate (MTFR) is 58 gpm. The depth of the polishing bed is 24 inches, and the EFTA of this cell is 8 square feet.

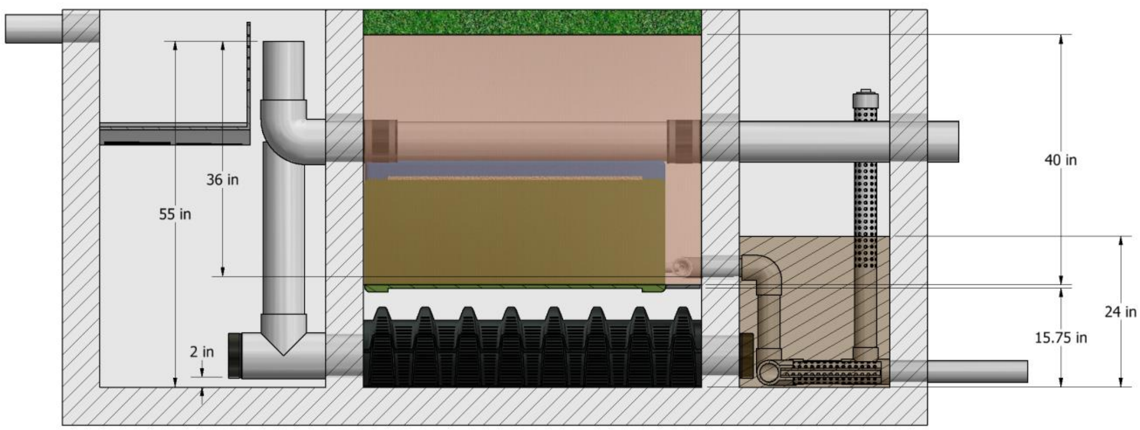


Figure 2b Key Dimensions of the EcoPure BioFilter™ 3-Cell

2. Laboratory Testing

Beginning in June 2020, one EcoPure BioFilter™ 3-Cell, 4’ x 10.5’ commercial size unit was installed at the BaySaver Laboratory in Mount Airy, Maryland, to evaluate the performance of the EcoPure BioFilter™ 3-Cell for the removal of copper, zinc, and phosphorus, in the presence of Total Suspended Solids (TSS). William R. Warfel, Boggs Environmental Consultants, Inc. (BEC) provided third-party review and oversight of all testing and data collection under general guidance of the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 2013)*, with additional guidance provided by the TAPE protocol (State of Washington Department of Ecology Publication no. 11-10-061, August 2011 revision of Publication no. 02-10-037, *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE)*). All copper, zinc, and phosphorus concentration samples were analyzed by Fredericktowne Labs (FTL), and their sister-lab Summit Environmental Technologies, Inc. (SET). All sediment particle size distribution (PSD) analyses were performed by Environmental Consulting Services (ECS), using the methodology of ASTM D422. All TSS analyses were performed at the BaySaver Laboratory using ASTM D3977 under the oversight of BEC. Prior to the start of testing, a Quality Assurance Project Plan (QAPP), revision dated June 3, 2020, was submitted, and approved by the New Jersey Corporation for Advanced Technology (NJCAT).

2.1 Test Setup

The testing system consisted of source tanks, feed pump, flow meter, flow control valve, contaminant dosing system (consisting of a screw-auger sediment dry-doser and two peristaltic pumps), and the EcoPure 3-Cell test system (**Figure 3**). Municipal tap water was used to fill the source tanks, and then pumped to the system. An inline flow meter (Seametrics IMAG4700P, pictured in **Figure 4**) measured and recorded the flow rate at one-minute intervals. Flow rate was controlled to the target of 58 gpm by a flow control valve downstream of the flow meter. Approximately four feet upstream of the system inlet, contaminants were introduced to the feed stream via a dosing port (pictured in **Figure 5**). The sediment dosing rate was controlled by a screw-auger Velodyne Barracuda 500A volumetric feeder with a ½ HP variable speed motor. The dosing rate was calculated to deliver an amount of sediment that, when mixed with the water from the source tank, produced influent water with a target 200 mg/L test sediment concentration. The metal and phosphorus dosing rates were controlled by two Anko Products MITYFLEX 913 peristaltic pumps, which were fed from stock solutions of contaminants. The dosing rates were calculated to deliver a specific amount of contaminants that, when mixed with the water from the source tank, produced influent water with a target zinc concentration of 0.25 mg/L, a target copper concentration of 0.015 mg/L, and a target phosphorus concentration of 0.4 mg/L. These target concentrations are in adherence with the TAPE Protocol, which specifies the influent concentrations should fall within the following ranges: zinc, 0.02-0.3 mg/L; copper, 0.005-0.02 mg/L; and phosphorus 0.1-0.5 mg/L.

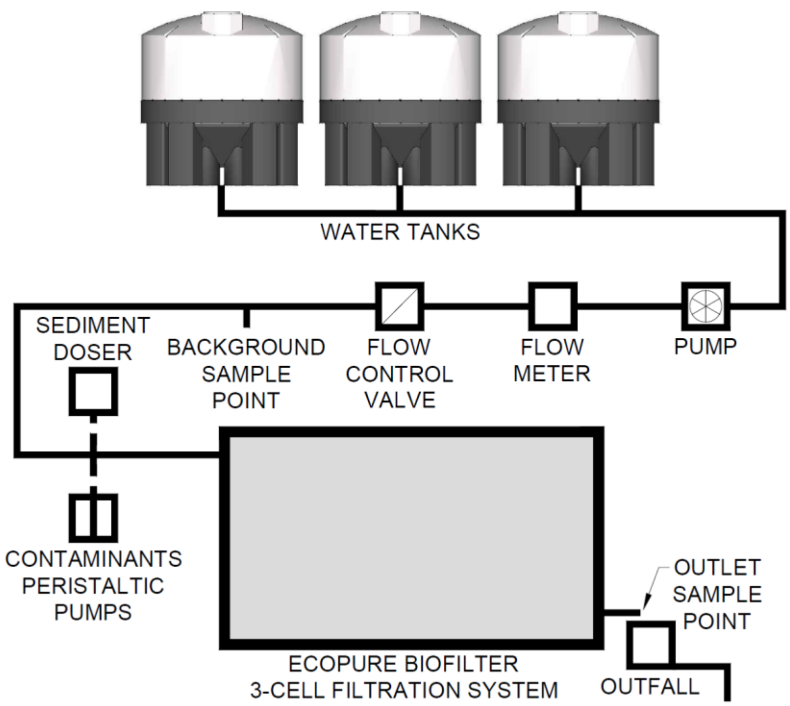


Figure 3 Schematic of the EcoPure BioFilter^{TM} 3-Cell Test Configuration

Figures 4 and 5 Photographs of Flow Meter and Sediment/Contaminant Delivery Port

The water source was potable water from the Town of Mount Airy, MD, Water and Sewer Department, obtained from an onsite tap. Municipal tap water was used to fill the source tanks, and then pumped to the system. Flow rate was controlled to the target of 58 gpm by a flow control valve. Sediment and other contaminants were introduced via the dosing port as described above. Flow entered the EcoPure BioFilter™ 3-Cell MTD via the influent pipe and began to fill the first cell. Once the water level reached the top of the riser pipes (**Label 8**; two PVC symmetrical pipes; only one is visible in **Figure 1**) in the first cell, water began to flow to the second cell and flowed through the filtration biomedia, driven by hydrostatic head. The water then flowed out the bottom of the second cell and into the polishing bed. When the water level reached the elevation of the exit pipe perforations (**Label 12**), the treated water then exited the system via the two effluent pipes (**Label 13**). A standpipe (**Label 11**) indicated the water head level during the testing.

Test Unit and Scaling Explanation

The EcoPure BioFilter™ 3-Cell model tested contains the same depth of media, composition of media, and gradation of media as all commercial models. The metals removal (adsorptive) cell effective treatment adsorptive rate is 7.25 gpm/ft^2, and the ratio of effective sedimentation treatment area to effective filtration treatment area (based on the second cell) is 0.5 (30/60). Given these parameters, ADS can effectively scale the test results for all commercial systems. See **Table A-1** for all 3-Cell Model sizes and design parameters.

Sample Collection

The grab sampling method was used for all sample collection.

For contaminant analysis, effluent samples were collected every ten minutes at the end of the effluent pipe. For TSS analysis, effluent samples were collected in coordination with each odd-numbered contaminant effluent sample (first, third, fifth). Background samples were collected upstream of the doser (**Figures 3 and 6**) in correspondence with the first and fifth contaminant effluent sample. Two evenly volume-spaced drawdown samples were taken after the flow, sediment, and contaminant feeds to the unit had been stopped.

Contaminant sample collection was done in plastic containers prepared and provided by FTL; TSS samples were collected by sweeping a wide-mouth 1-L glass jar through an open flowing stream, to ensure the full cross section of the flow was sampled. The start time for each run was recorded. The sampling schedule is provided in **Table 1**.

Contaminant stock solution and sediment delivery rates were calibrated prior to each run using a stopwatch. The duration of each run was 60 minutes.

Figure 6 Photograph of Background Sampling Port

Table 1 Sampling Schedule for the EcoPure BioFilter™ 3-Cell Tests

Time (min)	Sample(s)	Time (min)	Sample(s)
10	E1t, E1c, I1c, BG1t	50	E5t, E5c, I5c, BG5t
20	E2c	60	E6c
30	E3t, E3c, I3c	63	DD1t, DD1c
40	E4c	70	DD2t, DD2c

NOTE: E = effluent; I = influent; BG = background TSS only; DD = drawdown;
c = contaminant; t = TSS

A Chain of Custody (COC) form was used for each test run to record sampling date and time for externally analyzed samples. Copies of these forms were maintained by the BaySaver Laboratory and FTL. Sample bottles were labeled to identify the test run number and sample number, corresponding to the sample identification on the COC form. BEC was present and witnessed sampling, labeling, completion of COC forms, and packaging of samples for delivery to FTL. Each person taking or relinquishing possession of the samples was required to sign a COC form before samples changed hands.

For internal confirmation purposes, all TSS samples were analyzed in-house at the BaySaver Laboratory, under the supervision of BEC. The TSS removal capabilities of the EcoPure BioFilter^{TM} 2-Cell have already been verified by NJCAT and certified by NJDEP. These new TSS analyses were performed to confirm EcoPure 3-Cell sediment removal rates while simultaneously testing the removal capabilities for the other contaminants (metals and phosphorus).

Other Instrumentation and Measurement

Water temperature was recorded every minute by a HOBO data logger placed in the first cell of the EcoPure BioFilter^{TM} 3-Cell. The water level in the third cell of the EcoPure 3-Cell was recorded every 5 minutes by visual observation of an externally-mounted manometer (standpipe, **Label 11 in Figure 1**); these head level readings were performed by BEC. Run times were measured using a digital timer.

2.2 Test Sediment

The test sediment had the particle size distribution (PSD) presented in **Figure 7**. The test sediment blend was custom-blended using various commercially available silica sands; the resulting blended sediment was determined to have the particle size distribution meeting the specification described in the NJDEP Filter Protocol. The test sediment blend was batched, labeled, and stored in covered bins for the duration of this project. Under the supervision of BEC, 9 subsamples, taken from various locations within the test sediment containers, were composited. From the composite, 3 random samples were taken for analysis, which was performed by ECS, using the methodology of ASTM D422. The PSD test results are also summarized in **Table 2**. ECS results showed that 19% of the test sediment particles were less than 8 microns (µm) and 90% of the test sediment particles were less than 250 µm. The median particle size d_{50} value (approximately 60 µm) and a plot of the test sediment PSD (**Figure 7)** also indicated that there was no significant difference between the NJDEP target gradation and the ECS-analyzed gradation of the test sediment. Thus, the blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. ECS also analyzed the sediment samples for moisture. The average moisture content was 0.1%.

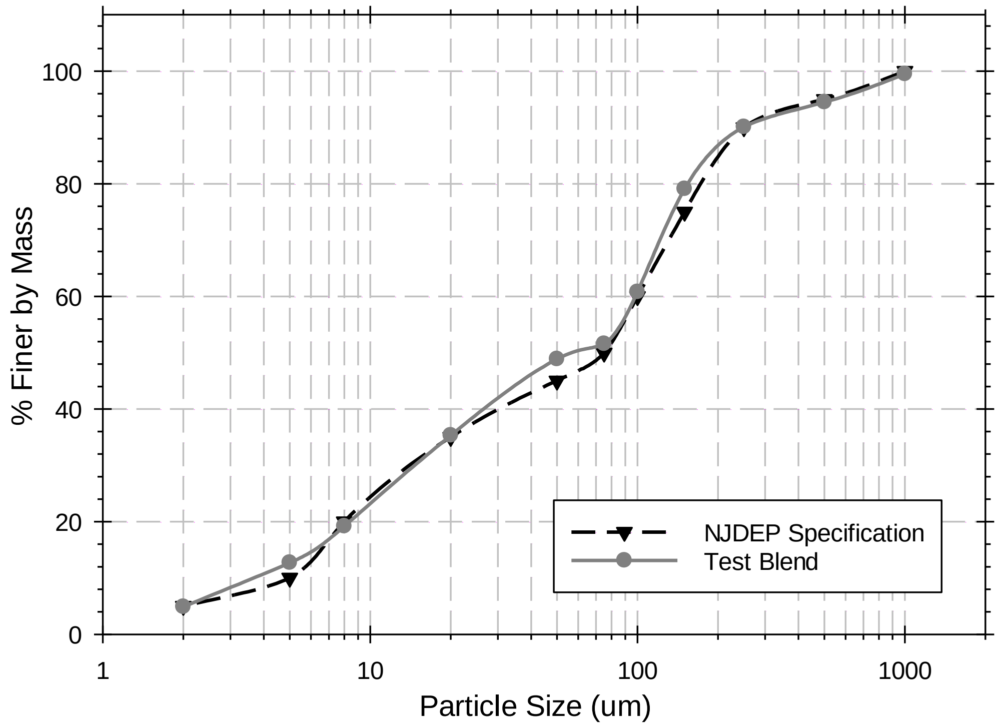


Figure 7 Average Particle Size Distribution of Test Sediment as Analyzed by ECS

Table 2 Particle Size Distribution of Test Sediment as Analyzed by ECS

Particle Size (µm)	Test Blend % Finer by Mass Analyzed by ECS				
	NJ Blend A	NJ Blend B	NJ Blend C	Average	NJDEP Specification (minimum % passing)
1000	99.5	99.6	99.5	99.5	98
500	94.5	94.5	94.4	94.5	93
250	90.3	90.1	89.9	90.1	88
150	79.4	78.9	78.7	79.0	73
100	60.8	60.2	60.0	60.3	58
75	51.5	51.1	51.0	51.2	50
50	49.3	48.9	48.6	48.9	43
20	35.0	35.9	35.0	35.3	33
8	19.4	19.4	18.8	19.2	18
5	12.5	12.8	12.8	12.7	8
2	5.0	5.0	5.0	5.0	3

2.3 Contaminant Stock Solutions

The contaminant stock solutions were made from distilled water mixed with copper, zinc, and phosphorus compounds (copper sulfate, zinc sulfate, potassium phosphate). The copper and zinc were combined into one stock solution, and the phosphorus was added to a separate stock solution. The mass of all compounds added was recorded and tracked to generate the total amount of contaminants dosed during each run. Furthermore, three influent grab samples were taken during each run to analyze the concentration of these three contaminants in the influent water.

2.4 Sediment Removal Efficiency Testing

Sediment removal efficiency testing was performed for internal confirmation only and not for NJCAT verification. However, testing procedures adhered to the guidelines set forth in Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. The target flow rate through the system was 58 gpm, with a target influent sediment concentration of 200 mg/L. All samples were collected in clean, 1-L wide-mouth bottles. Two background samples were taken at 10 and 50 minutes after the test began to ensure the tap water source met the sediment concentration requirement. According to the NJDEP Filter Protocol, these background concentrations cannot exceed a TSS of 20 mg/L.

The test sediment screw-auger feeder (doser, **Figures 3 and 5**) introduced the test sediment into the feed water stream to achieve the target influent TSS concentration of 200 mg/L. The doser was calibrated prior to each run. The total amount of sediment loaded into the doser at the beginning of each run was recorded, and the doser was unloaded at the end of each run to confirm the total amount delivered to the system. Sediment loading, unloading, and quantification was performed under the observation and oversight of BEC.

Effluent TSS sampling was performed by the grab sampling method during each run, according to the schedule in **Table 1**. During the drawdown period, two evenly volume-spaced effluent samples were collected after flow and sediment feed had stopped. All sediment concentration samples were analyzed in-house under observation by BEC using the ASTM D3977 "Standard Test Methods for Determining Sediment Concentrations in Water Samples."

2.5 Contaminant Removal Efficiency Testing

Contaminant removal efficiency testing followed the general guidelines set forth in Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs, with guidance from TAPE.

Two Anko Products MITYFLEX 913 peristaltic pumps delivered the stock solutions to influent water via the same dosing port as that used for the sediment (**Figures 3 and 5**).

Influent and effluent sampling was performed by the grab sampling method during each run, according to the schedule in **Table 1**. During the drawdown period, two evenly volume-spaced effluent samples were collected after flow and contaminant feed had stopped. All contaminant samples were analyzed by FTL/SET using EPA method 200.8 for dissolved zinc, dissolved copper, total zinc, and total copper; Standard Method 4500-P (Section E) for total phosphorus, and EPA method 300.0 for dissolved phosphorus as orthophosphate, to determine the contaminant concentrations.

3. Supporting Documentation

The Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from NJCAT states that copies of the laboratory test reports, all data from performance evaluation test runs, original data, pertinent calculations, and documentation of any maintenance activities that occur during the testing process are to be included in this section. NJCAT has decided that it would not be prudent or necessary to include all this information in verification reports. This information has been made available to NJCAT and is available upon request.

4. Testing Results

A total of 15 removal efficiency test runs were completed. The target flow rate and influent concentrations were 58 gpm, TSS 200 mg/L, dissolved copper 0.015 mg/L, dissolved zinc 0.25 mg/L, and dissolved phosphorus 0.4 mg/L.

4.1 Flow Rate

Flow rate was recorded by a Seametrics IMAG4700P Flow Meter every minute during each run. For each run, the flow rate was maintained within 10% of the 58 gpm target flow rate (52.2 – 63.8 gpm). The average flow rate for all 15 runs (100% MTFR) was 57.7 gpm. The flow rate data with coefficient of variation (COV) values for all 15 runs are summarized in **Table 3**.

4.2 Water Temperature

Temperatures were recorded every minute by a HOBO water level logger (U20L-04). The maximum temperature for all 15 runs was 78 degrees Fahrenheit, meeting the NJDEP Filter Protocol requirement to be no greater than 80 degrees Fahrenheit. Data are summarized in **Table 3**.

4.3 Head

The head level in the EcoPure 3-Cell adsorptive media bed was recorded to the nearest 1/8 inch (0.125 in) every five minutes by BEC, through visual observation of an externally-mounted manometer (standpipe, **Label 11 in Figure 1**). Maximum head for each run is summarized in **Table 4**.

Table 3 Flow Rate and Temperature Summary for All Runs

Run #	Max (gpm)	Min (gpm)	Average (gpm)	COV	Flow Compliance (COV < 0.1)	Maximum Temperature (Fahrenheit)	NJDEP Temp Compliance (< 80 F)
1	58.93	56.00	57.66	0.0123	Y	70	Y
2	61.07	56.53	58.50	0.0186	Y	70	Y
3	60.53	58.13	58.83	0.0080	Y	70	Y
4	58.93	57.87	58.51	0.0038	Y	71	Y
5	60.27	57.07	58.33	0.0100	Y	78	Y
6	58.73	49.07	57.85	0.0240	Y	70	Y
7	60.27	56.80	57.68	0.0155	Y	73	Y
8	57.60	56.27	57.05	0.0066	Y	72	Y
9	60.80	56.53	57.26	0.0134	Y	68	Y
10	57.87	56.00	56.92	0.0106	Y	68	Y
11	57.87	56.80	57.39	0.0039	Y	70	Y
12	57.60	56.00	57.19	0.0071	Y	71	Y
13	58.13	57.07	57.60	0.0046	Y	72	Y
14	57.60	56.80	57.43	0.0035	Y	70	Y
15	59.47	55.47	57.40	0.0144	Y	70	Y

Table 4 Maximum Head (inches) for All Runs

Run	Maximum Head (inches)	Run	Maximum Head (inches)
1	29.25	9	29.625
2	30.25	10	29.375
3	26.25	11	28.0
4	26.75	12	28.125
5	27.75	13	28.375
6	28.0	14	28.375
7	29.5	15	28.5
8	29.25		

Note: Per the requirements of the NJ Filter Protocol, the head measurements for this testing were made using a yard stick, read to the nearest 1/8 inch (0.125 in).

4.4 Sediment Concentration and Removal Efficiency

Background TSS

Municipal tap water was used as the water source during testing. Overall, the average background TSS concentration was 1.8 mg/L, which is well below the 20 mg/L NJDEP Protocol limit. Background TSS concentrations for each run are provided in **Table 5**. The average background TSS concentration for each run was subtracted from effluent and drawdown TSS concentrations to provide adjusted figures, per the protocol.

Sediment Dosing Rate and Influent TSS

Influent TSS concentration was calculated by dividing the total mass of sediment added during a given run by the total volume of water flowing through the MTD during the addition of test sediment during that run. The total mass of sediment added was obtained by performing a mass balance on the doser. The sediment rate was calibrated at the beginning of each run but was not measured during the run (i.e., the sediment dosing was not interrupted). The average influent TSS was 201 mg/L, with individual run averages ranging from 187 to 214 mg/L. All values are within the target range of 200 ± 20 mg/L. **Table 6** provides the sediment amount dosed for each run, and the resulting calculated influent TSS concentration. In these tables, NJDEP Protocol compliance is defined as a TSS concentration in the range 180 – 220 mg/L and COV ≤ 0.1.

Table 5 Background TSS Concentrations

Run #	Background TSS (mg/L)	NJDEP Background TSS Compliance (≤ 20 mg/L)	Run #	Background TSS (mg/L)	NJDEP Background TSS Compliance (≤ 20 mg/L)
1	0.7	Y	9	3.1	Y
2	0.4	Y	10	3.3	Y
3	1.1	Y	11	2.5	Y
4	1.5	Y	12	1.5	Y
5	3.3	Y	13	1.0	Y
6	4.5	Y	14	0.1	Y
7	2.3	Y	15	0.0	Y
8	2.1	Y			
MEAN Background TSS (mg/L) = 1.8 mg/L					

Table 6 Sediment Dosed

Run	Sediment Added to Doser (g)	Sediment Added to Doser (lb.)	Sediment Removed from Doser (g)	Sediment Removed from Doser (lb.)	Sediment Dosed to System (g)	Sediment Dosed to System (lb.)	Cum. Sediment Dosed (lb.)	Calc. Influent TSS (mg/L)	NJDEP Compliance
1	17737	39.10	15089	33.26	2648	5.84	5.84	202	Y
2	18638	41.09	15959	35.18	2679	5.91	11.74	202	Y
3	19157	42.23	16428	36.22	2729	6.02	17.76	204	Y
4	18544	40.88	15626	34.45	2918	6.43	24.19	219	Y
5	21098	46.51	17935	39.54	3163	6.97	31.17	239	Y
6	21538	47.48	18615	41.04	2923	6.44	37.61	222	Y
7	18181	40.08	15566	34.32	2615	5.76	43.38	199	Y
8	18453	40.68	15739	34.70	2714	5.98	49.36	209	Y
9	19679	43.38	17077	37.65	2602	5.74	55.09	200	Y
10	18764	41.37	16147	35.60	2617	5.77	60.86	201	Y
11	18343	40.44	15799	34.83	2544	5.61	66.47	195	Y
12	21277	46.91	18663	41.14	2614	5.76	72.24	201	Y
13	20485	45.16	17920	39.51	2565	5.65	77.89	196	Y
14	20128	44.37	17421	38.41	2707	5.97	83.86	208	Y
15	21358	47.09	18786	41.42	2572	5.67	89.53	197	Y

Effluent TSS

During each run, grab samples were taken of the effluent according to the schedule in **Table 1**, and all TSS analyses were conducted in-house. For each run, the average effluent concentration was adjusted by subtracting the average background TSS concentration. The average adjusted effluent TSS concentration during testing was 13 mg/L, with individual run averages ranging from 6 to 16 mg/L. Adjusted effluent TSS concentrations for each run are given in **Table 8**.

Drawdown TSS

According to the NJDEP Filter Protocol, the amount of sediment that leaves the filter during the drawdown period must be accounted for and documented. For each run, two evenly volume-spaced grab samples were taken of the effluent during drawdown, and all TSS analyses were conducted in-house under observation by BEC using ASTM D3977 “Standard Test Methods for Determining Sediment Concentrations in Water Samples.” For each run, the average drawdown concentration was adjusted by subtracting the average background TSS concentration. The average adjusted drawdown TSS was 12 mg/L, with individual run averages ranging from 7 to 16 mg/L. In order to estimate the volume of water during drawdown, under observation by BEC, the unit was filled prior to all testing with clean water and the drawdown volume as a function of time was measured using the timed bucket method. Total drawdown volume was estimated at 306 gallons at an operating head of 29.25 inches. The void fraction of the polishing media bed was then used to calculate the drawdown volume for incremental head levels above or below 29.25 inches. Adjusted average drawdown TSS concentrations and TSS drawdown losses are given in **Table 7**.

Table 7 TSS Removal Efficiency Drawdown Losses

Run #	Head Level at End of Run (in)	Drawdown Volume (gal)	Average Adjusted Drawdown TSS Conc. (mg/L)	Total Sediment Lost During Drawdown (g)
1	29.25	306	6.6	7.7
2	30.25	330	10.0	12.5
3	26.25	235	13.9	12.3
4	26.75	247	15.5	14.5
5	27.75	270	14.7	15.0
6	28.0	276	13.4	14.0
7	29.5	312	9.8	11.6
8	29.25	306	10.8	12.5
9	29.625	315	12.1	14.5
10	29.375	309	9.9	11.6
11	28.0	276	12.1	12.7
12	28.125	279	11.7	12.3
13	28.375	285	10.0	10.8
14	28.375	285	12.7	13.7
15	28.5	288	11.8	12.9
Average	28.5	288	11.7	12.6

Removal Efficiency Calculation

Removal efficiency for each run was calculated using the following equation from the NJDEP Filter Protocol:

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

For each run, sediment concentrations of background, influent, effluent, and drawdown, as well as calculated removal efficiency, are summarized in **Table 8**. As shown in this summary table, in-house analysis confirmed the EcoPure 3-Cell demonstrated a cumulative sediment removal efficiency of 93.6%, greater than the 88% NJCAT-verified performance for the EcoPure 2-Cell over the course of 15 test runs, while testing for simultaneous metals and phosphorus removal, confirming that the EcoPure 3-Cell meets the >80% TSS removal efficiency requirement.

Table 8 In-House Confirmed TSS Removal Efficiency

Run	Infl. TSS (mg/L)	Influent Test Water Volume (gal)	Cum. Influent Mass (g)	Adj. Effluent TSS (mg/L)	Effluent Water Volume (gal)	Cum. Eff. Mass (g)	Adj. DD TSS (mg/L)	DD Water Vol. (gal)	Cum. DD Mass (g)	Single Run Rem. Eff. (%)	Cum Rem. Eff. (%)
1	202	3459	2648	5.7	3153	68	6.6	306	8	97.1	97.1
2	202	3510	5327	9.3	3180	181	10.0	330	20	95.3	96.2
3	204	3530	8056	13.3	3295	347	13.9	235	33	93.5	95.3
4	219	3511	10974	14.6	3264	527	15.5	247	47	93.3	94.8
5	239	3500	14137	15.1	3229	712	14.7	270	62	93.7	94.5
6	222	3471	17060	14.2	3195	884	13.4	276	76	93.6	94.4
7	199	3461	19675	13.3	3149	1042	9.8	312	88	93.5	94.3
8	209	3423	22389	11.2	3117	1174	10.8	306	100	94.7	94.3
9	200	3436	24991	13.6	3121	1335	12.1	315	115	93.5	94.2
10	201	3415	27608	14.0	3106	1499	9.9	309	126	93.2	94.1
11	195	3443	30152	15.3	3167	1683	12.1	276	139	92.3	94.0
12	201	3431	32766	15.6	3152	1869	11.7	279	151	92.4	93.9
13	196	3456	35331	14.0	3171	2037	10.0	285	162	93.0	93.8
14	208	3446	38038	16.3	3161	2232	12.7	285	176	92.3	93.7
15	197	3444	40610	14.0	3156	2400	11.8	288	189	93.0	93.6
Ave	**207**	**3462**		**13**	**3174**		**12**	**288**		**93.6**	
Total Mass Loaded (lb)				**89.5**							
Total Mass Captured (lb)				**83.8**							

4.5 Contaminant Concentrations and Removal Efficiency

Background Phosphorus Concentrations

Municipal tap water was used as the water source during testing. After all performance testing was completed, ADS conducted a control run for any possible unknown background phosphorus levels in source water, sediments, and metal solutions. A discussion of phosphorus analyses is detailed later in this report; see **Appendix B**. Overall, the average background concentration for phosphorus was at or near a non-detection level of 0.05 mg/L.

Contaminant Dosing Rate and Influent Concentrations

Dissolved contaminant dosing rates were calibrated prior to each run, using a stopwatch and a standard 50 ml volume measurement. The delivery rate was not measured during the run (i.e., the contaminant dosing was not interrupted), but rather, a record was kept of the exact quantity of contaminants delivered during each run, through measurement of the stock solution volumes before and after each run. These dosed amounts of contaminants are shown in **Table 9**.

Table 9 Dissolved Contaminant Dosed Amounts for Each Run

Run	Copper Dosed (g)	Zinc Dosed (g)	Phosphorus Dosed (g)	Cum. Copper Dosed (g)	Cum. Zinc Dosed (g)	Cum. Phosphorus Dosed (g)
1	0.20	3.38	5.45	0.20	3.38	5.45
2	0.20	3.37	5.51	0.41	6.75	10.96
3	0.20	3.40	5.70	0.61	10.15	16.66
4	0.21	3.45	5.75	0.82	13.60	22.40
5	0.21	3.46	5.93	1.02	17.06	28.33
6	0.21	3.53	6.14	1.24	20.59	34.47
7	0.21	3.48	5.84	1.45	24.07	40.31
8	0.22	3.59	5.98	1.66	27.67	46.28
9	0.21	3.57	5.74	1.88	31.24	52.03
10	0.22	3.61	6.01	2.09	34.85	58.04
11	0.21	3.53	5.71	2.31	38.38	63.76
12	0.22	3.60	5.34	2.52	41.98	69.10
13	0.21	3.55	5.72	2.74	45.54	74.82
14	0.22	3.61	5.65	2.95	49.14	80.46
15	0.22	3.61	6.31	3.17	52.75	86.77

Table 10 summarizes the removal efficiency results for the metals and phosphorus contaminants. The cumulative removal efficiency for dissolved copper was 88.9%, which is above the TAPE requirement of 30%. The cumulative removal efficiency for dissolved zinc was 87.6%, which is above the TAPE requirement of 60%. The cumulative removal efficiency for dissolved phosphorus (as orthophosphate) was 71.1%, which is above the TAPE requirement for total phosphorus of 50%. The cumulative removal efficiency for total copper was 92.3%. The cumulative removal efficiency for total zinc was 82.5%.

Table 10 Summary of Contaminant Removal Efficiency Results

Contaminant	Cumulative Removal Efficiency (%)	TAPE Requirement (%)	Meets TAPE Requirement?
Dissolved Copper	88.9	30	Yes
Dissolved Zinc	87.6	60	Yes
Dissolved Phosphorus	71.1	50	Yes
Total Copper	92.3	30	Yes
Total Zinc	82.5	60	Yes

Effluent and drawdown contaminant water samples, taken in accordance with the schedule in **Table 1,** were submitted to FTL for analysis. Removal efficiency for each individual contaminant was calculated using the following equation.

$$Removal\ Efficiency\ (\%) = \frac{\begin{pmatrix} Average\ Influent \\ Contaminant \\ Concentration\ x \\ Total\ Volume\ of \\ Influent\ Water \end{pmatrix} - \begin{pmatrix} Average\ Effluent \\ Contaminant \\ Concentration\ x \\ Total\ Volume\ of \\ Effluent\ Water \end{pmatrix} - \begin{pmatrix} Average\ Drawdown \\ Contaminant \\ Concentration\ x \\ Total\ Volume\ of \\ Drawdown\ Water \end{pmatrix}}{Average\ Influent\ Contaminant\ Concentration\ x\ Total\ Volume\ of\ Influent\ Water} \text{ x 100}$$

For each run, dissolved metals and dissolved phosphorus contaminant concentrations of influent, effluent, and drawdown, as well as calculated removal efficiencies, are summarized in **Tables 11 – 15**, for dissolved copper, dissolved zinc, dissolved phosphorus (as orthophosphate), total copper, and total zinc, respectively. Total Phosphorus results are discussed in **Appendix B** for the reason explained below at the bottom of Page 18.

The average influent concentration for dissolved copper was 0.0178 mg/L, with individual run averages ranging from 0.0145 to 0.0203 mg/L. With the exception of two of these influent concentration values for dissolved copper, all were within the TAPE-guided target range of 0.005 – 0.020 mg/L. The influent dissolved copper concentrations for runs 8 and 9 were 0.0201 and 0.0203 mg/L, respectively. Per the TAPE protocol guidelines, these values were adjusted to 0.020 mg/L for the purpose of calculating removal efficiency for dissolved copper. One individual analytical data point for dissolved copper was excluded from the calculations for dissolved copper removal (Run 15, 40-minute effluent), as this value was an extreme outlier, greater than ten times all other effluent dissolved copper concentration data points. Influent concentrations for dissolved copper are given in **Table 11**.

The average influent concentration for dissolved zinc was 0.230 mg/L, with individual run averages ranging from 0.188 to 0.273 mg/L. All influent concentration values for dissolved zinc were within the TAPE-guided target range of 0.020 – 0.300 mg/L. Influent concentrations for dissolved zinc are given in **Table 12**.

The average influent concentration for dissolved phosphorus (as orthophosphate) was 0.424 mg/L, with individual run averages ranging from 0.280 to 0.548 mg/L. With the exception of two influent concentration values for dissolved phosphorus (as orthophosphate), all were within the TAPE-guided target range for total phosphorus of 0.1 – 0.5 mg/L. The influent dissolved phosphorus concentrations for runs 4 and 9 were 0.548 and 0.542 mg/L, respectively. Per the TAPE protocol guidelines, these values were adjusted to 0.500 mg/L for the purpose of calculating removal efficiency for dissolved phosphorus. Influent concentrations for dissolved phosphorus (as orthophosphate) are given in **Table 13**.

The average influent concentration for total copper was 0.0184 mg/L, with individual run averages ranging from 0.0148 to 0.021 mg/L. The TAPE protocol does not specify a target influent concentration range for total copper, but rather for dissolved copper, so for the purposes of this report, that same range will be used for total copper. With the exception of three influent concentration values for total copper, all were within the TAPE-guided target range for dissolved copper of 0.005 – 0.020 mg/L. The influent total copper concentrations for runs 3, 8, and 9 were 0.0209, 0.0207, and 0.0210 mg/L, respectively. Per the TAPE protocol guidelines, these values were adjusted to 0.020 mg/L for the purpose of calculating removal efficiency for total copper. Influent concentrations for total copper are given in **Table 14**.

The average influent concentration for total zinc was 0.227 mg/L, with individual run averages ranging from 0.177 to 0.271 mg/L. The TAPE protocol does not specify a target influent concentration range for total zinc, but rather for dissolved zinc, so for the purposes of this report, that same range will be used for total zinc. All influent concentration values for total zinc were within the TAPE-guided target range for dissolved zinc of 0.020 – 0.300 mg/L. Influent concentrations for total zinc are given in **Table 15**.

While Total Phosphorus (TP) analyses were performed for this verification, the reported influent TP concentration values are suspect. The average influent concentration, after dosing, reported for total phosphorus was 0.647 mg/L, with individual run averages ranging from 0.119 to 1.013 mg/L (with individual sample reported values ranging from non-detected to 1.41 mg/L). Therefore, the SET laboratory analysis of Total Phosphorus was brought into question, since no known source of phosphorus was present in the tap water prior to the addition of the metal and phosphorus compounds. Hence, it was expected that the Total Phosphorus concentration values should be equal to the influent concentrations resulting from the known dosed amount of phosphorus (0.4 mg/L). Since the analyses and reported TP concentrations are questionable, additional testing was performed to investigate possible explanations to this unexplained discrepancy (**Appendix B)**.

Table 11 Dissolved Copper Removal Efficiency Results

Run	Infl Diss Cu Conc mg/L	Adj Diss Cu Conc mg/L	Infl Water Vol (gal)	Infl Mass Diss Cu in Run (g)	Cum Infl Mass Diss Cu (g)	Effl Diss Cu Conc mg/L	Effl Water Vol (gal)	Effl Mass Diss Cu in Run (g)	Cum Effl Mass Diss Cu (g)	DD Diss Cu Conc mg/L	DD Water Vol (gal)	DD Mass Diss Cu in Run (g)	Cum DD Diss Cu Mass (g)	Mass Diss Cu Re-moved in Run (g)	Cum Mass Diss Cu Re-moved (g)	Sngl Run Rem Eff (%)	Cum Rem Eff (%)
1	0.0173	0.0173	3459	0.227	0.227	0.0006	3153	0.008	0.008	0.0011	306	0.001	0.001	0.218	0.218	96.0	96.0
2	0.0177	0.0177	3510	0.236	0.463	0.0009	3180	0.010	0.018	0.0018	330	0.002	0.003	0.223	0.441	94.6	95.3
3	0.0195	0.0195	3530	0.261	0.723	0.0009	3295	0.012	0.030	0.0014	235	0.001	0.005	0.248	0.689	95.0	95.2
4	0.0176	0.0176	3511	0.234	0.957	0.0046	3264	0.056	0.086	0.0048	247	0.004	0.009	0.173	0.862	74.0	90.0
5	0.0160	0.0160	3500	0.212	1.169	0.0034	3229	0.041	0.128	0.0042	270	0.004	0.013	0.166	1.028	78.5	87.9
6	0.0174	0.0174	3471	0.228	1.397	0.0048	3195	0.058	0.185	0.0061	276	0.006	0.020	0.164	1.192	71.9	85.3
7	0.0191	0.0191	3461	0.250	1.647	0.0035	3149	0.041	0.227	0.0038	312	0.004	0.024	0.204	1.396	81.7	84.8
8	0.0201	0.0200	3423	0.259	1.906	0.0035	3117	0.041	0.268	0.0027	306	0.003	0.028	0.215	1.611	82.9	84.5
9	0.0203	0.0200	3436	0.260	2.166	0.0008	3121	0.010	0.277	0.0014	315	0.002	0.029	0.249	1.860	95.7	85.9
10	0.0163	0.0163	3415	0.211	2.377	0.0012	3106	0.014	0.291	0.0019	309	0.002	0.031	0.195	2.055	92.3	86.4
11	0.0145	0.0145	3443	0.189	2.566	0.0001	3167	0.002	0.293	0.0015	276	0.002	0.033	0.186	2.240	98.3	87.3
12	0.0181	0.0181	3431	0.235	2.802	0.0012	3152	0.014	0.307	0.0017	279	0.002	0.035	0.219	2.460	93.2	87.8
13	0.0174	0.0174	3456	0.228	3.029	0.0009	3171	0.011	0.318	0.0017	285	0.002	0.037	0.215	2.675	94.5	88.3
14	0.0165	0.0165	3446	0.216	3.245	0.0012	3161	0.015	0.333	0.0017	285	0.002	0.038	0.199	2.874	92.3	88.6
15	0.0197	0.0197	3444	0.257	3.502	0.0012	3156	0.014	0.347	0.0019	288	0.002	0.041	0.241	3.115	93.6	88.9
Ave	0.0178	0.0178	3462	0.233		0.0019	3174	0.023		0.0025	288	0.003		0.208		89.0	

Table 12 Dissolved Zinc Removal Efficiency Results

Run	Infl Diss Zn Conc mg/L	Adj Diss Zn Conc mg/L	Infl Water Vol (gal)	Infl Mass Diss Zn in Run (g)	Cum Infl Mass Diss Zn (g)	Effl Diss Zn Conc mg/L	Effl Water Vol (gal)	Effl Mass Diss Zn in Run (g)	Cum Effl Mass Diss Zn (g)	DD Diss Zn Conc mg/L	DD Water Vol (gal)	DD Mass Diss Zn in Run (g)	Cum DD Diss Zn Mass (g)	Mass Diss Zn Re-moved in Run (g)	Cum Mass Diss Zn Re-moved (g)	Sngl Run Rem Eff (%)	Cum Rem Eff (%)
1	0.2163	0.2163	3459	2.83	2.83	0.0106	3153	0.13	0.13	0.0174	306	0.02	0.02	2.69	2.69	94.8	94.8
2	0.2170	0.2170	3510	2.88	5.72	0.0188	3180	0.23	0.35	0.0320	330	0.04	0.06	2.62	5.30	90.7	92.8
3	0.2627	0.2627	3530	3.51	9.23	0.0238	3295	0.30	0.65	0.0344	235	0.03	0.09	3.18	8.49	90.7	92.0
4	0.2263	0.2263	3511	3.01	12.23	0.0298	3264	0.37	1.02	0.0361	247	0.03	0.12	2.61	11.09	86.6	90.7
5	0.2060	0.2060	3500	2.73	14.96	0.0238	3229	0.29	1.31	0.0297	270	0.03	0.15	2.41	13.50	88.2	90.2
6	0.2280	0.2280	3471	3.00	17.96	0.0399	3195	0.48	1.79	0.0407	276	0.04	0.20	2.47	15.97	82.5	88.9
7	0.2483	0.2483	3461	3.25	21.21	0.0224	3149	0.27	2.06	0.0321	312	0.04	0.24	2.95	18.92	90.6	89.2
8	0.2523	0.2523	3423	3.27	24.48	0.0315	3117	0.37	2.43	0.0279	306	0.03	0.27	2.87	21.78	87.6	89.0
9	0.2730	0.2730	3436	3.55	28.03	0.0220	3121	0.26	2.69	0.0324	315	0.04	0.31	3.25	25.04	91.6	89.3
10	0.2017	0.2017	3415	2.61	30.64	0.0342	3106	0.40	3.09	0.0471	309	0.06	0.36	2.15	27.19	82.5	88.7
11	0.1880	0.1880	3443	2.45	33.09	0.0255	3167	0.31	3.40	0.0374	276	0.04	0.40	2.11	29.29	85.9	88.5
12	0.2330	0.2330	3431	3.03	36.12	0.0375	3152	0.45	3.84	0.0377	279	0.04	0.44	2.54	31.83	83.9	88.1
13	0.2367	0.2367	3456	3.10	39.21	0.0294	3171	0.35	4.20	0.0395	285	0.04	0.48	2.70	34.53	87.2	88.1
14	0.2053	0.2053	3446	2.68	41.89	0.0392	3161	0.47	4.67	0.0467	285	0.05	0.53	2.16	36.69	80.6	87.6
15	0.2520	0.2520	3444	3.29	45.18	0.0306	3156	0.36	5.03	0.0494	288	0.05	0.59	2.87	39.56	87.3	87.6
Ave	0.2298	0.2298	3462	3.01		0.0279	3174	0.34		0.0360	288	0.04		2.64		87.4	

Table 13 Dissolved Phosphorus (as Orthophosphate) Removal Efficiency Results

Run	Infl Diss Phos Conc mg/L	Adj Diss Phos Conc mg/L	Infl Water Vol (gal)	Infl Mass Diss Phos in Run (g)	Cum Infl Mass Diss Phos (g)	Effl Diss Phos Conc mg/L	Effl Water Vol (gal)	Effl Mass Diss Phos in Run (g)	Cum Effl Mass Diss Phos (g)	DD Diss Phos Conc mg/L	DD Water Vol (gal)	DD Mass Diss Phos in Run (g)	Cum DD Diss Phos Mass (g)	Mass Diss Phos Re-moved in Run (g)	Cum Mass Diss Phos Re-moved (g)	Sngl Run Rem Eff (%)	Cum Rem Eff (%)
1	0.457	0.457	3459	5.98	5.98	0.095	3153	1.13	1.13	0.043	306	0.05	0.05	4.80	4.80	80.3	80.3
2	0.405	0.405	3510	5.39	11.37	0.095	3180	1.15	2.28	0.112	330	0.14	0.19	4.10	8.90	76.1	78.3
3	0.426	0.426	3530	5.69	17.05	0.116	3295	1.44	3.72	0.140	235	0.12	0.31	4.12	13.02	72.4	76.3
4	0.548	0.500	3511	6.64	23.70	0.081	3264	1.01	4.73	0.108	247	0.10	0.42	5.54	18.55	83.3	78.3
5	0.447	0.447	3500	5.92	29.62	0.124	3229	1.51	6.24	0.128	270	0.13	0.55	4.28	22.83	72.3	77.1
6	0.428	0.428	3471	5.63	35.25	0.091	3195	1.10	7.34	0.089	276	0.09	0.64	4.44	27.27	78.8	77.4
7	0.325	0.325	3461	4.26	39.51	0.090	3149	1.08	8.42	0.102	312	0.12	0.76	3.06	30.33	71.9	76.8
8	0.372	0.372	3423	4.82	44.34	0.124	3117	1.46	9.88	0.121	306	0.14	0.90	3.22	33.56	66.8	75.7
9	0.542	0.500	3436	6.50	50.84	0.178	3121	2.10	11.98	0.198	315	0.24	1.14	4.16	37.72	64.0	74.2
10	0.472	0.472	3415	6.11	56.94	0.203	3106	2.38	14.37	0.208	309	0.24	1.38	3.48	41.20	57.0	72.3
11	0.338	0.338	3443	4.40	61.35	0.130	3167	1.55	15.92	0.063	276	0.07	1.44	2.78	43.98	63.2	71.7
12	0.280	0.280	3431	3.63	64.98	0.094	3152	1.12	17.05	0.035	279	0.04	1.48	2.47	46.45	68.0	71.5
13	0.461	0.461	3456	6.04	71.01	0.125	3171	1.50	18.54	0.153	285	0.17	1.65	4.37	50.82	72.4	71.6
14	0.368	0.368	3446	4.80	75.81	0.128	3161	1.53	20.08	0.155	285	0.17	1.81	3.10	53.92	64.6	71.1
15	0.496	0.496	3444	6.47	82.28	0.146	3156	1.74	21.82	0.166	288	0.18	1.99	4.54	58.47	70.3	71.1
Ave	0.424	0.418	3462	5.49		0.121	3174	1.45		0.121	288	0.13		3.90		70.8	

Table 14 Total Copper Removal Efficiency Results

Run	Infl Total Cu Conc mg/L	Adj Total Cu Conc mg/L	Infl Water Vol (gal)	Infl Mass Total Cu in Run (g)	Cum Infl Mass Total Cu (g)	Effl Total Cu Conc mg/L	Effl Water Vol (gal)	Effl Mass Total Cu in Run (g)	Cum Effl Mass Total Cu (g)	DD Total Cu Conc mg/L	DD Water Vol (gal)	DD Mass Total Cu in Run (g)	Cum DD Total Cu Mass (g)	Mass Total Cu Re-moved in Run (g)	Cum Mass Total Cu Re-moved (g)	Sngl Run Rem Eff (%)	Cum Rem Eff (%)
1	0.0195	0.0195	3459	0.255	0.255	0.0009	3153	0.010	0.010	0.0015	306	0.002	0.002	0.243	0.243	95.3	95.3
2	0.0187	0.0187	3510	0.248	0.503	0.0008	3180	0.010	0.020	0.0029	330	0.004	0.005	0.235	0.478	94.7	95.0
3	0.0209	0.0200	3530	0.267	0.771	0.0011	3295	0.014	0.034	0.0020	235	0.002	0.007	0.252	0.730	94.2	94.7
4	0.0189	0.0189	3511	0.251	1.022	0.0011	3264	0.014	0.047	0.0031	247	0.003	0.010	0.235	0.965	93.4	94.4
5	0.0165	0.0165	3500	0.219	1.241	0.0008	3229	0.010	0.057	0.0020	270	0.002	0.012	0.207	1.172	94.5	94.4
6	0.0185	0.0185	3471	0.243	1.483	0.0015	3195	0.018	0.076	0.0028	276	0.003	0.015	0.221	1.393	91.2	93.9
7	0.0192	0.0192	3461	0.252	1.735	0.0010	3149	0.012	0.087	0.0022	312	0.003	0.017	0.238	1.630	94.3	94.0
8	0.0207	0.0200	3423	0.259	1.995	0.0013	3117	0.015	0.102	0.0028	306	0.003	0.021	0.241	1.872	93.0	93.8
9	0.0210	0.0200	3436	0.260	2.255	0.0012	3121	0.015	0.117	0.0022	315	0.003	0.023	0.243	2.115	93.4	93.8
10	0.0153	0.0153	3415	0.198	2.453	0.0015	3106	0.018	0.135	0.0035	309	0.004	0.027	0.176	2.290	88.9	93.4
11	0.0148	0.0148	3443	0.193	2.645	0.0015	3167	0.018	0.153	0.0025	276	0.003	0.030	0.172	2.463	89.3	93.1
12	0.0184	0.0184	3431	0.239	2.885	0.0016	3152	0.019	0.172	0.0031	279	0.003	0.033	0.217	2.680	90.6	92.9
13	0.0178	0.0178	3456	0.232	3.117	0.0015	3171	0.018	0.190	0.0027	285	0.003	0.036	0.212	2.892	91.2	92.8
14	0.0171	0.0171	3446	0.224	3.341	0.0019	3161	0.022	0.212	0.0031	285	0.003	0.039	0.198	3.089	88.5	92.5
15	0.0192	0.0192	3444	0.250	3.591	0.0017	3156	0.021	0.233	0.0034	288	0.004	0.043	0.225	3.315	90.2	92.3
Ave	0.0184	0.0183	3462	0.239		0.0013	3174	0.015		0.0026	288	0.003		0.221		92.2	

Table 15 Total Zinc Removal Efficiency Results

Run	Infl Total Zn Conc mg/L	Adj Total Zn Conc mg/L	Infl Water Vol (gal)	Infl Mass Total Zn in Run (g)	Cum Infl Mass Total Zn (g)	Effl Total Zn Conc mg/L	Effl Water Vol (gal)	Effl Mass Total Zn in Run (g)	Cum Effl Mass Total Zn (g)	DD Total Zn Conc mg/L	DD Water Vol (gal)	DD Mass Total Zn in Run (g)	Cum DD Total Zn Mass (g)	Mass Total Zn Re-moved in Run (g)	Cum Mass Total Zn Re-moved (g)	Sngl Run Rem Eff (%)	Cum Rem Eff (%)
1	0.2333	0.2333	3459	3.06	3.06	0.0105	3153	0.13	0.13	0.0180	306	0.02	0.02	2.91	2.91	95.2	95.2
2	0.2190	0.2190	3510	2.91	5.97	0.0170	3180	0.20	0.33	0.0296	330	0.04	0.06	2.67	5.58	91.7	93.5
3	0.2713	0.2713	3530	3.63	9.59	0.0233	3295	0.29	0.62	0.0356	235	0.03	0.09	3.30	8.88	91.1	92.6
4	0.2227	0.2227	3511	2.96	12.55	0.0361	3264	0.45	1.07	0.0456	247	0.04	0.13	2.47	11.35	83.5	90.5
5	0.2043	0.2043	3500	2.71	15.26	0.0304	3229	0.37	1.44	0.0412	270	0.04	0.17	2.29	13.64	84.7	89.4
6	0.2207	0.2207	3471	2.90	18.16	0.0482	3195	0.58	2.02	0.0550	276	0.06	0.23	2.26	15.90	77.9	87.6
7	0.2397	0.2397	3461	3.14	21.30	0.0273	3149	0.32	2.35	0.0407	312	0.05	0.28	2.77	18.67	88.1	87.7
8	0.2533	0.2533	3423	3.28	24.58	0.0412	3117	0.49	2.83	0.0548	306	0.06	0.34	2.73	21.40	83.3	87.1
9	0.2713	0.2713	3436	3.53	28.11	0.0354	3121	0.42	3.25	0.0517	315	0.06	0.40	3.05	24.45	86.4	87.0
10	0.1877	0.1877	3415	2.43	30.53	0.0526	3106	0.62	3.87	0.0642	309	0.08	0.48	1.73	26.19	71.4	85.8
11	0.1770	0.1770	3443	2.31	32.84	0.0439	3167	0.53	4.39	0.0580	276	0.06	0.54	1.72	27.91	74.6	85.0
12	0.2253	0.2253	3431	2.93	35.77	0.0534	3152	0.64	5.03	0.0680	279	0.07	0.61	2.22	30.12	75.8	84.2
13	0.2303	0.2303	3456	3.01	38.78	0.0473	3171	0.57	5.60	0.0629	285	0.07	0.68	2.38	32.50	78.9	83.8
14	0.2070	0.2070	3446	2.70	41.48	0.0609	3161	0.73	6.33	0.0703	285	0.08	0.76	1.90	34.40	70.2	82.9
15	0.2393	0.2393	3444	3.12	44.60	0.0546	3156	0.65	6.98	0.0766	288	0.08	0.84	2.38	36.78	76.4	82.5
Ave	0.2268	0.2268	3462	2.97		0.0388	3174	0.47		0.0514	288	0.06		2.45		82.0	

4.6 Contaminant Loading

Table 16 below shows the total amount of each contaminant dosed to the system via the stock solutions. Based on the removal efficiencies for dissolved copper, zinc, and phosphorus, the amounts of contaminants captured by the system are provided in **Table 17**. This represents the loading accomplished over the course of 15 runs and may not be the full capacity of the system.

Table 16 Total Contaminants Dosed to the System

Run	Copper Dosed (g)	Zinc Dosed (g)	Phosphorus Dosed (g)	Cum. Copper Dosed (g)	Cum. Zinc Dosed (g)	Cum. Phosphorus Dosed (g)
1	0.20	3.38	5.45	0.20	3.38	5.45
2	0.20	3.37	5.51	0.41	6.75	10.96
3	0.20	3.40	5.70	0.61	10.15	16.66
4	0.21	3.45	5.75	0.82	13.60	22.40
5	0.21	3.46	5.93	1.02	17.06	28.33
6	0.21	3.53	6.14	1.24	20.59	34.47
7	0.21	3.48	5.84	1.45	24.07	40.31
8	0.22	3.59	5.98	1.66	27.67	46.28
9	0.21	3.57	5.74	1.88	31.24	52.03
10	0.22	3.61	6.01	2.09	34.85	58.04
11	0.21	3.53	5.71	2.31	38.38	63.76
12	0.22	3.60	5.34	2.52	41.98	69.10
13	0.21	3.55	5.72	2.74	45.54	74.82
14	0.22	3.61	5.65	2.95	49.14	80.46
15	0.22	3.61	6.31	3.17	52.75	86.77

Table 17 Total Dissolved Contaminants Captured by the System

Run	Copper Removal (%)	Zinc Removal (%)	Phosphorus Removal (%)	Copper Captured (g)	Zinc Captured (g)	Phosphorus Captured (g)	Cum. Copper Captured (g)	Cum. Zinc Captured (g)	Cum. Phosphorus Captured (g)
1	96.0	94.8	80.3	0.20	3.21	4.37	0.20	3.21	4.37
2	94.6	90.7	76.1	0.19	3.06	4.19	0.39	6.26	8.56
3	95.0	90.7	72.4	0.19	3.08	4.13	0.58	9.35	12.69
4	74.0	86.6	83.3	0.15	2.99	4.79	0.73	12.33	17.48
5	78.5	88.2	72.3	0.16	3.05	4.28	0.90	15.39	21.77
6	71.9	82.5	78.8	0.15	2.91	4.84	1.05	18.30	26.60
7	81.7	90.6	71.9	0.17	3.16	4.19	1.22	21.46	30.80
8	82.9	87.6	66.8	0.18	3.15	3.99	1.40	24.60	34.79
9	95.7	91.6	64.0	0.21	3.27	3.68	1.61	27.88	38.47
10	92.3	82.5	57.0	0.20	2.97	3.43	1.81	30.85	41.89
11	98.3	85.9	63.2	0.21	3.04	3.61	2.01	33.89	45.51
12	93.2	83.9	68.0	0.20	3.02	3.63	2.22	36.91	49.14
13	94.5	87.2	72.4	0.20	3.10	4.14	2.42	40.01	53.28
14	92.3	80.6	64.6	0.20	2.91	3.65	2.62	42.92	56.93
15	93.3	87.3	70.3	0.20	3.15	4.43	2.82	46.06	61.36

5. Performance Verification

The EcoPure 3-Cell used in this test demonstrated cumulative mass removal efficiencies as follows: dissolved copper 88.9%, dissolved zinc 87.6%, dissolved phosphorus (as orthophosphate) 71.1%, total copper 92.5%, and total zinc 82.5%, while also in the presence of total suspended solids (removal efficiency for which was demonstrated by the EcoPure 2-Cell New Jersey testing to be 88.0% and was exceeded while testing the removal efficiencies for the other above-mentioned contaminants). The MTFR's and maximum allowable drainage area for other EcoPure 3-Cell models are shown in **Table A-1**.

6. Design Limitations

Maximum Flow Rate

The 4’ x 10.5’ EcoPure 3-Cell system tested has an MTFR of 0.13 cfs (58 gpm; 1 gpm/ft^2 of effective filtration treatment area). The effective surface loading rate (based on the third cell) is 7.25 gpm/ft^2.

Slope

The EcoPure 3-Cell is recommended for installation with little-to-no slope to ensure proper, consistent operation. Steep slopes should be reviewed by ADS Water Quality Engineering.

Allowable Head Loss

There is an operational head loss associated with the EcoPure 3-Cell. The head loss will increase over time due to the sediment loading to the system. When configured with an internal bypass, a design head loss (measured from the invert of the effluent pipe from the third cell) of 54 inches should be used. Site-specific treatment flow rates, peak flow rates, pipe diameter, and pipe slopes should be evaluated to ensure there is appropriate head for the system to function properly.

Removal Capability

The EcoPure 3-Cell has the following removal efficiencies in the presence of TSS: dissolved copper 88.9%, dissolved zinc 87.6%, dissolved phosphorus (as orthophosphate) 71.1%, total copper 92.5%, and total zinc 82.5%.

Pre-treatment Requirements

The EcoPure 3-Cell does not require additional pretreatment.

Configurations

The EcoPure 3-Cell is available in multiple configurations, with curb, gutter, grated inlet, or straight-in pipe inlets. The EcoPure 3-Cell can be installed above, at, or below grade and with or without a planting bed to allow maximum design flexibility.

Structure Load Limitations

The EcoPure 3-Cell is typically located adjacent to a roadway and therefore, the precast vault or structure is designed to handle H-20 traffic loads. For deeper installations or installations requiring a greater load capacity, the system will be designed and manufactured to meet those requirements. The ADS Water Quality Team provides full-service technical design support throughout the life of a project and can help ensure the system is designed for the appropriate structural load requirements.

7. Maintenance Plan

*General Inspect*ion

The ADS inspection process for the EcoPure 3-Cell system is detailed in the Operation and Maintenance Guidelines and is available electronically at: EcoPure-BioFilter-Maintenance-Manual-2-21.pdf (baysaver.com). It is also provided to the owner at the time of installation and detailed in this report.

ADS recommends inspection of the EcoPure 3-Cell on a quarterly basis for the first year of service, and after every significant storm event occurring during the first six months. The definition of a significant storm event will vary depending on the geographic area, but if the event is greater than 1 inch of intensity within an hour or 3 inches within a 24-hour period, the system should be inspected. After the first year, systems should be inspected at least bi-annually and ideally before the spring or rainy season and after the summer season, or prior to fall or winter seasons. It is recommended that some general "good housekeeping" maintenance be performed at the beginning of the rainy or spring season every year.

For maintenance needs related to the top plant section of the EcoPure 3-Cell the process follows the practices used for handling standard bioretention systems (i.e., general landscaping, cover management, and replacement planting of surface plants). Additional maintenance involving removing some of the captured sediment is not possible in many bioretention systems (both generic and proprietary) in that once sediment is introduced and lost into the media of those systems, it cannot be readily extracted. For the EcoPure 3-Cell, a sizable amount of collected sediment can be removed from the pretreatment cell and the bottom cavity of the bioretention cell before it enters into the bioretention media matrix. This ability assists in "adding" to the longevity of the EcoPure 3-Cell bioretention soil media. This is explained in greater detail below in the General Inspection and Maintenance Procedure section (see the 5th and 6th paragraphs).

Inspection and General Maintenance Equipment

The following is a list of equipment recommended for inspection and general maintenance:

- Personal Protection Equipment - (pants, steel-toed shoes, safety glasses, gloves, safety vest, hard hat, etc.)
- Manhole Hook
- Traffic Cones and Signage
- Stadia Rod and Tape Measure
- Inspection Operation & Maintenance Log (provided in the O&M Manual) or other recording method
- Flashlight
- Trash Removal "Net" Device
- Shovel, rake, broom, and trash receptacle
- Vactor Truck (if more extensive maintenance is required)
- Light Duty Construction Equipment (if media replacement is required)

General Inspection and Maintenance Procedure

Routine inspection will ensure that the system is performing at optimal conditions and that the risk of flooding is low. The EcoPure 3-Cell inspection involves a visual inspection of the plant surface area, structure inlet, pretreatment cell, metals polishing bay (the final cell in an EcoPure 3-Cell) and clean-out ports. This can all be done at the surface and requires no confined-space entry into the EcoPure 3-Cell. An Inspection O&M log should be used, and dates and weather conditions should be noted.

If the EcoPure 3-Cell is located in a traffic area (i.e., roadway or automobile travel way), and inspection is not possible without entering the vehicular area, safety measures should be employed in accordance with local permitting requirements, including set-up of safety cones, traffic control, etc., prior to performing the inspection and maintenance.

A visual inspection of the general appearance of the EcoPure 3-Cell should be performed, and notes should be taken detailing the condition of the surface plant life, invasive species intrusion, erosion in the planting area and any signs of standing water or disturbed or "shifted" surface soil bed area. This general system condition should be noted in the inspection/maintenance log.

If the plant life and surface media show signs of distress, general landscaping O&M should be performed, i.e., raking, weeding (removal of invasive plants), and general planting replacement to maximize the cover area in the planting bed/media treatment cell. If signs of excessively high water levels (i.e., damp wet conditions still visible in the top planting area) are seen in the bio-media treatment cell and the last rain event was greater than 24 hours prior, further inspection should be performed to ensure the effluent pipe is not blocked. All blocked pipes should be cleared and cleaned. Inspecting the bypass piping in the pretreatment cell is also advised to see if the system is going into bypass during recent storms (i.e., signs of debris in bypass piping). If the inspection results in the conclusion that the bio-media is compromised or has reached its service life, total replacement of the media is recommended. ADS should be contacted for material specifications and replacement parts. Media replacement will involve utilizing small construction excavation equipment. It is generally agreed that if the second (bio-media) cell media is at the end of its service life, then the metals removal cell media (i.e., third cell) should be replaced, as well.

For inspection of the pretreatment cell, the manhole cover should be safely removed (i.e., using a manhole hook). A visual inspection of the condition of the surface concrete and any inlet grates should be noted. If grates are missing or inlets are damaged, contact ADS for recommendation of repair. The suspended trash grate area should be relatively clear of debris. If excessive debris is observed, a trash capture net should be employed, and debris removed. Next, a stadia rod should be sent down to the bottom of the pretreatment cell and the level of debris should be recorded in the maintenance log. When the debris in the sump reaches 10 inches in average depth, a vactor truck should be used to remove the accumulated sump debris. Employing a vactor truck for cleaning the pretreatment cell follows the typical guidelines used for cleaning hydrodynamic stormwater devices.

For inspection and cleaning of the chamber section of the EcoPure 3-Cell (open cavity under the bio-media cell), it is generally recommended that if the 10-inch sediment mark has been reached in the pretreatment cell, the owner should backwash the chamber section of the bio-media cell. With the pretreatment cell cleaned and dewatered, the cleanout risers should be exercised, and low-pressure water (60-80 psi) should be introduced to force and move sediment within the chamber cavities into the pretreatment cell (the riser tees have a removable cap to facilitate a "bottom" exit at the floor of the first cell). See the O&M guide for details of backflushing this unit. Once it is deemed that most of the sump sediment from the bio-media cell has been backflushed, clean water flow should cease. The pretreatment cell should be vacuumed dry (during this backflushing procedure), the trash rack reinstalled/repositioned, and the manhole cover replaced. The backflushing process may require confined-space entry, and all rules and precautions should be adhered to, based on OSHA requirements and the practices and procedures in place for the entity performing the work.

Disposal of material from the pretreatment cell, trash debris rack, and chamber cavity should be in accordance with the local municipality's requirements. Typically, traditional municipal landfills can be used for disposal of solids and trash obtained from servicing the EcoPure 3-Cell. The same disposal methods should be used if the media (bio-media or metals removal media) is replaced. Call ADS at 1-800-821-6710 for further information.

8. Statements

A statement from the third-party observer (Boggs Environmental Consultants, Inc.) is provided on the following page.

BOGGS
ENVIRONMENTAL CONSULTANTS

Middletown, MD & Morgantown, WV

Administrative Office:
200 W Main Street Office (301) 694-5687
Middletown, Maryland 21769 Fax (301) 694-9799

December 3, 2020

ATTENTION To Whom it May Concern

REFERENCE: No Conflict of Interest Statement for Third Party Review of
Testing Procedures Conduced on the EcoPure BioFilter™ 3-Cell Filtration System at the
BaySaver Technologies, LLC-Laboratory
1207 Park Ridge Drive
Mount Airy, MD 21771

BOGGS ENVIRONMENTAL CONSULTANTS, INC. (BEC) was hired by BaySaver Technologies, LLC (a subsidiary of Advanced Drainage Systems, Inc.) to provide Third Party Review Services and onsite observations of test runs and analysis of the EcoPure BioFilter™ 3-Cell Filtration System (EcoPure 3-Cell) to evaluate if the required testing meets established certification standards. Onsite observations and evaluations by BEC were conducted at the BaySaver Technologies Laboratory, 1207 Park Ridge Drive, Mount Airy, Maryland from June 2, 2020 to June 25, 2020.

I want to ensure you that there is no conflict of interest between BEC and BaySaver Technologies, LLC or Advanced Drainage Systems, Inc. for the following reasons:

- BEC has no ownership stake in BaySaver Technologies, LLC or Advanced Drainage Systems, Inc.
- BEC receives no commission for selling a manufactured treatment device for BaySaver Technologies, LLC or Advanced Drainage Systems, Inc.
- BEC has no licensing agreement with BaySaver Technologies, LLC or Advanced Drainage Systems, Inc., and
- BEC receives no funding or grants associated with the testing program from BaySaver Technologies, LLC or Advanced Drainage Systems, Inc.

Please give me call if you have any questions.

Sincerely,
BOGGS ENVIRONMENTAL CONSULTANTS, INC.

William R Warfel

William R. Warfel
Principal Environmental Scientist

ENVIRONMENTAL SCIENCE, ENGINEERING & INDUSTRIAL HYGIENE SERVICES

Verification Appendix: Appendix A

Specifications

Introduction

- Manufacturer – Advanced Drainage Systems, Inc, 4640 Trueman Blvd, Hilliard, OH 43026 Website: https://www.ads-pipe.com. Phone: 800-229-7283.
- MTD - EcoPure BioFilter™ 3-Cell verified models are shown in **Table A-1.**
- TSS Removal Rate – 80%
- Dissolved phosphorus (as orthophosphate) removal rate– 71%
- Dissolved copper removal rate – 89%
- Dissolved zinc removal rate – 88%
- Total copper removal rate – 92%
- Total zinc removal rate – 82%

Detailed Specification

- NJDEP sizing tables and physical dimensions of EcoPure 3-Cell verified models are attached (**Table A-1**). These sizing tables are valid for NJ following NJDEP Water Quality Design Storm Event of 1.25" in 2 hours (NJAC 7:8-5.5(a)).
- Maximum inflow drainage area
  - The maximum inflow drainage area is governed by the maximum treatment flow rate of each model as presented in **Table A-1.**
- Driving head will vary for a given EcoPure 3-Cell model based on the site-specific configuration. The maximum head available until bypass is 55” (from bottom of the vault), but the minimum head varies depending on the flow rate through the unit and the cumulative mass captured in the biofiltration cell over time. Design support is given by Advanced Drainage Systems for each project, and site-specific drawings (cut sheets) will be provided that show pipe inverts, finish surface elevation, and peak treatment and maximum flow rates through the unit.
- The drawdown flow exits via two effluent pipes at the bottom of the filter bed. A clean filter draws down in approximately 20 minutes.
- See Advanced Drainage Systems EcoPure BioFilter™ Three-Cell Filtration Design Manual I & M Section for inspection and maintenance procedures at: EcoPure-BioFilter-Maintenance-Manual-2-21.pdf (baysaver.com)

Table A-1 EcoPure BioFilter™ 3-Cell Model Sizes and Treatment Capacities

Overall Unit (ft)	Pre-treatment Cell (ft)	Filter Bed (ft)	3rd Cell Bed (ft)[4]	Effective Filtration Treatment Area (EFTA) (ft^2)[1]	Effective Sedimentation Treatment Area (ESTA) (ft^2)	ESTA/EFTA	Wet Volume (WV) (ft^3)	WV/EFTA	MTFR (cfs)[2]	Mass Capture Capacity (lbs)	Drainage Area (acres)[3]
4 x 10.5	4 x 3	4 x 4.5	4 x 2	60	30	0.50	56	0.94	0.134	194.5	0.324
4 x 13	4 x 4	4 x 5.5	4 x 2.5	75	38	0.51	73	0.97	0.167	242.4	0.404
4 x 15.5	4 x 5	4 x 6.5	4 x 3	90	46	0.51	90	1.00	0.201	291.8	0.486
4 x 18	4 x 6	4 x 7.5	4 x 3.5	105	54	0.51	106	1.01	0.234	339.6	0.566
4 x 20.5	4 x 7	4 x 8.5	4 x 4	120	62	0.52	123	1.03	0.268	389.0	0.648
8 x 15.5	8 x 5	8 x 6.5	8 x 3	180	92	0.51	179	0.99	0.401	583.5	0.973
8 x 20.5	8 x 7	8 x 8.5	8 x 4	240	124	0.52	246	1.02	0.535	778.0	1.297
8 x 26	8 x 8.5	8 x 11	8 x 5.5	315	156	0.50	304	0.96	0.702	1021.1	1.702
8 x 31	8 x 10.5	8 x 13	8 x 6.5	375	188	0.50	371	0.99	0.836	1215.6	2.026

1. Effective Filtration Treatment Area (EFTA) is defined as the surface area of the ADS AdvanEDGE pipe that is available for flow from the bioretention filter media layer.
2. Based on 1 gpm/ft^2 of EFTA.
3. Drainage Area is based on Mass Capture Capacity (194.5/60 = 3.24 lbs/ft^2 of EFTA) and the equation in the NJDEP Filter Protocol wherein drainage area is calculated by dividing the pounds of mass captured by 600 lbs/acre.
4. Based on 7.5 gpm/ft^2 of 3rd cell bed surface area.

Total Phosphorous: Appendix B

Total Phosphorus Data and Summary

The analytical laboratory concentration analysis results for Total Phosphorus (TP) are detailed below. The selected laboratory, FTL, subcontracted out this portion of the analyses to SET. Review of the data led ADS to believe these data are questionable and likely flawed.

During the course of the 15 runs, a known amount of phosphorus was dosed to the system, and the expected influent phosphorus concentration was on the order of 0.4 mg/L. The analytical results for dissolved phosphorus (as orthophosphate) are in alignment with these expectations, e.g., 0.424 mg/L average (**Table 13**), while those for influent TP are not. The major issue with the performance test TP analytical data is that the TP influent levels are much higher than the added "dissolved" phosphorus, i.e., 0.647 mg/L.

The background phosphorus levels in the clean potable water (PW) source were expected to contain minimal (non-detect) Total Phosphorus or Dissolved Phosphorus, as determined by EPA Method 365.3 and SM Method 4500-P (Section E). Following receipt of the performance test results, ADS ran a control run wherein sediment and metals (copper and zinc) were dosed to the system in the same manner as for the original 15 runs. Three influent samples were sent to FTL, as well as to Phase Separation Sciences (PSS), a laboratory located just outside of Baltimore, MD, to confirm our expectation and to document the level of TP in the influent water. The results are shown in **Table B-1**. Results are shown at 10, 30 and 50 minutes during the one-hour test.

As seen in the table, all results were as expected (phosphorus levels below the detection limits), except for those from SET for TP. The TP results from PSS were below the detection limits, and all orthophosphate, reported as phosphorus, results were below the detection limit. Only the TP results from SET were out of alignment (an average of 0.163 mg/L). This indicates an inherent issue with the execution of the method SET uses for TP.

Table B-1 EcoPure BioFilter™ 3-Cell Influent PW Phosphorous Concentrations

	mg/L					
	SET Lab		PSS Lab			
	OrthoPhos	TP	OrthoPhos	OrthoPhos	TP	TP
Result	Method 300.0	Method SM 4500-P (Section E)	Method EPA 365.3	Method SM 4500-P (Section E)	Method EPA 365.3	Method SM 4500-P (Section E)
RL	0.100	0.020	0.050	0.050	0.050	0.050
10	ND	0.195	ND	ND	ND	ND
30	ND	0.133	ND	ND	ND	ND
50	ND	0.162	ND	ND	ND	ND
Average	ND	0.163	ND	ND	ND	ND

RL = Reporting Limit; ND = Non-detect

After reviewing these data and following discussions with NJCAT, ADS agreed to run another "control" run with clean potable water only flowing through the 3-Cell, and to measure influent and effluent dissolved and total phosphorous to eliminate any concern that TP is coming from either bed media. All procedures for this additional run were overseen by BEC. Six influent and six effluent samples were taken at 10-minute intervals during this run, and the results were sent to Phase Separation Sciences (PSS). Results are shown in **Table B-2.**

Table B-2 EcoPure BioFilter™ 3-Cell Influent and Effluent Phosphorus Concentrations

Sample #	Sample Time (min)	OrthoPhosphate Method SM 4500-P (Section E)		Total Phosphorus Method SM 4500-P (Section E)		Reporting Limit (mg/L)
		Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)	
1	**10**	0.060	ND	ND	ND	0.050
2	**20**	0.055	ND	ND	ND	0.050
3	**30**	0.052	ND	ND	ND	0.050
4	**40**	0.050	ND	ND	ND	0.050
5	**50**	0.050	ND	ND	ND	0.050
6	**60**	ND	ND	ND	ND	0.050

It is therefore opined that the Total Phosphorus SET data (both influent and effluent) from the 15-run performance testing are inaccurate, and only the dissolved phosphorus data could be used as a surrogate for TP in this study, or, alternatively, no removal efficiency value for TP can be claimed.

Third Cell Metal Capacity Test: Appendix C

Third Cell Metal Capacity Test Data and Summary

For the purpose of determining the maintenance cycle of the polishing (metal removal) bed of the EcoPure 3-Cell, a bench-scale metal capacity test of the third-cell media was conducted. For maintenance of the EcoPure 3-Cell, ADS recommends replacement of the third-cell media when the second-cell media is replaced. This metal capacity test was conducted to show that the third-cell maintenance cycle is at least as long as, or longer than, that of the second cell to ensure adequate removal of copper and zinc prior to replacement.

The EcoPure BioFilter (2-Cell), verified by NJCAT and certified by NJDEP, included dosing the test unit with sediment for a total of 26 one-hour runs at 60 gpm. The test showed a maximum sediment mass capture of 194.5 lbs of sediment. Based on the requirement that the minimum interval between required filter maintenance be one year, and an assumed annual sediment loading of 600 lbs, a maximum drainage area of 0.324 acres for the tested unit was prescribed.

Had the EcoPure 3-Cell system been run for a total of 26 hours at 60 gpm, with an influent dissolved copper concentration of 0.015 mg/L, the total mass of copper dosed would be 5.31 g. Likewise, for an influent dissolved zinc concentration of 0.250 mg/L, the total mass of zinc dosed would be 88.58 g. These concentrations are essentially what was tested (Cu-0.0178 mg/L; Zn-0.230 mg/L).

The objective of the bench-scale test was to demonstrate that the third-cell media is capable of maintaining dissolved copper and dissolved zinc removal efficiencies of at least 30% and 60%, respectively, up to the mass loading amounts above, scaled to the size of the bench-scale system. The bench-scale test set-up consisted of a 2-inch diameter PVC column with a 24” deep bed of the same media used in the third-cell of the full-scale EcoPure 3-Cell test. Feed water to the system was dosed with dissolved copper and dissolved zinc, and the cumulative mass loading of these contaminants was tracked. The flow rate was set so as to have the same surface loading rate as the full-scale system (7.5 gpm/ft^2; full-scale = 60 gpm; column = 0.163 gpm).

Paired influent and effluent samples were taken over the course of 70 hours, and the samples were taken to FTL for analysis. Concentration data are given in **Table C-1**. Mass loading and cumulative mass removal data are given in **Tables C-2 and C-3**. As seen from the tables, the cumulative mass removal for dissolved copper over the duration of the test was 69.4%, and the cumulative mass removal for dissolved zinc over the duration of the test was 60.1%. These dissolved copper and dissolved zinc cumulative mass removal efficiencies exceed the targets of 30% and 60%, respectively. The total mass of copper loaded was 30.8 mg, and the total mass of zinc loaded was 337.7 mg. Scaling by a ratio of cross-sectional area (8 ft^2 for the third cell of the EcoPure, and 0.02181 ft^2 for the bench-scale column), these loading amounts are equivalent to 11.3 g of copper and 123.9 g of zinc for the full-scale EcoPure 3-Cell system; these loading amounts exceed the minimum targets of 5.31 g and 88.58 g, by 112% and 40%, respectively.

It is therefore opined that the third-cell of the EcoPure 3-Cell has a maintenance cycle at least 40% longer than that of the second-cell.

Table C-1 EcoPure BioFilter™ 3-Cell Metal Capacity Test Data: Concentrations and Individual Run Removal Efficiencies

		Dissolved Copper			Dissolved Zinc		
	Time	Influent	Effluent	Removal	Influent	Effluent	Removal
Sample #	(Hours)	(mg/L)	(mg/L)	(%)	(mg/L)	(mg/L)	(%)
1	8	0.01080	0.00248	77.0	0.03360	0.00655	80.5
2	16	0.01070	0.00225	79.0	0.03840	0.00807	79.0
3	20	0.01070	0.00272	74.6	0.02990	0.01340	55.2
4	24	0.01070	0.00250	76.6	0.02960	0.01180	60.1
5	26	0.01060	0.00349	67.1	0.05690	0.02320	59.2
6	30	0.01040	0.00428	58.8	0.05420	0.02190	59.6
7	38	0.01260	0.00427	66.1	0.19300	0.08480	56.1
8	46	0.01250	0.00419	66.5	0.19300	0.07630	60.5
9	54	0.01260	0.00462	63.3	0.19800	0.06940	64.9
10	62	0.01260	0.00422	66.5	0.20000	0.09530	52.4
11	70	0.01350	0.00413	69.4	0.21300	0.08490	60.1

Table C-2 EcoPure BioFilter™ 3-Cell Metal Capacity Test Data: Mass Loading and Cumulative Mass Removal for Dissolved Copper

		Dissolved Copper					
Sample	Time	Influent	Effluent	Cum Infl Mass	Cum Eff Mass	Cum Mass Rem	EcoPure Infl Mass
#	(Hours)	(mg)	(mg)	(mg)	(mg)	(%)	(g)
1	8	3.20	0.73	3.20	0.73	**77.0**	1.17
2	16	3.17	0.67	6.37	1.40	**78.0**	2.34
3	20	1.58	0.40	7.95	1.80	**77.3**	2.92
4	24	1.58	0.37	9.54	2.17	**77.2**	3.50
5	26	0.78	0.26	10.32	2.43	**76.4**	3.79
6	30	1.54	0.63	11.86	3.07	**74.2**	4.35
7	38	3.73	1.26	15.59	4.33	**72.2**	5.72
8	46	3.70	1.24	19.30	5.57	**71.1**	7.08
9	54	3.73	1.37	23.03	6.94	**69.9**	8.45
10	62	3.73	1.25	26.76	8.19	**69.4**	9.82
11	70	4.00	1.22	30.76	9.41	**69.4**	11.28

Table C-3 EcoPure BioFilter™ 3-Cell Metal Capacity Test Data: Mass Loading and Cumulative Mass Removal for Dissolved Zinc

Sample #	Time	Dissolved Zinc					
		Influent	Effluent	Cum Infl Mass	Cum Eff Mass	Cum Mass Rem	EcoPure Infl Mass
	(Hours)	(mg)	(mg)	(mg)	(mg)	(%)	(g)
1	8	9.95	1.94	9.95	1.94	**80.5**	3.65
2	16	11.37	2.39	21.32	4.33	**79.7**	7.82
3	20	4.43	1.98	25.75	6.31	**75.5**	9.45
4	24	4.38	1.75	30.14	8.06	**73.2**	11.05
5	26	4.21	1.72	34.35	9.78	**71.5**	12.60
6	30	8.03	3.24	42.37	13.02	**69.3**	15.54
7	38	57.16	25.12	99.54	38.14	**61.7**	36.51
8	46	57.16	22.60	156.70	60.74	**61.2**	57.48
9	54	58.64	20.55	215.34	81.29	**62.3**	78.99
10	62	59.23	28.23	274.57	109.51	**60.1**	100.71
11	70	63.08	25.14	337.66	134.66	**60.1**	123.85