NJCAT TECHNOLOGY VERIFICATION

HydroChain™ Main Header Row

Xerxes Corporation

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1. Description of Technology

HydroChain™ Chambers are open bottom arch-shaped chambers that connect together to create rows, that when embedded in stone, form underground stormwater storage systems. There are four chamber model sizes as shown below in **Figure 1**. Chamber color is dependent on the type of resin used so that chambers are typically green or black. A typical HydroChain Chamber storage system is shown in **Figure 2**.

			
M-6	C-10	S-22	S-29/S29B

Figure 1 HydroChain Open-bottom Arch-shaped Chamber Models

Figure 2 Typical HydroChain Storage System

The HydroChain Main Header Row (MHR) is the row or rows of chambers used to bring incoming stormwater into the system. Chambers in the MHR include single layers of non-woven geotextiles that prevent pollutants, like fine sediments, from entering the downstream chambers. As shown in **Figure 3**, HydroChain MHR woven geotextile is placed between the base stone and the open bottom of the MHR chambers. Untreated stormwater that enters the MHR passes through the woven geotextile into a stone base layer that is used to provide structural support, distribute treated flow to the remainder of the chambers and provide a single point of access for inspections and maintenance.

After Stormwater flows through the MHR and into the rest of the HydroChain chamber system it is either infiltrated into the soils below or passed at a controlled rate through an outlet manifold and outlet control structure. **Since this technology fits under the infiltration basin BMP in the New Jersey Stormwater BMP Manual, it is not eligible for NJDEP MTD certification.**

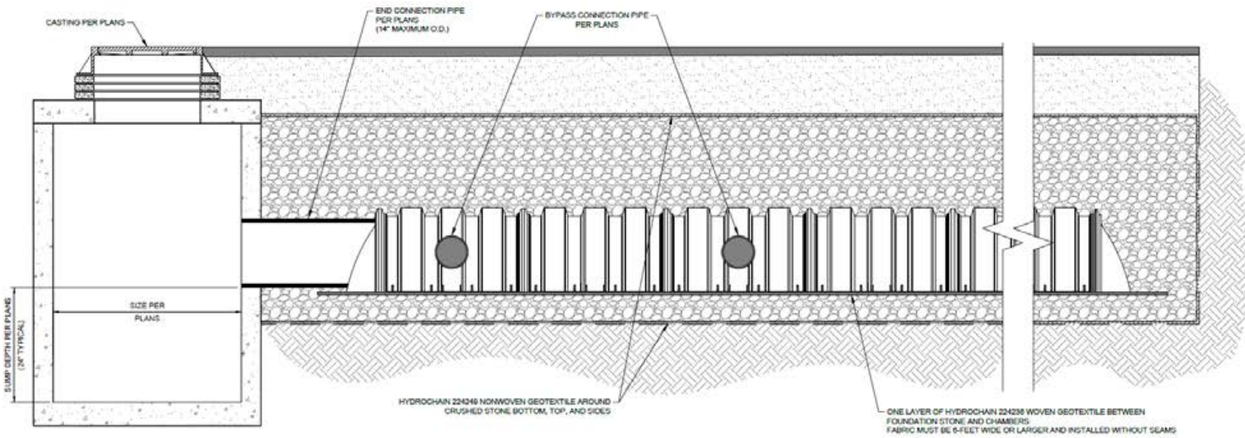

Figure 3 HydroChain Main Header Row Detail

2. Laboratory Testing

The test program was conducted at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direct supervision of Alden's senior stormwater engineer, James Mailloux. Alden has performed verification testing on Hydrodynamic Separator and Filtration Manufactured Treatment Devices (MTDs) for manufacturers under various state and federal testing protocols. Particle size distribution (PSD) analysis was conducted by GeoTesting Express, Inc., Acton, Massachusetts. GeoTesting is an A2LA ISO/IEC 17025 accredited independent laboratory. Water quality samples collected during the testing process were analyzed in Alden's Stormwater Laboratory, which is ISO 17025 accredited.

Laboratory testing was done in accordance with the New Jersey Department of Environmental Protection "Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device", January 2022 (updated April 2023), (NJDEP Filtration Protocol). Prior to starting the performance testing program, a quality assurance project plan (QAPP) was submitted to, and approved by, the New Jersey Corporation for Advanced Technology (NJCAT).

2.1 Test Setup

A Main Header Row (MHR) was constructed and tested to quantify the sediment removal and sediment mass capture efficiency. The tested MHR, shown in **Figure 4**, included two HydroChain M-6 chambers with end caps. The M-6 chamber is one of four full-scale commercially available chamber models (**Figure 1**).

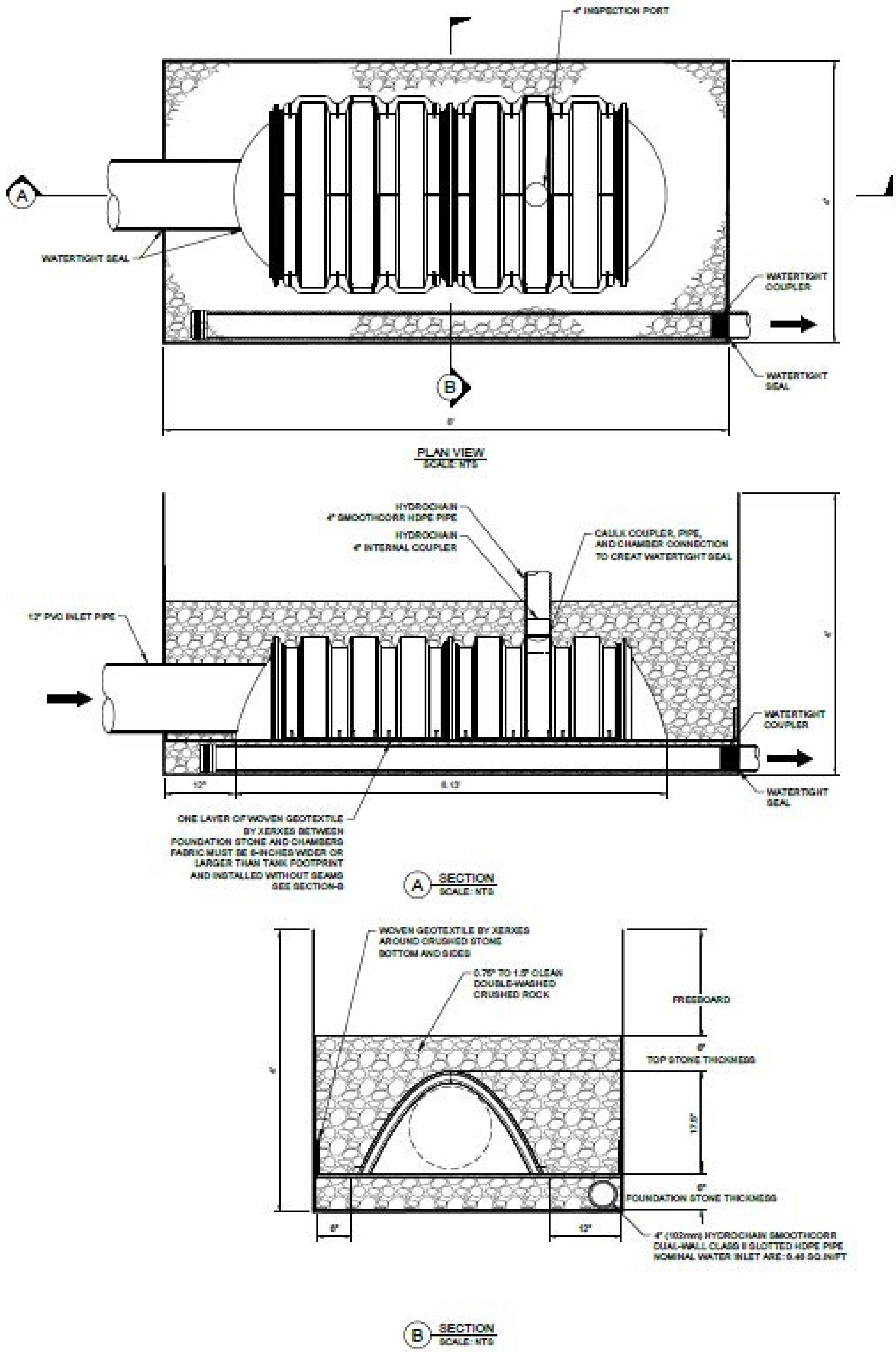

Figure 4 HydroChain Main Header Row Treatment Unit

The tested MHR measured approximately 6.1 ft long by 2.5 ft wide by 1.5 ft high. The two M-6 chamber system effective filtration treatment area was 14.1 ft^2. The setup included a 6" base of AASHTO #57 (3/4"-1-1/2") double-washed angular granite, a single layer of woven geotextile fabric, the MHR chamber components and a top layer of the #57 granite, extending 6" above the crown of the chamber. A 4" outlet pipe (underdrain) was located within the base stone and positioned to one side of the chamber. Flow was conveyed into the chamber by means of a 12" PVC influent pipe with a 1% slope. After entering the chamber, flow passed through the woven geotextile fabric into the 6-inch stone foundation layer. Flow collecting in the foundation layer was discharged through the underdrain.

The MHR was installed in a test loop in Alden's Stormwater Testing Facility, shown in **Figure 5**. A water-tight test flume, approximately 8'L x 4'W x 4'H was utilized for installing and testing the MHR chamber components. The installation was conducted in the same manner as in the field to meet the specifications of the protocol. All stone used for the test set-up was washed prior to installation. All pipe penetrations were sealed prior to testing. Flow was supplied to the unit with a laboratory pump drawing water from a 40,000-gallon supply sump, which can be heated or cooled to maintain a target temperature of approximately 68° F +/- 5° F. The test flow of 56.4 gpm (4 gpm/ft^2) was set and measured using a flow control valve and 1.5" calibrated orifice flow meter, constructed to ASME guidelines. Flow measurement accuracy is within ±1%. During all test runs, the allowable variation is ±10% of the target flow and the Coefficient of Variance (COV) must be ≤0.03.

Flow was conveyed to the test unit by means of a straight 12" diameter smooth-wall PVC influent pipe, with a length of approximately 20 pipe diameters. The pipe was set with a 1% slope. A 12-inch tee was located 2 ft upstream of the test unit for injecting the test sediment into the crown of the influent pipe. Sediment injection was accomplished with the use of a volumetric screw feeder. A calibrated isokinetic sampler was installed in the upstream vertical riser pipe for collection of the background samples. The system outflow from the underdrain discharged into an effluent channel containing a calibrated V-notch weir and returned to the sump. Sediment that is captured by the treatment device results in a gradual blinding of the filter fabric causing water levels to rise within the MHR since the MTFR is not decreased. Measuring the elevation at the end of each run and test program allowed monitoring the increase in driving head, and the manufacturer to set an upstream bypass level to prevent surcharging. Filtration of the supply sump flow was performed with an inline filter wall containing 1-micron filter bags.

Water temperature measurements within the supply sump were obtained using a calibrated Omega® DP25 temperature probe and readout device. The calibration was performed at the laboratory prior to testing. The temperature measurement was documented at the start and end of each test, to assure an acceptable testing temperature of ≤ 80 degrees F. A mid-test temperature reading was not necessary, as it was a recirculating closed-loop system.

Water levels within the chamber and at the V-notch weir were measured with the use of Piezometer taps, water manometers and a calibrated pressure transducer. The low and water elevations were measured and recorded every 5 seconds throughout the duration of each test run, including the drawdown period. Photographs of the test setup are shown on **Figure 6** to **Figure 8**.

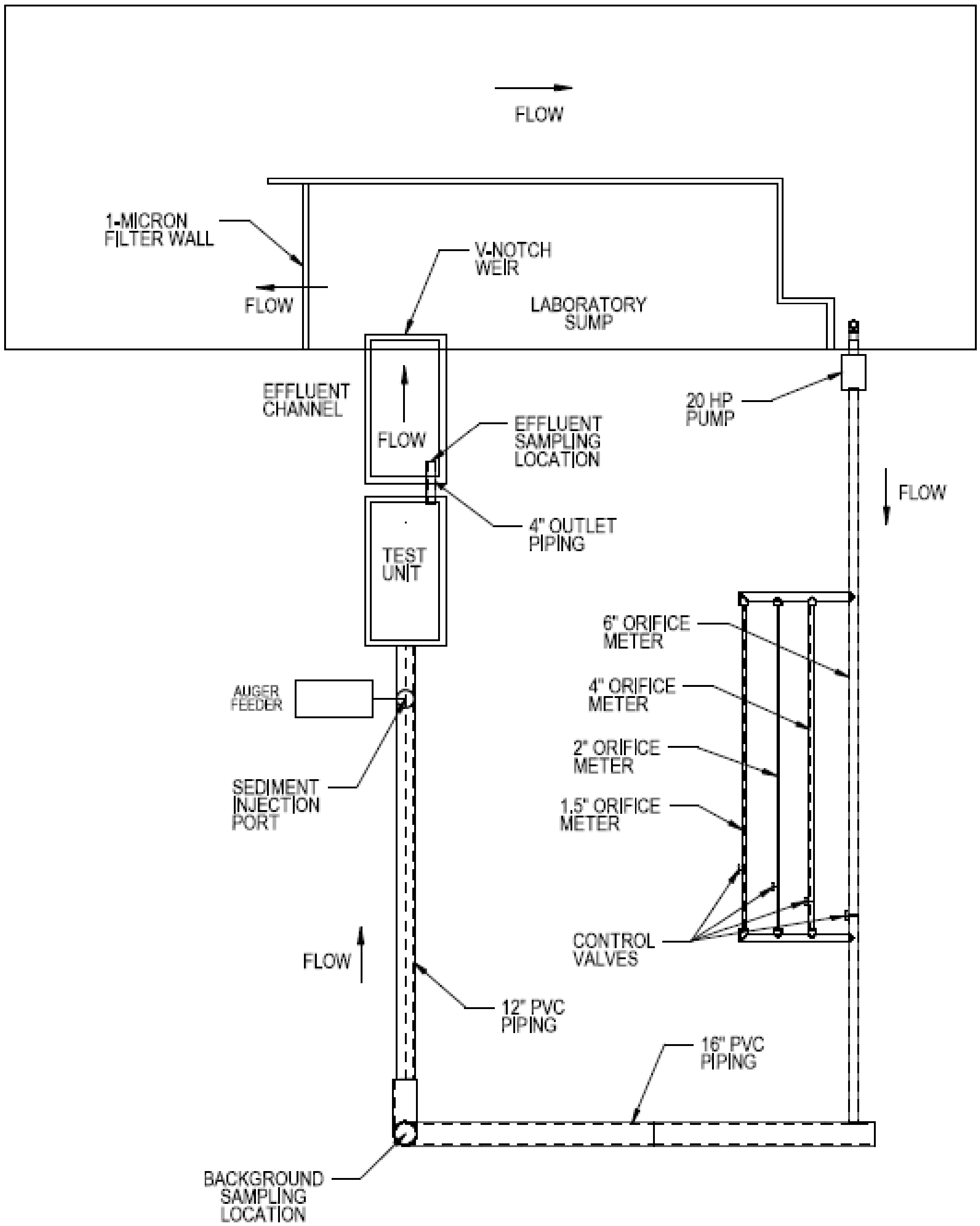

Figure 5 Alden's Stormwater Flow Loop

Figure 6 HydroChain Main Header Row Chamber Test Setup

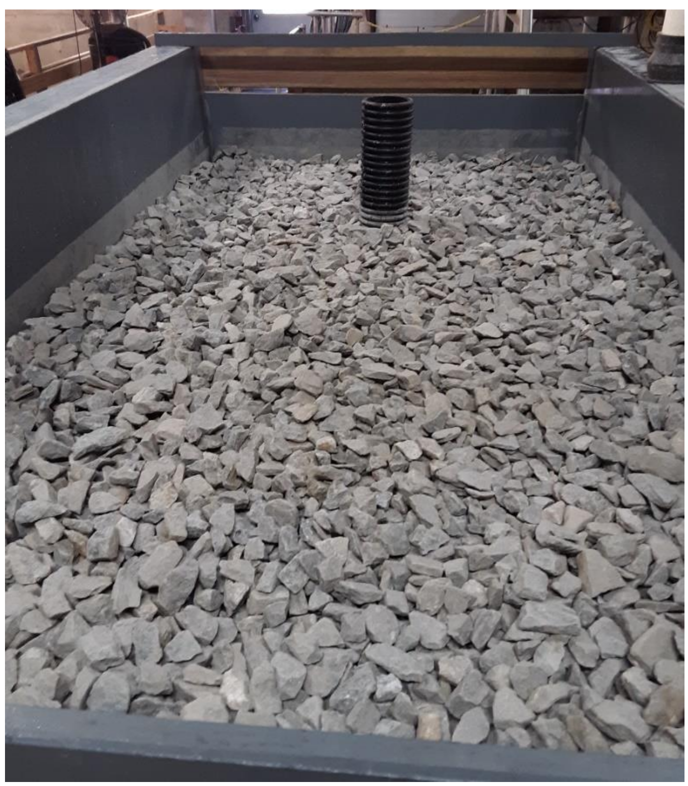

Figure 7 Installed HydroChain Main Header Row Chamber

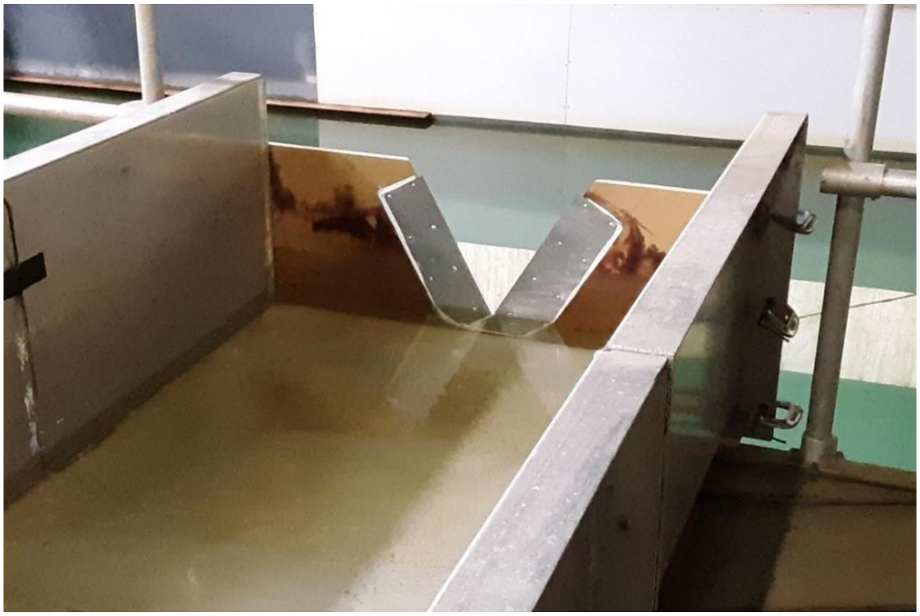

Figure 8 Effluent Channel Drawdown Flow V-notch Weir

2.2 Removal Efficiency Testing

Sediment removal testing was conducted to determine sediment removal efficiency. All tests were run with clean water containing a background sediment solids concentration (SSC) of ≤20 mg/L.

The sediment testing was conducted on an initially clean system at the 100% MTFR of 56.4 gpm (4 gpm/ft^2 selected by Xerxes). A minimum of ten (10) qualifying 30-minute test runs were required to be conducted to meet the removal efficiency criterion of a cumulative removal efficiency >80%. Additional follow on runs were conducted to determine the maximum mass loading capacity. The captured sediment was not removed from the system between test runs.

The total mass injected into the system was quantified for each run by subtracting the mass remaining in the feeder from the starting mass corrected for the sediment mass collected for feed rate calibration. This value was used in calculating the influent mass/volume concentration.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in **Table 1**. The sediment was silica based, with a specific gravity of 2.65. Three random PSD samples of the test sediment were analyzed by GeoTesting Express, and the results are shown in **Section 3.1**.

Table 1 NJDEP Sediment Particle Size Distribution

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..

Verification/Determination of Sediment Influent Concentrations

The target influent concentration was 200 mg/L (±20 mg/L) for all tests. Verification of the injected sediment concentration was achieved by taking a minimum of three timed dry samples from the auger feeder, including one sample at the start of dosing, one sample in the middle of each run, and one sample just prior to the conclusion of dosing. The samples were collected over a duration of one minute. The collected samples were weighed to establish the g/min feed rate for each sample. The sample concentration COV did not exceed 0.10. The influent concentration was calculated using the following two methods:

1. The auger sediment feed rate data was used in conjunction with the corresponding recorded flow data to establish an influent concentration of 200 mg/L (±10%) throughout the test run and demonstrate that the feed rate COV was ≤0.10.

2. The sediment mass in the volumetric screw feeder was quantified at the start and end of each test run and corrected for the 3 feed calibration samples to determine the mass fed into the test unit. This mass was divided by the total volume of water flowing through the test unit during sediment dosing to determine the average influent TSS concentration.

Sampling

All sediment testing was conducted using the indirect (sampling) methodology, as per the NJDEP protocol. A minimum of 5 effluent samples were collected using 2-L beakers and the end-of-pipe grab sampling methodology. The required background samples were collected upstream of the influent pipe using 2-L beakers and a calibrated isokinetic sampler installed in the center of the upstream vertical riser of the inflow piping.

For each 30-minute test run, a minimum of five 1-liter effluent samples were collected. Samples were collected 3 detention times after the initiation of sediment dosing, as well as after the interruption of dosing for injection measurements. A minimum of 3 evenly spaced background samples were collected in correspondence with the odd-numbered effluent samples (first, third, fifth). At the termination of the test run, 2 evenly volume-spaced effluent samples were collected during the drawdown period and used in the removal efficiency calculation. The drawdown volume was calculated by measuring the effluent using a calibrated v-notch weir located at the end of the effluent channel. All effluent and drawdown concentrations were adjusted for background.

Removal Efficiency Calculation

The sediment removal efficiency was calculated as follows:

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

Determination of Sample Concentrations

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2019), “Standard Test Methods for Determining Sediment Concentration in Water Samples”. Alden is ISO 17025 accredited for conducting the ASTM D 3977 analysis. Alden has assigned a Non-Detection Limit (NDL) of 1.0 mg/L. To be conservative, all concentrations below the NDL were assigned a value of 0.5 mg/L.

2.3 Mass Loading Capacity Testing

The sediment mass loading capacity testing is a continuation of the removal efficiency testing and was conducted to determine the point of filter occlusion. The testing was conducted until the following condition had occurred:

- The maximum driving head was reached, at which point the flow was reduced to 90% of the MTFR and testing resumed until the maximum driving head was again reached (cumulative mass removal efficiency average remained >80%).

The total mass captured in the system was quantified at the conclusion of the testing. This data was used for determination of the maximum inflow drainage area (acres) per the NJDEP protocol.

From the data collected the following graphs were produced to show the life cycle performance of the Xerxes chamber treatment unit:

- Removal Efficiency vs. Sediment Mass Loading (**Figure 10**)
- Driving Head vs. Sediment Mass Loading (**Figure 11**)

2.4 Data Management and Acquisition

A designated Laboratory Records Book was used to document the conditions and pertinent data entries for each test conducted. All entries are initialed and dated.

A personal computer running an Alden in-house Labview® Data Acquisition program was used to record all data related to instrument calibration and testing. A 16-bit National Instruments® NI6212 Analog to Digital (A/D) board was used to convert the voltage signal from the pressure cells. Alden's in-house data collection software, by default, collects one-second averages of data collected at a raw rate of 250 Hz. The system allows very long contiguous data collection by continuously writing the collected 1-second averages and their RMS values to disk. The data output from the program is in tab delimited text format with user-defined number of significant figures.

Test flow and pressure data were continuously collected at a frequency of 250 Hz. The flow data was averaged and recorded to file every 5 seconds. The recorded data files were imported into Excel for further analysis and plotting.

Excel based data sheets were used to record all sediment related data used for quantifying injection rate, effluent and background sample concentrations, flow, pressure, mass, and PSD data. The data was input to the designated spreadsheet for final processing.

2.5 Quality Assurance and Control

All instruments were calibrated prior to testing and periodically checked throughout the test program. Instrumentation calibrations were provided to NJCAT.

Flow

The flow meters and pressure cells were calibrated in Alden's Calibration Laboratory, which is ISO 17025 accredited. All pressure lines were purged of air prior to initiating each test. A standard water manometer board and Engineers Rule were used to measure the differential pressure and verify the computer measurement of the flow meter.

Sediment Injection

The sediment feed (g/min) was verified with the use of a NIST traceable digital stopwatch and 2200 g x 0.1g calibrated digital scale. The tare weight of the sample container was recorded prior to collection of each sample. The samples were a minimum of 0.1 liters in size, with a maximum collection time of 1-minute. The reported overall mass/volume sediment concentrations were adjusted for moisture.

3. Supporting Documentation

The NJDEP Procedure (NJDEP, 2021) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP, and it was agreed that as long as such documentation could be made available by NJCAT upon request it would not be prudent or necessary to include all this information in this verification report. This information was provided to NJCAT and is available upon request.

3.1 Test Sediment PSD Analysis

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1–1000-micron silica particles with a SG of 2.65. The sediment batches were prepared by Alden to meet the protocol specifications using commercially-available silica products. A random sample from each test batch was analyzed in accordance with ASTM D6913/D7928, by GeoTesting Express, an AALA ISO/IEC 17025 accredited independent laboratory. The specified less-than (%-finer) values of the sample average were within the 2 percentage-point tolerance listed in the protocol.

Sediment test batches of approximately 30 lbs each were prepared in individual 5-gallon buckets, which were arbitrarily selected for testing the MHR. A well-mixed sample was collected from each test batch and analyzed for PSD by GeoTesting Express. The average of the samples was used for compliance with the protocol specifications. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 9.**

Table 2 PSD Analyses of Alden NJDEP 1-1000 micron Mix

Particle size (µm)	NJDEP	Batch 2	Batch 3	Batch 4	Average	QA/QC Compliant
1000	100%	99%	99%	99%	99%	Y
500	95%	95%	95%	95%	95%	Y
250	90%	88%	88%	89%	88%	Y
150	75%	79%	79%	79%	79%	Y
100	60%	62%	62%	62%	62%	Y
75	50%	53%	52%	53%	53%	Y
50	45%	45%	45%	46%	46%	Y
20	35%	37%	38%	36%	37%	Y
8	20%	25%	24%	24%	24%	Y
5	10%	17%	17%	16%	17%	Y
2	5%	9%	9%	9%	9%	Y
D50	75	66	66	65	66	Y

The sediment particle size distribution (PSD) used for removal efficiency testing exceeded the NJDEP PSD sediment specifications (**Table 1**) across the entire distribution. The D_{50} of 66 microns was less than the required 75 microns.

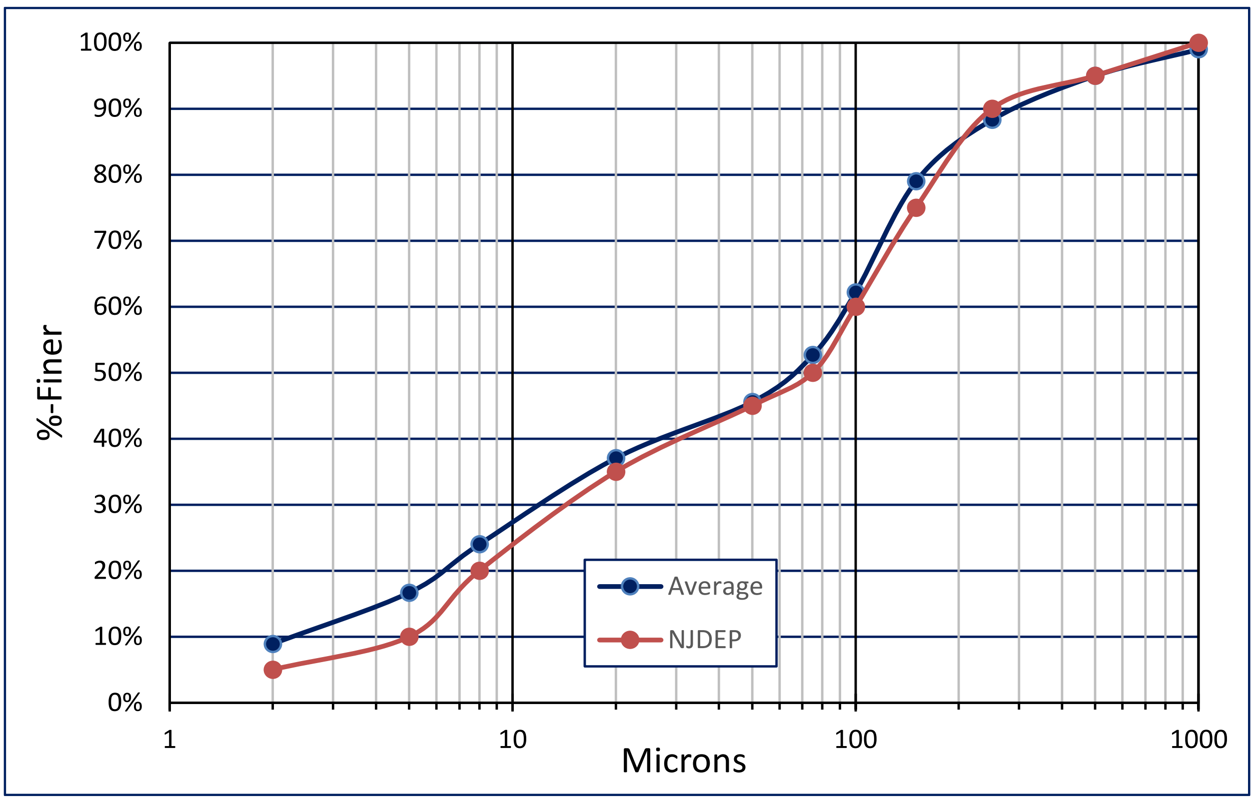

Figure 9 PSD Curves of 1-1000 micron Test Sediment

3.2 Removal Efficiency and Mass Loading Capacity Testing

Testing Summary

Thirteen tests were conducted at a MTFR target flow of 56.4 gpm. The measured water elevation above the test flume bottom exceeded the target driving head of 3.0 ft at the end of the thirteenth run. The flow was reduced to 50.8 gpm (90% MTFR per the protocol requirement) and two more runs were conducted. The measured 100% MTFR flows ranged from 56.2 gpm to 56.4 gpm, with an average flow of 56.35 gpm. The measured 90% MTFR flows were 50.8 gpm each. The calculated COV for all test runs ranged from 0.001 to 0.004. The maximum recorded temperatures ranged from 70.1 to 77.8 degrees F. The measured injected influent concentration averages ranged from 195.6 to 210.0 mg/L. The injection COV ranged from 0.010 to 0.074. The calculated mass/volume influent concentrations ranged from 187.2 to 213.8 mg/L. The calculated removal efficiencies ranged from 79.8% to 90.9%, with a cumulative average removal of 84.6% after the first 10 runs, and 85.1 after all 15 runs. The total cumulative injected and captured mass was 63.53 lbs and 54.13 lbs, respectively. The final end-of-run elevation was 2.92 ft demonstrating the strong relationship between required driving head and mass loading. Recorded and calculated test data are shown in **Tables 3** through **7** and on **Figure 10** and **Figure 11**.

Table 3 Testing Sample Collection Timestamps (minutes)

Run #	Eff 1, BG 1	Eff 2	Eff 3, BG 2	Eff 4	Eff 5, BG 3	Drawdown 1	Drawdown 2
1	13	15	17	31	33	38.33	39.58
2	13	15	17	31	33	38.5	40
3	14	16	18	33	35	40.83	42.83
4	16	18	20	36	38	44.33	46.5
5	19	21	23	43	45	51.75	55.42
6	21	23	25	47	49	56.17	59.67
7	18	20	22	41	43	50.75	54.83
8	18	20	22	41	43	50.5	54.83
9	19	21	23	43	45	52.67	57.25
10	20	22	24	45	47	54.83	59.67
11	22	24	26	49	51	58.83	64
12	23	25	27	50	52	59.75	64.83
13	22	24	26	49	51	59.17	64.5
14	22	24	26	49	51	58.83	64
15	24	26	28	53	55	63	68.67

Table 4 Measured Removal Efficiency Test Parameters

Test Run #	Measured Flow		Maximum Water Temperature	End of Run Water El. Above Floor	Influent Concentration (mg/L)					QA/QC Compliant
	gpm	COV	Deg. F	ft	Minimum	Maximum	Average	COV	Mass/Volume	
1	56.3	0.001	73.1	0.966	191.0	201.4	197.2	0.028	187.2	Y
2	56.3	0.001	74.4	1.117	202.8	207.9	205.2	0.012	207.6	Y
3	56.4	0.001	71.7	1.244	196.0	199.7	198.4	0.010	203.5	Y
4	56.4	0.001	71.3	1.419	195.6	202.4	198.1	0.019	203.7	Y
5	56.2	0.004	71.2	1.577	198.5	211.5	203.2	0.035	208.1	Y
6	56.4	0.001	70.5	1.883	199.5	211.0	204.4	0.029	202.5	Y
7	56.4	0.001	70.1	2.140	181.6	207.7	198.6	0.074	198.6	Y
8	56.3	0.002	71.7	2.216	190.9	198.2	195.6	0.021	197.1	Y
9	56.4	0.001	73.7	2.384	199.2	211.0	206.1	0.030	213.8	Y
10	56.4	0.002	72.9	2.606	200.2	211.7	206.2	0.028	207.0	Y
11	56.4	0.001	73.5	2.681	194.3	200.6	198.2	0.018	195.8	Y
12	56.4	0.001	73.9	2.565	198.2	209.4	202.4	0.030	197.8	Y
13	56.3	0.001	73.9	3.144	204.3	214.2	210.0	0.024	210.7	Y
14	50.8	0.001	77.7	2.699	190.3	199.3	196.2	0.026	198.0	Y
15	50.8	0.001	77.8	2.920	188.8	209.8	199.3	0.053	200.8	Y

Table 5 Measured Sample Concentrations

Run #	Max Background	Adjusted Effluent Concentrations (mg/L)						Adjusted Drawdown Concentrations (mg/L)		
	mg/L	E1	E2	E3	E4	E5	**Average**	DD1	DD2	**Average**
1	0.5	36.6	37.3	38.8	42.7	40.6	**39.2**	25.7	23.0	**24.3**
2	0.5	34.3	35.6	35.5	37.8	38.7	**36.4**	23.6	18.4	**21.0**
3	0.5	32.2	30.1	29.3	29.4	33.6	**30.9**	17.1	15.1	**16.1**
4	1.4	33.1	33.8	35.1	35.0	34.1	**34.2**	14.7	13.4	**14.1**
5	0.5	35.1	35.1	35.0	37.4	38.2	**36.2**	26.9	19.3	**23.1**
6	1.2	35.6	37.5	35.1	34.3	33.3	**35.2**	31.5	10.0	**20.8**
7	0.5	27.1	12.0	14.6	16.9	25.0	**19.1**	21.1	4.4	**12.8**
8	0.5	32.7	31.8	34.7	33.0	32.8	**33.0**	20.7	3.0	**11.9**
9	0.5	33.8	33.6	32.8	33.4	34.9	**33.7**	32.3	16.3	**24.3**
10	1.1	35.8	36.3	36.8	34.3	34.9	**35.6**	30.0	16.5	**23.3**
11	0.5	30.1	31.5	29.9	27.8	27.8	**29.4**	18.0	9.4	**13.7**
12	0.5	34.5	33.2	33.7	34.6	34.7	**34.1**	18.9	9.1	**14.0**
13	3.4	35.1	32.3	29.0	32.9	31.8	**32.2**	19.2	16.0	**17.6**
14	0.5	28.4	26.4	26.6	27.7	27.3	**27.3**	20.9	13.1	**17.0**
15	0.5	29.4	30.4	28.2	29.7	29.5	**29.4**	15.0	11.5	**13.2**

Table 6 Removal Efficiency Injected and Captured Mass

Run #	Test Duration	Injected Mass	Total Mass Injected	Mass Captured	Total Mass Captured
	minutes	lbs	lbs	lbs	lbs
1	33.5	2.95	2.95	2.35	2.35
2	33.5	3.27	6.22	2.73	5.08
3	35.5	3.40	9.61	2.91	7.99
4	38.5	3.69	13.30	3.12	11.11
5	45.5	4.44	17.75	3.71	14.82
6	49.5	4.72	22.46	3.95	18.77
7	43.5	4.06	26.53	3.70	22.46
8	43.5	4.03	30.55	3.43	25.90
9	45.5	4.58	35.13	3.89	29.79
10	47.5	4.62	39.75	3.88	33.66
11	51.5	4.74	44.50	4.09	37.76
12	52.5	4.88	49.38	4.12	41.88
13	51.5	5.10	54.48	4.39	46.27
14	51.5	4.32	58.80	3.77	50.03
15	55.5	4.72	63.53	4.10	54.13

Table 7 Removal Efficiency Testing Results

Run #	Mass/Volume Influent Concentration	Average Adjusted Effluent Concentration	Average Adjusted Drawdown Concentration	Influent Volume	Effluent Volume	Drawdown Volume	Removal Efficiency	Cumulative Average
	mg/L	mg/L	mg/L	L	L	L	%	%
1	187	39.2	24.3	7142	6467	675	**79.8**	**79.8**
2	208	36.4	21.0	7141	6245	896	**83.4**	**81.6**
3	204	30.9	16.1	7573	6616	957	**85.7**	**83.0**
4	204	34.2	14.1	8217	7040	1177	**84.6**	**83.4**
5	208	36.2	23.1	9682	8325	1357	**83.5**	**83.4**
6	203	35.2	20.8	10559	9042	1518	**83.7**	**83.5**
7	199	19.1	12.8	9280	7683	1598	**90.9**	**84.5**
8	197	33.0	11.9	9274	7623	1651	**85.2**	**84.6**
9	214	33.7	24.3	9708	7961	1747	**85.0**	**84.7**
10	207	35.6	23.3	10131	8329	1802	**83.8**	**84.6**
11	196	29.4	13.7	10985	9157	1828	**86.3**	**84.7**
12	198	34.1	14.0	11203	9422	1780	**84.4**	**84.7**
13	211	32.2	17.6	10973	8808	2165	**86.1**	**84.8**
14	198	27.3	17.0	9905	8070	1836	**87.2**	**85.0**
15	201	29.4	13.2	10669	8731	1938	**86.8**	**85.1**

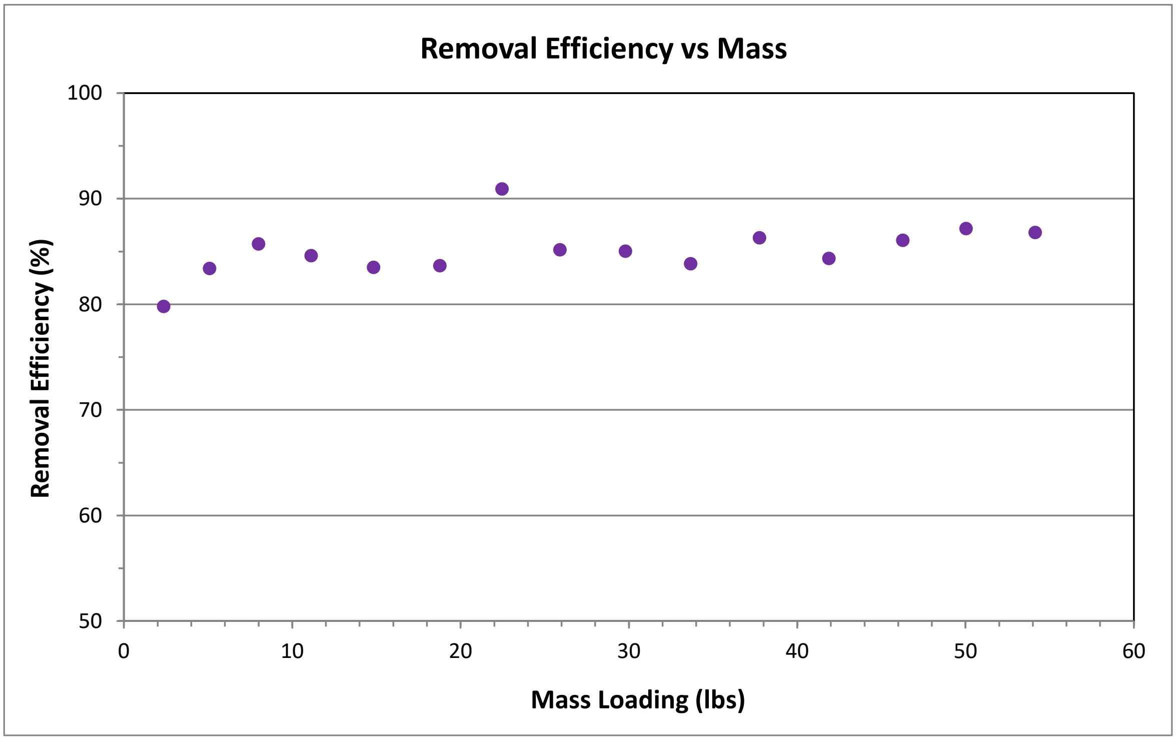

Figure 10 HydroChain MHR Removal Efficiency vs Mass Loading

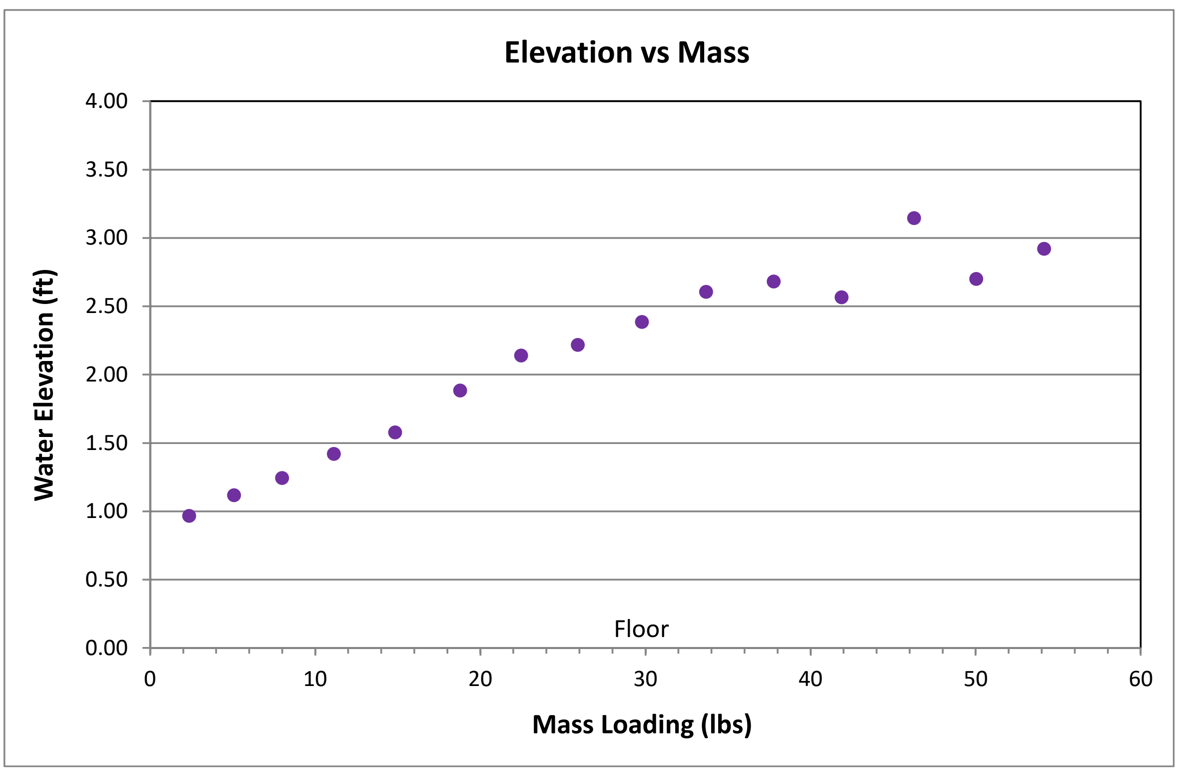

Figure 11 HydroChain MHR Water Elevations

4. Design Limitations

Xerxes has in-house engineers to assist with site specific needs to ensure the proper design of a HydroChain Chamber storage system. Working closely with site design engineers, a HydroChain Chamber system must consider site specific storage volumes, available footprint, geotechnical data for bearing capacities and infiltration rates, connections to the storm drain system, and available cover and footprint. The following design limitations are specific to the MHR.

Maximum Flow Rate
The HydroChain MHR unit has an MTFR calculated using the chamber model's open bottom area, which is the effective filtration treatment area, and a maximum loading rate of 4 gpm/ft^2. Refer to **Table 8** for different chamber model MTFR's.

Slope
The HydroChain Chamber storage system and MHR is recommended for installation with little to no slope to ensure proper, consistent operation.

Allowable Head Loss
The allowable headloss for each project is primarily determined by the required storage volume, available footprint and cover, and the height of each HydroChain Chamber model. Over time, the MHR will require more driving head due to the sediment loading to the system. Including a 6-inch stone foundation layer, the height of the chamber plus 6-inches above the stone cover is usually adequate for providing the necessary driving head. However, site-specific treatment flow rates, peak flow rates, pipe diameter, and pipe slopes should be evaluated to ensure there is an appropriate head for the system to function properly.

Sediment Load Capacity
Based on laboratory testing results, the HydroChain MHR has a mass loading capacity of 3.84 lbs/ft^2 of effective filtration treatment area while operating at a sediment removal efficiency greater than 80% without the water elevation exceeding 36 inches measured from the bottom of the 6-inch stone foundation layer.

Pre-treatment Requirements
The HydroChain MHR does not require additional pre-treatment, but it can be considered for sites known to have high pollutant loading. Pretreatment options can include hydrodynamic separators or catch basins with sumps, screens or traps.

Configurations
The HydroChain MHR is integrated into the storage system's design. Its modular design provides flexibility to meet project specific design volumes or flow rates.

Structure Load Limitations
The HydroChain MHR, as part of the overall chamber system, is designed to meet the full scope of design requirements of the American Society of Testing Materials (ASTM) International

specification F2787 "Standard Practice for Structural Design of Thermoplastic Corrugated Wall Stormwater Collection Chambers" and ASTM F2418 "Standard Specification for Polypropylene (PP) Corrugated Stormwater Collection Chambers". HydroChain Chambers provide the full AASHTO safety factors for live loads and permanent earth loads and are intended for applications under vehicular traffic loads.

Installation Limitations
A HydroChain Chamber system must be installed on soils with adequate bearing capacity. The minimum and maximum burial depth and vehicle loads are provided in the installation manual.

Depth to Seasonal High-Water Table
The integrity of a HydroChain Chamber system should not be affected by high-water table. However, most jurisdictions require, and Xerxes recommends, that systems within proximity to the seasonal high-water table be installed with an impermeable liner.

5. Maintenance

Maintenance of the MHR is required to keep the storage system functioning for its expected service life. As pollutants are conveyed into the MHR, they accumulate on the woven geotextile and over time will limit flow into the stone foundation layer and remaining chambers. Accumulation of pollutants is site specific which requires regular inspections to monitor the annual loads and establish a maintenance schedule.

The frequency of inspection and maintenance varies by location. A routine inspection schedule needs to be established for each individual location based upon site specific variables. The type of land use (i.e., industrial, commercial, residential), anticipated pollutant load, percent imperviousness, climate, etc., all play a critical role in determining the actual frequency of inspection and maintenance practices. At a minimum, Xerxes recommends annual inspections, and the MHR should be inspected every 6 months for the first year of operation. For subsequent years, the inspection should be adjusted based upon previous observations.

Design of the MHR includes a combination of standard manhole(s) with sumps and strategically located inspection ports (as needed). Pretreatment practices, like hoods and screens, can be used in the upstream manhole and should also be inspected. The chamber inspection ports allow for access to the system from the surface so that confined space entry for inspections is not required. If upon visual inspection it is found that sediment has accumulated a measurement stick, such as a stadia rod, can be inserted into the vertical inspection ports to determine the depth of sediment from the surface. When the average depth of sediment exceeds 3 inches throughout the length of the MHR, clean-out of the upstream and downstream manhole sumps and MHR should be performed.

Maintenance is accomplished using a standard vactor truck with jetting equipment. A high-pressure self-propelling water nozzle is used to scour and suspend pollutants as it moves through the MHR . As the nozzle is retrieved, the captured pollutants are flushed back into the manhole for vacuuming. The vactor and jetting process should only be performed on chambers that have the Xerxes woven geotextile. Complete details of the design, operation, and maintenance of the MHR can be found in the HydroChain Chamber MHR O&M Manual, available online at:

HydroChain Chamber O&M Link

6. Performance Claims

The HydroChain™ Main Header Row, with two M-6 chambers and two endcaps, demonstrated a cumulative average TSS removal efficiency of 85.1% and a sediment mass loading capacity of 3.84 lb/ft^2 of geotextile fabric filtration area when operated with the water elevation < 3.0 ft at a hydraulic loading rate of 4 gpm/ft^2 of geotextile fabric filtration area over 15 runs. The MTFRs and maximum allowable drainage area for other HydroChain™ MHR models are shown in **Table 8**.

Table 8 HydroChain MHR Single Chamber Model MTFRs and Maximum Drainage Areas

Chamber Model	Single Chamber Surface Loading Rate[1]	Single Chamber Effective Filtration Treatment Area[2]	Single Chamber MTFR[3]	Single Chamber Mass Loading Capacity[4]	Single Chamber Drainage Area[5]
	(gpm/ft^2)	(ft^2)	(gpm)	(lbs)	(acres)
S-29/S29B	4.0	11.8	47.2	45.3	0.076
S-22	4.0	9.4	37.6	36.1	0.060
C-10	4.0	7.3	29.2	28.0	0.047
M-6	4.0	6.0	24.0	23.0	0.038

Notes:
1. The surface loading rate area is based on the tested MHR with two M-6 chambers and end caps, which has a total EFTA of 14.1 ft^2 and flow rate of 56.4 gpm.
2. The Effective Filtration Treatment Area is the open bottom area of a single chamber.
3. The MTFR is calculated using the EFTA of a single chamber and the surface loading rate of 4.0 gpm/ft^2.
4. Maximum Loading Capacity based on 3.84 lbs/ft^2.
5. Drainage Area based on NJDEP Filter Protocol calculations that assume an annual sediment loading rate of 600 lbs/acre.

7. Statements

The following statements are from Alden Research Laboratory (Alden), the independent laboratory that conducted the verification testing and NJCAT. These statements are included as a requirement for the verification process.

July 31, 2023

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

Conflict of Interest Statement

Alden Research Laboratory (ALDEN) is a non-biased independent testing entity which receives compensation for testing services rendered. ALDEN does not have any vested interest in the products it tests or their affiliated companies. There is no financial, personal, or professional conflict of interest between ALDEN and Xerxes Corporation.

Protocol Compliance Statement

Alden performed verification testing on the M-6 HydroChain™ Main Header Row (MHR). The Technical Report and all required supporting data documentation has been submitted to NJCAT as required by the NJDEP protocol.

Testing performed by ALDEN on the MHR met or exceeded the requirements as stated in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device", January 14, 2022 (Updated April 25, 2023).

James T. Mailloux

Senior Consultant

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Hoboken, NJ 07030-0000

August 11, 2023

David Scott
Senior Manager, Water Systems and Solutions
Xerxes
7901 Xerxes Ave S., Suite 201
Minneapolis, MN 55431-1288

Dear Mr. Scott,

Based on my review, evaluation and assessment of the testing conducted on the Xerxes HydroChain Main Header Row (MHR) at the Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts, under the direction of Alden's senior stormwater engineer, James Mailloux, the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" January 2022 (updated April 2023) were met or exceeded. Specifically:

Test Sediment Feed

The test blend was custom-blended using various commercially available silica sands by Alden to meet the protocol specifications. A random sample from each test batch was analyzed in accordance with ASTM D6913/D7928, by GeoTesting Express, an AALA ISO/IEC 17025 accredited independent laboratory. The specified less-than (%-finer) values of the sample average were within the 2 percentage-point tolerance listed in the protocol. The D50 of 66 microns was less than the NJDEP protocol required 75 microns.

Removal Efficiency Testing

Thirteen (13) removal efficiency test runs were completed in accordance with the NJDEP filter protocol. The target MTFR was 56.4 gpm, and the target influent sediment concentration was 200 mg/L. The average flow rate for all 13 runs was 56.35, with a coefficient of variation (COV) below the flow compliance (COV) $\leq$ 0.1 for all the runs. Likewise, for all runs the sediment feed rate COV was below the $\leq$ 0.03 protocol limit. The HydroChain MHR demonstrated a cumulative sediment removal efficiency after 10 runs of 84.6% and 84.8% over the course of the 13 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted concurrently with removal efficiency testing. The measured water elevation exceeded the target water elevation of 3.0 ft at the end of the thirteenth run. Per the protocol, the flow was reduced to 50.8 gpm (90% MTFR) and two more runs were conducted at which the target water elevation was once again exceeded. Testing was stopped, and the mass capture loading finalized. The HydroChain MHR M-6 model tested system has a mass loading capture capacity of 54.1 lbs (3.84 lbs/ft^2 of filtration area).

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

Scour Testing

No scour testing was performed. Hence the HydroChain MHR is verified for offline installation only.

Sincerely,

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

8. References

ASME (1971), *"Fluid Meters Their Theory and Application- Sixth Edition"*.

ASTM (2017), *"Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis",* Annual Book of ASTM Standards, D6913 / D6913M-17, Vol. 4.09

ASTM (2019), *"Standard Test Methods for Determining Sediment Concentration in Water Samples"*, Annual Book of ASTM Standards, D3977-97, Vol. 11.02.

ASTM (2019), *"Standard Test Methods for Determination of Water (Moisture) Content of Soil by Direct Heating"*, Annual Book of ASTM Standards, D2216, Vol. 04.08.

ASTM (2021), *"Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis",* Annual Book of ASTM Standards, D7928-21e1, Vol. 4.09.

NJDEP (2021). *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology.* Trenton, NJ. August 4, 2021.

NJDEP (2022). *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device.* Trenton, NJ. January 14, 2022 (Updated April 24, 2023).

Specifications

Introduction

- Manufacturer – Xerxes Corporation, 7901 Xerxes Ave S., Suite 201, Minneapolis, MN 55431-1288
- Website: http://www.Xerxes.com. Phone: 952-887-1890
- MTD – HydroChain Main Header Row verified models are shown in **Table 8**
- TSS Removal Rate – 80%
- Offline installation

Detailed Specification

- NJDEP sizing tables and physical dimensions of HydroChain Main Header Row verified chamber models are shown in **Table 8**. These sizing tables are valid for the 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 mass loading capacity of each chamber model as presented in **Table 8**.
- Driving head will vary for a given HydroChain MHR chamber model based on the site-specific configuration. The maximum water elevation, measured from the bottom of a 6-inch foundation layer, without bypass is 36", but the minimum water elevation varies depending on the flow rate through the unit. Design support is given by Xerxes 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 the underdrain. A clean filter draws down in approximately 15 minutes.