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Verification Testing of the Lane Enterprises SK75 Stormkeeper Chamber Sediment Strip and Prinsco Hydrostor HS75 Sediment Row In Accordance with the NJDEP Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device, 2013

Technical Evaluation Report

Alden Report No. : 1162LESSCSVT-R1

Submitted to:

Lane Enterprises

Camp Hill, PA

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1.0 INTRODUCTION

Under a contract from Lane Enterprises (Lane), verification testing was conducted on the Lane Enterprises SK75 Stormkeeper Chamber Sediment Strip and Prinsco Hydrostor HS75 Sediment Row treatment system, at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts.

The purpose of the testing was to define the performance characteristics of the sediment strip chamber under controlled laboratory conditions, utilizing established standard testing methodologies. The testing was conducted in accordance with "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device", 2013, to establish the following parameters:

a) **Hydraulic Characteristic Curves:**

b) **Sediment Removal Efficiency at Maximum Treatment Flow Rate (MTFR)**

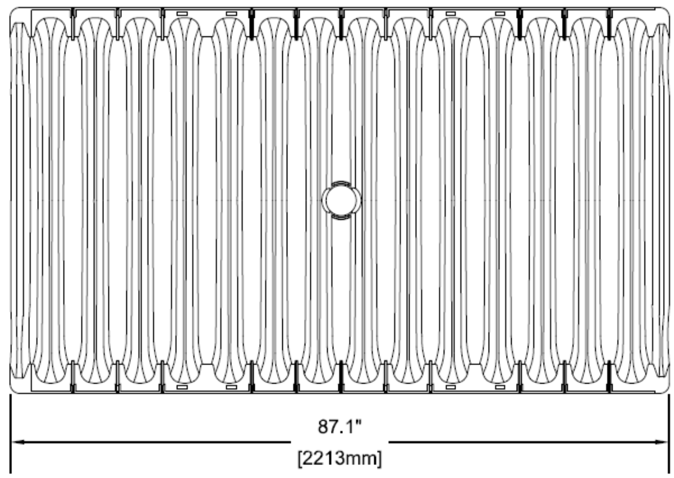
c) **Filter Blinding (Occlusion) and/or maintenance statement.**

d) **At a minimum, the particle size distribution of the influent material for sediment test conditions.**

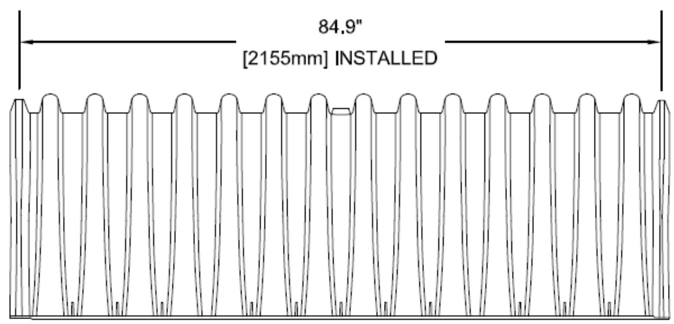
2.0 TEST UNIT DESCRIPTION

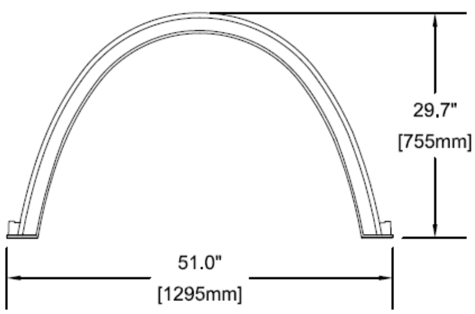
The tested treatment chamber was an arched stormwater detention/retention sediment collection and filtering device, measuring approximately 51" wide x 30" high x 7 ft long. Both ends of the chamber were sealed with the use of end caps. A water-tight tank was used to house the test chamber system. The chamber was installed on top of a 1-ft base of ¾"-2" double-washed stone containing a 6" underdrain pipe, which penetrated the downstream tank wall. Two layers of woven Geotextile fabric were placed between the stone base and chamber to collect particulate contaminants, as well as protect the stone base from scouring. The fabric had an open-area of 1% and opening size of 425 microns. The top fabric layer was used to fully wrap the chamber and end caps. The chamber floor filtration area was approximately 30 ft^2. Water was conveyed into the chamber by means of a 12"-diameter inlet pipe, which penetrated the upstream end cap. The junction was wrapped in non-woven fabric. The invert of the pipe was approximately flush with the chamber floor. Additional stone was installed around the outside of the chamber until fully buried. A 4" diameter x 2-ft tall PVC standpipe was installed into the crown of the chamber. In a typical field installation, water passing through the base fabric seeps into the stone base and is either re-infiltrated into the surrounding soil, enter the underdrain and is conveyed into an outlet control structure, or is distributed into other chambers in the stormwater management system. Although the primary function of the sediment strip chamber is to capture and retain sediment particles, the Geotextile membrane possesses filtering characteristics and therefore, was tested as such. On-line scour testing was not conducted, as the system is designed for an off-line application with the inclusion of an upstream bypass weir. The weir was not included in the laboratory set-up.

Drawings of the SK75 test unit are shown on **Figure 1**. A Photograph showing the wrapped unit installed in the test tank is shown on **Figure 2.** The final installation is shown on **Figure 3**. A photograph of the test loop is shown on **Figure 4**.

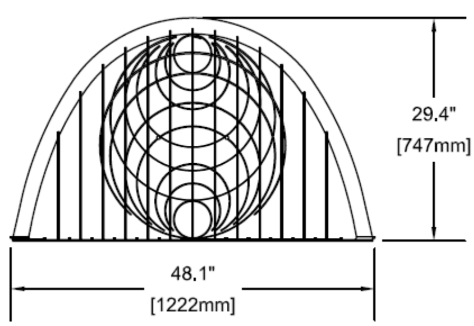


Chamber Specifications	
Chamber Size (L x W x H)	87.1" x 51.0" x 29.7" (2,212 x 1295 x 754 mm)
Installed Length	84.9" (2,156 mm)
Chamber Storage	46.4 ft^3 (1.31 m^3)
Min. Installed Storage*	74.9 ft^3 (2.12m^3)
Weight / Chamber	70 lbs (32 kg)
Chambers / Pallet	33
Approx. Weight / Pallet	2,500 lbs (1,134 kg)





End Cap Specifications	
End Cap Size (L x W x H)	11.6" x 48.1" x 29.4" (295 x 1,222 x 747 mm)
Installed Length	8.0" (203 mm)
End Cap Storage	2.75 ft^3 (0.08 m^3)
Min. Installed Storage*	12.02 ft^3 (0.34 m^3)
Weight	12 lbs (5.44 kg)



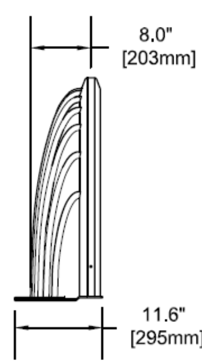


Figure 1: Drawing of the SK75 Treatment Unit

Figure 2: Lane SK75 Test Unit Installed in the Test Tank Prior to Backfilling

Figure 3: Lane SK75 Test Unit Fully Installed in the Test Tank

Figure 4: Photograph of the Test Set Up

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL DESIGN

The SK75 test unit was installed in the Alden test loop, shown on **Figure 5,** which is set up as a recirculation system. The loop is designed to provide metered flow up to approximately 17 cfs. Flow was supplied to the unit with one or two selected laboratory pumps (20HP, 50HP), drawing water from a 50,000-gallon supply sump. The test flow was set and measured using one of five differential-pressure meters and corresponding control valves. A Differential Pressure (DP) cell and computer Data Acquisition (DA) program was used to record the test flow. 25 feet of straight 12" PVC influent pipe conveyed the metered flow to the unit. 2 feet of 6" PVC pipe free-discharged the effluent flows to a receiving tank, which contained a calibrated V-notch weir at the downstream end for measuring drawdown flow. The influent and effluent pipes were set at 1% slopes. A 12" tee was located 4 pipe-diameters (4 ft) upstream of the test unit for injecting sediment into the crown of the influent pipe using a variable-speed auger feeder.

Filtration of the supply sump, to reduce background concentration, was performed with an in-situ filter wall containing 1-micron bag filters.

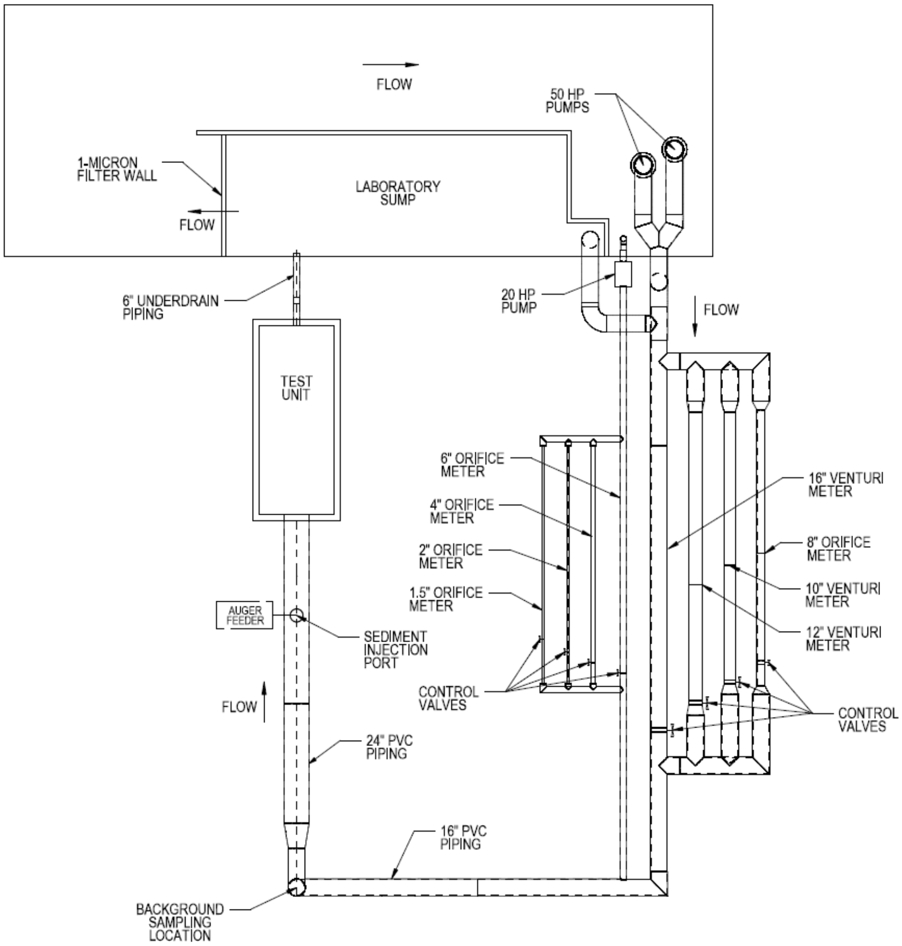


Figure 5: Plan View of Alden Flow Loop

3.1.1 Hydraulic Testing

The SK75 unit was tested with clean water to determine its hydraulic characteristic curves, including loss coefficients (Cd's) and/or K factors. Flow and water level measurements were recorded during steady-state flow conditions using a computerized Data-Acquisition (DA) system, which included a data collect program, 0-250" Rosemount Differential Pressure (DP) cell (flow), and Omegadyne PX419 0-2.5 psi Single-ended Pressure (SP) cell (water elevations). Flows were set and measured using the calibrated flow meters and control valves. Each test flow was set and operated at steady state for approximately 10 minutes, after which time a minimum of 30 seconds of flow and pressure data were averaged and recorded for each pressure tap location. Water elevations were measured above and below the fabric layer outside of the chamber. Measurements within the influent and effluent pipes were taken one pipe-diameter upstream and downstream of the unit.

3.1.2 Removal Efficiency Testing

Sediment testing was conducted to determine the removal efficiency, as well as sediment mass loading capacity.

The sediment testing was conducted on an initially clean system at the 100% MTFR of 120 gpm (as selected by Lane). A minimum of ten 30-minute test runs were required to be conducted. The captured sediment was not removed from the chamber between tests.

The total mass injected into the system was quantified at the conclusion of the 10 runs. This data was used for determination of the required maintenance frequency.

The test sediment was prepared by Alden to meet the PSD gradation of 1-1000 microns in accordance with the distribution shown in column 2 of **Table 1**. The sediment is silica based, with a specific gravity of 2.65. Three random PSD samples of the test sediment were analyzed by an independent certified analytical laboratory using ASTM D 422-63 (Reapproved 2007) "Standard Test Method for Particle Size Analysis of Soils". The average of the three samples was used for compliance with the protocol. Additional discussion of the sediment is presented in Section 3.4.

Table 1: Test 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..

The target influent sediment concentration was 200 mg/L (+/-20 mg/L) for all tests. The concentration was verified by collecting a minimum of three timed dry samples at the injector and correlating the data with the measured average flow to verify the influent concentration values for each test. The allowed Coefficient of Variance (COV) for the measured samples is 0.10. The moisture content of the test sediment was determined using ASTM D4959-07 for each test conducted and was utilized in the final removal calculation.

The protocol requires the temperature of the supply water to be below 80 degrees F.

Five (5) time-stamped effluent samples were collected from the end of the outlet pipe during each run. A minimum of three detention times were allowed to pass before collecting a sample after the start of sediment feed and when the feed was interrupted for measurements. Three (3) background samples of the supply water were collected during each run. The samples were collected with each odd-numbered effluent sample (1, 3 & 5). Collected samples were analyzed for Suspended Solids Concentration (SSC) using the ASTM D3977-97 (2013).

At the conclusion of a run, the injection feed was stopped and time-stamped. The flow was stopped after one (1) detention time had passed. The drawdown flow was measured at the V-notch weir every five (5) seconds until the effluent was reduced to 1% of the test flow. Two (2) evenly-spaced effluent samples were collected from the pipe during drawdown.

3.2 INSTRUMENTATION AND MEASURING TECHNIQUES

Instrument calibrations are presented in **Appendix B**.

3.2.1 Influent Flow

The inflow to the test unit was measured using one of six (6) calibrated differential-pressure flow meters (2”, 4”, 6”, 8”, 10” or 12”). Each meter is fabricated per ASME guidelines and calibrated in Alden’s Calibration Department prior to the start of testing. The high and low pressure lines from each meter were connected to manifolds containing isolation valves. Flows were set with a butterfly valve and the differential head from the meter was measured using a Rosemount® 0 to 250-inch Differential Pressure (DP) cell, also calibrated at Alden prior to testing. All pressure lines and cells were purged of air (bled) prior to the start of each test. The test flow was averaged and recorded every 5 seconds throughout the duration of the test using an in-house computerized data acquisition (DA) program. The accuracy of the flow measurement is ±2%. A photograph of the flow meters is shown on **Figure 6** and the pumps on **Figure 7.**

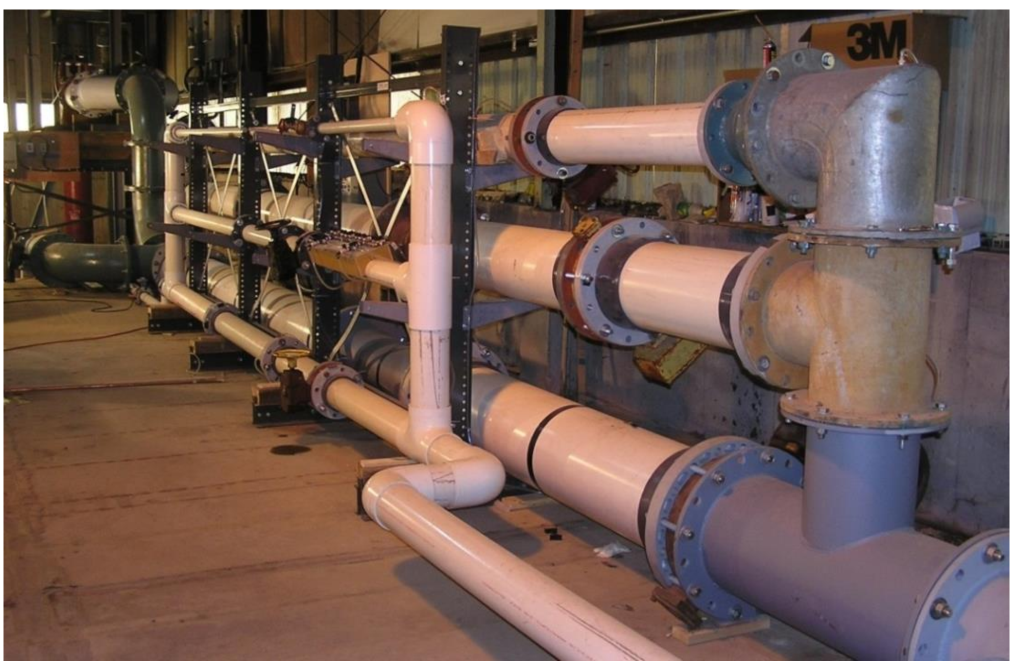


Figure 6: Photograph Showing Laboratory Flow Meters

Figure 7: Photograph Showing Laboratory Pumps

3.2.2 Drawdown Flow

The drawdown flow was measured with the use of a V-notch weir installed at the end of the effluent tank. The weir was fabricated in accordance with the Bureau of Reclamation Water Measurement Manual guidelines. The weir was calibrated through the full range of flows prior to initiating the removal testing. The calculated and measured weir curves are shown on **Figure 8**.

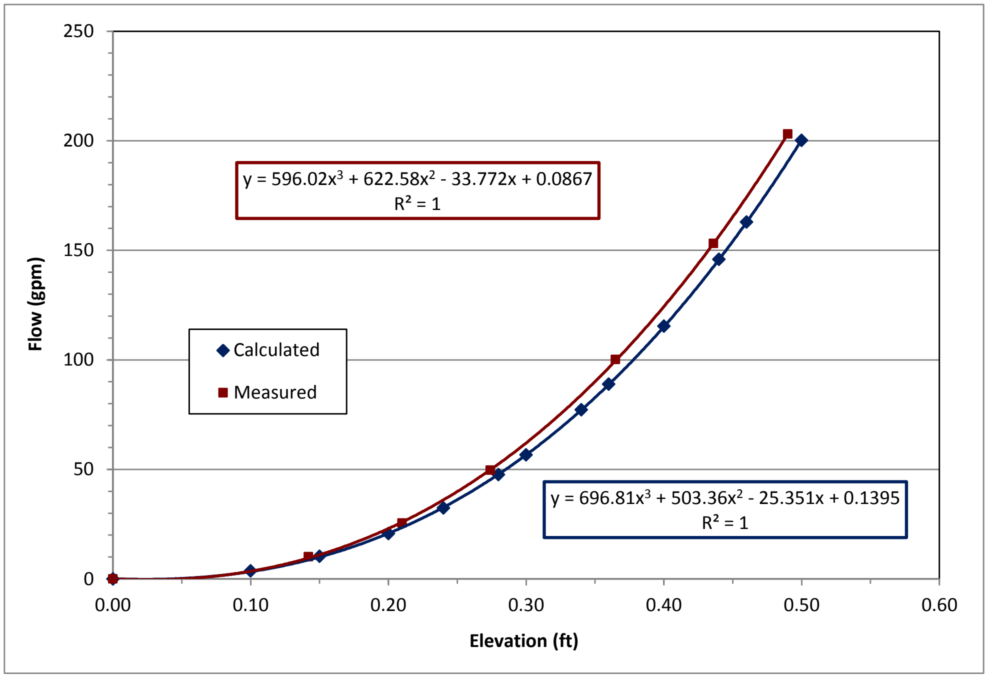


Figure 8: Drawdown V-notch Weir Flow vs Head Curves

3.2.3 Temperature

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 reading was documented at the start and end of each test, to assure an acceptable testing temperature of less than 80 degrees F.

3.2.4 Pressure Head

Pressure head measurements were recorded at multiple locations using piezometer taps and a Omegadyne PX419, 0 - 2.5 psi cell. The pressure cell was calibrated at Alden prior to testing. Accuracy of the readings is ± 0.001 ft. The cell was installed at a known datum in relation to the tank floor, allowing for elevation readings through the full range of flows. A minimum of 30 seconds of pressure data was averaged and recorded for each pressure tap during hydraulic testing, under steady-state flow conditions, using the computerized DA program. Driving head and effluent weir measurements were averaged and recorded every 5 seconds during removal efficiency testing. A photograph of the pressure instrumentation is shown on **Figure 9**.

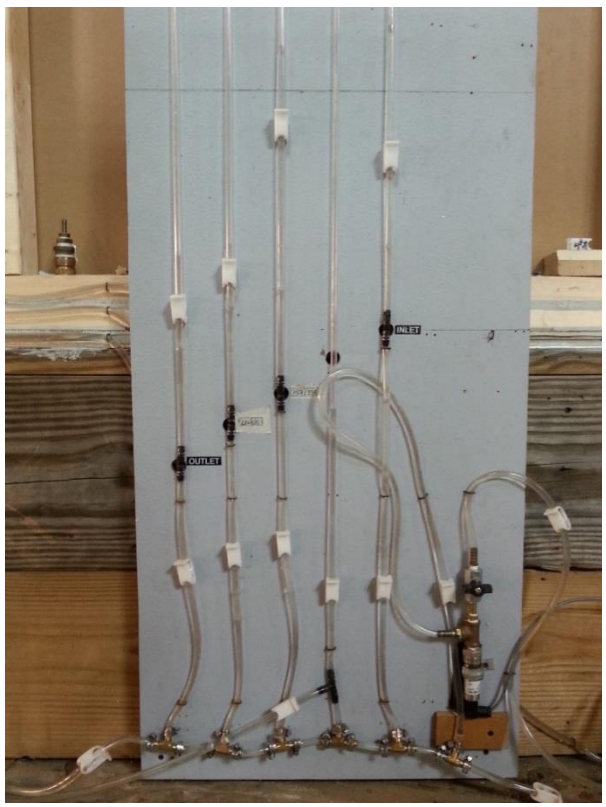


Figure 9: Pressure Measurement Instrumentation

3.2.5 Sediment Injection

The test sediment was injected into the crown of the influent pipe using an Auger® volumetric screw feeder, model VF-1, shown on **Figure 10**. The auger feed screw, driven with a variable-speed drive, was calibrated with the test sediment prior to testing, to establish a relationship between the auger speed (0-100%) and feed rate in grams/minute. The calibration, as well as test verification of the sediment feed was accomplished by collecting timed dry samples of 0.1-liter, up to a maximum of 1-minute, and weighing them on an Ohaus® 4000g x 0.1g, model SCD-010 digital scale. The feeder has a hopper at the upper end of the auger to provide a constant supply of dry test sand. The allowable Coefficient of Variance (COV) for the injection is 0.10.

Figure 10: Photograph Showing Variable-speed Auger Feeder

3.2.6 Sample Collection

Effluent samples were collected in 2-liter containers from the end of the 6-inch effluent pipe. Background concentration samples were collected from the center of the vertical pipe upstream of the test unit with the use of a calibrated isokinetic sampler, shown on **Figure 11**.

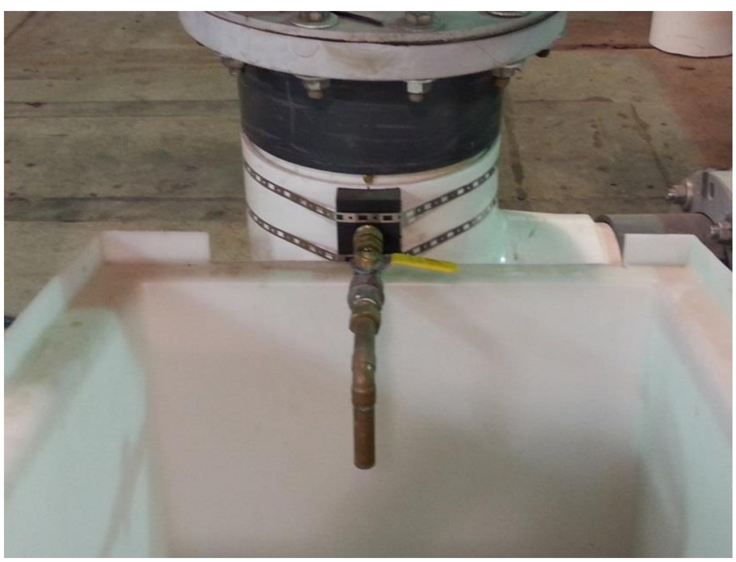


Figure 11: Photograph Showing the Background Isokinetic Sampler

3.2.7 Sample Concentration Analyses

Effluent and background concentration samples were analyzed by Alden in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2013), "Standard Test Methods for Determining Sediment Concentration in Water Samples". The required silica sand used in the sediment testing did not result in any dissolved solids in the samples and therefore, simplified the ASTM testing methods for determining sediment concentration. Associated instrumentation included:

- 2-Liter collection beakers
- Ohaus® 4000g x 0.1g digital scale, model SCD-010
- Oakton® StableTemp gravity convection oven, model 05015-59
- Sanplatec Dry Keeper® desiccator, model H42056-0001
- AND® 0.0001-gram analytical balance, model ER-182A
- Advantec 3-way filtration manifold
- Whatman® 934-AH, 47-mm, 1.5-micron, glass microfiber filter paper

Samples were collected in graduated 2-Liter beakers which were cleaned, dried and weighed to the nearest 0.1-gram, using an Ohaus® 4000g x 0.1g digital scale, model SCD-010, prior to sampling. Collected samples were also weighed to the nearest 0.1-gram using the Ohaus® digital scale. Each collected sample was filtered through a pre-rinsed Whatman® 934-AH, 47-mm, 1.5-micron, glass microfiber filter paper, using a laboratory vacuum-filtering system. Prior to processing, each filter was rinsed with distilled water and placed in a designated dish and dried in an Oakton® StableTemp gravity convection oven, model 05015-59, at 225 degrees F for a minimum of 2.5 hours. Each dried filter was placed in a Sanplatec Dry Keeper® desiccator, model H42056-0001, to cool and then weighed to the nearest 0.0001-gram to determine the tare weight, using an AND® analytical balance, model ER-182A. Once filtered, each sample and dish was dried at a temperature between 175 and 210 degrees F (below boiling) for 20 to 30 minutes until visually dry. The oven temperature was increased to 225 degrees F and the samples were dried for an additional 2.5 hours. The dry samples and dishes were then cooled in the desiccator and weighed to the nearest 0.0001-gram, using the AND® balance. Net sediment weight (mg) was determined by subtracting the dried filter weight (tare) from the dried sample weight and multiplying the result by 1,000. The net sample volume, in liters, was determined by subtracting the beaker and net sediment weight from the overall sample weight and dividing by 1,000. Each sample sediment concentration, in mg/liter, was determined by dividing the net sediment weight by the net sample volume.

Photographs of the utilized laboratory instrumentation are shown on **Figure 12** and **Figure 13**.

Figure 12: Laboratory Sample Filtration Equipment and Scale

Figure 13: Sample Analysis Laboratory Equipment

3.3 DATA MANAGEMENT AND ACQUISITION

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

A personal computer running an Alden in-house Labview® Data Acquisition (DA) 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 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 a user-defined number of significant figures.

Test flow and pressure data was continuously collected at a frequency of 250 Hz. The flow data was averaged and recorded to file every 5 seconds. Steady-state pressure data was averaged and recorded over a duration of 30 seconds for each point. The recorded data files were imported into a spreadsheet 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. The data was input to the designated spreadsheet for final processing.

3.4 PREPARATION OF TEST SEDIMENT

The sediment particle size distribution (PSD) used for removal efficiency testing was comprised of 1-1000 micron silica particles, as shown in **Table 1**. The Specific Gravity (SG) of the sediment mixes was 2.65. A commercially-available blend of each mix was provided by AGSCO Corp., a QAS International ISO-9001 certified company, and adjusted by Alden as required. Samples were collected from random bags and analyzed in accordance with ASTM D422-63 (2007), by GeoTesting Express, an ISO/IEC 17025 accredited independent laboratory. The average %-finer values of the stock material were found to be outside of the NJDEP acceptance criteria of 2% for particle sizes ≤ 20 microns. The test mix was adjusted to within the NJDEP acceptance criteria with the addition of commercially-available US-Silica Min-U-Sil 10, with a PSD of approximately 1-25 microns. Test batches of approximately 30 lbs each, were prepared in individual 5-gallon buckets, which were arbitrarily selected for the removal testing. A well-mixed random sample was collected from three random test batches and analyzed for PSD by GeoTesting Express. The average of the samples was used for compliance to the protocol specifications listed in Column 2 of **Table 1**. The D_{50} of the samples ranged from 61 to 63 microns, with an average of 62 microns. The PSD data of the samples are shown in **Table 2** and the corresponding curves are shown on **Figure 14**.

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

Particle size (µm)	NJDEP	Sample 1	Sample 2	Sample 3	Average
1000	100%	100%	100%	100%	100%
500	95%	96%	95%	96%	96%
250	90%	92%	91%	92%	92%
150	75%	79%	79%	79%	79%
110	60%	65%	65%	65%	65%
75	50%	53%	53%	53%	53%
53	45%	48%	47%	47%	47%
20	35%	34%	32%	36%	34%
8	20%	20%	19%	19%	19%
5	10%	14%	13%	13%	13%
2	5%	4%	4%	4%	4%
75	D_{50}	61	63	63	62

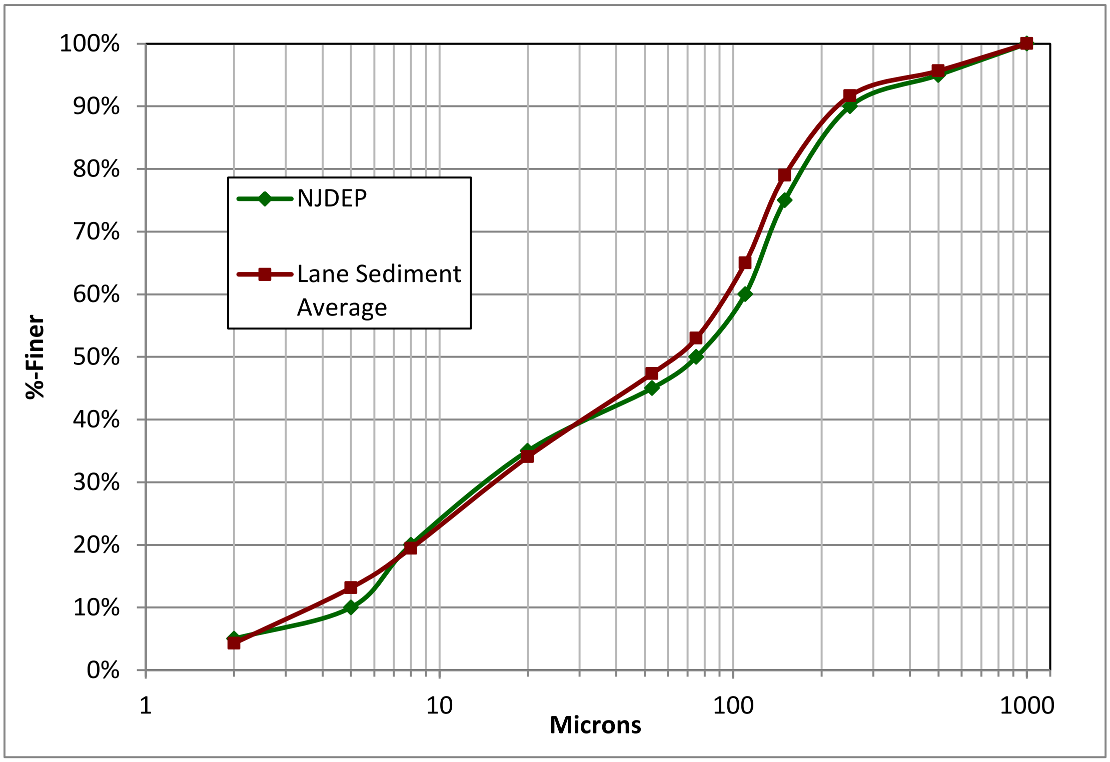


Figure 14: PSD Curves of 1-1000 micron Test Sediment and NJDEP Specifications

3.5 DATA ANALYSIS

The following equations and procedures were used in analyzing the data collected on the Lane SK75 test unit:

3.5.1 Hydraulics

The pressure cell was mounted at a height of 4.942 ft above the floor of the test unit. This datum value was added to all recorded measurements to correct the water height above the unit floor. The system energy loss across the unit was determined by adding the velocity head to the piezometric measurements taken in the inlet and outlet pipes.

The velocity head is defined by:

$$\mathbf{H = V^2/2g} \tag{1}$$

where,

H = velocity head (ft), V = velocity (ft/sec), and g = gravity (32.17 ft/sec^2).

The velocity is defined by:

$$\mathbf{V = Q/A} \tag{2}$$

where,

V = velocity (ft/sec), Q = flow (ft^3/sec), and A = wetted area (ft^2).

The area in the partial pipe flow was calculated using:

$$\boldsymbol{A = 0.125(\theta - Sin\theta)D^2} \tag{3}$$

where,

A = wetted area (ft^2), θ = angle of inclusion (radians), and D = pipe diameter (ft).

The angle of inclusion of the water surface (θ) was calculated using:

$$\boldsymbol{\theta = 2\pi - 2(ACos\left(\frac{y - \frac{D}{2}}{\frac{D}{2}}\right))} \tag{4}$$

where,

Y = measured water depth (ft), and D = pipe diameter (ft).

3.5.2 Removal Efficiency

The injected mass of each run was calculated by:

$$\mathbf{M_{inj} = \Delta M - (\Delta M \times w)} \tag{5}$$

where,

M_{inj} = final mass of injected sediment (grams), ΔM = measured mass of injected sediment (grams), w = moisture content of sediment (%).

The injected concentration was calculated by:

$$\mathbf{C_{inj} = M_{inj} / Vol} \tag{6}$$

where,

C_{inj} = injected concentration (mg/L), M_{inj} = final mass of injected sediment (grams), Vol = total volume of water during sediment dosing (L).

The sediment removal efficiency was calculated by:

$$\mathbf{\%\ Removal = (((M_{inf})-(M_{eff})-(M_{dd}))\ /\ M_{inf}) \times 100} \tag{7}$$

where,

M_{inf} = Influent Mass: Average Influent TSS Concentration x Total Volume of water flowing through the filtration MTD during the addition of test sediment or Total Mass Added.
M_{eff} = Effluent Mass: Adjusted (for background TSS concentration) Effluent TSS Concentration x Total Effluent Volume of water flowing through the filtration MTD during the addition of test sediment.

M_{dd} = Drawdown Mass: Average Drawdown TSS Concentration x Total Volume of water flowing from the filtration MTD during drawdown

The effluent and background sample concentrations were calculated as follows:

$$\textbf{Concentration (mg/L) = Sediment Wt (mg) / Sample Volume (L)} \quad (8)$$

The auger injector verification concentrations were determined by the following:

$$C_i = M_f / Q_{avg} \quad (9)$$

where,

C_i = influent concentration (mg/L), M_f = sediment mass feed (mg/min),
Q_{avg} = average flow (lpm)

3.6 LABORATORY ANALYSIS

The following Test Methods were used to analyze the various dry and aqueous sediment samples:

- Sediment Concentration

  ASTM Designation: D 3977-97 (Re-approved 2013), “Standard Test Methods for Determining Sediment Concentration in Water Samples”

- Sediment Moisture Content

  ASTM Designation: D4959-07, “Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating”

- Dry Sediment Particle Size Distribution

  ASTM D422-63 (2007), “Standard Test Method for Particle Size Analysis of Soils”

3.7 QUALITY ASSURANCE AND CONTROL

All instruments were calibrated prior to testing and periodically checked throughout the test program. The instrumentation calibrations are shown in Appendix B.

3.7.1 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 selected flow meter.

3.5.1 Sediment Injection

The sediment feed (g/min) was verified with the use of a digital stop watch and 4000g 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.

3.7.2 Sediment Concentration Analysis

All sediment concentration samples were processed in accordance with the ASTM D3977-97 (2013) analytical method. Gross sample weights were measured using a 4000g x 0.1g calibrated digital scale. The dried sample weights were measured with a calibrated 0.0001g analytical balance. Any change in filter weight due to processing was accounted for by including three control filters with each test set. The average of the three values, which was +/- 0.1-0.5 mg, was used in the final concentration calculations.

Analytical accuracy was verified by preparing two blind control samples and processing using the ASTM method. The final calculated values were within 0.26% and 0.87% of the theoretical sample concentrations, with an average of 0.57% accuracy. This value was not corrected for particles smaller than the filter designation of 1.5 microns and therefore, is considered conservative.

4.0 RESULTS AND DISCUSSION

4.1 SEDIMENT REMOVAL PERFORMANCE

Ten (10) removal efficiency test runs were conducted at a target flow of 120 gpm (100% MTFR), corresponding to a normalized flow of 4 gpm/ft^2. The minimum duration of the runs was 38 minutes, with a target influent sediment concentration of 200 mg/l. All test runs met or exceeded the protocol testing criteria. An additional run (#11) was conducted at a flow of 108 gpm (90% MTFR) and influent concentration of 200 mg/L, to meet the mass loading criteria. The duration of the run was 69 minutes, during which nine (9) effluent samples (11 including drawdown) and five (5) background samples were collected.

The measured flow for the 10 runs ranged from 119.5 gpm to 120.8 gpm, with an average flow of 119.9 gpm. The calculated COVs ranged from 0.001 to 0.004. The average measured flow for the mass loading run was 107.7 gpm, with a COV of 0.001. The maximum recorded temperature for all the runs ranged from 67.2 to 78.4 degrees F. The calculated mass/volume influent concentrations ranged from 189 to 207 mg/L, with an average concentration of 201 mg/L. The measured injected influent concentrations ranged from 198 to 203 mg/L, with an average concentration of 200 mg/L. The injection COVs ranged from 0.001 to 0.005. The average adjusted effluent concentrations ranged from 29.2 to 41.5 mg/L and the average drawdown concentrations ranged from 5.0 to 25.7 mg/L. The drawdown duration for the eleven (11) runs increased sequentially from 29 minutes to approximately 80 minutes. The calculated removal efficiencies utilizing the mass/volume concentration ranged from 85.5% to 82.6%, with an average removal of 83.9%. The removal efficiency utilizing the injected concentration ranged from 85.5% to 82.9%, with an average removal of 83.8%. The maximum driving head, which was recorded at the end of run #10, was 3.26 ft, which correlates to 0.76 ft above the crown of the chamber. This value was set as the target for the mass loading testing.

The removal efficiencies were calculated using both the mass/volume and injected influent concentrations, and are shown in **Table 3.** The measured and calculated data for the eleven (11) runs is shown in **Table 4** and **Table 5**. The influent concentration and removal curves are shown on **Figure 15.** The recorded driving head at the end of each run is shown on **Figure 16**.

Table 3: Removal Efficiency Summary

Run #	Removal Efficiency	
	mass/volume	Injection Rate
1	**85.5%**	85.5%
2	**85.4%**	85.0%
3	**82.7%**	83.6%
4	**83.8%**	83.5%
5	**84.2%**	83.9%
6	**84.1%**	83.9%
7	**83.6%**	83.3%
8	**82.9%**	83.2%
9	**83.2%**	82.8%
10	**84.5%**	84.2%
11	**82.6%**	82.9%
Average	**83.9%**	**83.8%**

Table 4: Measured Influent Parameters

Run #	Measured Flow		Max Temp	Influent Concentration (mg/L)		
	gpm	COV	Deg. F	mass/volume	Injection Rate	Injection COV
1	120.8	0.004	78.4	198	198	0.002
2	119.6	0.001	78.1	207	201	0.002
3	119.7	0.002	74.8	189	200	0.003
4	119.7	0.001	74.6	203	200	0.001
5	119.5	0.001	74.8	204	201	0.001
6	120.2	0.001	70.5	202	200	0.001
7	119.7	0.001	70.7	204	200	0.002
8	120.1	0.001	69.7	196	199	0.002
9	119.8	0.001	68.6	204	200	0.002
10	119.9	0.001	67.2	203	200	0.001
11 (90% MTFR)	107.7	0.001	71.7	199	203	0.005
Average #1-10	**119.9**		**Average**	**201**	**200**	

Table 5: Measured Sample Concentrations

Run #	Maximum Background	Adjusted Effluent Concentrations (mg/L)						Drawdown Concentrations (mg/L)		
	mg/L	#1	#2	#3	#4	#5	**Average**	#1	#2	**Average**
1	1.7	21.39	19.71	19.94	43.56	41.30	**29.18**	12.33	39.14	**25.73**
2	3.0	19.75	23.25	25.22	63.47	44.35	**35.21**	9.19	5.51	**7.35**
3	4.3	38.33	35.94	39.79	40.91	39.69	**38.93**	9.39	4.76	**7.07**
4	0.9	37.31	40.21	41.01	41.24	41.60	**40.28**	7.32	3.43	**5.37**
5	1.0	36.04	37.24	41.02	40.58	41.34	**39.24**	7.86	3.11	**5.48**
6	0.2	37.81	37.48	41.27	40.86	40.02	**39.49**	7.60	3.28	**5.44**
7	0.6	37.44	39.24	40.07	42.90	43.45	**40.62**	7.69	3.77	**5.73**
8	1.0	39.21	39.05	41.13	42.64	40.48	**40.50**	6.50	3.39	**4.95**
9	0.9	38.24	41.77	42.78	41.84	42.91	**41.51**	9.69	4.58	**7.14**
10	6.6	32.24	35.76	46.27	39.88	36.87	**38.20**	12.14	5.56	**8.85**
Mass Loading Test		#1 / #2	#3 / #4	#5 / #6	#7 / #8	#9				
11	1.1	36.06 / 38.25	41.89 / 39.93	38.14 / 37.42	40.14 / 36.55	39.92	**38.70**	9.82	6.09	**7.95**

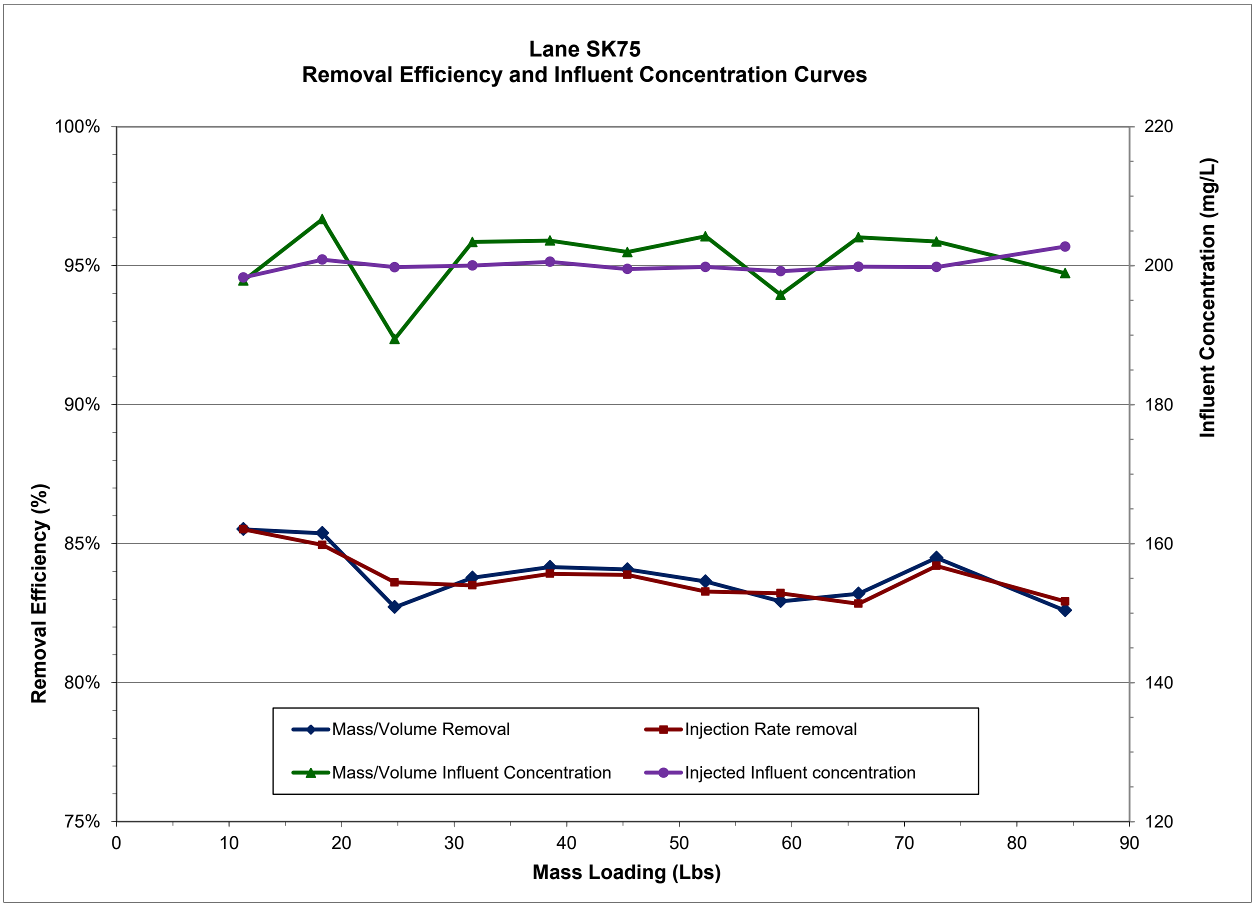


Figure 15: Lane SK75 Removal Efficiency and Influent Concentration Curves

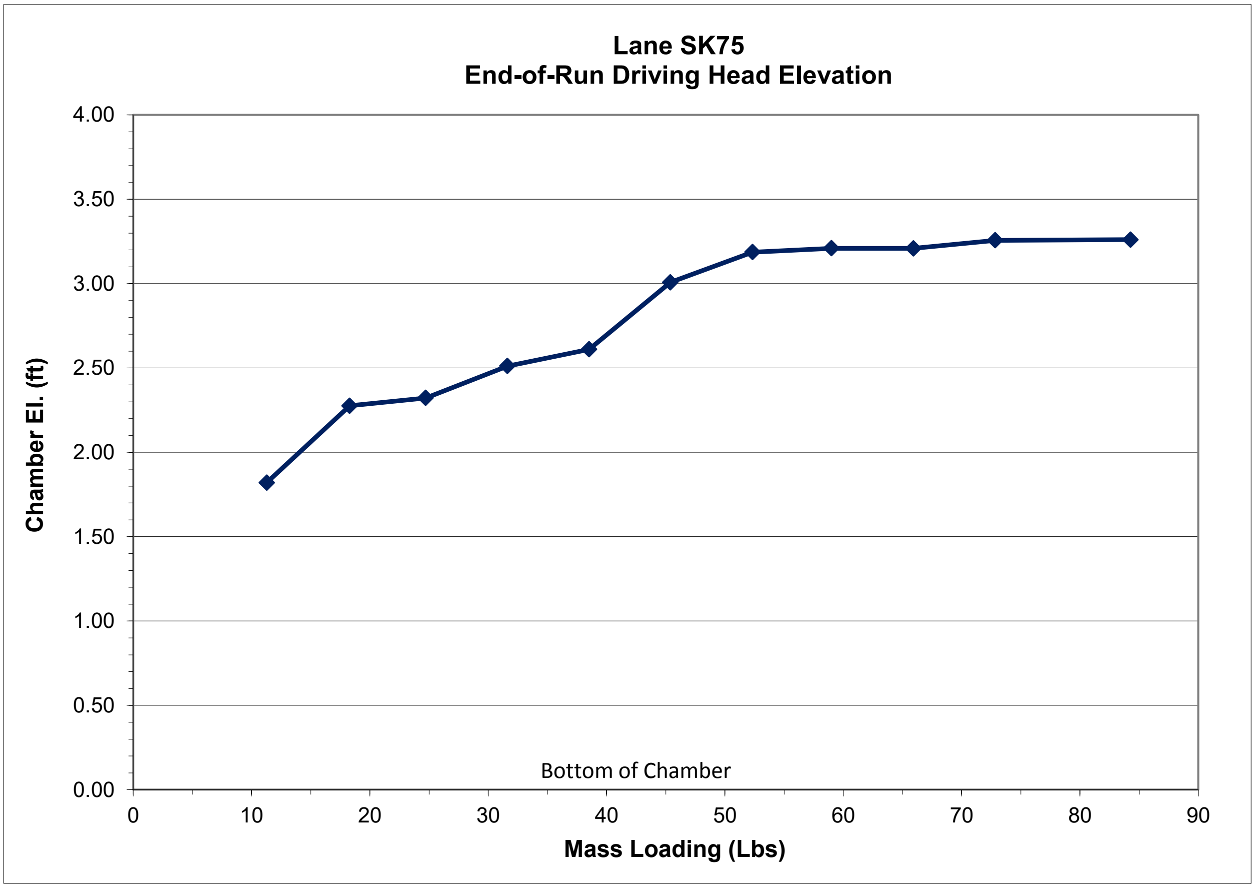


Figure 16: Lane SK75 Recorded Driving Head Elevations

4.2 Hydraulic Measurements

Steady-state pressure measurements were recorded on the clean chamber to establish the hydraulic characteristic curves. Recorded flows ranged from 10 to 353 gpm (0.33 to 11.75 gpm/ft^2). The recorded data is shown in **Table 6** and corresponding curves on **Figure 17**.

Table 6: Measured Hydraulic Data

Flow			Inlet El. (A') Corrected for Energy	Outlet El. (D') Corrected for Energy	System Energy Loss
gpm	cfs	gpm/sq-ft	ft	ft	A'-D'
0	0				
10.1	0.02	0.34	**1.281**	**0.389**	**0.892**
25.4	0.06	0.85	**1.331**	**0.446**	**0.886**
49.6	0.11	1.65	**1.385**	**0.513**	**0.873**
100.1	0.22	3.34	**1.494**	**0.619**	**0.875**
153.1	0.34	5.10	**1.578**	**0.708**	**0.870**
203.1	0.45	6.77	**1.832**	**0.787**	**1.046**
246.1	0.55	8.20	**2.112**	**0.855**	**1.257**
305.5	0.68	10.18	**2.583**	**0.939**	**1.644**
352.5	0.79	11.75	**2.984**	**1.010**	**1.975**

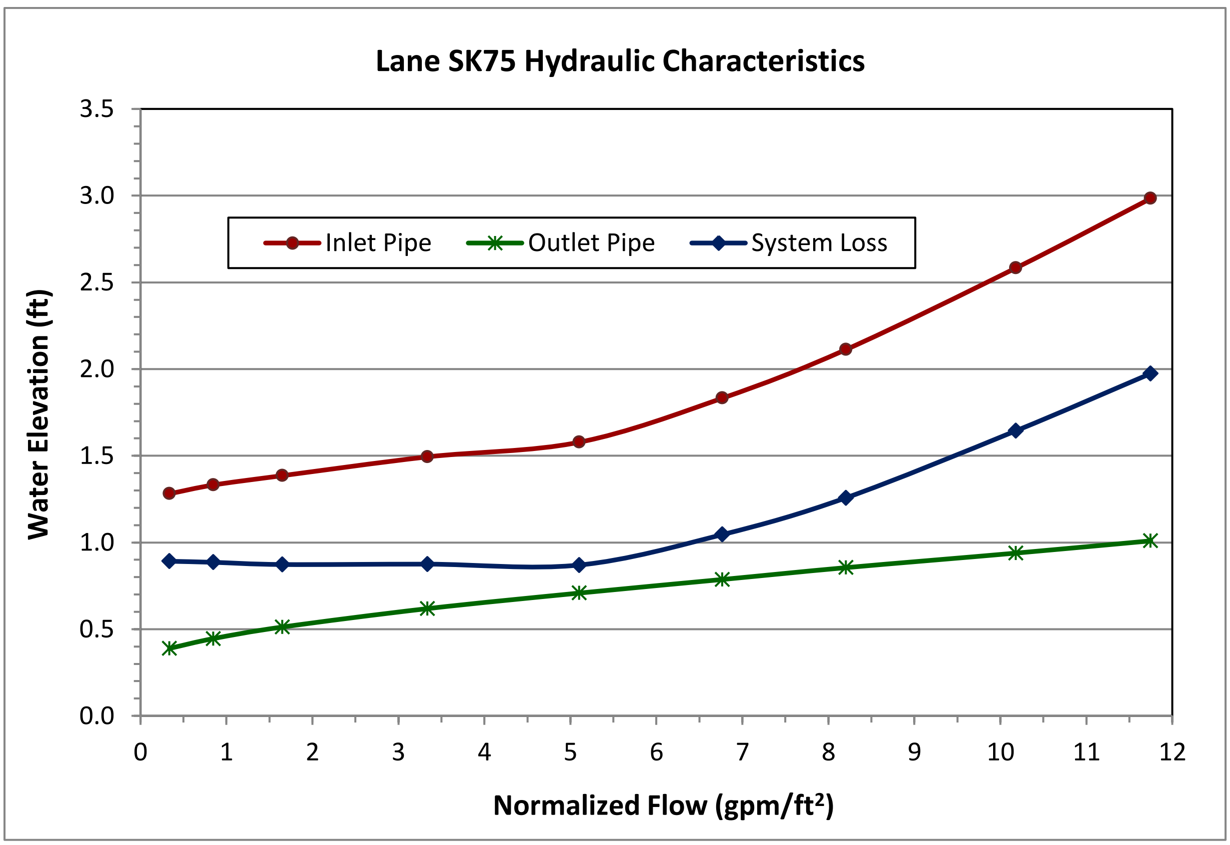


Figure 17: Lane SK75 Hydraulic Characteristic Curves

5.0 CONCLUSIONS

The Lane SK75 Stormkeeper Chamber Sediment Strip and Prinsco Hydrostor HS75 Sediment Row achieved a sediment removal efficiency of 83.9% for the eleven (11) runs conducted using 1-1000 micron NJDEP sediment, meeting the NJDEP filtration testing protocol criteria. The total mass introduced into the unit was 72.9 lbs for the ten (10) runs conducted at 120 gpm (MTFR). An additional 11.4 lbs was introduced during the 90% mass loading test, for a total of 84.3 lbs.

All testing conducted on the Lane SK75 Stormkeeper Chamber Sediment Strip and Prinsco Hydrostor HS75 Sediment Row met or exceeded the requirements as set forth in the 2013 NJDEP Testing Protocol.

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NOMENCLATURE AND ABBREVIATIONS

A	= area	(L^2)
Cd	= coefficient of discharge	
Ci	= influent sediment concentration	(M/L^3)
Cfs	cubic feet per second	(L^3/T)
COV	= coefficient of variance	
D	= diameter	(L)
D_{50}	= median particle size	(L)
DA	= data acquisition	
DP	= differential pressure	(ΔL)
°F	= degree Fahrenheit	(T)
Ft	= feet	(L)
Ft/s	= feet per second	(L/T)
g	= grams	(M)
g	= gravity	(L/T^2)
gpm	gallons per minute	(L^3/T)
H	= head	(L)
Hz	= hertz	(T)
L	= liters	(L^3)
Lbs	= pounds	(M)
mg/L	= milligram per liter	(M/L^3)
min	= minute	(T)
PSD	= particle size distribution	
Q	= flow	(L^3/T)
sec	= seconds	(T)
SLR	= surface loading rate	($L^3/T/L^2$)
SSC	= suspended solids concentration	
V	= velocity	(L/T)
w	moisture content (%)	

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Appendix A ALDEN QUALIFICATIONS

Founded in 1894, Alden is the oldest continuously operating hydraulic laboratory in the United States and one of the oldest in the world. From the early days of hydropower development and aviation, through World Wars I and II, and into the modern world defined by environmental needs, Alden has been a recognized leader in the field of fluid dynamics consulting, research and development. In the 21st Century, Alden is a vibrant, growing organization consisting of engineers, scientists, biologists, and support staff in five specialty areas. Much of our work supports the power generating, environmental, manufacturing, and process industries.

Alden offers a scope of specialized services including: conceptual design, detailed design, verification testing, analytical modeling, Computational Fluid Dynamics (CFD), field measurements, physical modeling, precision flow meter and instrumentation calibrations (ISO 17025 certified), and field testing. Decades of combined experience in numerical simulation techniques, physical modeling, and field studies provide the broad knowledge that is essential for recognizing which method is best suited to solving a problem.

Unusually large facilities (more than 125,000 square feet of enclosed space) and sophisticated data acquisition systems are available for each study. Approximately twenty buildings, located on thirty acres at our headquarters in Holden, MA are equipped with flow supplies and control systems for conducting hydraulic modeling, verification and equipment testing, fish testing, air/gas flow modeling, and numerous other types of flow testing. Fixed facilities providing air and water flow and an inventory of movable flow related equipment such as pumps, valves, meter devices, fish screens, etc. are located on the premises at our Massachusetts laboratory. Fully equipped and staffed carpentry, machine, and instrumentation shops provide rapid and efficient project support.

Alden has performed verification testing on approximately twenty Hydrodynamic Separator and Filtration Manufactured Treatment Devices (MTDs) for multiple manufacturers under various state and federal testing protocols. Alden's senior stormwater engineer, James Mailloux, has served on the ASTM and SWEMA Stormwater Technical committees, providing guidance in the area of testing methodologies. He has a Master's Degree in Environmental Engineering from Worcester Polytechnic Institute and has been conducting testing at Alden for more than 25 years. Mr. Mailloux has contributed to articles related to laboratory testing in Stormwater Magazine, as well as presented on multiple testing and regulatory topics at various conferences, including StormCon, WefTec and National Precast Concrete Association training seminars.

Appendix B INSTRUMENTATION CALIBRATIONS