TOTAL SUSPENDED SOLIDS REMOVAL TEST OF A HIGH DENSITY POLYETHYLENE WATER QUALITY UNIT

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1.0 INTRODUCTION

Under a contract from Advanced Drainage Systems, Inc. (ADS), a Total Suspended Solid (TSS) removal test of the ADS High Density Polyethylene (HDPE) Water Quality Unit, using F-95 and OK110 silica sand, was conducted at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts.

2.0 TEST FACILITY DESCRIPTION

The test unit was a modified ADS N-12 pipe, 5 feet in diameter and approximately 20 feet long, with an inlet and outlet pipe diameter of 12 inches. The unit contained a sediment chamber, which was formed by installing an overflow weir plate approximately 12 feet downstream of the inlet pipe, and an oil chamber, formed by installing a baffle wall 2 feet from the downstream end. The overflow weir had a crest elevation approximately 1.75 inches below the invert of the inlet pipe and the opening below the baffle wall was 12 inches high.

A closed test loop was constructed in a laboratory testing facility. The test loop consisted of a 15 HP pump drawing water from a laboratory sump, 12 inch flow meter, influent piping, test unit, effluent piping and a channel to return the water to the sump. The influent piping contained two sampling ports: an upstream port for collecting background samples and one located approximately 3 feet upstream of the test unit, for collecting the influent concentration samples. A 12 inch tee for injecting the sediment was positioned 12 diameters upstream of the sampling port to assure thorough mixing. A sampling port for obtaining the effluent concentration samples was located approximately 3 feet downstream of the test unit. All sample ports were oriented 30 degrees from vertical and consisted of a 12 inch x 4 inch reducing tee, 4 inch pipe and quick-turn butterfly valve.

3.0 INSTRUMENTATION AND MEASURING TECHNIQUES

3.1 Flow

The inflow to the test unit was set with a 12 inch butterfly valve and measured using an orifice plate fabricated and installed per ASME guidelines. The accuracy of the flow measurement is estimated at ±2%. The differential head from the orifice meter was measured using a standard water manometer board and a hand held engineer's folding rule.

3.2 Sediment Injection

F-95 and OK110 silica sands were used to test the HDPE unit. Each test sand was introduced into the system using an Auger volumetric screw feeder, model VF-1. The feed auger was driven with a variable speed drive, which was calibrated prior to testing to produce the desired feed rates for the various test conditions. The feed unit contains a 1.5 cubic foot hopper at the upper end of the auger to provide a constant supply of dry test sand.

3.3 Temperature

Temperature measurements were achieved using an Omega DP41 temperature probe and readout device, which was calibrated at the laboratory prior to testing.

3.4 Sample Analysis

Samples of approximately 1 Liter were collected from each port in graduated 2-Liter beakers. The samples were weighed to the nearest 0.1g, using an Ohaus 4000g x 0.1g digital scale, model SCD-010. Each sample was filtered through a Whatman 934-AH, 42 mm, 1.5-micron, glass microfiber filter paper. Each sediment sample was dried and then weighed to the nearest 0.0001g, using an AND analytical balance, model ER-182A.

4.0 TEST PROCEDURE

The ADS HDPE Water Quality Unit was tested in accordance with the Maine DEP Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems. Test flows ranged from 1 to 2 cfs, with a TSS (total suspended solids) concentration of approximately 250 mg/L.

The system flow rate was set and allowed to stabilize. A background sample was collected, the temperature was recorded, and then the test sand was introduced into the inflow line. Three system volumes were allowed to pass through the system prior to the collection of TSS samples. Five pairs of inflow/outflow samples were collected, with the outflow samples taken 1 unit residence time after the inflow sample. At the completion of the sediment collection, the sediment injection was stopped and three system volumes were again passed through the unit, after which time another background sample was collected and temperature recorded.

The collected samples were filtered and analyzed in accordance with Method B, as described in ASTM Designation: D 3977-97 (Re-approved 2002), "Standard Test Methods for Determining Sediment Concentration in Water Samples." This method of analysis corresponds to an SSC (Suspended Sediment Concentration) form of testing, as opposed to a TSS test, the difference being that an SSC method uses the entire sample in the analysis, where as a TSS method only uses a small portion of the sample in the analysis. Although different in the methodology, when performed correctly, the two methods will produce comparable results.

5.0 RESULTS

Results of all the tests are shown in Tables 1 through 11 and are discussed in the following sub-sections.

5.1 F95 Silica Sand Tests

5.1.1 2 cfs Test

The measured inflow TSS concentrations ranged from 211.9 mg/L to 441.4 mg/L, with a mean concentration of 332 mg/L. The outflow TSS concentrations ranged from 78.1 mg/L to 111.3 mg/L, with a mean concentration of 92 mg/L. The background concentrations were negligible.

The TSS concentration removal efficiencies ranged from 54.3% to 82.3%, with a mean of 72.3%, see Table 1.

5.1.2 1.5 cfs Test

The measured inflow TSS concentrations ranged from 240.3 mg/L to 433 mg/L, with a mean concentration of 319 mg/L. The outflow TSS concentrations ranged from 30.6 mg/L to 106.1 mg/L, with a mean concentration of 49.5 mg/L. The average background concentration was 1.10 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 69.9% to 93.1%, with a mean of 84.8%, see Table 2.

5.1.3 1.0 CFS Test

The measured inflow TSS concentrations ranged from 241.5 mg/L to 474.9 mg/L, with a mean concentration of 355.4 mg/L. The outflow TSS concentrations ranged from 13.0 mg/L to 87.8 mg/L, with a mean concentration of 38.1 mg/L. The average background concentration was 0.63 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 77.0% to 97.0%, with a mean of 89.4%, see Table 3.

5.2 OK110 Silica Sand Tests using a 1.5 inch Auger Screw

OK110 Silica sand is the medium that is mandated in the Maine DEP Laboratory Testing Protocol for Manufactured Stormwater Treatment Systems. Tests 5.2.1 through 5.2.4 were conducted with the sand being injected into the system using a 1.5 inch auger screw, which was originally sized for the higher flow rates.

5.2.1 1.5 cfs Test

The measured inflow TSS concentrations ranged from 135 mg/L to 414.2 mg/L, with a mean concentration of 238.5 mg/L. The outflow TSS concentrations ranged from 60 mg/L to 74.3 mg/L, with a mean concentration of 67.6 mg/L. The average background concentration was 0.31 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 55.6% to 83.8%, with a mean of 71.8%, see Table 4.

5.2.2 1.0 cfs Test

The measured inflow TSS concentrations ranged from 327.1 mg/L to 375.3 mg/L, with a mean concentration of 351.7 mg/L. The outflow TSS concentrations ranged from 22.4 mg/L to 40.5 mg/L, with a mean concentration of 31.4 mg/L. The average background concentration was 2.23 mg/L.

The TSS concentration removal efficiencies ranged from 88.7% to 94.3%, with a mean of 91.6%, see Table 5.

5.2.3 1.25 cfs Test

The measured inflow TSS concentrations ranged from 114.9 mg/L to 307 mg/L, with a mean concentration of 211.6 mg/L. The outflow TSS concentrations ranged from 34.4 mg/L to 43.2 mg/L, with a mean concentration of 38.4 mg/L. The average background concentration was 0.99 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 66.5% to 88.8%, with a mean of 82.2%, see Table 6.

5.2.4 1.25 cfs Repeat Test

The measured inflow TSS concentrations ranged from 114.6 mg/L to 262.6 mg/L, with a mean concentration of 176.8 mg/L. The outflow TSS concentrations ranged from 30.9 mg/L to 42.3 mg/L, with a mean concentration of 36.5 mg/L. The average background concentration was 0.26 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 70.2% to 85.9%, with a mean of 79.5%, see Table 7.

5.3 OK110 Silica Sand Tests using a 1.0 inch Auger Screw

Tests 5.3.1 through 5.3.4 were conducted with the sand being injected into the system using a 1.0 inch auger screw, to obtain a more consistent feed rate for the verification testing.

5.3.1 1.25 cfs Test

The measured inflow TSS concentrations ranged from 396.9 mg/L to 482.1 mg/L, with a mean concentration of 442.7 mg/L. The outflow TSS concentrations ranged from 31.1 mg/L to

45.3 mg/L, with a mean concentration of 38.1 mg/L. The average background concentration was 0.90 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 90.4% to 93.7%, with a mean of 91.5%, see Table 8.

5.3.2 1.25 cfs Repeat Test

The measured inflow TSS concentrations ranged from 226.7 mg/L to 299.3 mg/L, with a mean concentration of 263.2 mg/L. The outflow TSS concentrations ranged from 17.6 mg/L to 23.0 mg/L, with a mean concentration of 21.0 mg/L. The average background concentration was 1.96 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 90.4% to 94.3%, with a mean of 92.7%, see Table 9.

5.3.3 1.5 cfs Test

The measured inflow TSS concentrations ranged from 179.0 mg/L to 320.0 mg/L, with a mean concentration of 254.8 mg/L. The outflow TSS concentrations ranged from 27.1 mg/L to 30.4 mg/L, with a mean concentration of 28.7 mg/L. The average background concentration was 0.20 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 83.1% to 91.2%, with a mean of 88.8%, see Table 10.

5.3.4 1.5 cfs Maine DEP Verification Test

The measured inflow TSS concentrations ranged from 116.7 mg/L to 292.3 mg/L, with a mean concentration of 186.9 mg/L. The outflow TSS concentrations ranged from 19.1 mg/L to

23.8 mg/L, with a mean concentration of 22.1 mg/L. The average background concentration was 0.29 mg/L.

The TSS concentration removal efficiencies, adjusted for the background concentration, ranged from 80.6% to 93.6%, with a mean of 88.3%, see Table 11.

Table 1
2 cfs FLOW TEST
F95 Sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.0000**	441.4	78.1	**82.3**	441.4	78.1	**82.3**
2	**0.0000**	368.5	111.3	**69.8**	368.5	111.3	**69.8**
3	**0.0000**	222.1	101.4	**54.3**	222.1	101.4	**54.3**
4	**0.0000**	416.3	84.8	**79.6**	416.3	84.8	**79.6**
5	**0.0000**	211.9	84.6	**60.1**	211.9	84.6	**60.1**
MEAN	**0.0000**	332.0	92.0	**72.3**	332.0	92.0	**72.3**

Table 2
1.5 cfs FLOW TEST
F95 Sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**1.1049**	349.7	106.1	**69.7**	348.6	105.0	**69.9**
2	**1.1049**	240.3	34.6	**85.6**	239.2	33.4	**86.0**
3	**1.1049**	287.5	30.6	**89.4**	286.4	29.5	**89.7**
4	**1.1049**	284.5	45.6	**84.0**	283.4	44.5	**84.3**
5	**1.1049**	433.0	30.7	**92.9**	431.9	29.6	**93.1**
MEAN	**1.1049**	319.0	49.5	**84.5**	317.9	48.4	**84.8**

Table 3
1.0 cfs FLOW TEST
F95 Sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.6293**	241.5	56.1	**76.8**	240.9	55.4	**77.0**
2	**0.6293**	474.9	87.8	**81.5**	474.2	87.2	**81.6**
3	**0.6293**	313.2	14.8	**95.3**	312.5	14.1	**95.5**
4	**0.6293**	413.9	13.0	**96.9**	413.2	12.3	**97.0**
5	**0.6293**	333.4	19.0	**94.3**	332.8	18.4	**94.5**
MEAN	**0.6293**	355.4	38.1	**89.3**	354.7	37.5	**89.4**

Table 4
1.5 cfs FLOW TEST
OK110 sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.3132**	217.4	74.3	**65.8**	217.1	74.0	**65.9**
2	**0.3132**	135.0	60.0	**55.5**	134.7	59.7	**55.6**
3	**0.3132**	211.3	63.2	**70.1**	211.0	62.9	**70.2**
4	**0.3132**	414.2	67.3	**83.8**	413.8	67.0	**83.8**
5	**0.3132**	214.7	73.2	**65.9**	214.4	72.9	**66.0**
MEAN	**0.3132**	238.5	67.6	**71.7**	238.2	67.3	**71.8**

Table 5
1.0 cfs FLOW TEST
OK110 sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**2.2285**	353.5	22.4	**93.7**	351.3	20.2	**94.3**
2	**2.2285**	360.7	26.7	**92.6**	358.5	24.5	**93.2**
3	**2.2285**	375.3	30.7	**91.8**	373.1	28.4	**92.4**
4	**2.2285**	327.1	36.8	**88.7**	324.9	34.6	**89.4**
5	**2.2285**	341.9	40.5	**88.2**	339.7	38.3	**88.7**
MEAN	**2.2285**	351.7	31.4	**91.1**	349.5	29.2	**91.6**

Table 6
1.25 cfs FLOW TEST
OK110 sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.9943**	307.0	35.3	**88.5**	306.0	34.3	**88.8**
2	**0.9943**	239.7	43.2	**82.0**	238.7	42.2	**82.3**
3	**0.9943**	114.9	39.2	**65.9**	114.0	38.2	**66.5**
4	**0.9943**	220.5	34.4	**84.4**	219.5	33.4	**84.8**
5	**0.9943**	176.0	40.0	**77.3**	175.0	39.0	**77.7**
MEAN	**0.9943**	211.6	38.4	**81.8**	210.6	37.4	**82.2**

Table 7

1.25 cfs REPEAT FLOW TEST

OK110 sand, 1.5" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.2639**	120.3	30.9	**74.3**	120.0	30.6	**74.5**
2	**0.2639**	212.2	37.6	**82.3**	212.0	37.3	**82.4**
3	**0.2639**	262.6	37.3	**85.8**	262.3	37.0	**85.9**
4	**0.2639**	174.2	42.3	**75.7**	173.9	42.0	**75.8**
5	**0.2639**	114.6	34.3	**70.0**	114.3	34.1	**70.2**
MEAN	**0.2639**	176.8	36.5	**79.4**	176.5	36.2	**79.5**

Table 8

1.25 cfs FLOW TEST

OK110 sand, 1" auger

Sample	**Background Samples**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**1.1931**	396.9	37.5	**90.6**	395.8	36.3	**90.8**
2	**0.4654**	440.3	39.9	**90.9**	439.8	39.4	**91.0**
3		471.5	45.3	**90.4**	470.6	44.4	**90.6**
4	**0.9140**	482.1	31.1	**93.6**	481.2	30.2	**93.7**
5	**1.0263**	422.4	36.8	**91.3**	421.4	35.8	**91.5**
MEAN	**0.8997**	442.7	38.1	**91.4**	441.8	37.2	**91.6**

Table 9

1.25 cfs FLOW TEST

OK110 sand (140 lbs), 1" auger

Sample	**Background Samples**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.6927**	226.7	22.4	**90.1**	226.0	21.7	**90.4**
2	**5.6432**	272.5	21.0	**92.3**	266.9	15.3	**94.3**
3		299.3	21.3	**92.9**	297.4	19.3	**93.5**
4	**0.7237**	242.9	17.6	**92.7**	242.1	16.9	**93.0**
5	**0.7759**	274.6	23.0	**91.6**	273.8	22.2	**91.9**
MEAN	**1.9589**	263.2	21.0	**92.0**	261.2	19.1	**92.7**

Table 10

1.5 cfs FLOW TEST

OK110 sand (140 lbs), 1" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.1989**	179.0	30.4	**83.0**	178.8	30.2	**83.1**
2	**0.1989**	192.6	29.6	**84.6**	192.4	29.4	**84.7**
3	**0.1989**	306.6	28.3	**90.8**	306.4	28.1	**90.8**
4	**0.1989**	320.0	28.4	**91.1**	319.8	28.2	**91.2**
5	**0.1989**	275.7	27.1	**90.2**	275.5	26.9	**90.2**
MEAN	**0.1989**	254.8	28.7	**88.7**	254.6	28.6	**88.8**

Table 11

1.5 cfs Maine DEP Verification Test

OK110 sand (140 lbs), 1" auger

Sample	**Background Average**	Influent mg/L Unadjusted	Effluent mg/L Unadjusted	**Efficiency (%) Unadjusted**	Influent mg/L Adjusted	Effluent mg/L Adjusted	**Efficiency (%) Adjusted**
1	**0.2837**	137.8	23.8	**82.7**	137.5	23.5	**82.9**
2	**0.2837**	292.3	19.1	**93.5**	292.0	18.8	**93.6**
3	**0.2837**	175.2	21.8	**87.5**	174.9	21.5	**87.7**
4	**0.2837**	212.4	23.1	**89.1**	212.1	22.8	**89.2**
5	**0.2837**	116.7	22.9	**80.4**	116.5	22.6	**80.6**
MEAN	**0.2837**	186.9	22.1	**88.1**	186.6	21.9	**88.3**