EXHIBIT 4: Alden Laboratory Lab Report dated September 23, 2008

Alden Laboratory Report is attached as an email

VERIFICATION TESTING OF THE TERRE KLEEN™ TK18 HYDRODYNAMIC SEPARATOR STORMWATER TREATMENT UNIT

FINAL REPORT

By

James T. Mailloux

Amie Humphrey

Submitted to

TERRE HILL STORMWATER SYSTEMS

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2.0 TEST FACILITY DESCRIPTION

Figure 3 shows the closed test loop, located in Alden's laboratory/test facility, which was used to test the TK18 Treatment Unit. Water was supplied to the unit with the use of one (1) 20HP and two (2) 50HP pumps (flow capacity of approximately 17cfs) which draw water from a 50,000-gallon heated laboratory sump (70^0 F +/- 5^0). Six (6) calibrated flow meters (2, 4, 6, 8, 12 and 16-inch), connected to a 16-inch diameter manifold carry the test flow to a section of 16-inch piping, a 90-degree elbow and 15-feet of 18-inch influent pipe. Water then passes through the test unit and 24-inch diameter effluent pipe to return to the laboratory sump. To collect the influent and effluent sediment concentration samples, isokinetic sampling-tube arrays were located approximately 5 feet upstream of the test unit, within the influent piping (size dependent on flow) and 3 feet downstream of the test unit, within the 24-inch effluent piping. Each array consisted of one (1) to four (4) vertically adjustable sampling tubes (water level dependent), containing a flow-control shut-off valve. Sediment was injected into the crown of the influent pipe through a vertical pipe connected to a tee. The tee was located approximately 10 influent pipe diameters upstream of the influent sampling ports. In order to produce a sufficiently high velocity and maintain sediment suspension at the samplers the influent pipe diameter from the injector to downstream of the sampling ports varied from 6 inches to 18 inches, depending on the test flow. Photographs of the testing instrumentation are shown in **Figures 4 through 7**.

3.0 INSTRUMENTATION AND MEASURING TECHNIQUES

3.1 Flow

The inflow to the test unit was measured using one of six (6) calibrated flow meters. Each meter was fabricated per ASME guidelines and calibrated in Alden's Calibration Department prior to the start of testing. 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. The test flow was averaged and recorded approximately every 9 seconds throughout the duration of the test using a computerized data acquisition (DA) program.

inches in diameter, depending on the pipe diameter, test flow and location within the pipe. Each tube array was vertically adjusted and calibrated prior to testing, to match the velocities for each flow condition. A photograph of the influent sampling array is shown in **Figure 4**.

3.6 Sample Concentration Analyses

Sample concentrations can be analyzed using one of two analytical methods: Suspended Solids Concentration (SSC), or Total Suspended Solids (TSS). SSC methodology utilizes the entire sample in the analysis, as opposed to the TSS method, which requires the sample to be split prior to processing. Two sets of samples were collected to allow both analytical methods to be used for the present study. The SSC samples were processed at Alden as described below and the TSS samples were processed at Alpha Analytical Labs per Standard Methods 2540D.

<u>SSC Analysis:</u>

Collected samples were filtered and analyzed by Alden 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". 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.

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 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 hours. Each dried filter/dish set was then weighed to the nearest 0.0001-gram, using an AND® analytical balance, model ER-182A. Once filtered, each sample and dish was dried at a temperature between 175 and 220 degrees F (below boiling) for 20 to 30 minutes until visually showing the capture efficiency of the selected test sediment for five (5) flows at 100, 200 and 300mg/L concentration per flow. In accordance with the guideline, these tests were to be conducted with initial sediment loading corresponding to 50% of the unit's capture capacity (as stated by Terre Hill). Terre Hill revised the sediment loading level for the testing from 50% to 100% of the recommended sediment maintenance depth during sediment removal efficiency testing. Terre Hill elected to reduce and redefine the sediment loading after obtaining the results of the required re-entrainment testing. This 100% sediment loading for sedimentation efficiency testing is more conservative than the guideline. The 100% capacity that was utilized for the efficiency testing was 16.5 inches (31.3 ft^3). Re-entrainment testing was conducted with the unit preloaded to 50% (8.25 inches or 15.6 ft^3) and 100% (16.5 inches or 31.3 ft^3) of the stated loading capacity (by Terre Hill). Additionally, the test matrix was expanded to include the Suspended Sediment Concentration (SSC) analysis.

Testing of the TK18 was conducted in three phases, as described below:

4.1 Phase 1 - Hydraulic Capacity and Characteristics

The unit was tested without sediment to determine its maximum hydraulic capacity (MHC) and characteristic curves. Flow and pressure head measurements across the unit were recorded for 10 conditions. Each test flow was set and allowed to reach steady state, at which time a minimum of 2 minutes of flow and pressure data were recorded and averaged for each pressure tap location. Observations were documented throughout the test, including conditions upstream and downstream of the Terre Kleen Insert (internal measurements) and water elevations in the influent and effluent pipes (system measurements). Pressure head measurements were recorded at the following 6 locations (see **Figure 10**): approximately one pipe diameter upstream of the test unit (Tap A), along the Terre Kleen Insert wall in the primary chamber (Tap B), in the internal flow-through duct (IFTD) (Tap C), in the inclined Lamella plates (Tap D), at the shelf upstream of the outlet (Tap E), and one pipe diameter downstream of the test unit (Tap F). The discharge and loss coefficients (Cd and K) were calculated for both the internal and system losses.

4.3 Phase 2b - Re-entrainment and Washout

Re-entrainment tests were conducted at sediment loadings corresponding to 50% and 100% (15.6 and 31.3 ft^3, respectively) of the unit's capture capacity as claimed by Terre Hill. The unit was slowly filled to the invert of the effluent pipe and the system remained idle for a minimum of 24 hours prior to testing.

Testing was conducted by incrementally increasing the flow of clean water (no sediment) into the unit under steady-state conditions, while continuously obtaining flow data and video documentation of sediment retention and/or re-entrainment. Effluent samples, for SSC and PSD analyses, were obtained at the first sign of sediment bed movement, and/or at the targeted flows (25, 50, 75, 100 and 125%), at which time four (4) samples were collected incrementally over a period of 15 minutes for each steady-state flow.

4.4 Phase 3 – Low-Flow Removal Testing

Phase 3 testing was used to establish the sediment removal efficiencies at low-flow conditions. These tests were performed with an initial bed load of 50% and followed the testing methodology described in Section 4.2.

4.5 Effective Sedimentation Area

The effective sedimentation area of Terre Kleen TK18 is comprised of 18 sedimentation cells at a 55-degree incline. The length of each cell is 53.625 inches and the width is 30 inches. The area used for calculating the plan surface loading is 115 ft^2.

4.6 Surface loading

Surface loading for Terre Kleen is the flow rate in gpm divided by the Effective Sedimentation Area of 115 ft^2.

$A = A_{lamella} + A_{IFTD}$ in ft^2

Δh = headloss across the unit in ft

As seen in **Figure 12**, the calculated System Cd (influent to effluent) ranged from 0.013 to 0.161 for recorded lamella flows of 202 to 3,017 gpm (0.45 to 6.7 cfs). The Cd drops off to approximately 0.145 at closed-conduit inflow (~4,000 gpm) due to the increased influent/effluent differential. The Cd ranged from 0.107 to 0.135 for recorded flows ranging from 4,326 to 7,362 gpm (9.6 to 16.4 cfs), corresponding to flows passing through the lamella plates and IFTD.
The calculated internal Cd (primary chamber to effluent shelf) ranged from 0.058 to 0.268 for recorded lamella flows, and 0.192 to 0.170 for flows passing through the lamella plates and IFTD.

5.2 Sediment Removal Efficiency

Removal efficiency tests were conducted at five (5) flows ranging from 517 to 2587 gpm (1.15 to 5.76 cfs) with influent sediment concentrations of 100, 200 and 300 mg/l. Preliminary testing was used to establish the 100% flow rate at 2070 gpm, or 18 gpm/sf.

As stated in Section 4.2, verification of each injected sediment concentration was achieved by taking timed dry samples from the auger feeder at regular intervals throughout each test. The difference between the collected influent sample concentrations and adjusted concentrations ranged from 3% (low flow) to approximately 40% (high flow), resulting in differences up to 55% in the removal efficiency. The average calculated removal efficiencies ranged from -38.5% to 45.5% for the TSS data, -26.6% to 71.6% for the unadjusted influent data and 9.2% to 71.7% for the adjusted influent data. The corresponding weighted removal efficiencies were 16.9%, 41.9% and 50.3%. It should be noted that background concentrations were not subtracted from the TSS data, as the overall weighted efficiency would have been reduced to 12.8%.
These results are considered to be conservative, due to the fact that the unit was preloaded to 100% capacity. The average effluent concentration data from the re-entrainment testing was used to estimate the differential in removal efficiency due to the higher sediment bed. It is

(d_{90} – 24.3μm), (d_{75} – 16.2μm), (d_{50} – 9.0μm), (d_{25}-4.5μm). The effluent %-Finer PSD Curve is shown in **Figure 19**.

<u>200 mg/L</u>

The average flow recorded for the entire test was 2585.3 gpm (5.76 cfs), with a standard deviation (SD) of 5.33. The recorded temperature for the test was 70.0 degrees F. The measured influent sample concentrations ranged from 107.0 mg/L to 146.3 mg/L, with a mean concentration of 131.0 mg/L and SD of 13.8. The effluent concentrations ranged from 154.7 mg/L to 190.8 mg/L, with a mean concentration of 179.0 mg/L and SD of 13.3. The background concentrations ranged from 6.7 mg/L to 71.5 mg/L. The resulting sediment removal efficiency for the SSC method was -36.6%. The adjusted influent concentrations ranged from 200.0 mg/L to 205.9 mg/L, with a mean concentration of 201.6 mg/L and SD of 2.43. The corresponding adjusted removal efficiency was 11.2%. The measured influent TSS concentrations ranged from 78 mg/L to 130 mg/L, with a mean concentration of 102.6 mg/L and SD of 19.2. The effluent concentrations ranged from 100 mg/L to 160 mg/L, with a mean concentration of 136 mg/L and SD of 21.9. The resulting sediment removal efficiency for the TSS method was -32.6% (see **Table 3**.)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 26.3μm), (d_{75} – 18.7μm), (d_{50} – 10.5μm), (d_{25}-4.7μm). The effluent %-Finer PSD Curve is shown in **Figure 19**.

<u>100 mg/L</u>

The average flow recorded for the entire test was 2588.0 gpm (5.77 cfs), with a standard deviation (SD) of 5.56. The recorded temperature for the test was 70.0 degrees F. The measured influent sample concentrations ranged from 46.7 mg/L to 85.6 mg/L, with a mean concentration of 67.7 mg/L and SD of 13.9. The effluent concentrations ranged from 90.5 mg/L to 104.9 mg/L, with a mean concentration of 97.1 mg/L and SD of 5.6. The background concentrations ranged from 8.8 mg/L to 39.7 mg/L. The resulting sediment removal efficiency for the SSC method was -43.5%. The adjusted influent concentrations ranged from 98.1 mg/L to 106.2 mg/L, with a

200 mg/L

The average flow recorded for the entire test was 2075.4 gpm (4.62 cfs), with a standard deviation (SD) of 4.54. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 89.6 mg/L to 176.2 mg/L, with a mean concentration of 135.0 mg/L and SD of 30.6. The effluent concentrations ranged from 137.1 mg/L to 158.7 mg/L, with a mean concentration of 147.8 mg/L and SD of 7.91. The background concentrations ranged from 2.5 mg/L to 60.3 mg/L. The resulting sediment removal efficiency for the SSC method was -9.5%. The adjusted influent concentrations ranged from 191.2 mg/L to 200.4 mg/L, with a mean concentration of 196.2 mg/L and SD of 3.43. The corresponding adjusted removal efficiency was 24.7%. The measured influent TSS concentrations ranged from 38 mg/L to 58 mg/L, with a mean concentration of 46.4 mg/L and SD of 8.26. The effluent concentrations ranged from 60 mg/L to 88 mg/L, with a mean concentration of 72.4 mg/L and SD of 10.5. The resulting sediment removal efficiency for the TSS method was -56.0% (see **Table 6**.)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 25.5μm), (d_{75} – 18.7μm), (d_{50} –11.6μm), (d_{25}-5.5μm). The effluent %-Finer PSD Curve is shown in **Figure 20**.

100 mg/L

The average flow recorded for the entire test was 2072.3 gpm (4.62 cfs), with a standard deviation (SD) of 4.44. The recorded temperature for the test was 70.0 degrees F. The measured influent sample concentrations ranged from 45.0 mg/L to 89.1 mg/L, with a mean concentration of 58.3 mg/L and SD of 14.9. The effluent concentrations ranged from 75.5 mg/L to 81.9 mg/L, with a mean concentration of 79.7 mg/L and SD of 2.69. The background concentrations ranged from 3.7 mg/L to 40.5 mg/L. The resulting sediment removal efficiency for the SSC method was -36.7%. The adjusted influent concentrations ranged from 95.2 mg/L to 99.6 mg/L, with a mean concentration of 96.9 mg/L and SD of 1.65. The corresponding adjusted removal efficiency was 17.8%. The measured influent TSS concentrations ranged from 29 mg/L to 41 mg/L, with a mean concentration of 32.8 mg/L and SD of 4.97. The effluent concentrations ranged from 44 mg/L to 58 mg/L, with a mean concentration of 49.2 mg/L and SD of 5.40. The resulting mg/L to 113.9 mg/L, with a mean concentration of 109.6 mg/L and SD of 4.85. The background concentrations ranged from 0.8 mg/L to 48.9 mg/L. The resulting sediment removal efficiency for the SSC method was 49.8%. The adjusted influent concentrations ranged from 195.2 mg/L to 211.9 mg/L, with a mean concentration of 207.1 mg/L and SD of 6.91. The corresponding adjusted removal efficiency was 47.1%. The measured influent TSS concentrations ranged from 120 mg/L to 270 mg/L, with a mean concentration of 194 mg/L and SD of 59.4. The effluent concentrations ranged from 96 mg/L to 120 mg/L, with a mean concentration of 105.2 mg/L and SD of 9.76. The resulting sediment removal efficiency for the TSS method was 45.8% (see **Table 9**.)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 26.9μm), (d_{75} – 19.0μm), (d_{50} –10.7μm), (d_{25}-5.1μm). The effluent %-Finer PSD Curve is shown in **Figure 21**.

<u>100 mg/L</u>

The average flow recorded for the entire test was 1539.5 gpm (3.43 cfs), with a standard deviation (SD) of 12.9. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 104.8 mg/L to 143.6 mg/L, with a mean concentration of 118.9 mg/L and SD of 14.1. The effluent concentrations ranged from 54.4 mg/L to 65.2 mg/L, with a mean concentration of 60.8 mg/L and SD of 3.23. The background concentrations ranged from 8.9 mg/L to 35.8 mg/L. The resulting sediment removal efficiency for the SSC method was 48.9%. The adjusted influent concentrations ranged from 99.8 mg/L to 104 mg/L, with a mean concentration of 101.8 mg/L and SD of 1.78. The corresponding adjusted removal efficiency was 40.3%. The measured influent TSS concentrations ranged from 56 mg/L to 110 mg/L, with a mean concentration of 86.4 mg/L and SD of 20.6. The effluent concentrations ranged from 47 mg/L to 72 mg/L, with a mean concentration of 60 mg/L and SD of 11.4. The resulting sediment removal efficiency for the TSS method was 30.6% (see **Table 10**.)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 26.1μm), (d_{75} – 16.5μm), (d_{50} –7.7μm), (d_{25}-3.4μm). The effluent %-Finer PSD Curve is shown in **Figure 21**.

mean concentration of 148 mg/L and SD of 37.0. The effluent concentrations ranged from 88 mg/L to 140 mg/L, with a mean concentration of 113.6 mg/L and SD of 21.3. The resulting sediment removal efficiency for the TSS method was 23.2% (see **Table 12.**)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 24.4μm), (d_{75} – 17.7μm), (d_{50} –10.3μm), (d_{25}-5.1μm). The effluent %-Finer PSD Curve is shown in **Figure 22.**

100 mg/L

The average flow recorded for the entire test was 1030.8 gpm (2.30 cfs), with a standard deviation (SD) of 3.20. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 93.5 mg/L to 126.8 mg/L, with a mean concentration of 110.5 mg/L and SD of 12.6. The effluent concentrations ranged from 35.5 mg/L to 39.1 mg/L, with a mean concentration of 37.0 mg/L and SD of 1.47. The background concentrations ranged from 3.9 mg/L to 23.1 mg/L. The resulting sediment removal efficiency for the SSC method was 66.5%. The adjusted influent concentrations ranged from 97.6 mg/L to 98.8 mg/L, with a mean concentration of 98.4 mg/L and SD of 0.52. The corresponding adjusted removal efficiency was 62.4%. The measured influent TSS concentrations ranged from 72 mg/L to 100 mg/L, with a mean concentration of 85.4 mg/L and SD of 11.6. The effluent concentrations ranged from 58 mg/L to 76 mg/L, with a mean concentration of 62.2 mg/L and SD of 7.76. The resulting sediment removal efficiency for the TSS method was 27.2% (see **Table 13.**)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 29.0μm), (d_{75} – 19.6μm), (d_{50} –11.0μm), (d_{25}-5.1μm). The effluent %-Finer PSD Curve is shown in **Figure 22.**

5.2.5 Sediment Removal Efficiencies at 25% (517 gpm, 1.15 cfs, 4.5 gpm/sf)

300 mg/L

The average flow recorded for the entire test was 517.9 gpm (1.15 cfs), with a standard deviation (SD) of 4.46. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 301.0 mg/L to 347.8 mg/L, with a mean concentration of

100 mg/L

The average flow recorded for the entire test was 516.1 gpm (1.15 cfs), with a standard deviation (SD) of 2.59. The recorded temperature for the test was 69.8 degrees F. The measured influent sample concentrations ranged from 71.7 mg/L to 102.8 mg/L, with a mean concentration of 89.8 mg/L and SD of 9.83. The effluent concentrations ranged from 27.6 mg/L to 30.1 mg/L, with a mean concentration of 28.8 mg/L and SD of 0.86. The background concentrations ranged from 0.5 mg/L to 14.1 mg/L. The resulting sediment removal efficiency for the SSC method was 67.9%. The adjusted influent concentrations ranged from 94.4 mg/L to 99.8 mg/L, with a mean concentration of 97.4 mg/L and SD of 2.62. The corresponding adjusted removal efficiency was 70.4%. The measured influent TSS concentrations ranged from 55 mg/L to 160 mg/L, with a mean concentration of 96.2 mg/L and SD of 41.4. The effluent concentrations ranged from 37 mg/L to 71 mg/L, with a mean concentration of 48 mg/L and SD of 13.6. The resulting sediment removal efficiency for the TSS method was 50.1% (see **Table 16.**)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 26.2μm), (d_{75} – 18.1μm), (d_{50} –9.8μm), (d_{25}-4.7μm). The effluent %-Finer PSD Curve is shown in **Figure 23.**

5.2.6 Low-Flow Tests

Additional tests were conducted at flows below 517 gpm to establish the efficiency removal at lower flows. Each test was conducted at influent concentrations of 200 mg/L.

Sediment Removal Efficiency at 300 gpm, 0.67 cfs, 2.6 gpm/sf

The average flow recorded for the entire test was 298.8 gpm (0.67 cfs), with a standard deviation (SD) of 0.57. The recorded temperature for the test was 76.5 degrees F. The measured influent sample concentrations ranged from 156.9 mg/L to 178.4 mg/L, with a mean concentration of 163.8 mg/L and SD of 8.86. The effluent concentrations ranged from 47.8 mg/L to 52.3 mg/L, with a mean concentration of 50.0 mg/L and SD of 1.66. The background concentrations ranged from 0 mg/L to 18.7 mg/L. The resulting sediment removal efficiency for the SSC method was

73.0%. The adjusted influent concentrations ranged from 191 mg/L to 214 mg/L, with a mean concentration of 202.9 mg/L and SD of 9.51. The corresponding adjusted removal efficiency was 79.8% (see **Table 19**.)

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} –23.1μm), (d_{75} –15.1μm), (d_{50} –8.2μm), (d_{25}-4.5μm). The effluent %-Finer PSD Curve is shown in **Figure 26**.

5.3 Re-entrainment and Washout

Re-entrainment tests were performed at flows ranging from 0 to 2587 gpm, with the revised initial sediment loadings of 100% (31.3 ft^3) and 50% (15.6 ft^3) of the unit's capacity (stated by Terre Hill). The unit flow was incrementally increased, with effluent samples collected for concentration analysis. A series of four (4) samples were collected every 5 minutes at steady-state target flows of 517, 1,035, 1,552, 2,070 and 2,587 gpm to allow insight into trends and/or anomalies of sediment movement. A single sample was collected at 70 gpm during each test.

5.3.1 50% Loading

Observations of sediment transport (bedload and suspended) were conducted in both the primary and secondary chambers. Bedload movement and scour were observed in the primary chamber throughout the test. This was verified with the presence of sediment settling in the secondary chamber. There was no apparent movement of the secondary sediment bed throughout the test. However, increasing amounts of suspended sediment from the primary bed was observed being carried upward into the Lamella plates. The ability of the secondary chamber to capture sediment particles was evident throughout the test, as particles were continuously falling to the bed even at 125% flow. Measured sediment concentrations were considered low for all flow conditions, with quantities ranging from 2.9 to 25.3 mg/L. The first sample collected at each target flow had the highest concentrations, indicating an initial displacement of fine particles with a sudden increase of flow (approximately 2 minutes elapsed time). A graph of the recorded flow data and corresponding sediment concentration analyses are shown in **Figures 27 and 28**. The effluent

6.0 SUMMARY

The Terre Kleen 18 Stormwater Treatment Unit, tested at Alden Research Laboratory, achieved a 100% treatment flow of 4,326 gpm (9.6 cfs), after which point some of the flow diverted to the Internal Flow-Through Duct. A flow of 7,362 gpm (16.4 cfs) was passed through the Terre Kleen insert and proportioned over the inclined cells and flow-through duct, at which point the pump capacity had reached its maximum and testing for higher flows was abandoned.

Sediment removal efficiency testing was conducted using the NJCAT-specified PSD test sediment for 5 flows ranging from 517 gpm (1.15 cfs) to 2,587 gpm (5.76 cfs), with influent sediment concentrations of 100, 200 and 300 mg/L. The removal efficiencies were evaluated using both the indirect sampling method, as well as the sediment injection rate, for the influent concentrations (reported as unadjusted and adjusted efficiencies). Additional samples were evaluated for TSS using the Standard Methods 2540D. The efficiencies ranged from (-)26.6% to 71.6% for the unadjusted data, 9.2% to 71.7% for the adjusted data and (-)38.4% to 45.5% for the TSS data. The weighted efficiencies were 41.9%, 50.3% and 16.9% for the unadjusted, adjusted and TSS data, respectively. This rating is considered conservative due to the 100% pre-loading of the test unit. A correlation to a theoretical 50% bed was made using the effluent concentrations measured during the re-entrainment testing. It is estimated that a 50% bed would produce removal efficiencies ranging from ~18% to 72%, with a weighted average of ~58%. A sediment removal efficiency of 79.8% was achieved at a flow of 100 gpm (0.22 cfs), utilizing a 50% bed loading. It was shown that the unit was effective at capturing relatively small particles during efficiency testing, with maximum D_{90} and D_{50} values of ~28 microns and ~12 microns, respectively.

Re-entrainment testing indicated relatively low re-suspension of the sediment bed at 50% loading capacity, with effluent concentrations ranging from 2.9 to 25.3 mg/L for flows up to 2588 gpm (5.77 cfs). PSD results show that the unit is able to retain the majority of particles over 40 microns, with approximate D_{10}, D_{50} and D_{90} values of 4, 17 and 40 microns, respectively. 100% loading capacity testing resulted in effluent concentrations ranging from 0.28 to 43.6 mg/L, with

TABLES

Table 2
Sediment Removal Efficiency
125%, 2587 gpm, (5.76 cfs)
22.5 gpm/sf
300 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	5.7		
B2	9.1		
B3	32.6		
B4	71.1		
B5	113.2		
1	245.9	SPILLED	
2	232.9	249.5	
3	232.7	233.3	
4	246.2	262.3	
5	262.9	265.7	
6	317.1	272.2	
7	260.9	254.0	
			Efficiency (%)
MEAN	256.9	256.2	**0.3**
	Adjusted Influent		
1	NOT TAKEN		
2	287.9		
3	287.1		
4	297.2		
5	297.2		
			Efficiency (%)
MEAN	292.4	256.2	**12.4**
	TSS Sample Analysis		
Sample	Influent mg/L	Effluent mg/L	
1	160.0	170.0	
2	160.0	220.0	
3	150.0	180.0	
4	170.0	150.0	
5	190.0	250.0	
			Efficiency (%)
MEAN	166.0	194.0	**-16.9**

Table 3
Sediment Removal Efficiency
125%, 2587 gpm, (5.76 cfs)
22.5 gpm/sf
200 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	6.7		
B2	13.0		
B3	26.0		
B4	47.9		
B5	71.5		
1	146.3	154.7	
2	120.1	179.2	
3	107.0	168.7	
4	133.0	180.6	
5	128.3	188.3	
6	141.3	190.7	
7	140.9	190.8	
			Efficiency (%)
MEAN	131.0	179.0	**-36.6**
	Adjusted Influent		
1	201.1		
2	200.3		
3	200.0		
4	200.8		
5	205.9		
			Efficiency (%)
MEAN	201.6	179.0	**11.2**
	TSS Sample Analysis		
Sample	Influent mg/L	Effluent mg/L	
1	78.0	140.0	
2	95.0	100.0	
3	110.0	160.0	
4	130.0	140.0	
5	100.0	140.0	
			Efficiency (%)
MEAN	102.6	136.0	**-32.6**

Table 4
Sediment Removal Efficiency
125%, 2587 gpm, (5.76 cfs)
22.5 gpm/sf
100 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	10.3		
B2	8.8		
B3	16.7		
B4	28.3		
B5	39.7		
1	64.7	92.0	
2	46.7	97.5	
3	78.6	98.2	
4	55.5	90.5	
5	64.2	103.6	
6	85.6	93.1	
7	78.2	104.9	
			Efficiency (%)
MEAN	67.7	97.1	**-43.5**
	Adjusted Influent		
1	98.1		
2	100.2		
3	101.2		
4	100.0		
5	106.2		
			Efficiency (%)
MEAN	101.1	97.1	**4.0**
	TSS Sample Analysis		
Sample	Influent mg/L	Effluent mg/L	
1	19.0	37.0	
2	17.0	39.0	
3	27.0	42.0	
4	23.0	43.0	
5	43.0	53.0	
			Efficiency (%)
MEAN	25.8	42.8	**-65.9**

Table 8

Sediment Removal Efficiency
75%, 1552 gpm (3.46 cfs)
13.5 gpm/sf
300 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	6.9		
B2	13.1		
B3	20.5		
B4	50.2		
B5	74.0		
1	315.0	147.2	
2	219.7	148.3	
3	242.1	151.9	
4	202.1	151.3	
5	281.9	155.8	
6	212.4	152.6	
7	238.9	146.5	
			Efficiency (%)
MEAN	**244.6**	**150.5**	**38.5**
Adjusted Influent			
1	299.8		
2	295.3		
3	301.9		
4	303.2		
5	307.4		
			Efficiency (%)
MEAN	**301.5**	**150.5**	**50.1**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	200.0	150.0	
2	280.0	130.0	
3	260.0	200.0	
4	260.0	180.0	
5	260.0	160.0	
			Efficiency (%)
MEAN	**252.0**	**164.0**	**34.9**

Table 9

Sediment Removal Efficiency
75%, 1552 gpm (3.46 cfs)
13.5 gpm/sf
200 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	1.8		
B2	0.8		
B3	11.3		
B4	32.9		
B5	48.9		
1	144.6	113.5	
2	172.7	107.9	
3	254.0	107.5	
4	202.0	111.5	
5	282.9	112.6	
6	231.7	113.9	
7	239.0	100.3	
			Efficiency (%)
MEAN	**218.2**	**109.6**	**49.8**
Adjusted Influent			
1	209.5		
2	211.7		
3	207.3		
4	211.9		
5	195.2		
			Efficiency (%)
MEAN	**207.1**	**109.6**	**47.1**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	150.0	96.0	
2	120.0	100.0	
3	270.0	100.0	
4	220.0	110.0	
5	210.0	120.0	
			Efficiency (%)
MEAN	**194.0**	**105.2**	**45.8**

Table 10

Sediment Removal Efficiency
75%, 1552 gpm (3.46 cfs)
13.5 gpm/sf
100 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	10.6		
B2	8.9		
B3	13.7		
B4	21.0		
B5	35.8		
1	104.8	60.4	
2	143.6	61.9	
3	113.2	54.4	
4	108.3	60.9	
5	130.1	61.9	
6	109.2	65.2	
7	123.2	60.9	
			Efficiency (%)
MEAN	**118.9**	**60.8**	**48.9**
Adjusted Influent			
1	100.3		
2	99.8		
3	101.7		
4	103.0		
5	104.0		
			Efficiency (%)
MEAN	**101.8**	**60.8**	**40.3**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	85.0	47.0	
2	100.0	69.0	
3	56.0	49.0	
4	81.0	63.0	
5	110.0	72.0	
			Efficiency (%)
MEAN	**86.4**	**60.0**	**30.6**

Table 14
Sediment Removal Efficiency
25%, 517 gpm (1.15 cfs)
4.5 gpm/sf
300 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	1.6		
B2	4.1		
B3	17.1		
B4	30.3		
B5	46.8		
1	319.9	82.5	
2	326.2	85.4	
3	347.8	84.1	
4	310.2	84.9	
5	307.4	86.1	
6	325.6	79.7	
7	301.0	75.8	
			Efficiency (%)
MEAN	319.7	82.6	**74.2**
Adjusted Influent			
1	296.2		
2	299.1		
3	311.8		
4	304.0		
			Efficiency (%)
MEAN	302.8	82.6	**72.7**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	240.0	94.0	
2	200.0	130.0	
3	230.0	110.0	
4	210.0	110.0	
5	220.0	200.0	
			Efficiency (%)
MEAN	220.0	128.8	**41.5**

Table 15
Sediment Removal Efficiency
25%, 517 gpm (1.15 cfs)
4.5 gpm/sf
200 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	2.3		
B2	2.5		
B3	17.0		
B4	25.1		
B5	35.4		
1	191.5	52.6	
2	215.9	55.1	
3	196.9	56.7	
4	189.0	57.8	
5	235.0	54.6	
6	186.6	54.3	
7	203.0	55.0	
			Efficiency (%)
MEAN	202.6	55.2	**72.8**
Adjusted Influent			
1	205.3		
2	178.1		
3	208.2		
4	192.6		
5	195.7		
6	196.4		
			Efficiency (%)
MEAN	196.0	55.2	**71.9**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	170.0	64.0	
2	180.0	61.0	
3	120.0	110.0	
4	170.0	100.0	
5	150.0	100.0	
			Efficiency (%)
MEAN	158.0	87.0	**44.9**

Table 16
Sediment Removal Efficiency
25%, 517 gpm (1.15 cfs)
4.5 gpm/sf
100 mg/L Concentration

SSC Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
B1	0.5		
B2	1.1		
B3	4.3		
B4	9.7		
B5	14.1		
1	87.3	28.6	
2	71.7	30.1	
3	86.0	28.6	
4	90.6	27.6	
5	92.8	28.4	
6	102.8	29.8	
7	97.0	28.6	
			Efficiency (%)
MEAN	89.8	28.8	**67.9**
Adjusted Influent			
1	99.6		
2	98.4		
3	99.8		
4	94.8		
5	94.4		
			Efficiency (%)
MEAN	97.4	28.8	**70.4**
TSS Sample Analysis			
Sample	Influent mg/L	Effluent mg/L	
1	89.0	48.0	
2	160.0	45.0	
3	110.0	39.0	
4	67.0	37.0	
5	55.0	71.0	
			Efficiency (%)
MEAN	96.2	48.0	**50.1**

Table 20
50% Re-entrainment
SSC Sample Analysis

Flowrate (gpm)	396		517		1036		1556		2076		2586	
Background Sample (mg/L)	B1	2.39	B2	0.06	B3	1.85	B4	6.64	B5	12.64	B6	13.71
Effluent Sample (mg/L)			1	2.82	3	4.50	7	15.59	11	33.50	15	21.96
(adjusted for background)			2	3.03	4	3.56	8	12.92	12	28.02	16	19.75
					5	3.72	9	11.00	13	20.09	17	14.36
					6	2.73	10	11.53	14	19.51	18	10.52
Average Effluent (mg/L)				**2.93**		**3.63**		**12.76**		**25.28**		**16.65**

Table 21
100% Re-entrainment
SSC Sample Analysis

Flowrate (gpm)	214		523		1060		1557		2086		2598	
Background Sample (mg/L)	B1	0	B2	0	B3	4.09	B4	20.84	B5	17.07	B6	17.99
Effluent Sample (mg/L)			1	0	3	22.63	7	48.02	11	37.18	15	36.63
(adjusted for background)			2	0.56	4	16.94	8	45.09	12	48.50	16	37.67
					5	10.78	9	39.28	13	34.22	17	23.97
					6	7.88	10	41.96	14	20.58	18	24.28
Average Effluent (mg/L)				**0.28**		**14.56**		**43.58**		**35.12**		**30.64**

FIGURES

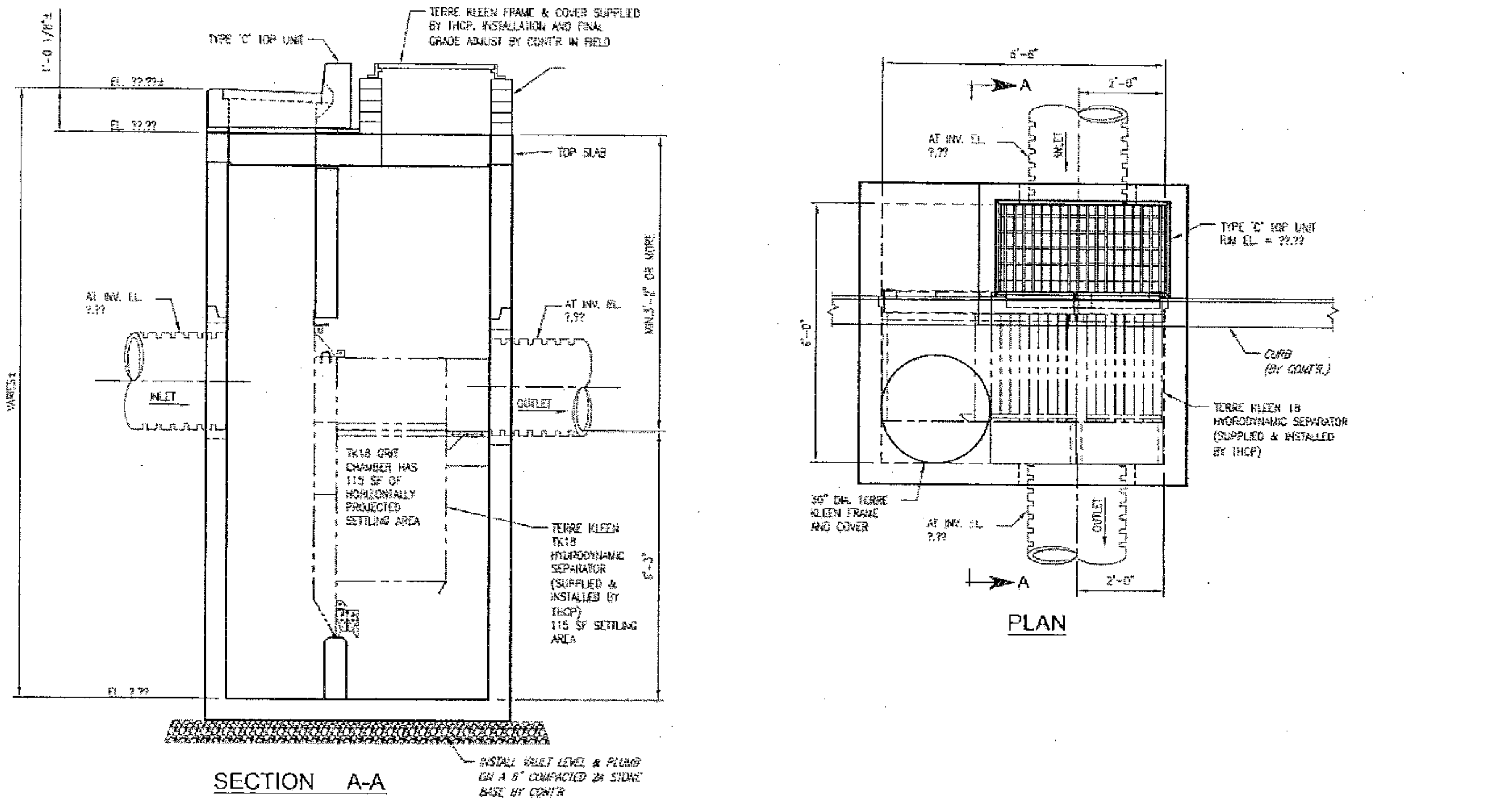

Figure 1: Terre Hill TK18 Test Unit

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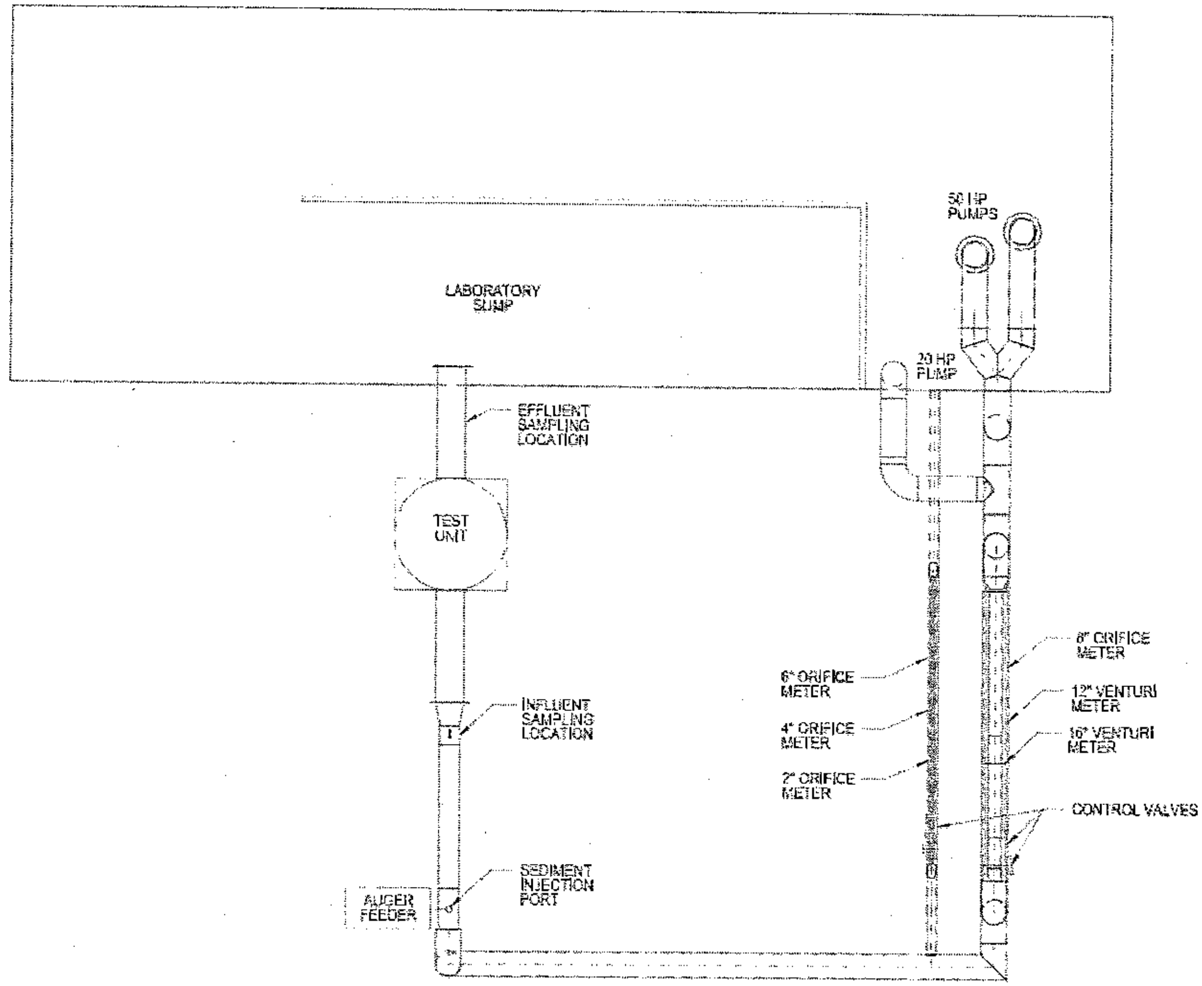
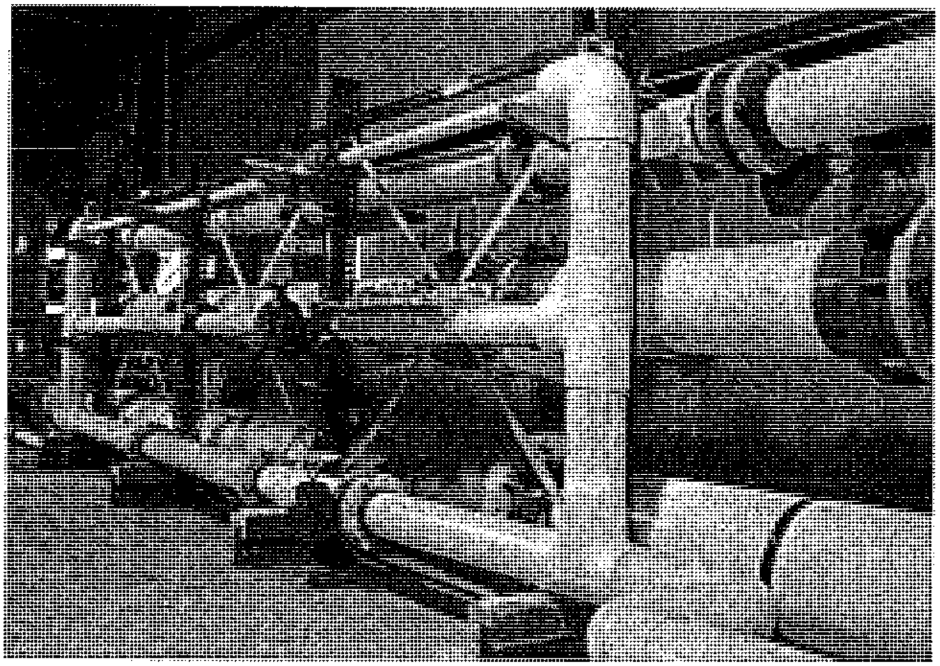
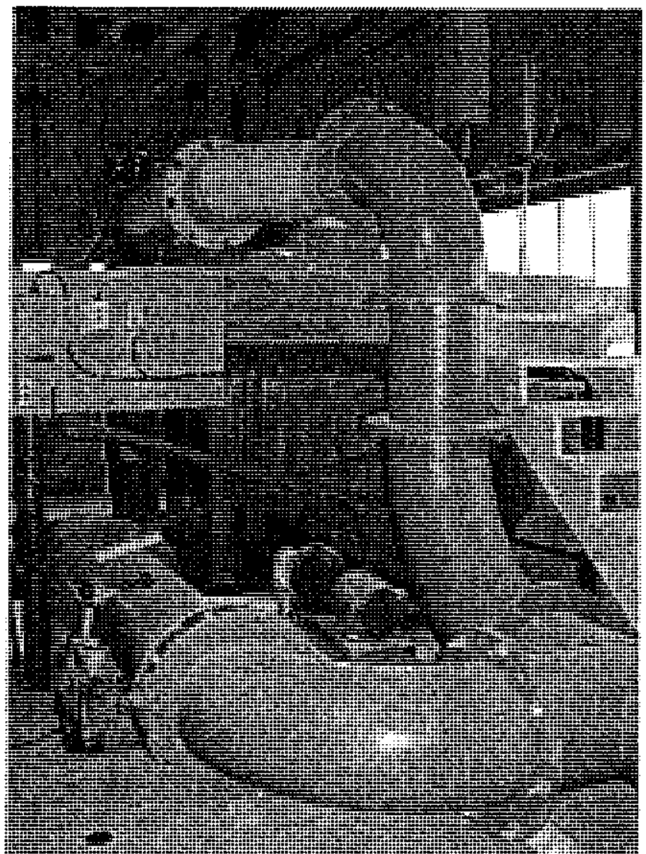


Figure 3: Alden's Stormwater Laboratory Flow Loop





Figures 6 & 7: Test Loop Flow Meters and 50 HP Pumps

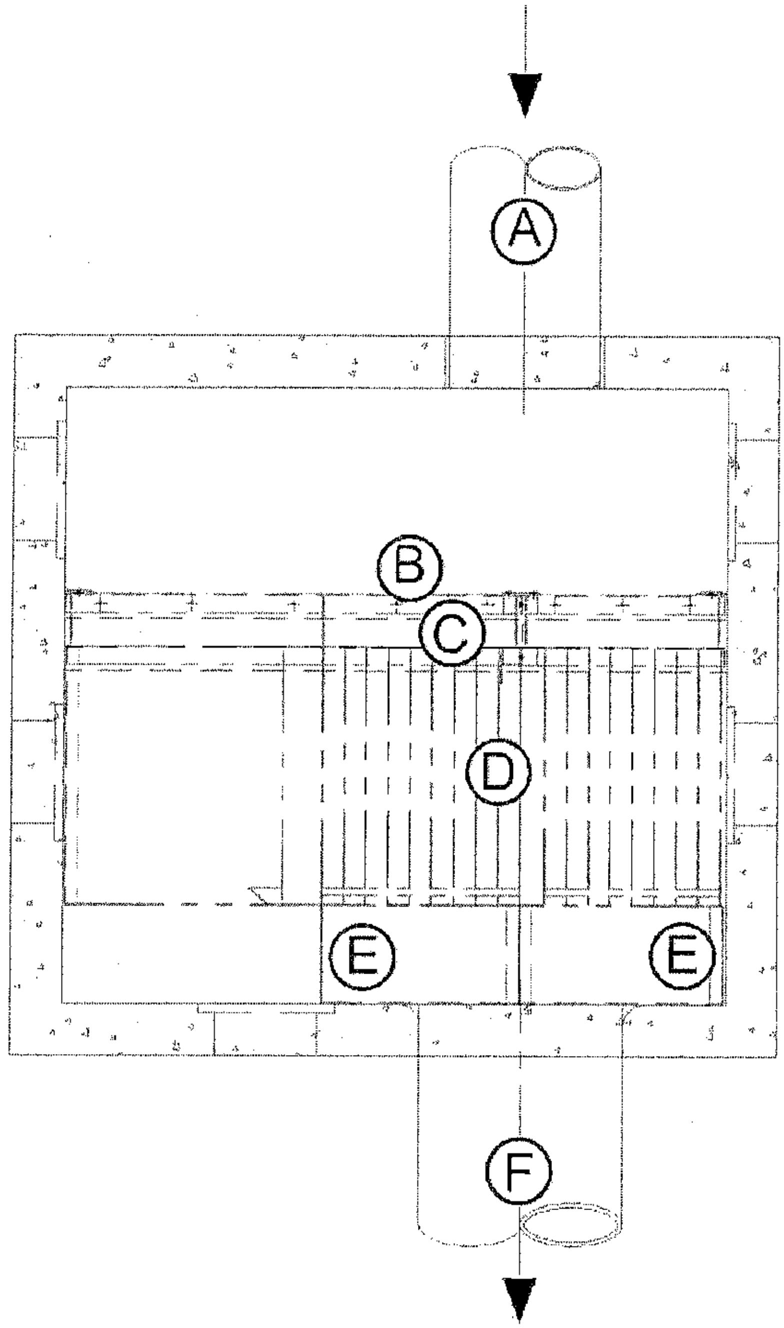


Figure 10: Pressure Tap Locations

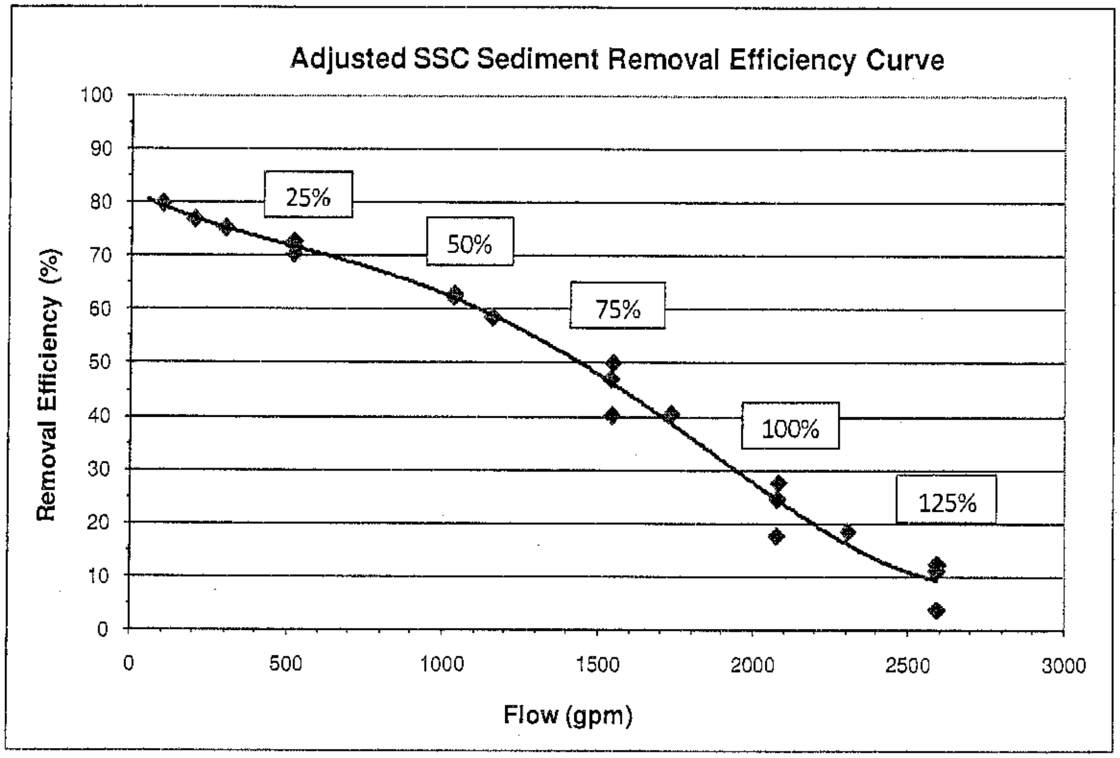


Figure 13: SSC Adjusted Sediment Removal Efficiency Curve

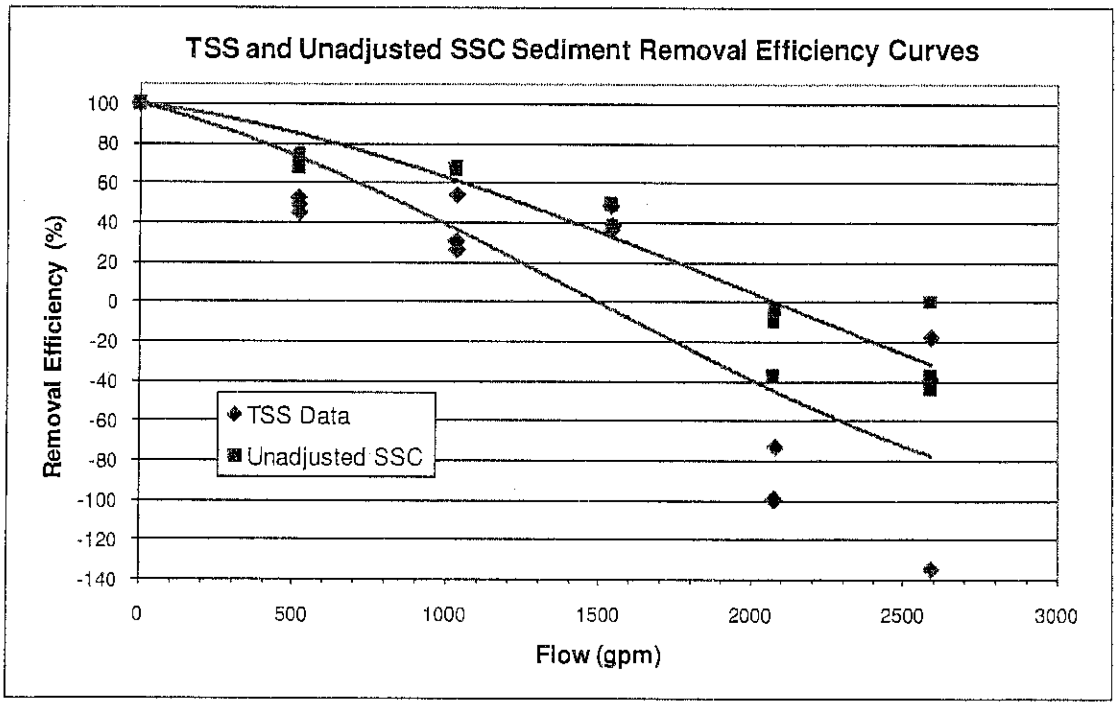


Figure 14: TSS and Unadjusted SSC Removal Efficiency Curves

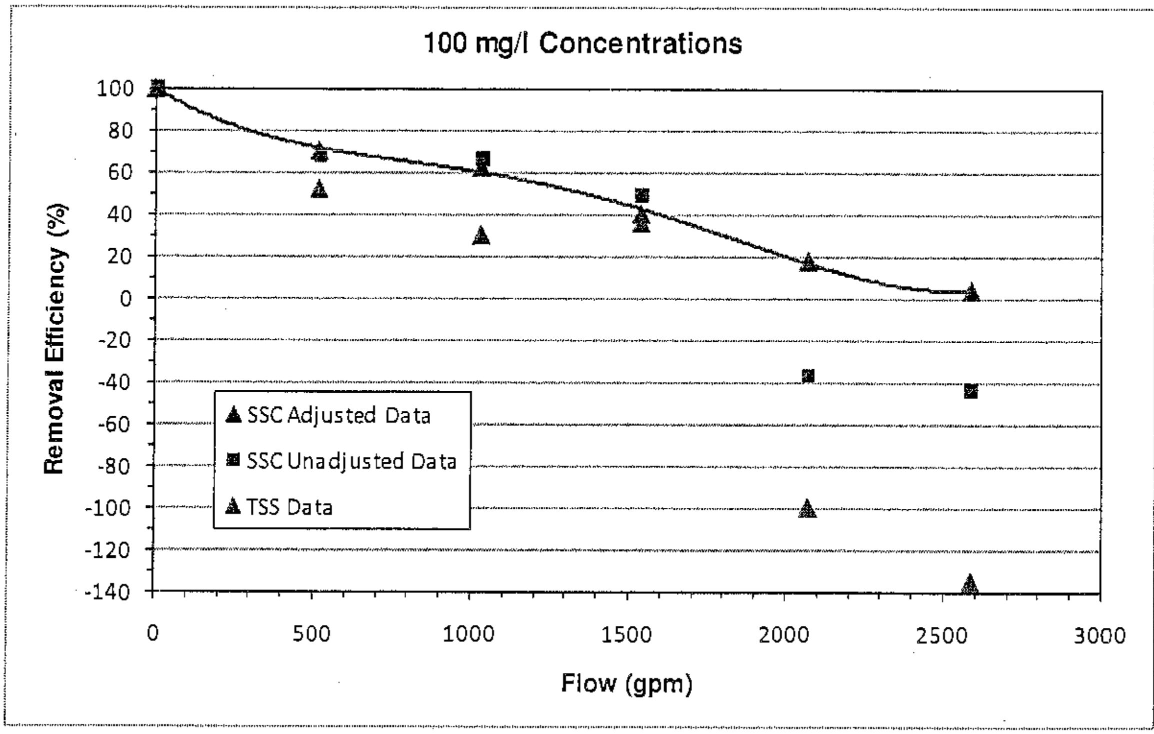


Figure 17: SSC Efficiency Curves at 100 mg/L

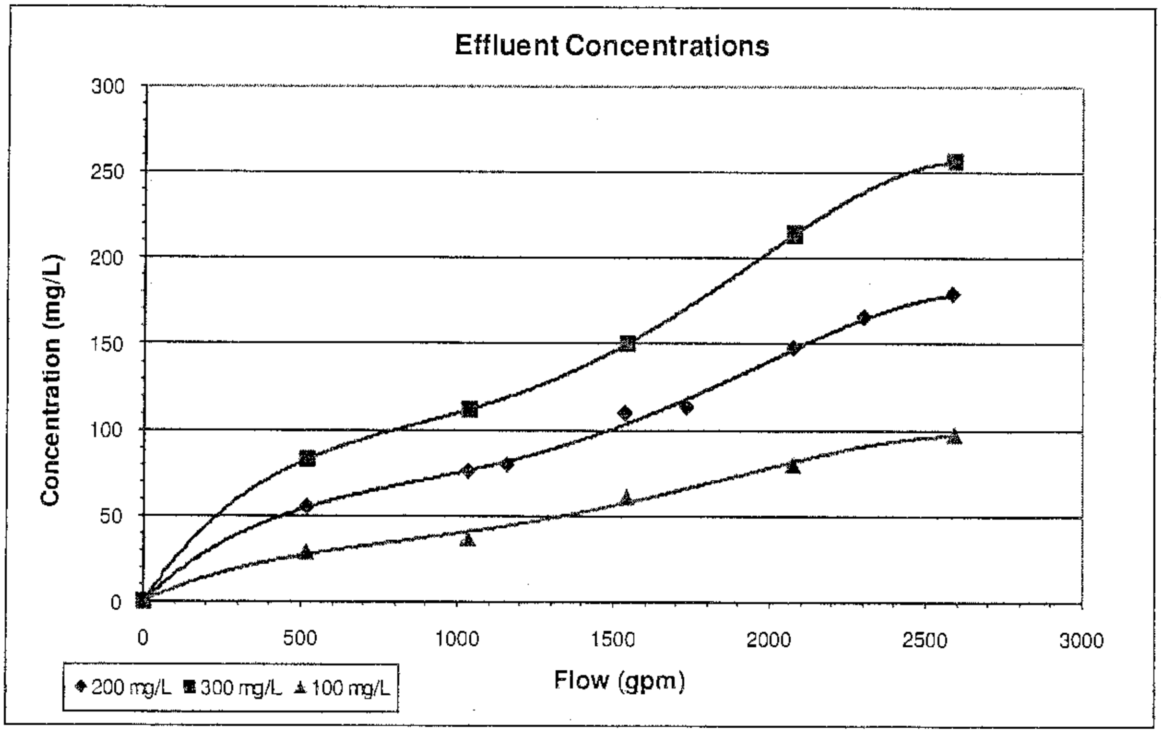


Figure 18: SSC effluent Concentration Curves

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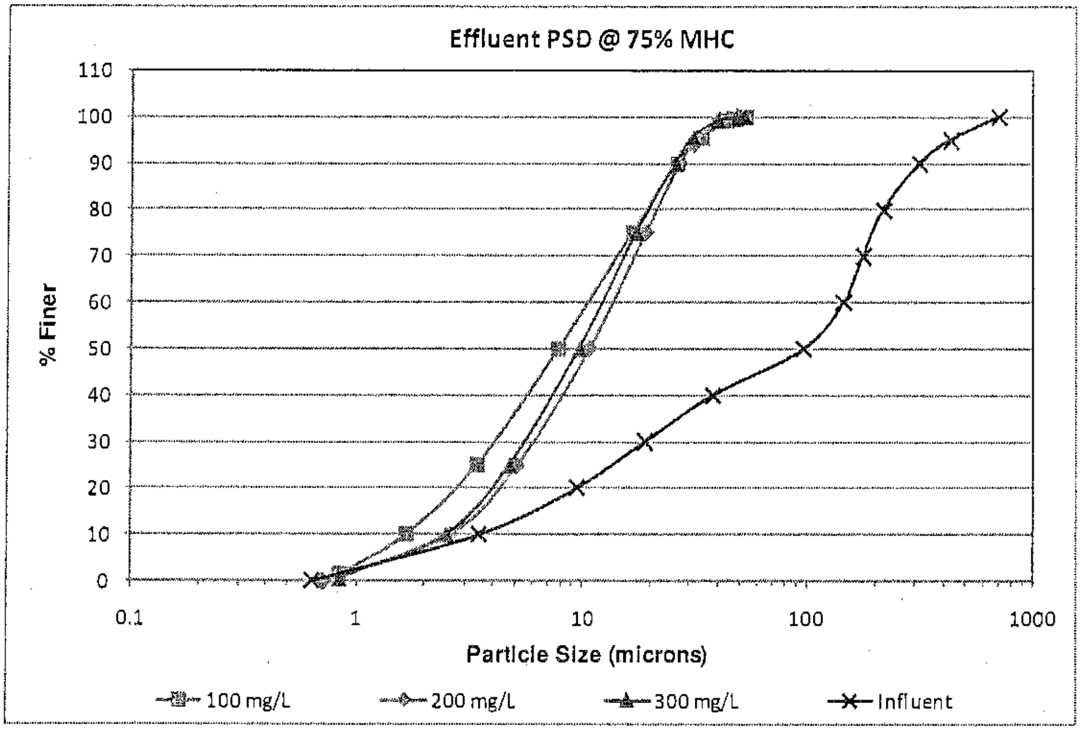

Figure 21: Effluent PSD Curve, 75%

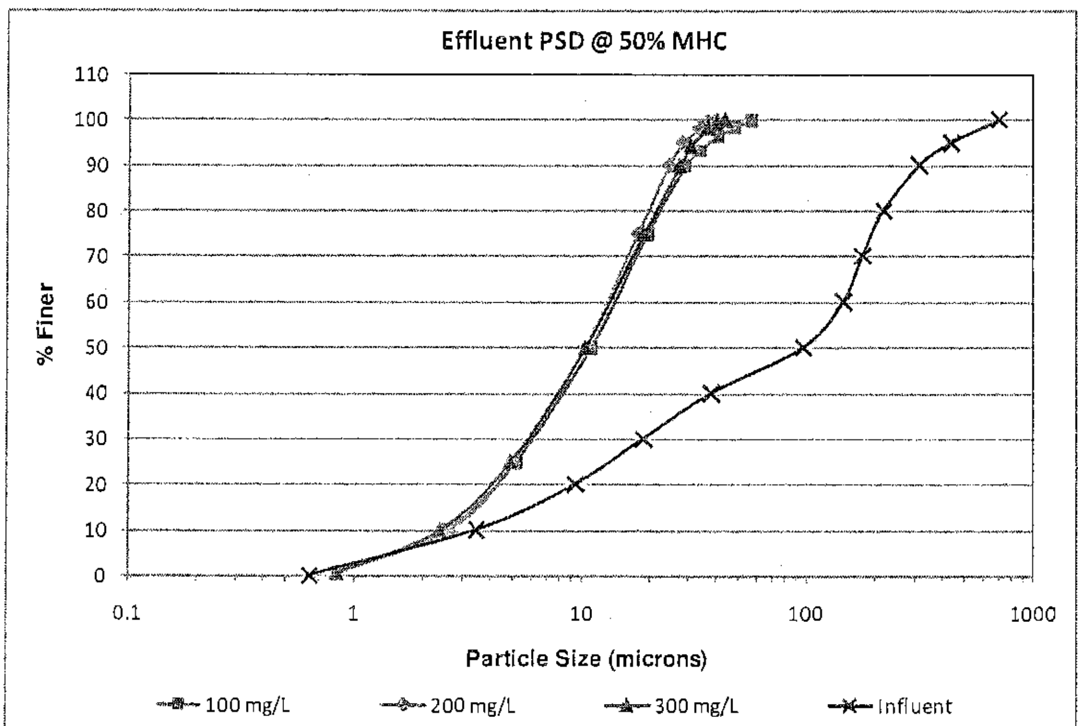

Figure 22: Effluent PSD Curve, 50%

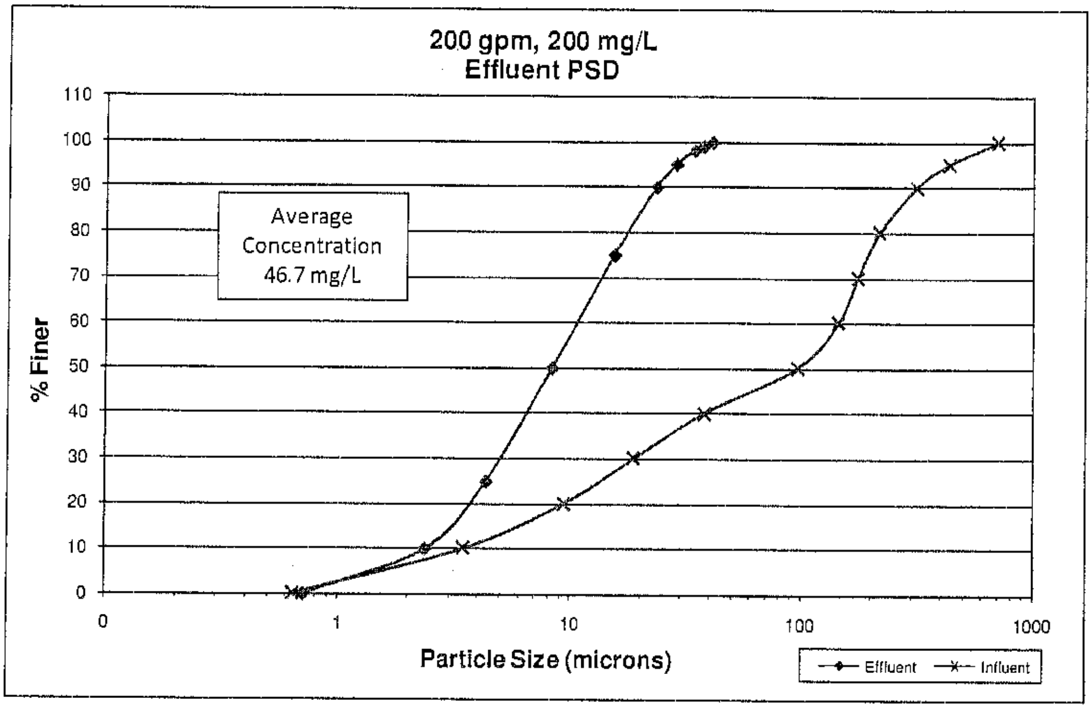

Figure 25: Effluent PSD Curve, 200 gpm

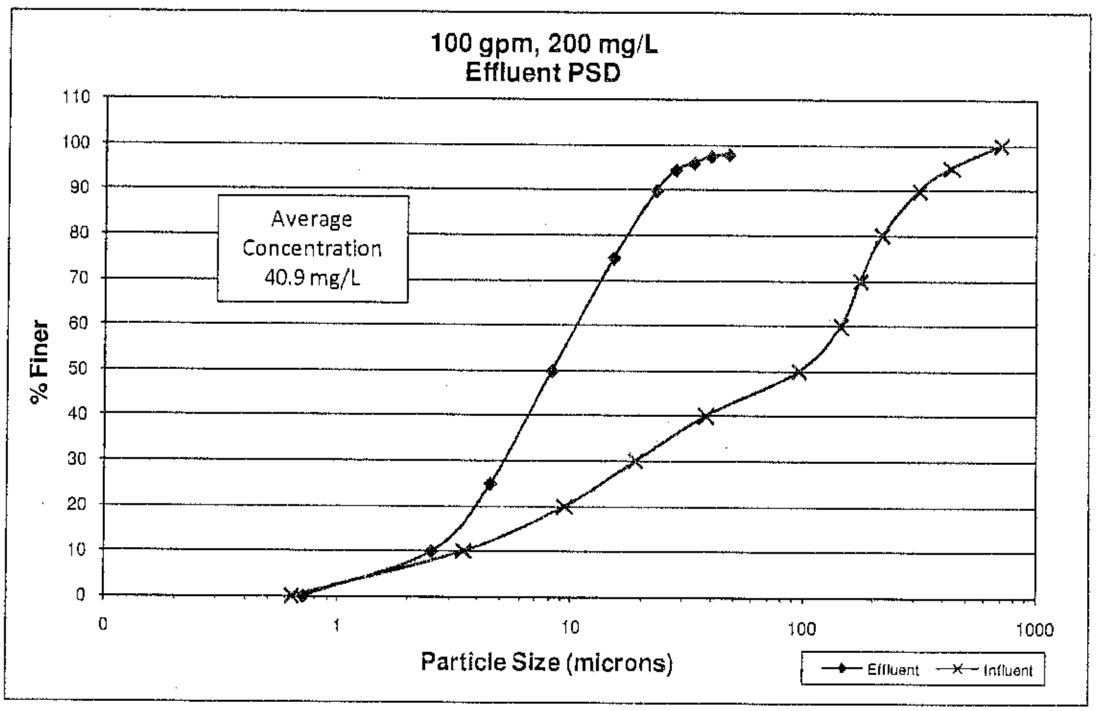

Figure 26: Effluent PSD Curve, 100 gpm

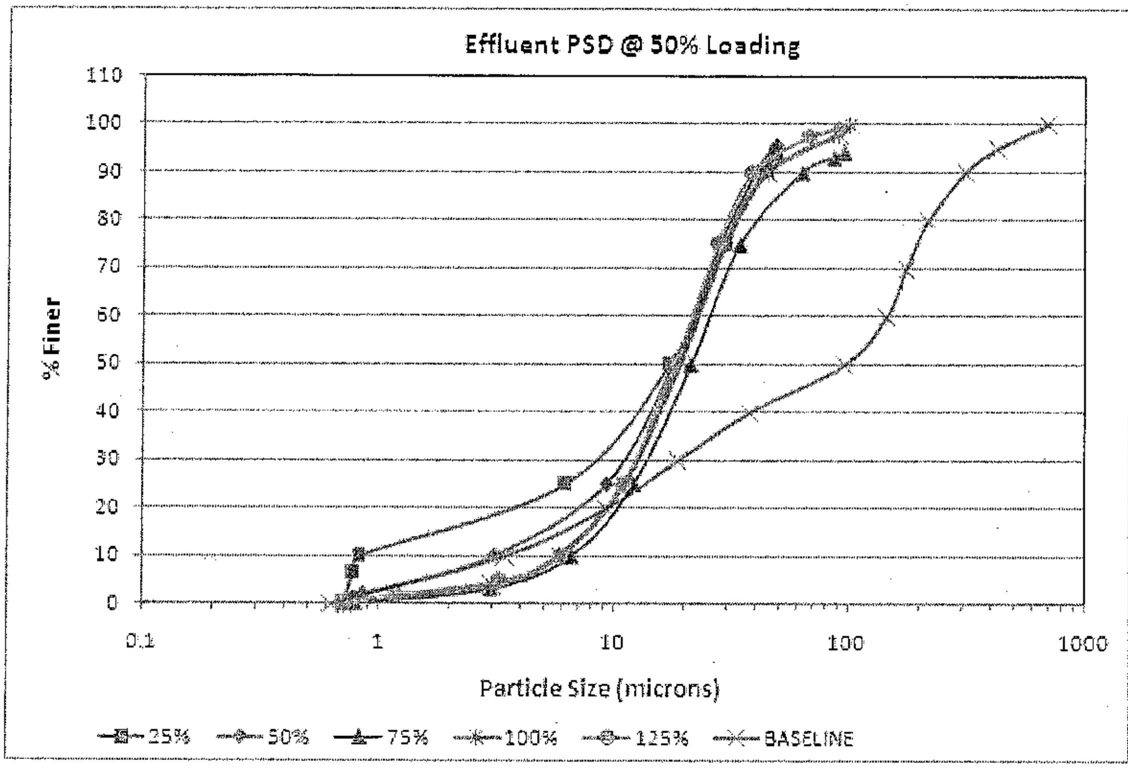

Figure 29: Re-Entrainment Effluent PSD Analyses at 50% Loading Capacity

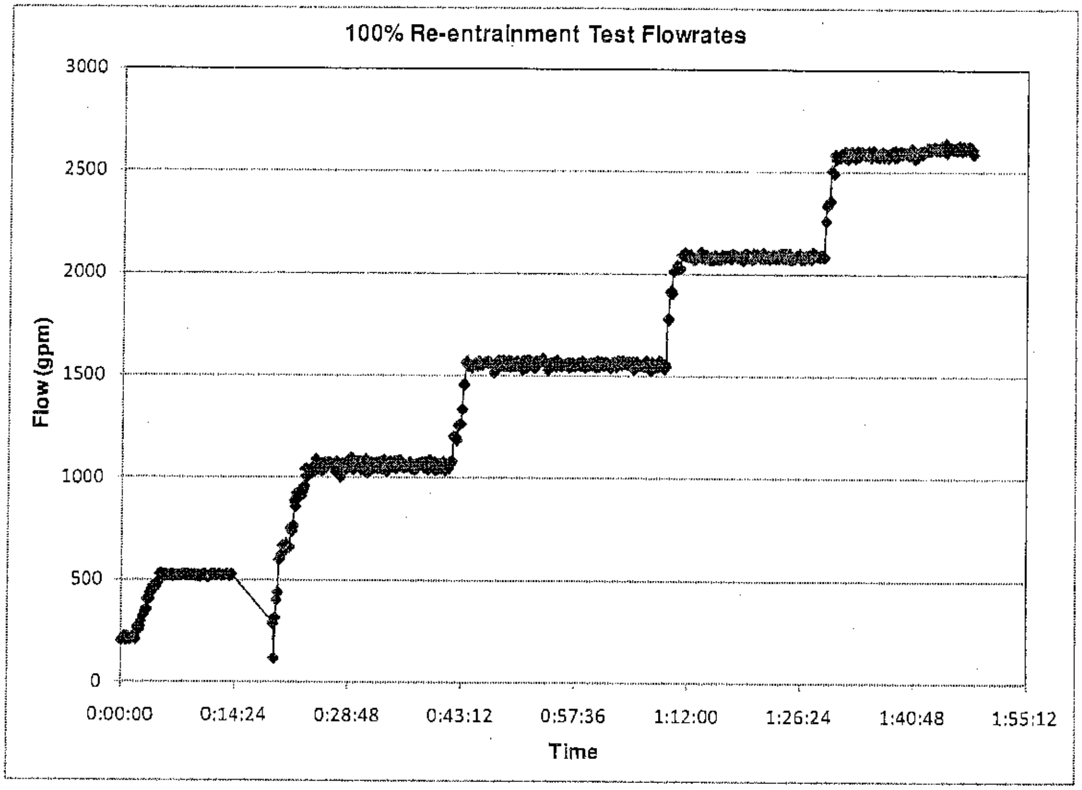

Figure 32: 100% Flow Trace Graph

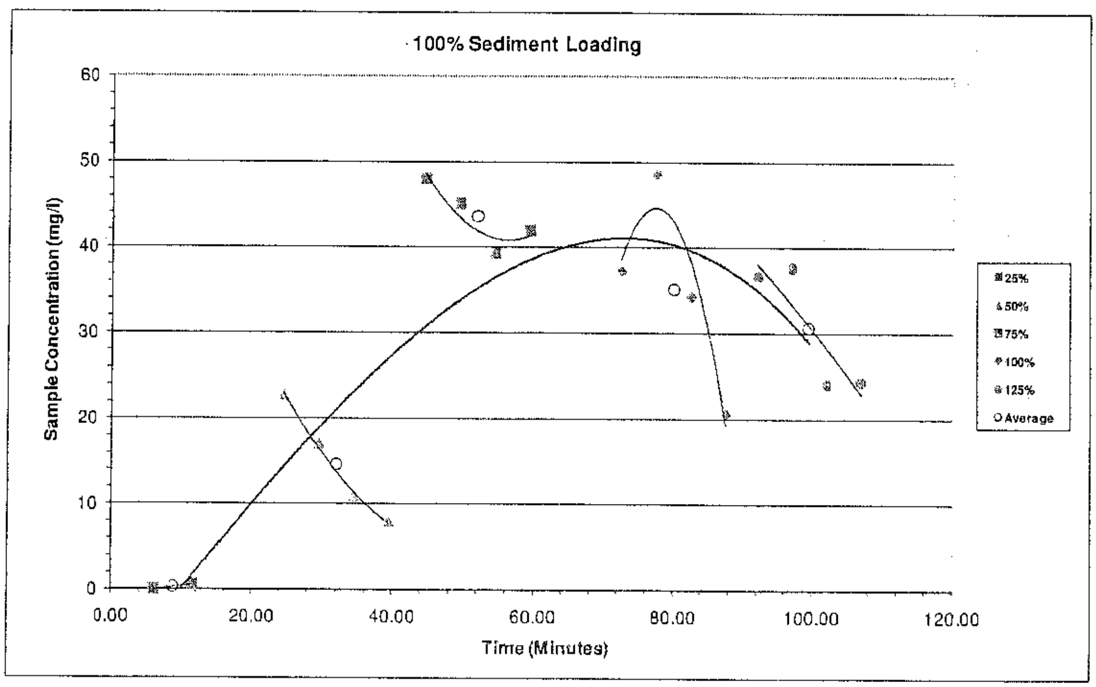

Figure 33: Re-entrainment Effluent Sample Concentrations

Figure 35: 100% Sediment Bed Prior to Re-entrainment Testing

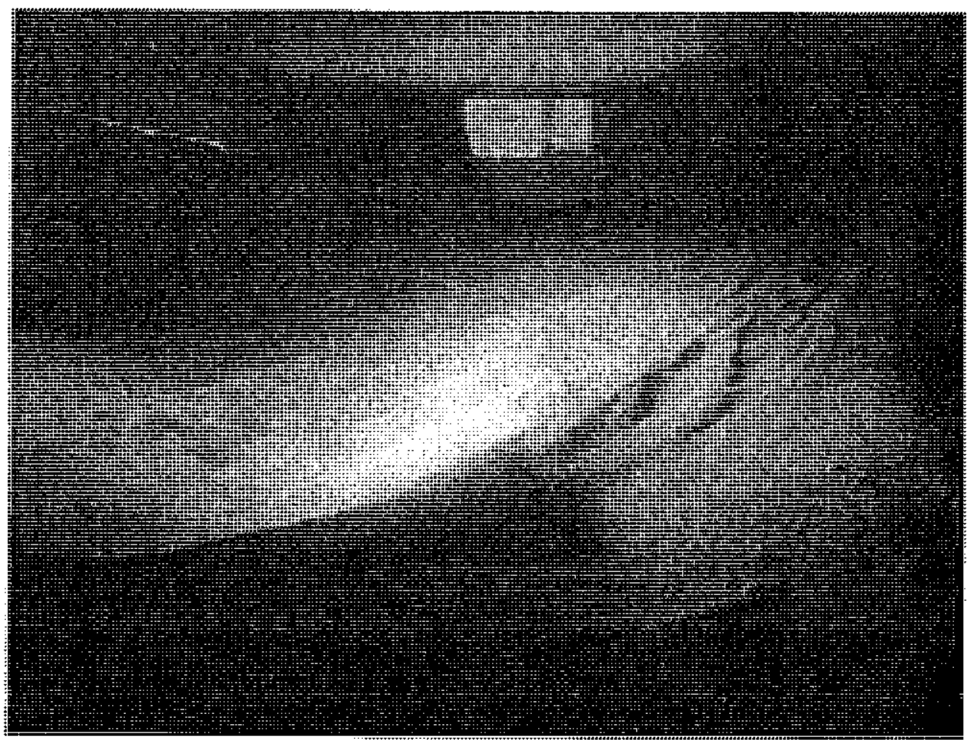

Figure 36: 100% Sediment Bed After Re-entrainment Testing

APPENDIX A
NJCAT LABORATORY TESTING PROTOCOL

loading at 50% and 100% of the unit's capture capacity. These tests will be utilized to check the potential for TSS resuspension and washout.

D. The test runs should be conducted at a temperature between 73-79 degrees Fahrenheit or colder.

3. Measuring treatment efficiency
   A. Calculate the individual removal efficiency for the 15 test runs.
   B. Average the three test runs for each operating rate.
   C. The average percent removal efficiency will then be multiplied by a specified weight factor (see table below) for that particular operating rate.
   D. The results of the 5 numbers will then be summed to obtain the theoretical annual TSS load removal efficiency of the system.

Treatment operating rate	Weight factor	
25%	.25	
50%	.30	
75%	.20	
100%	.15	
125%	.10	

Notes:

Weight factors were based upon the average annual distribution of runoff volumes in New Jersey and the assumed similarity with the distribution of runoff peaks. This runoff volume distribution was based upon accepted computation methods for small storm hydrology and a statistical analysis of 52 years of daily rainfall data at 92 rainfall gages.

A vendor shall submit for review and approval a quality assurance project plan supporting the above TSS Lab Test Procedure to the NJDEP and NJCAT prior to commencement of the full-scale lab tests. The plan shall provide procedures and methods to be followed in conducting the lab test (i.e. sampling design and methods, laboratory procedures, analytical methods, quality control, schematic of testing apparatus).

Therefore, the average concentration determined from the collected samples will not be the true average concentration in the pipe, unless all particles are uniformly distributed and fully suspended along the cross-section, which is unlikely. The concentration profiles will differ significantly from the velocity profile, as larger particles will occupy the bottom regions and finer suspended particles will occupy the top regions of the pipe, resulting in higher than average concentrations along the bottom half and lower than the average concentrations along the top half of the pipe. The average of the concentrations from only a few locations (such as one to four locations), will not be the same as the true average that can be only be obtained by sampling numerous points along a cross-section of the pipe.

b) For a given particle size distribution and properties of the injected sediment, the concentration distribution along the influent pipe cross-section would vary with the flow. The higher the influent flow, the higher will be the suspended load and lower will be the bed load and vice versa. Hence, it would be expected that the influent concentration determined by sampling would be more accurate at higher flows than at lower flows. But, unfortunately, this may not necessarily be the case, as the flow in the pipe becomes more turbulent at the higher flows. Due to the random nature of turbulence, the number and size of particles at any given location within the cross-sectional area, is influenced by the turbulent velocity fluctuations and could vary, reflecting random variations of concentrations of particles in the collected samples. As the particle weight is proportional to the cube of the particle size, the presence, or lack thereof, of few relatively larger particles in a given collected sample, could mean a significant difference in the concentrations determined from the samples at that location.

Based on the above discussion of the limitations of sampling methods, it is recommended that efficiency calculations of stormwater sediment removal devices, tested at Alden Research Laboratory, be performed using the average influent concentrations as determined by the dry weight sediment injection rate and flow rate, as opposed to those determined by sampling methods. With the added efforts to improve the injection system to allow uniform injection rates (full range of auger screw sizes) and measurement techniques to accurately measure the rate of injection (additional digital scale), Alden can calculate the average influent concentrations with significantly more accuracy than typical sampling methods have shown to produce.