EXHIBIT 5: NJCAT VERIFICATION REPORT DATED JANUARY 2010

http://www.nj.gov/dep/stormwater/treatment.html

NJCAT VERIFICATION REPORT DATED JANUARY 2010 is attached as an email attachment

NJCAT TECHNOLOGY VERIFICATION

Terre Kleen™ TK18 Separator

Terre Hill Stormwater Systems

April 2011 Addendum to this report starts on page 44

January 2010

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1. INTRODUCTION

1.1 New Jersey Corporation for Advanced Technology (NJCAT) Program

NJCAT is a not-for-profit corporation to promote in New Jersey the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization;
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated;
- Facilitate funding and commercial relationships/alliances to bring new technologies to market and new business to the state; and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. Thus, suppliers have the competitive edge of an independent third party confirmation of claims.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) the New Jersey Department of Environmental Protection (NJDEP) and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies the net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter into reciprocal environmental technology agreements concerning evaluation and verification protocols with the United States Environmental Protection Agency, other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

- The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the Energy and Environment Technology Verification Program.

1.2 Technology Verification Report

In January 2007, Terre Hill Silo Co. d/b/a Terre Hill Stormwater Systems (THSS), PO Box 10, 485 Weaverland Valley Road, Terre Hill, PA 17581, received NJCAT Technology Verification for the Terre Kleen™ TK18. NJCAT verified that the Terre Kleen™ Hydrodynamic Separator (Terre Kleen™) Model TK18 had a sediment removal efficiency rate of 78% of weighted net annual Total Suspended Solids (TSS) at a design flow rate of 2.5 gpm/ft² (NJCAT 2007). This NJCAT verification was based upon the review and analysis of a laboratory test report utilizing an outdoor, once through flow system prepared by Penn State University (PSU) on behalf of THSS.

The technology proposed by THSS, the Terre Kleen™ is a stacked inclined plate hydrodynamic gravity separator used for the removal of sediment and their associated pollutants, together with floatables such as Total Petroleum Hydrocarbons (TPH), grease, trash, debris, and litter.

The test flow rates attained in the previous verification were limited to 287.5 gpm due to the capability of the THSS equipment. The Terre Kleen™ TK18 model tested has 18 stacked inclined plates with horizontally projected sedimentation surface area of 115 ft², resulting in a verified design flow rate of 2.5gpm/ft² (287.5/115 = 2.5gpm/ft²)

In August 2007, THSS contracted with Alden Research Laboratory, Inc. (Alden), Holden, MA to perform NJDEP protocol-based laboratory tests on a Terre Kleen™ TK18. The primary purpose of the Alden test was to test the Terre Kleen™ TK18 at higher flow rates in a more controlled environmental test facility. Alden submitted a test report documenting their findings in September, 2008.

In late 2008, THSS requested NJCAT to perform a new verification of the Terre Kleen™ TK18 based on the 2008 Alden test report.

The request (after pre-screening by NJCAT staff personnel in accordance with the technology assessment guidelines) was accepted into the verification program. This verification report covers the evaluation based upon the performance claim of the vendor, Terre Hill (see **Section 4**). The verification report differs from typical NJCAT verification reports in that final verification of the Terre Kleen™ (and subsequent NJDEP certification of the technology) awaits completed field testing that meets the full requirements of the Technology Acceptance and Reciprocity Partnership (TARP) – Stormwater Best Management Practice Tier II Protocol for Interstate Reciprocity for stormwater treatment technology. This verification report is intended to evaluate the Terre Kleen™ performance claim for the technology based on carefully conducted laboratory studies. The performance claim is expected to be modified and expanded following completion of the TARP required field-testing.

This verification project primarily involved the evaluation of THSS manuals and literature and the 2008 Alden laboratory test report to verify that the Terre Kleen™ satisfies the performance claim made by Terre Hill.

1.3 Technology Description

1.3.1 Technology Status: general description including elements of innovation/uniqueness/competitive advantage

In 1990, Congress established deadlines and priorities for EPA to require permits for discharges of stormwater that is not mixed or contaminated with household or industrial wastewater. Phase I regulations established that a NPDES (National Pollutant Discharge Elimination System) permit is required for stormwater discharge from municipalities with a separate storm sewer system that serves a population greater than 100,000 and certain defined industrial activities.

To receive a NPDES permit, the municipality or specific industry has to develop a stormwater management plan and identify Best Management Practices for stormwater treatment and discharge. Best Management Practices (BMPs) are measures, systems, processes or controls that reduce pollutants at the source to prevent the pollution of stormwater runoff discharge from the site. Phase II stormwater discharges include discharges from classes of smaller municipalities than those specifically classified as Phase I discharge.

The nature of pollutants emanating from differing land uses is very diverse. Terre Hill has developed a technology for separating and retaining floating and sinking pollutants including sediment, hydrocarbons and debris under rapid flow conditions using an inclined plate hydrodynamic separator. Between maintenance events, pollutants accumulate within the system and are therefore removed from the natural environment. Maintenance is performed from above by a vacuum truck and without interference from internal components. The technology, based on inclined plate settling, has been used for treatment of potable water and wastewater (AWWA 1999, Metcalf & Eddy 2003).

The Terre Kleen™ device combines a baffle, screen, internal by-pass duct and self cleaning inclined sedimentation cells above a scour protected hopper, to create a primary chamber, grit sedimentation chamber, and oil, litter and debris/sediment storage into a self-contained concrete structure. The inclined cells are stacked in the grit chamber and operate in parallel. The overlap of the cells reduces the required footprint of the system.

1.3.2 Specific Applicability

The Terre Kleen™ is a stormwater quality treatment device suited for the following applications:

a. General removal of sediments
b. Pretreatment for natural or manufactured BMPs in a treatment train configuration
c. Parking lots or other impervious surfaces that create stormwater runoff
d. Stormwater water quality retrofits for existing sites
e. Brownfields or other redevelopment sites

f. Urban or other densely populated areas, especially where there exists other underground utilities, where compact footprint of structure will minimize utility and right of way conflicts
g. Automobile, truck or other vehicular use or service areas or facilities
h. Airports
i. Industrial sites
j. Hot spots where TPH spills or contamination may occur
k. New land developments

1.3.3 Range of Contaminant Characteristics

The Terre Kleen™ captures various pollutants from stormwater. The pollutants consist of TPH, grease, trash, debris litter, floatable organic matter such as leaves, and sediment. Absorbed contaminants such as phosphorous and other nutrients, heavy metals, hydrocarbon and other petroleum products are also removed from stormwater.

1.3.4 Range of Site Characteristics

The Terre Kleen™ is designed to accommodate a wide range of flows and volumes. Ten sizes **(Table 1)** are available; each is designed to treat a range of flows at a specific particle size. The Terre Kleen™ is a primary treatment device, which requires no pretreatment. However, it can be used as a pretreatment device before other BMPs such as infiltration systems, detention systems, filters, bio-retention systems, mitigating wetlands or other polishing systems. The use of a pretreatment device will prolong the useful life of the subsequent BMPs in the treatment train.

1.3.5 Material Overview, Handling and Safety

The Terre Kleen™ is designed with clear access to the primary and grit chambers. A vacuum truck, or similar trailer mounted equipment, can be used to clean both chambers by lowering the suction hose through the openings.

Solids recovered from the Terre Kleen™ can typically be land filled and liquids disposed of at a wastewater treatment plant. It is possible that there may be some specific land use activities that create contaminated solids, which will be captured in the system. Such material would have to be handled and disposed of in accordance with hazardous waste management requirements.

Table 1. Terre Kleen™ Sizes and Specifications

Performance						Approximate Size		Miscellaneous Data			
Model	Flow Capacity in CFS	Minimum Particle Size Removal in Microns (Note 1)	Grit Chamber Projected Surface Area in Ft^2	Sediment Storage up to 16.5 inch Depth in Grit Chamber only in Ft^3	Maximum Possible System Storage Capacity in Ft^3 Note 2	Inside Length	Inside Width	Oil Storage Capacity in Gallons (2'-6" Primary Chamber Width NOTE 2)	Grit Chamber Loading Rate in GPM per Ft^2 (Note 1)	Primary Chamber Loading Rate in GPM per Ft^2 (Note 1)	Head Loss through Terre Kleen Insert in Inches (Note 1)
TK01	0.13 to 2.50	28 to 123	8	11	44	6"-0"	4'-0"	279	7 to 140	2 to 47	0.00 to 0.08
TK02	0.21 to 4.20	28 to 123	13	18	60	6"-0"	4'-0"	192	7 to 145	6 to 114	0.00 to 0.21
TK05	0.54 to 10	28 to 123	32	44	127	8'-0"	6'-0"	279	7 to 140	11 to 210	0.00 to 0.56
TK09	0.95 to 19.7	28 to 123	57	25	77	7'-0"	4'-6"	157	7.5 to 155	24 to 505	0.13 to 55
TK18	1.9 to 36.5	28 to 123	115	36	99	7'-0"	6'-6"	227	7.5 to 155	49 to 936	0.16 to 58
TK27	2.85 to 59	28 to 123	172	47	121	8'-6"	7'-0"	297	7.5 to 155	73 to 1513	0.18 to 75
TK36	3.8 to 79	28 to 123	230	58	143	10'-6"	7'-0"	367	7.5 to 155	97 to 2026	0.19 to 82
TK45	4.6 to 98	28 to 123	288	69	165	12"-6"	7'-0"	436	7.5 to 155	118 to 2513	0.19 to 85
TK54	5.5 to 118	28 to 123	346	80	187	14'-6"	7'-0"	506	7.5 to 155	141 to 3026	0.21 to 99
TK63	6.4 to 138	28 to 123	403	91	209	16'-6"	7'-0"	576	7.5 to 155	164 to 3539	0.22 to 101

Note 1: Top range corresponds with the maximum value of flow capacity and bottom range with the minimum flow capacity. Particles are presumed to be 2.65 in specific gravity, in 70 degrees Fahrenheit water.
Note 2: Additional storage can be provided with off-standard dimensions.

Note: The above numerical values were provided by the vendor and do not represent the verified information.

1.4 Project Description

This project included the evaluation of THSS manuals and literature, and the 2008 Alden laboratory test report to verify that the Terre Kleen™ TK18 meets the performance claim of Terre Hill Concrete Products.

1.5 Key Contacts

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2. EVALUATION OF THE APPLICANT

2.1 Corporate History

Terre Hill Concrete Products began business in 1919 by the Martin family. It has been in continuous operation since that date. Terre Hill Concrete Products began as a manufacturer of concrete silo staves for use in the agricultural industry.

In 1970, Terre Hill Concrete Products began manufacturing precast products for building construction, sanitary sewer, storm sewer, and transportation infrastructure. This has expanded to manufacture of precast bridges and other heavy precast products.

In the late 1990's Terre Hill Concrete Products patented manhole rehabilitation products, which are currently being manufactured and installed by a separate company, Terre Hill Composites, Inc.

In 1999, Terre Hill Concrete Products began research and development of the Terre Kleen™ stacked inclined plate hydrodynamic separator and related products in Terre Hill Stormwater Systems.

Terre Hill Stormwater Systems (THSS) is a division of Terre Hill Silo Company, which also trades as Terre Hill Concrete Products. On January 5, 2002, Terre Hill Silo Company applied for a patent for a Surface Water Purifying Catch Basin. On January 13, 2004 Terre Hill received a US Patent (# 6,676,832 B2). Thereafter, THSS began marketing and selling the Surface Water Purifying Catch Basin under the trade name Terre Kleen™. The first Terre Kleen™ installation occurred on May 19, 2004 in Adams County, PA.

2.2 Organization and Management

President / CEO: A. Eugene Martin

Vice President for Production: Nelson Martin

Director of New Product Development: Dale Groff

2.3 Operating Experience with respect to the Proposed Technology

One hundred and thirty eight (138) Terre Kleen™ devices have been installed (as of January 2010) including three (3) TK54 units, ten (10) TK 45, six (6) TK 36, nineteen (19) TK27, thirty nine (39) TK18, fifty four (54) TK09, one (1) TK 2, and six (6) TK 1.

2.4 Patents

The design of the Terre Kleen™ received a US Patent (# 6,676,832 B2) in January of 2004.

2.5 Technical Resources, Staff and Capital Equipment

Terre Hill Stormwater Systems, as a division of Terre Hill Silo Company d/b/a Terre Hill Concrete Product, has unlimited access to all of the technical resources, staff and capital equipment of Terre Hill Concrete Products.

Terre Hill Concrete Products has been in business since 1919. It is sufficiently capitalized to underwrite the development of the Terre Kleen™. It has four (4) manufacturing plants located in Lancaster and Lebanon counties, PA. The manufacturing plants are NPCA certified and DOT approved. Each plant has in house capability for testing the precast concrete structures to assure compliance with product specifications and regulations.

Terre Hill Stormwater Systems has designed and engineered plans and specifications for the manufacture, fabrication and assembly of the stacked inclined plate Terre Kleen™ component.

Terre Hill Stormwater Systems contracts with an outside metal fabrication company to manufacture and fabricate the various aluminum and stainless steel components that are then assembled by Terre Hill Stormwater Systems into completed Terre Kleen™ inserts that are job specific. Terre Hill Stormwater Systems personnel maintain regular communication with the metal fabrication contractor and regularly visit the metal fabrication contractor to assure strict compliance with all plans and specifications.

The fully assembled Terre Kleen™ component is then installed into a job specific precast concrete structure that has been designed, engineered and manufactured at the manufacturing plant of Terre Hill Concrete Products. The manufacture of the precast concrete structure and the installation of the Terre Kleen™ insert are overseen and coordinated by the Project Manager, Dale Groff. This controlled manufacture and assembly process assures quality control.

Terre Hill Stormwater Systems will deliver and/or install the Terre Kleen™ at the job site, when requested; however, installation service is an infrequent request. Terre Hill Stormwater Systems sends an installation liaison to each job site when any Terre Kleen™ is installed. The liaison is experienced in both the manufacture and assembly of the Terre Kleen™ and in construction site installation issues.

This focus on all phases from design to installation assures that each Terre Kleen™ will result in standardized manufacturing processes, consistent product quality, and reliable performance in accordance with its published and verified performance claims.

Terre Hill Concrete Products has an in house design and engineering staff that assists in the design and engineering of each Terre Kleen™. In addition, when the situation requires, Terre Hill Stormwater Systems contracts with consulting engineers and other professionals to obtain the necessary expertise to accomplish a particular task.

Key personnel involved in the research, development, design, engineering and manufacture of the Terre Kleen™ are: A. Eugene Martin, President and Nelson Martin, Vice President & COO; having over fifty (50) years combined experience in precast concrete design and manufacturing; Dale Groff, Project Manager, having over thirty (30) years experience in construction and precast concrete manufacturing; Hans de Bruijn, the lead inventor of Terre Kleen, Sales Engineer, having over thirty (30) years in design and engineering of complex structures and systems in the water, waste water and stormwater industries; and Gene LaManna having over thirty (30) years experience in regulatory compliance matters.

3. TREATMENT SYSTEM DESCRIPTION

The Terre Kleen™ (**Figure 1**) is a stacked, inclined plate hydrodynamic separator that has been developed by Terre Hill Concrete Products, d/b/a Terre Hill Stormwater Systems for separating and retaining floating and sinking pollutants, including sediment, oil, grease, trash, litter and debris under specified flow conditions.

The Terre Kleen™ is a marine grade aluminum (#5052) insert that is housed in a precast concrete rectangular structure. Stormwater enters the primary chamber wherein floatables such as oil, grease, trash, litter, and debris and larger sediment particles are captured. The stormwater then passes through a screen about midway the water depth and equal proportions flow into the sides of the stacked inclined cells located in the secondary chamber (the grit chamber) where the finer sediment particles are removed by the gravitational sedimentation process. The treated water exits the cells over a weir at the top of the cells and flows to the effluent pipe. The sediment slides along the inclined plate surface to a protected hopper below the cells. The inclined cell surfaces remain cleansed for future flow events. The sediment remains undisturbed in the protected hopper.

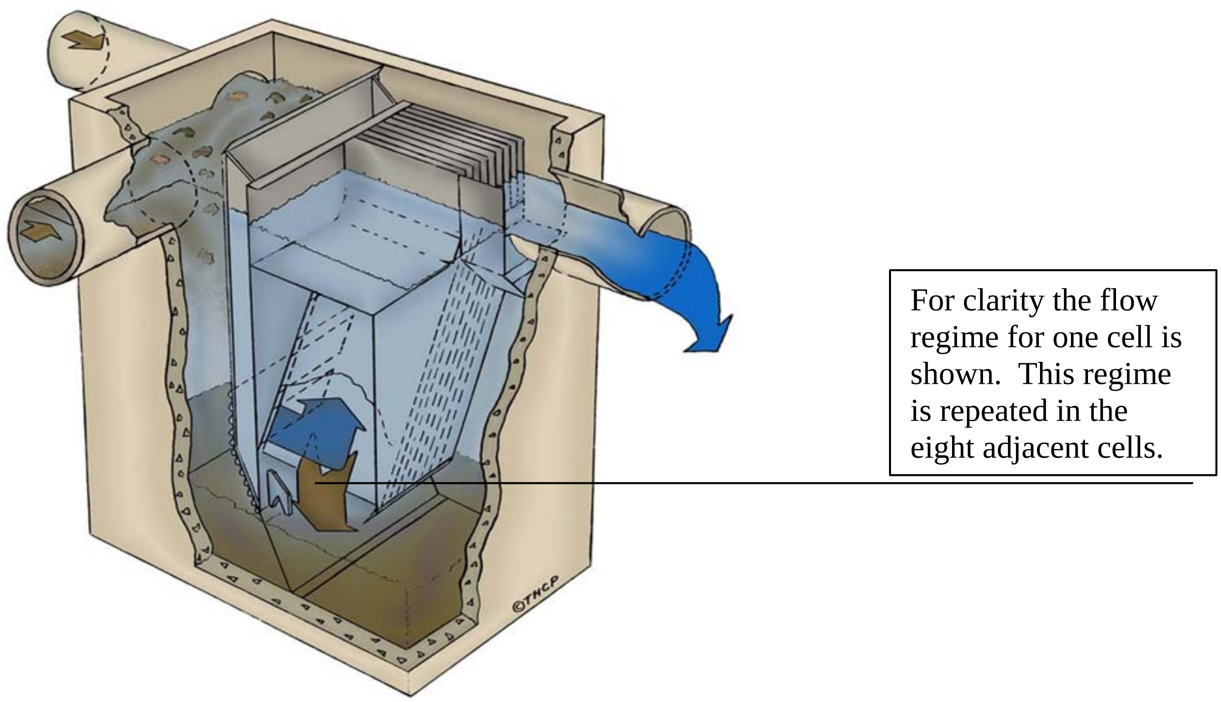


Figure 1. **Schematic of the Terre Kleen™ TK09**

Specification

Terre Kleen™ units can be designed to provide specific removal efficiencies based on the size characteristics of the suspended solids and the flow rate to the device. The standard models of

Terre Kleen™ are sold in multiples of nine sedimentation cells, i.e. TK9; TK18; TK27; TK36; TK45; TK54. Larger Terre Kleen™ units are available. Smaller units, TK1, TK2, and TK5, are available as well.

Installation

Fabrication of the inclined cell separator (i.e., settler) is in strict accordance with the design drawings of Terre Hill Concrete Products. The settlers are provided with mounting brackets for installation into the concrete holding tank with stainless steel mounting anchors. The settler is provided with a flow channel on the effluent side of the settler and a clean-out opening next to the channel. The classification screen is placed as an extension of the baffle wall at the entrance to the parallelogram port in the divider wall. Certified welders experienced in the welding of specified thin metals place all welds. The fabricator is responsible for removing shop soils, discoloration, and welding slag.

The utility contractor installing the vault is responsible for providing a watertight structure. The vault is installed level and plumb at the specified elevation on a compacted stone sub base 150 mm (6 inch) thick.

4. TECHNICAL PERFORMANCE CLAIM

Claim: The Terre Kleen™, Model TK18, at a flow rate of 2070 gpm (4.61 ft^3/s, 18 gpm/ft^2 of horizontally projected sedimentation area), has been shown to have a 57.8% removal efficiency, measured as suspended sediment concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency), for a sediment mix with an average d_{50} particle size of 70 microns, an average influent concentration of 200 mg/L and 50% (8.25 inches or 15.6 ft^3) initial sediment loading in laboratory studies using simulated stormwater.

5. TECHNICAL SYTEM PERFORMANCE

Under a contract from Terre Hill Stormwater Systems verification testing of a 6-ft x 6.5-ft Terre Kleen™ TK18 Hydrodynamic Separator (TK18) was conducted at Alden Research Laboratory, Inc. (Alden), Holden, Massachusetts. Testing was conducted in three phases. Phase 1 testing measured head-loss values and hydraulic characteristic curves of the TK18 insert at various flow rates. Phase 2 testing was conducted according to the protocols set forth by the New Jersey Department of Environmental Protection (NJDEP 2003), for determining the sediment removal efficiencies (using NJDEP specified particle distribution) and evaluating the re-entrainment conditions for various flows. Phase 3 testing was conducted to determine additional points of removal of the 200 mg/l NJDEP sediment concentration to identify the performance curve extension at virtually no flow.

5.1 Laboratory Testing

The TK18 is a rectangular separating device using an 18-inch diameter influent pipe discharging into a 6.5-ft long x 2-ft wide primary gravel chamber, a secondary settling/grit chamber, an internal flow-through duct, eighteen (18) inclined Lamella plates, an overflow weir and an outlet shelf chamber. The 18-inch influent pipe has an invert located 75 inches above the wetted floor. The outlet pipe is 24 inches in diameter, with an invert of approximately 75 inches and contains a 3-inch rounding at the entrance. The inlet and outlet pipes are oriented with 3% slopes and the centerlines of both pipes are located 2 feet from the left wall (looking downstream). The test unit supplied by Terre Hill included five (5) 12-inch viewing windows, located approximately 30 inches above the floor, to facilitate observations and documentation of sediment movement. **Figure 2** shows a layout drawing of the TK18 test unit and **Figure 3** shows a photograph of the unit installed in Alden's test facility.

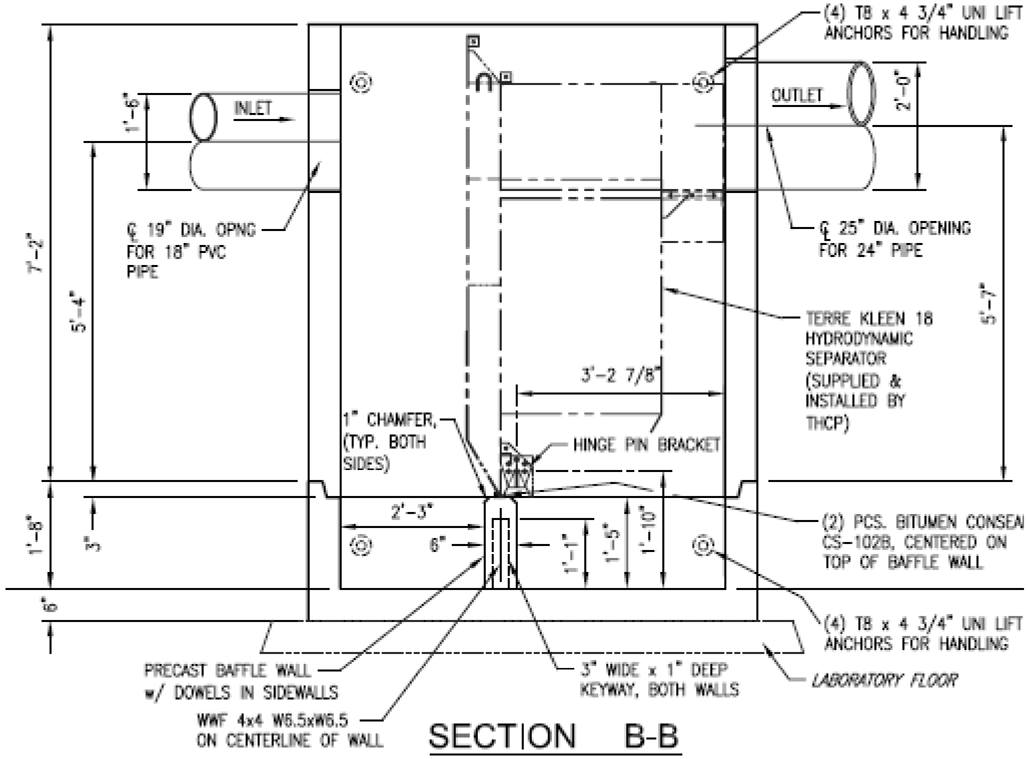
5.1.1 TEST FACILITY DESCRIPTION

Figure 4 shows the closed test loop, located in Alden's laboratory/test facility, which was used to test the TK18 Hydrodynamic Separator. Water was supplied to the unit with the use of one (1) 20HP and two (2) 50HP pumps (flow capacity of approximately 17 cfs) 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.

5.1.2 INSTRUMENTATION AND MEASURING TECHNIQUES

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. The accuracy of the flow measurement is estimated at ±2%.



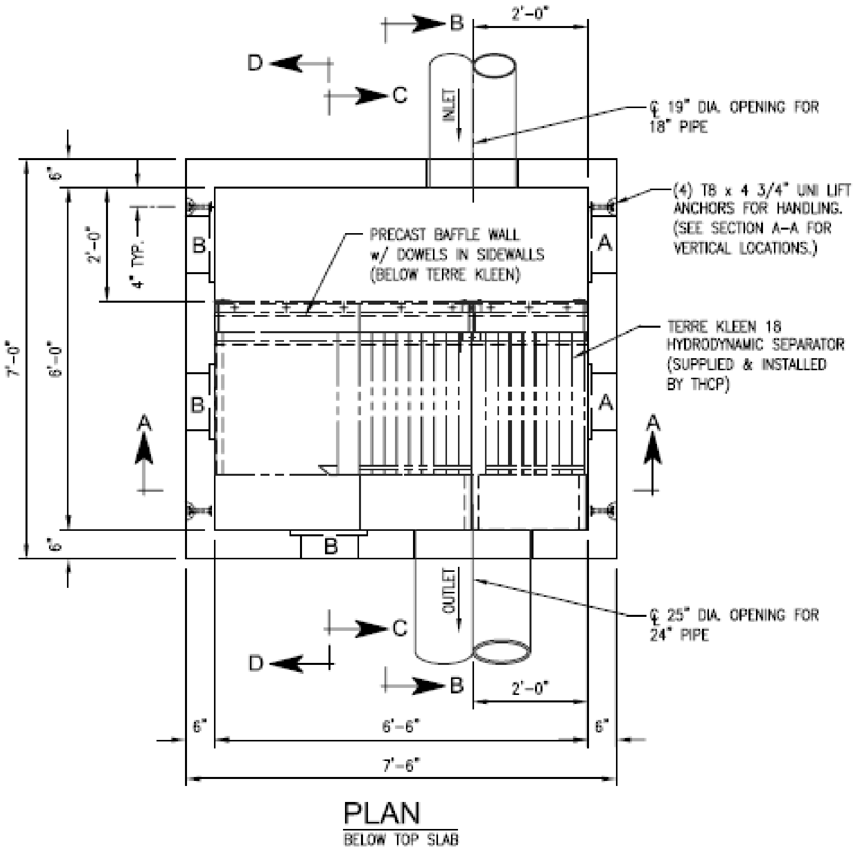


Figure 2. Terre Hill TK18 Test Unit

Figure 3. TK18 in Alden's Test-Loop

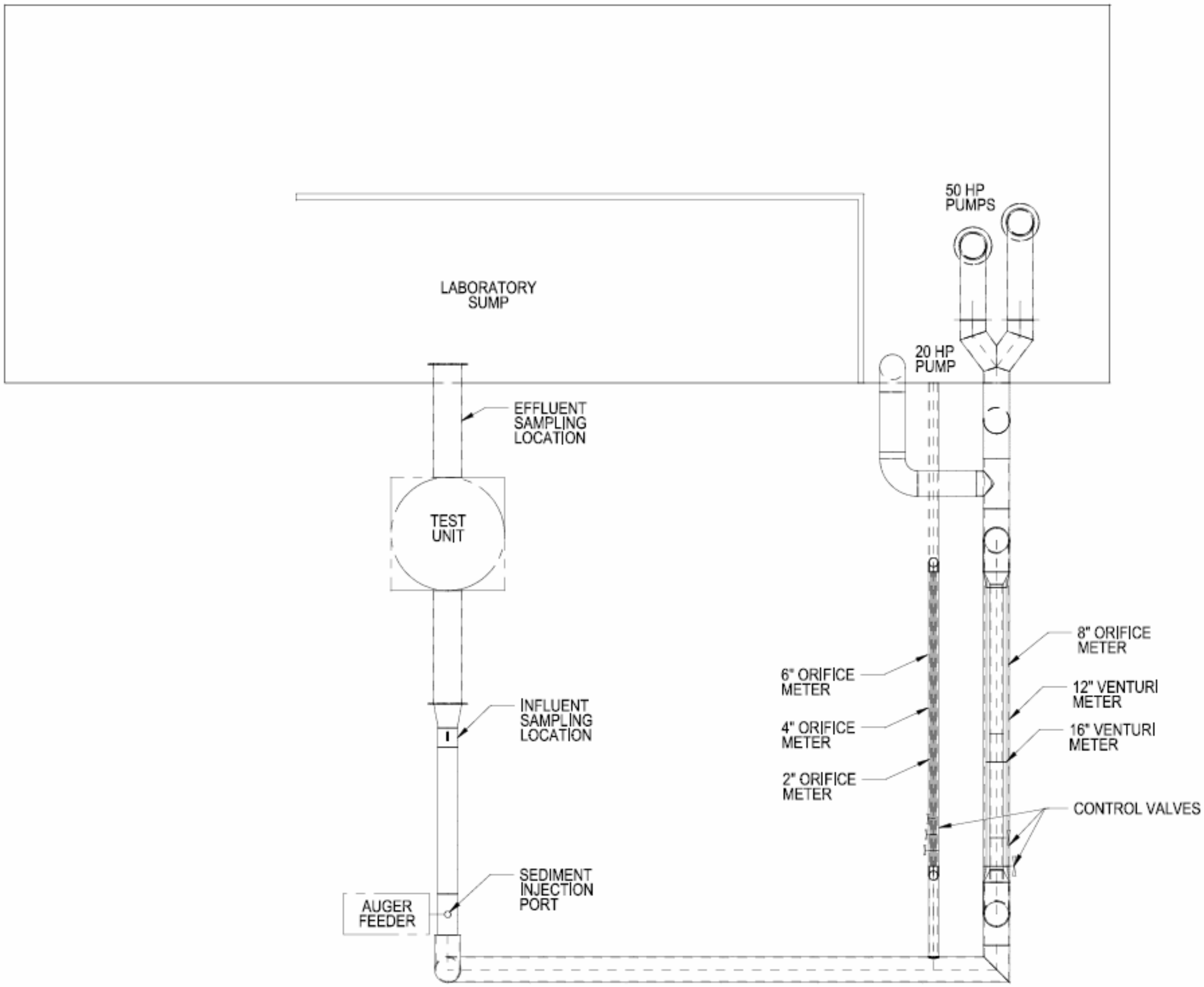


Figure 4. Alden's Stormwater Laboratory Flow Loop

Temperature

Water temperature measurements within the sump were obtained using a calibrated Omega® DP41 temperature probe and readout device. The calibration was performed at the laboratory prior to testing. The temperature reading was entered into the DA program at the start of each test for use in the flow measurement calculations.

Pressure Head

The pressure head readings throughout the system were measured using a Rosemount® 0 to 60-inch DP cell. The pressure cell was calibrated at Alden prior to testing. Fourteen (14) 9-second averages were recorded using a computerized DA program.

Sediment Injection

NJCAT protocol sediment, with a Specific Gravity of 2.65, was used to test the TK18 unit. The test sand was introduced into the influent pipe using one or two (flow dependent) Auger® volumetric screw feeders, model VF-1. The Auger feed screws used in testing ranged in size from 1.0 to 1.5 inches, depending on the test flow and influent concentration. Each auger screw, driven with a variable speed drive, was calibrated with the test sediment prior to testing, in order to establish a relationship between screw RPM and feed rate in mg/minute. The feeders have a 1.5 cubic foot hopper at the upper end of the augers to provide a constant supply of dry test sand.

Sample Collection

As described in Section 2.0, isokinetic sampling tubes were located within the influent and effluent piping to collect the sediment concentration samples. The tubes ranged from 0.50 to 1.0 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 5**.

Sample Concentration Analyses

Sample concentrations can be analyzed using one of two analytical methods: Suspended Sediment 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.

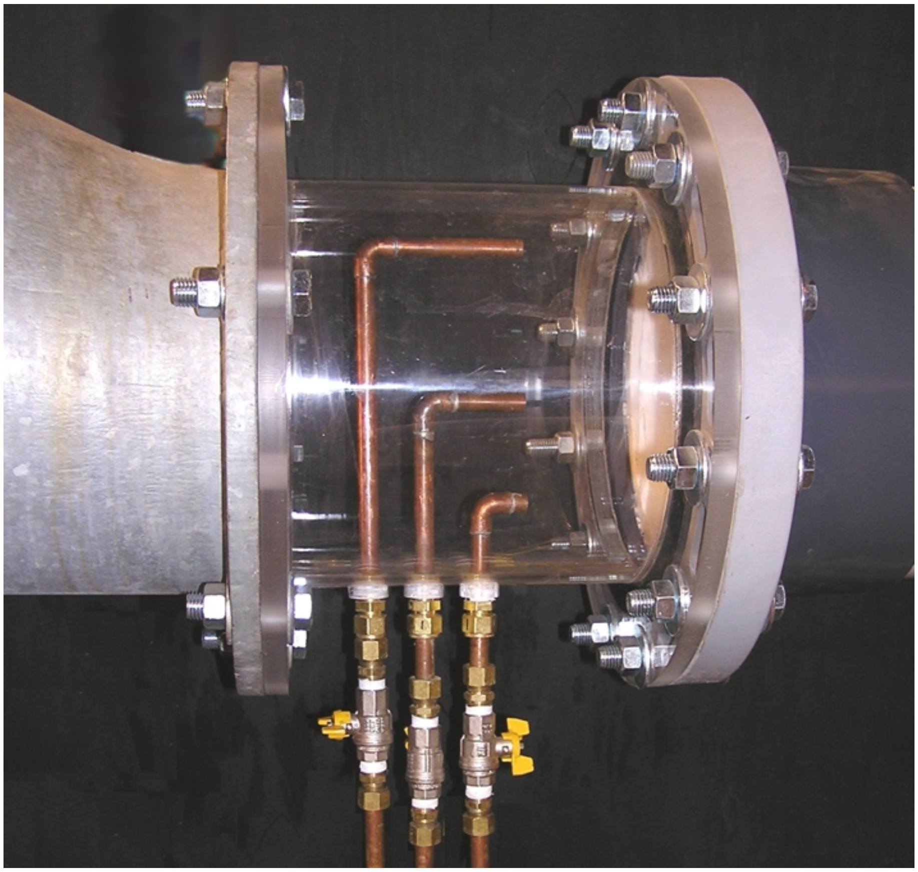


Figure 5. Sampling Tube Array

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 dry. The oven temperature was increased to 225 degrees F and the samples were dried for an additional 2-½ to 3 hours. The dry samples and dishes were then weighed to the nearest 0.0001-gram, using the AND® balance. Net sediment weight (mg) was determined by subtracting the dried filter weight 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. The removal efficiency for each flow condition was calculated using the following equation:

$$\% \text{ Efficiency} = \frac{(\text{Mean Influent Concentration} - \text{Mean Effluent Concentration})}{(\text{Mean Influent Concentration})} \times 100$$

It should be noted that the influent and effluent concentrations are adjusted for background prior to calculating the removal efficiency.

Test Sediment and Particle Size Distribution

In order to satisfy the particle size distribution set forth by NJCAT testing protocol, Alden has developed a sediment mix composed of NJ#00N, OK110 and Min-U-Sil 40 silica sand, available from US Silica. **Table 2** shows the theoretical PSD of each grade of sand, as well as the mix ratios and resulting percentages. The D_{50} size for the mix, as seen in **Figure 6**, is approximately 70 microns, which matches well with the NJDEP estimated D_{50} of 67 microns.

5.2 Test Procedures

The TK18 unit was tested in accordance with the NJCAT testing protocol for Stormwater Treatment Devices. The guideline requires, at a minimum, documentation showing the capture efficiency of the selected test sediment for five (5) flows at 100, 200 and 300 mg/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. 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 unit was conducted in three phases, as described below:

Table 2. Test Sediment Mix Using Commercially Available US Silica Sand

Range	**Target**	Mesh	Microns	NJ # 00N	OK-110	Min-U-Sil 40	%	%	%	**Total**
	NJCAT			11%	46%	43%				
		20	850							
500-1000	**5%**	30	600	45			5.0			**5.0**
		40	425	52			5.7			
250-500	**5%**	50	300	3			0.3			**6.1**
		70	212							
		100	150		1			0.5		
100-250	**30%**	120	125		15			6.9		
		140	106		48			22.1		**29.4**
		170	88		24			11.0		
50-100	**15%**	200	75		9.7			4.5		
		270	53		1.9			0.9		**16.4**
8-50	**25%**					60			25.8	**25.8**
2-8	**15%**					28			12.0	**12.0**
1-2	**5%**					12			5.2	**5.2**
		Total		100	99.6	100				**99.8**

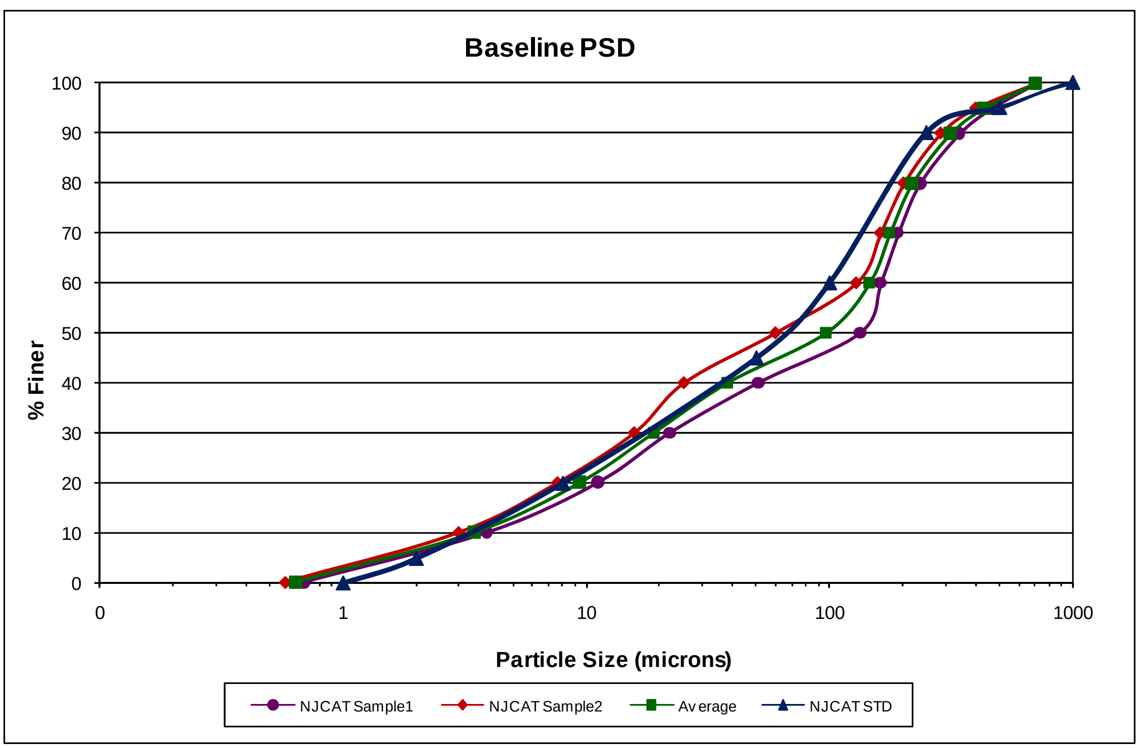


Figure 6. Test Sediment Mix PSD

5.2.1 Capacity and Characteristics Phase 1 - Hydraulic

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 7**): 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.

5.2.2 Phase 2a - Sediment Removal Efficiency Testing

As described in the introduction to **Section 5.1**, the test unit was pre-loaded with the NJCAT sediment mix to a depth of 16.5 inches, corresponding to 100% of the stated capacity, as claimed by Terre Hill. Sediment removal efficiency testing was performed using the indirect method (sampling), as described below.

The test flow was set and allowed to reach steady state. The test sediment was introduced into the inflow line and three (3) system volumes were allowed to pass through the test-loop prior to the collection of samples. A minimum of 5 pairs of influent/effluent samples, of approximately 1 Liter each, were collected during each test, with each effluent sample taken one residence time after the influent sample. At the completion of the sample collections, sediment injection was stopped and the system continued to operate for the duration of time necessary to assure that all the sediment has entered the unit. Background samples were taken at regular intervals throughout the test (corresponding to the influent samples), at a location upstream of the injection point. The dynamic background concentrations were subtracted from the corresponding influent and effluent concentrations to establish the sediment concentration levels for each sample. Each collected sample was processed as described in **Section 5.1.2**.

In addition to the collection of influent samples, verification of the injected sediment concentration was achieved by taking timed dry samples from the auger feeder at regular intervals throughout each test. The collected samples were weighed to establish the mg/min feed rate for each sample. The additional calculated concentrations are reported in the data sets as *"Adjusted Influent Concentrations"*. Coupled with the recorded flow data, Alden has found that this methodology for establishing the average influent concentration has a higher degree of accuracy over the indirect (isokinetic) sampling. This is due to many variables including the turbulent flow regime, velocity at the samplers, as well as the mixing and dispersion of the test sediment within the pipe. The isokinetic effluent samples were used in the efficiency calculations, as the fine particles are fully mixed and suspended throughout the pipe.

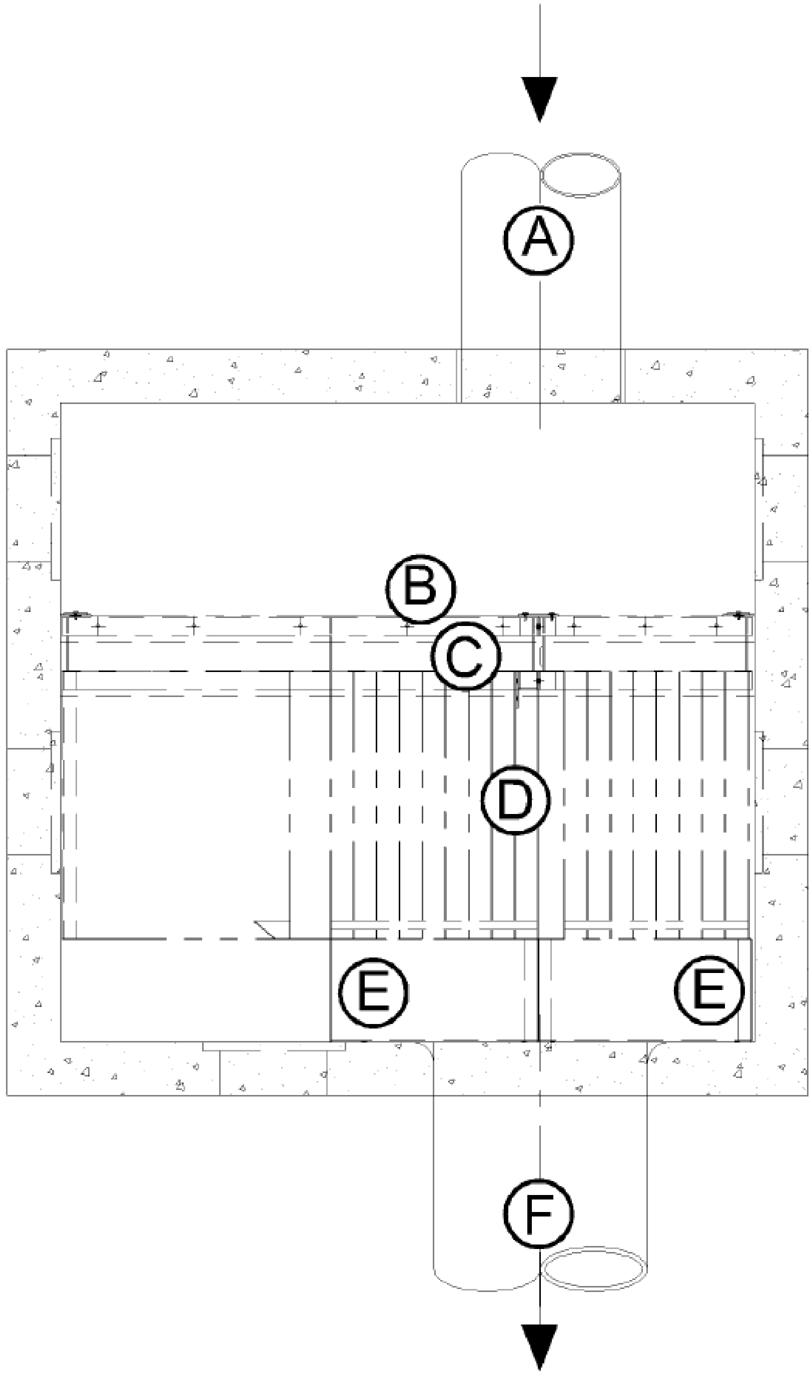


Figure 7. Pressure Tap Locations

5.2.3 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.

5.2.4 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 5.2.2.**

5.2.5. Analysis of Particle Size Distribution of Effluent Samples

One effluent sample was collected during each test for particle size distribution (PSD) analysis. Each sample was analyzed using the Beckman Multisizer3 coulter counter.

5.2.6 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 the plane surface loading is 115 ft^2. The area per cell is calculated as shown in **Figure 8.** The effective area is the product of the cell area and the number of cells.

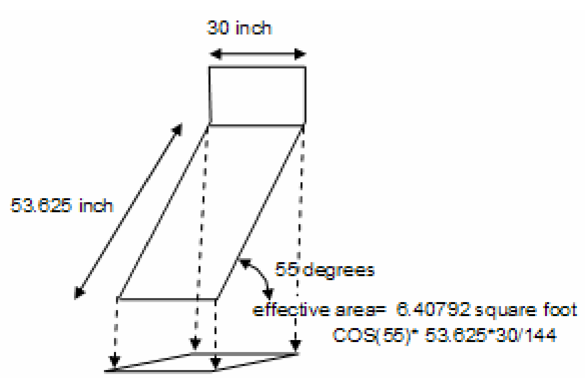


Figure 8. Horizontal Projection of Cell Area

5.2.7 Surface loading

Surface loading for Terre Kleen TK18 is the flow rate in gpm divided by the Effective Sedimentation Area of 115 ft^2.

5.3 Verification Procedures

All the data provided to NJCAT were reviewed to fully understand the capabilities of the Terre Kleen™. To verify Terre Hill's claim, the Alden laboratory procedures and data were reviewed and compared to the NJDEP TSS laboratory testing procedure.

5.3.1 Hydraulic Capacity

Flow (gpm) and water level (inches) within the unit were measured for 10 flows ranging from 0 to 7,362 gpm (16.4 cfs). The Internal Flow-Through Duct (IFTD) was activated at 4,326 gpm (9.6 cfs), at which point treatment flow is divided and distributed to both the inclined cells and the IFTD. The influent pipe was estimated to be flowing full at approximately 4,000 gpm (8.9 cfs). The Elevation Curves for each pressure tap location are shown in **Figure 9**.

The elevation curve at the influent pipe tap steadily increases through the open-channel flow regime. A hydraulic jump was present at the entrance to the unit; however, the position of the jump as it moved up the pipe was not documented during testing. The elevation recorded in the Primary Chamber (tap B) reflected the highest differential curve due to the impact of the influent flow on the downstream wall and subsequent welling-up of the water surface. The elevations at taps C, D, E were virtually identical, indicating minimal loss through the Lamella plates. The 3-inch rounding minimized the entrance loss at the outlet pipe, as indicated in the graph. Head loss through the Terre Kleen™ insert averaged 1" per 1018 gpm before activation of the IFTD and 1" per 280 gpm after passage through the IFTD was occurring.

5.3.2 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/ft^2.

As stated in **Section 5.2.2**, 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 (isokinetic samples) and the adjusted influent concentrations (auger) ranged from 3% (low flow) to approximately 40% (high flow), resulting in differences up to 55% in the removal efficiency for individual runs.

The average calculated removal efficiencies ranged from -38.5% to 45.5% for the TSS data, 26.6% to 71.6% for the isokinetic 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%.

The high flow rates required to conduct the TK18 testing resulted in increasing levels of background sediment concentrations in the closed-loop test system returning influent throughout a test run. As discussed in **Section 5.3.4** how to defensibly account for these background concentrations required considerable discussion.

Removal efficiencies calculated in these three different ways for the 100% sediment bed are shown in **Figures 10 and 11**. The testing data summary is shown in **Table 3**, which includes the NJCAT weighted efficiencies. It should be noted that the background concentrations were subtracted from the SSC data, but not the TSS data, shown in the table since it was measured as SSC. (Note: Inclusion of the background concentrations in the TSS data would have reduced the overall weighted efficiency from 16.9% to 12.8 %.)

The specifics of each test run including that for low flows are discussed in more detail in Appendix A.

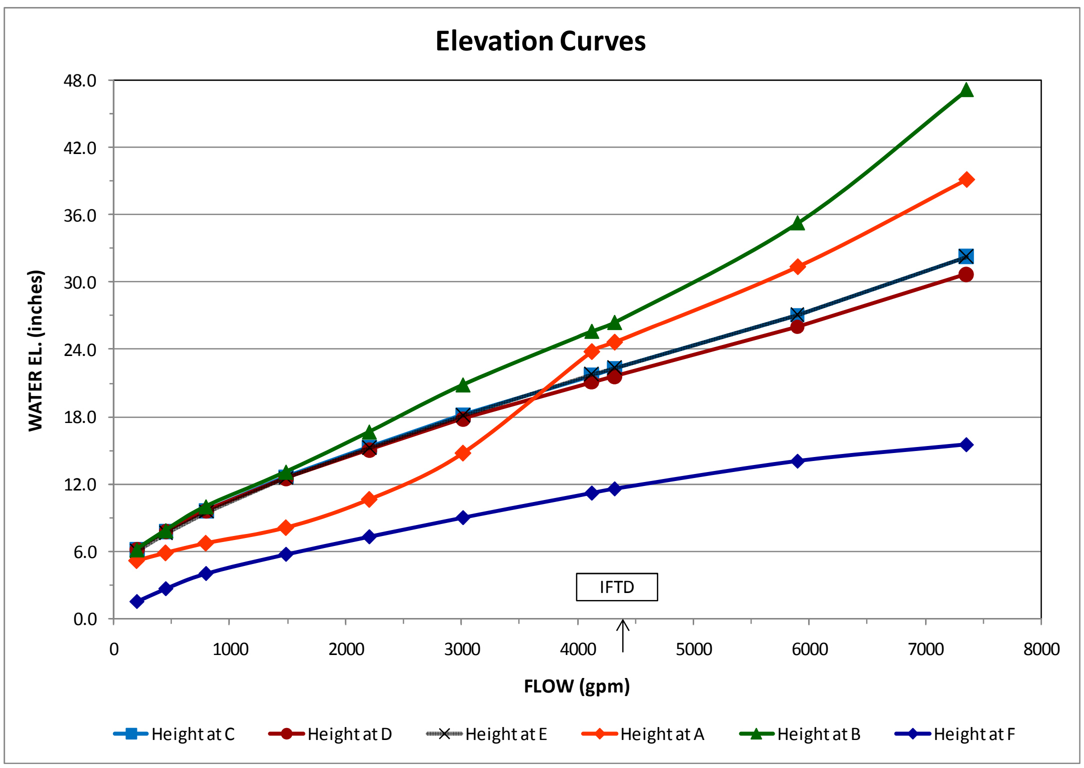


Figure 9. Elevation Curves, Relative to Invert of Effluent Pipe

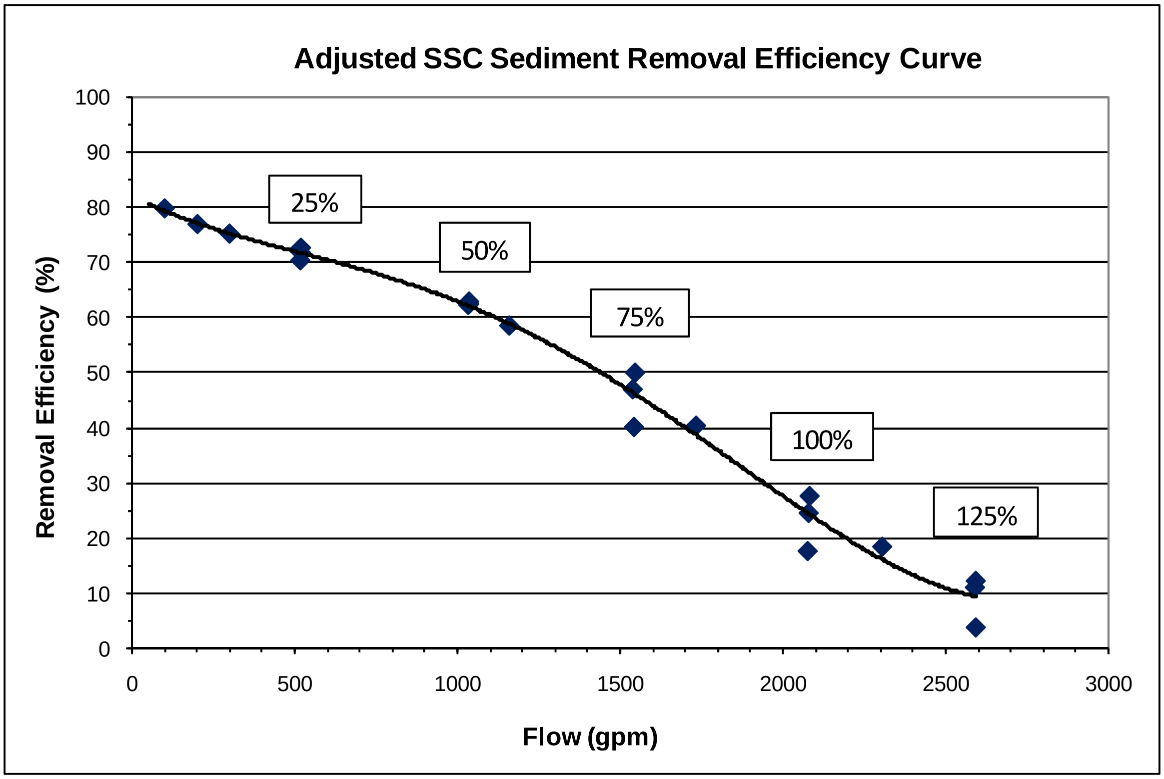


Figure 10. SSC Adjusted Sediment Removal Efficiency Curve

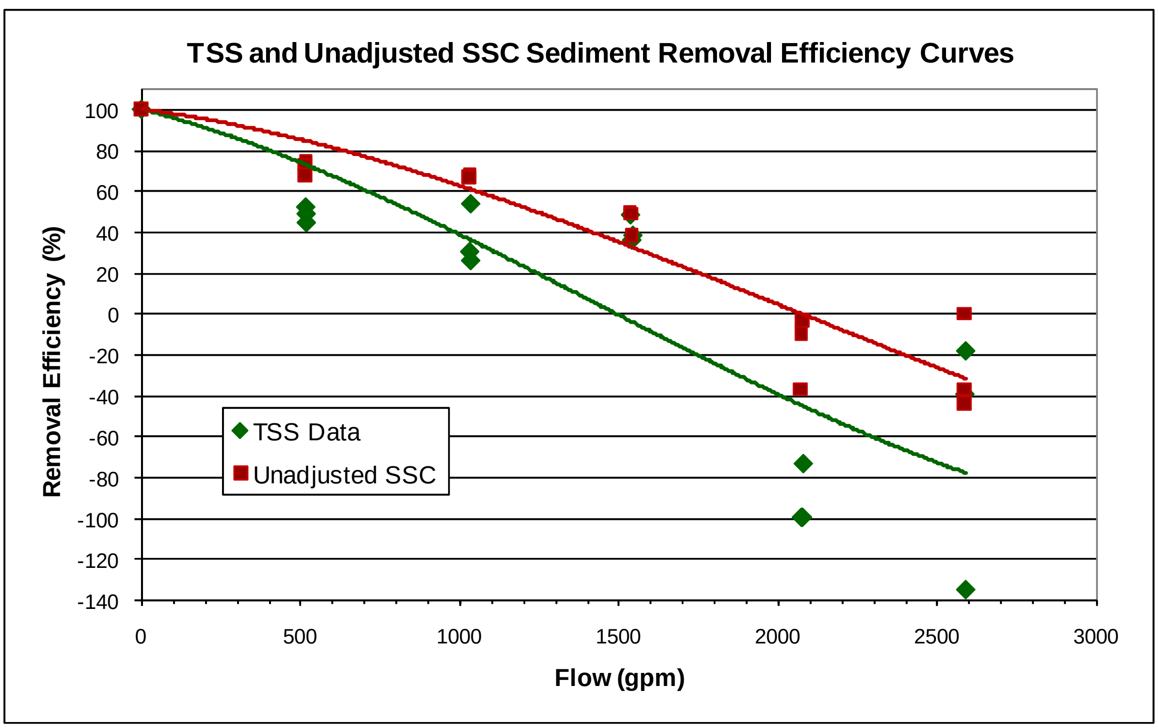


Figure 11. TSS and Unadjusted SSC Removal Efficiency Curves

Table 3. Sediment Removal Efficiency Testing Summary 100% Capacity Sediment Bed

			Sampling Data				Sampling Data with Influent Adjustment				TSS Data			
% Revised MHC	Flow gpm	Concentration mg/L	Influent mg/L	Effluent mg/L	Efficiency %	Avg. Efficiency %	Influent mg/L	Effluent mg/L	Efficiency %	Avg. Efficiency %	Influent mg/L	Effluent mg/L	Efficiency %	Avg. Efficiency %
Preliminary Tests	3446.3	200	279.5	188.6	32.5		201.4	188.6	6.4					
	2301.1	200	159.7	165.6	-3.7		203.4	165.6	18.6					
	1730.0	200	189.1	113.2	40.1		190.2	113.2	40.5					
	1156.9	200	148.1	79.8	46.1		192.7	79.8	58.6					
	298.8	200	163.8	50.0	69.5		202.0	50.0	75.3					
	200.5	200	161.2	46.7	71.0		203.0	46.7	77.0					
	99.9	200	151.3	40.9	73.0		202.9	40.9	79.8					
125.0	2587.9	300	256.9	256.2	0.3		292.4	256.2	12.4		166	194	-16.9	
124.9	2585.3	200	131.0	179.0	-36.6		201.6	179.0	11.2		103	136	-32.6	
125.0	2588.0	100	67.7	97.1	-43.5	-26.6	101.1	97.1	4.0	9.2	26	43	-65.9	-38.5
100.4	2078.2	300	207.1	213.7	-3.2		295.7	213.7	27.8		85	130	-53.7	
100.3	2075.4	200	135.0	147.8	-9.5		196.2	147.8	24.7		46	72	-56.0	
100.1	2072.3	100	58.3	79.7	-36.7	-16.4	96.9	79.7	17.8	23.4	33	49	-50.0	-53.2
74.5	1543.1	300	244.6	150.5	38.5		301.5	150.5	50.1		252	164	34.9	
74.2	1535.7	200	218.2	109.6	49.8		207.1	109.6	47.1		194	105	45.8	
74.4	1539.5	100	118.9	60.8	48.9	45.7	101.8	60.8	40.3	45.8	86	60	30.6	37.1
49.9	1033.9	300	342.1	111.1	67.5		296.4	111.1	62.5		236	121	48.9	
49.9	1033.7	200	225.2	75.9	66.3		204.9	75.9	63.0		148	114	23.2	
49.8	1030.8	100	110.5	37.0	66.5	66.8	98.4	37.0	62.4	62.6	85	62	27.2	33.1
25.0	517.9	300	319.7	82.6	74.2		302.8	82.6	72.7		220	129	41.5	
25.0	517.4	200	202.6	55.2	72.8		196.0	55.2	71.9		158	87	44.9	
24.9	516.1	100	89.8	28.8	67.9	71.6	97.4	28.8	70.4	71.7	96	48	50.1	45.5
	0			0.0	100.0			0.0	100				100.0	
						Weighted Eff. 41.9				**Weighted Eff. 50.3**				**Weighted Eff. 16.9**

5.3.3 Re-entrainment and Washout

Re-entrainment tests were performed at flows ranging from 0 to 2587 gpm, with the 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.

50% Loading

Observations of sediment transport (bed-load and suspended) were conducted in both the primary and secondary chambers. Bed-load 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 12 and 13**. (Note: Time in **Figure 12** is expressed in hours: minutes: seconds.)

The effluent PSD results show that the unit is able to capture the majority of particles over 50 microns, with approximate D10, D50 and D90 values of 4, 17 and 40 microns, respectively.

100% Loading

Observations similar to the 50% loading test were documented for the 100% test, where sediment transport (bed-load and suspended) were observed in both the primary and secondary chambers. Bed-load movement and scour were again observed in the primary chamber throughout the test. There was observed movement of the secondary sediment bed during the test which was not present in the 50% test. However, the ability of the secondary chamber to capture sediment particles was once again evident, as particles were continuously falling to the bed even at 125% flow. Measured sediment concentrations were still relatively low for all flow conditions, with quantities ranging from 0.28 to 43.6 mg/L. The first sample collected at each target flow typically 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 14 and 15**. (Note: Time in **Figure 14** is expressed in hours: minutes: seconds.)

The effluent PSD results show that the unit is able to capture the majority of particles over 50 microns, with D10, D50 and D90 values of approximately 5, 16 and 35 microns, respectively.

5.3.4 Exclusion of Background Concentrations from the Removal Efficiency Calculations

As indicated in **Section 5.2.2**, the "Adjusted Influent Concentrations" (derived from the sediment feed rate and the water flow rate) were used in calculating the SSC removal efficiency, that is, the background concentrations in the influent were not included in the calculations. To be consistent, the background concentrations were subtracted from the measured effluent concentrations in the calculations as well. The scientific justification for taking this approach is described in the next paragraph.

The background concentrations can be excluded from the removal efficiency calculations **only if** the particles entered from the background are so fine and/or light that they will not settle out in the treatment device. Alden Lab did not collect and process the background samples for PSD analysis to confirm this requirement. However, the background PSD was estimated by Alden using the operating flow rates, dimensions of the laboratory sump, and Cheng's (1997) established particle settling velocity equation. Water depth in the sump was 4 ft, width of the sump 10 ft and length of the sump 140 ft. The analysis indicated that at the low flow rate of 517 gpm, only particles smaller than 20 microns would have remained suspended in the laboratory sump and entered the treatment device. At the high flow rate of 2,070 gpm, only particles smaller than 40 microns particles would have remained suspended in the laboratory sump and entered the treatment device. Moreover, only a small fraction of the particles in the background would have the size approaching 20 microns and 40 microns, respectively, since the source of the particles to the sump was the effluent from the treatment device containing the very fine particles in the influent that were not removed in the TK18. The vast majority, if not all, of the particles in the background were sufficiently fine that they would have passed through the treatment device without settling. That is, the background concentrations can be reasonably excluded from the removal efficiency calculations.

NJCAT has reviewed the Alden analysis and agrees that not including the background concentration in either the influent or effluent concentrations for removal efficiency calculations is scientifically defensible as was done for the SSC data in **Table 3**.

5.3.5 Adjustment of Sediment Removal Efficiency to 50% Bed Loading

The results of measured sediment removal efficiencies **(Table 3)** are considered to be conservative, due to the fact that the unit was preloaded to 100% capacity. The respective average effluent concentration data from the 50% and 100% bed loading re-entrainment tests was used to estimate the differential in removal efficiency due to the higher sediment bed. It is estimated that a 50% bed would produce removal efficiencies ranging from 17.7% to 71.7%, with a weighted average of 57.8%. The adjusted efficiency data and fitted curve for the 50% bed are shown in **Figure 16** and the corresponding values are shown in **Table 4**. The adjusted removal efficiencies at the five tested flow rates were used in calculating the weighted removal efficiency, not the values from the fitted curve.

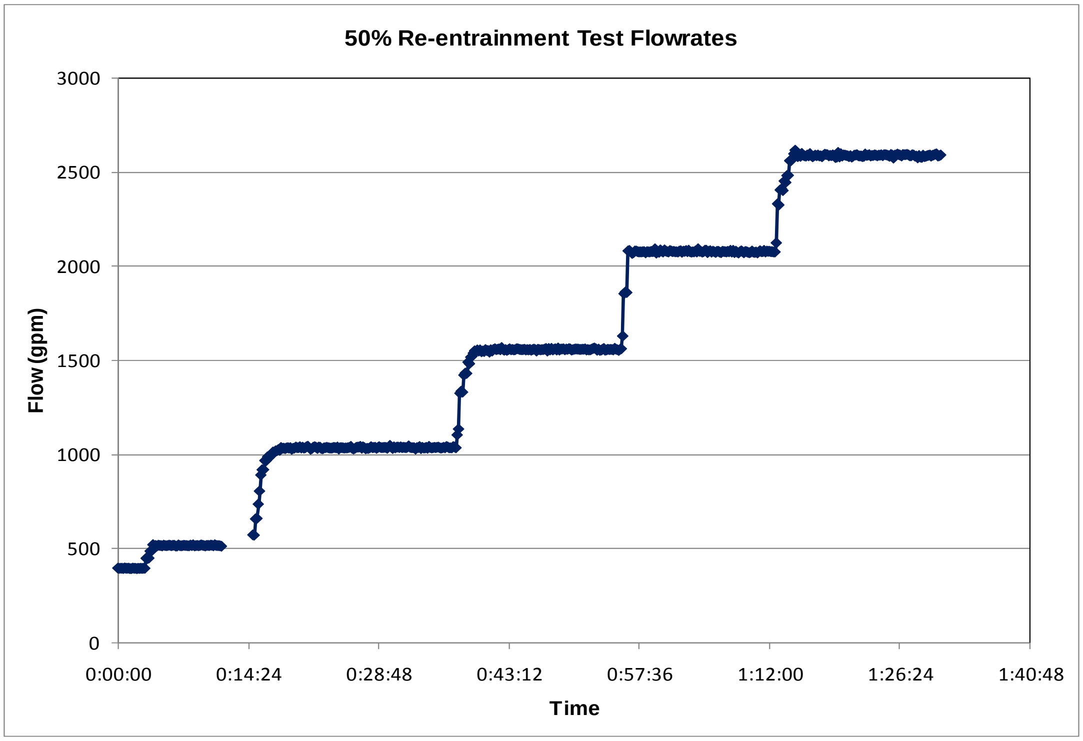


Figure 12. 50% Flow Trace Graph

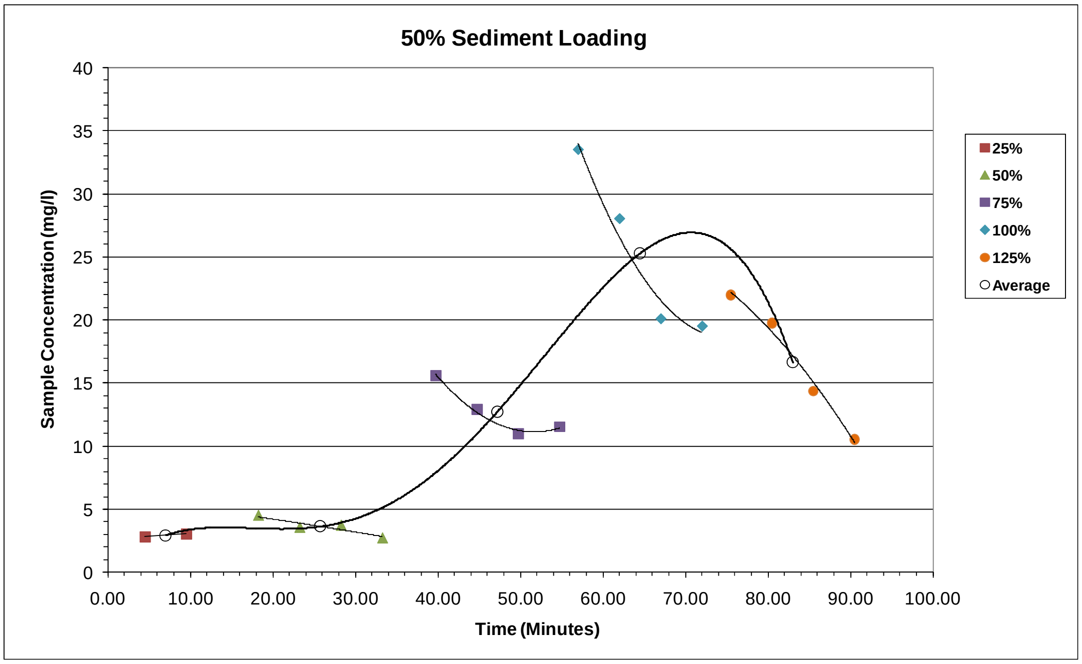


Figure 13. Re-entrainment Effluent Sample Concentrations

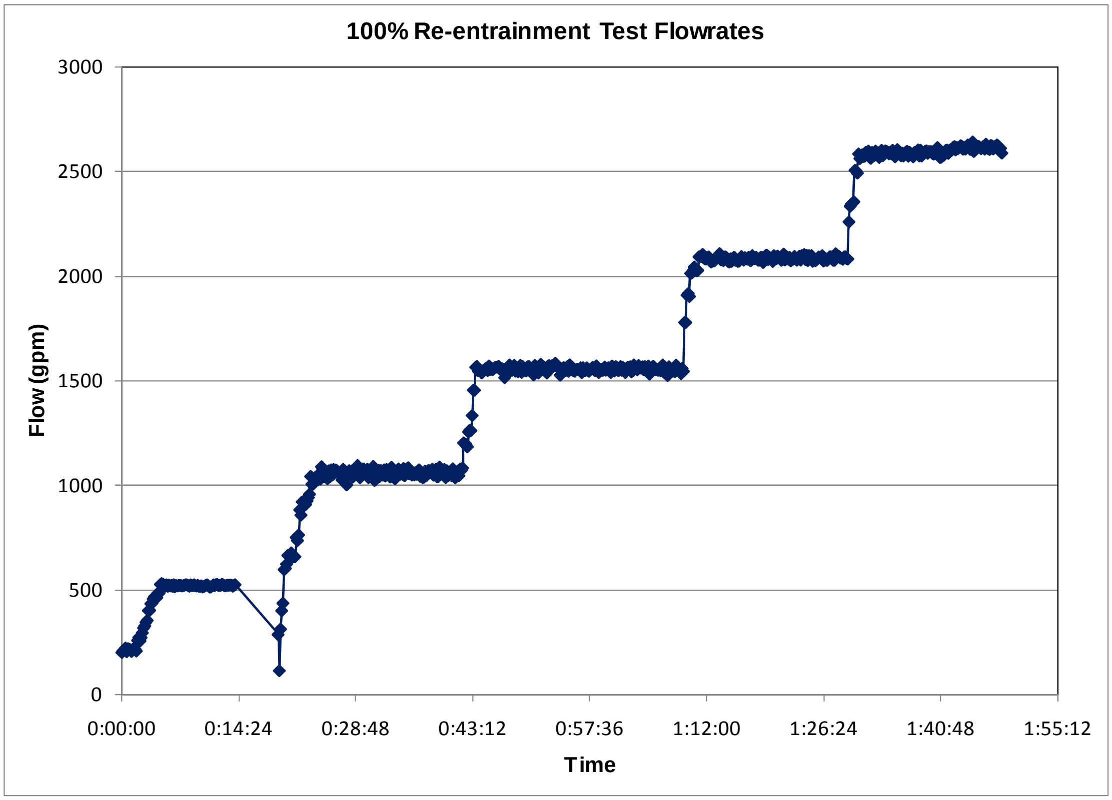


Figure 14. 100% Flow Trace Graph

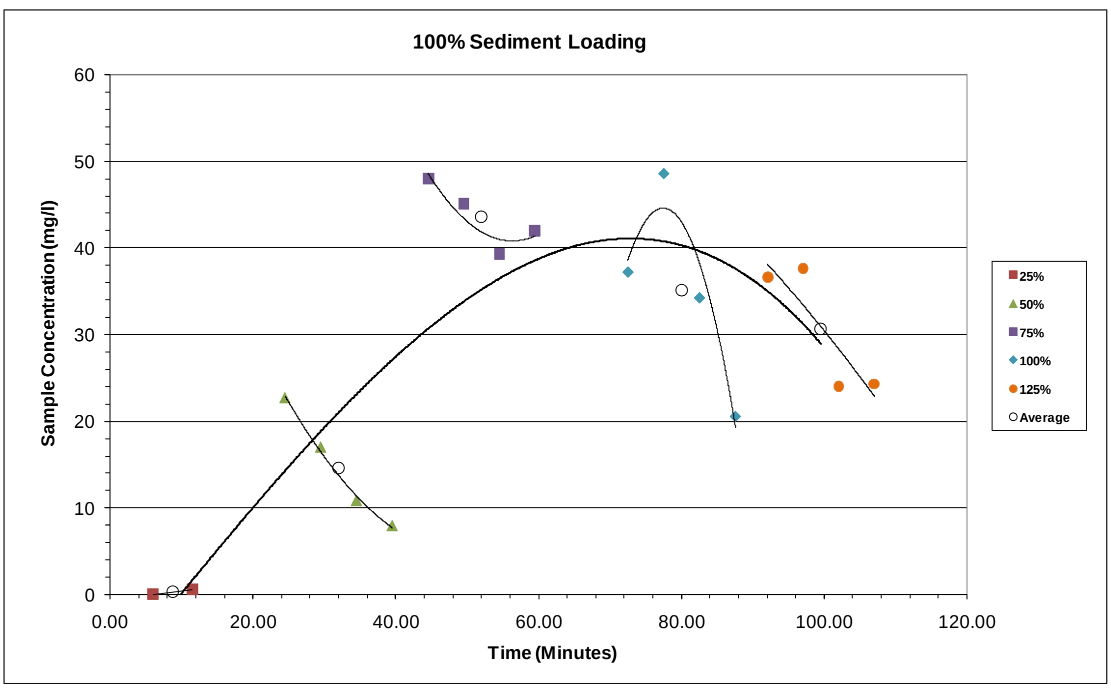


Figure 15. Re-entrainment Effluent Sample Concentrations

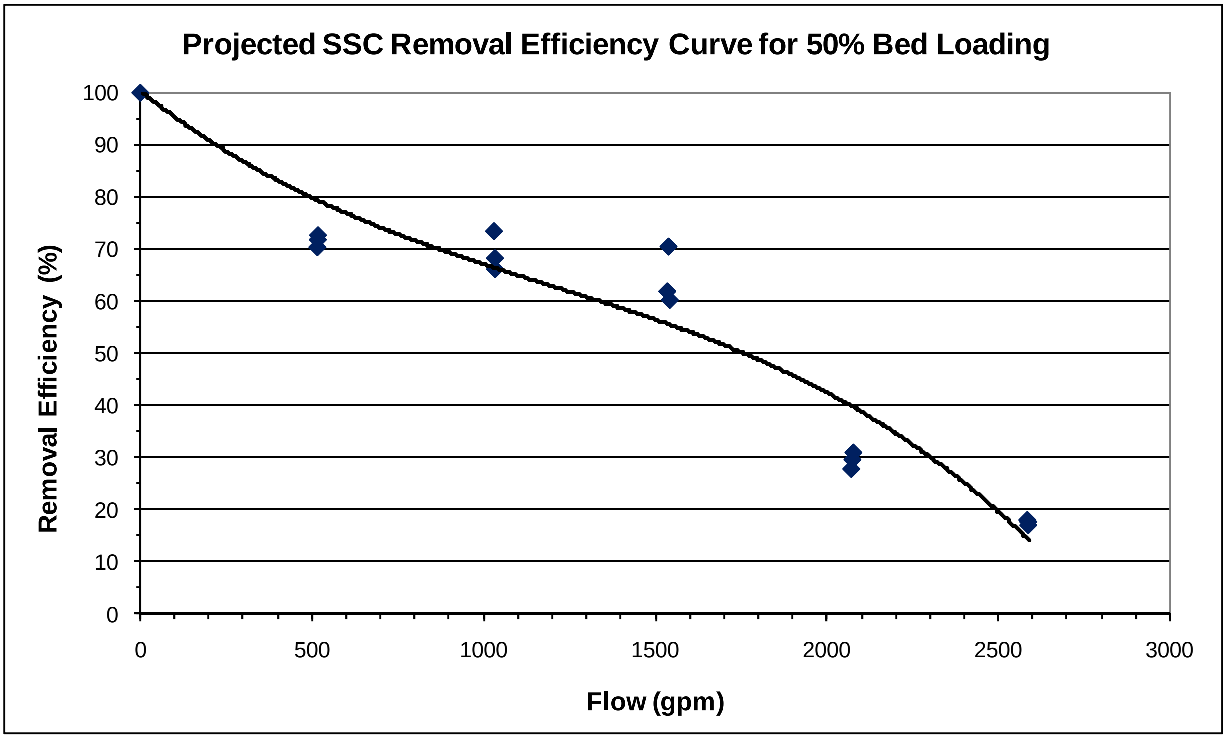


Figure 16. Adjusted Removal Efficiency Curve for a 50% Preloaded Sediment Bed

Table 4. Adjusted Sediment Removal Efficiency Data for a 50% Capacity Sediment Bed

Adjusted SSC data					
Flowrate (%)	Influent mg/L	Effluent mg/L	Effluent Adj. mg/L	Efficiency %	Avg. Efficiency %
125	292.4	256.2	242.2	17.2	
	201.6	179.0	165.0	18.2	
	101.1	97.1	83.1	17.8	17.7
100	295.7	213.7	203.8	31.1	
	196.2	147.8	137.9	29.7	
	96.9	79.7	69.8	28.0	29.6
75	301.5	150.5	119.7	60.3	
	207.1	109.6	78.8	62.0	
	101.8	60.8	30.0	70.5	64.3
50	296.4	111.1	100.2	66.2	
	204.9	75.9	64.9	68.3	
	98.4	37.0	26.1	73.5	69.3
25	302.8	82.6	-	72.7	
	196.0	55.2	-	71.9	
	97.4	28.8	-	70.4	71.7
					Weighted Eff.
					57.8

5.3.6 Size Scaling and Design Flow Rates

Model TK 18 of the Terre Kleen^{TM} was evaluated above for solids removal performance. The eighteen inclined sedimentation cells are identical. There is a need to scale the size up or down (i.e. add or remove cells) in order for other units to take a higher or lower treatment flow rate. The particle settling in the plate settlers is fundamentally based on the horizontally projected plate surface area. Therefore, the design flow rate can be expressed in terms of flow rate per unit area of the horizontally projected plate surface area. That is, the verified flow rate of 2070 gpm for the Terre Kleen^{TM} Model TK18 can be expressed as 18 gpm (0.040 cfs) per square foot of the horizontally projected plate surface area. Applying this verified treatment flow rate to other model sizes yields the treatment flow rates for other models **(Table 5)**.

Table 5. Terre Kleen™ Treatment Flow Rates

Terre Kleen™ Model	Number of sedimentation cells in the Grit-Chamber	Horizontally Projected Sedimentation Area (ft^2)	Design Flow Rate (cfs)
TK01	1	8	0.32
TK02	2	13	0.52
TK05	5	32	1.28
TK09	9	57	2.29
TK18	18	115	4.61
TK27	27	172	6.90
TK36	36	230	9.22
TK45	45	288	11.55
TK54	54	346	13.88
TK63	63	403	16.19
TK(X)	X	X*6.4079	X*0.257

5.4 Maintenance

Maintenance Trigger: When the captured sediment reaches a height of 8.25 inches cleanout of the Terre Kleen™ should take place. The measurement of the height of the captured sediment takes place from grade using any suitable measuring device.

Maintenance Method: All clean out of captured pollutants can be performed from grade, and no confined space entry is required. Physical access is obtained through manhole and/or inlet openings above the primary chamber and the grit chamber. Oil booms can be removed manually. Floating trash and debris may be removed from the primary chamber either by hand or vacuum truck hose. A vacuum truck is the most efficient method to clean out bottom sediment from a Terre Kleen™. This removal method is facilitated by the pressurization of the sludge dispersion manifold. This action causes the loosening and suspension of the capture sediment and directs it to the suction hose of the vacuum truck. Without the sludge dispersion manifold, the removal of captured sediment located under the stacked inclined plates would be difficult due to the limited suction range of the vacuum truck hose. Unless testing shows that the captured pollutants are hazardous, the removed pollutants can be land filled and the water taken to a waste water plant.

Maintenance Frequency: As each site is different, it is recommended that during the first year after installation, quarterly inspections are made to observe and document the accumulation of captured pollutants and to arrive at a maintenance frequency schedule. This estimated maintenance schedule is subject to modification depending upon precipitation event frequency and intensity, duration and volume and loading characteristics.

Physical Integrity: The Terre Kleen™ insert is made from marine grade aluminum (#5052) to resist corrosion from stormwater. It is assembled using stainless steel connection components to prevent adverse dissimilar materials degradation. In field inspection and monitoring there has not been any observed corrosion or other potential or actual impairment of the structural integrity of the Terre Kleen ™ insert. Each precast structure is HS 20 rated or designed for other user specified rating.

Field Monitoring Studies: Inspection, monitoring and documentation of installed Terre Kleen™ units is an ongoing activity of Terre Hill Stormwater Systems. Terre Hill Stormwater Systems is under contract with the Pennsylvania Turnpike Commission to inspect, monitor and document sediment accumulation and the condition of Terre Kleen™ units located at various turnpike facilities. Terre Hill Stormwater Systems is currently evaluating suitable sites for commencement of field testing under the NJDEP TARP TIER II field test protocol.

6. TECHNICAL EVALUATION ANALYSES

6.1 Verification of Performance Claim

Based on the evaluation of the results from laboratory studies, sufficient data are available to support the Terre Hill Claim.

Claim: The Terre Kleen™, Model TK18, at a flow rate of 2070 gpm (4.61 ft^3/s, 18 gpm/ft^2 of horizontally projected sedimentation area), has been shown to have a 57.8% removal efficiency, measured as suspended sediment concentration (SSC) (as per the NJDEP methodology for calculation of treatment efficiency), for a sediment mix with an average d_{50} particle size of 70 microns, an average influent concentration of 200 mg/L and 50% (8.25 inches or 15.6 ft^3) initial sediment loading in laboratory studies using simulated stormwater.

6.2 Limitations

6.2.1 Factors Causing Under-Performance

The design and materials used to manufacture the Terre Kleen™ insert and the precast concrete structure minimize the possibility of structural failure, wear or corrosion to negligible proportions. The lack of moving parts minimizes the possibility of malfunction due to breakage or binding.

Failure to adhere to recommended maintenance schedules and procedures will cause reduced operational efficiency. This failure will also result in pollutants becoming an obstruction of the stormwater flow.

6.2.2 Pollutant Transformation and Release

The Terre Kleen™ will not increase the net pollutant load to the downstream environment. However, pollutants may be transformed within the unit. For example, organic matter may decompose and release nitrogen in the form of nitrogen gas or nitrate. These processes are similar to those in wetlands but probably occur at slower rates in the Terre Kleen™ due to the absence of light and mixing by wind, thermal inputs and biological activity. Accumulated sediment should not be lost from the system at or under the design flow rate.

6.2.3 Sensitivity to Heavy Sediment Loading

Heavy loads of sediment will increase the needed maintenance frequency.

6.2.4 Mosquitoes

The Terre Kleen™ contains standing water in both chambers. If both chambers are covered with manhole covers no surface area of the standing water is directly exposed to air and, thus, in this configuration there is no breeding ground for mosquitoes.

In those installations where the primary chamber also serves as an inlet, the standing water in the primary chamber is exposed to air and, thus, may be a breeding ground for mosquitoes. In most sites, the stormwater will contain certain amounts of TPH and grease, and water will not warm up as easily as under direct sunlight. These substances and conditions are not conducive to mosquito breeding.

7. NET ENVIRONMENTAL BENEFIT

Once the Terre Kleen™ has been verified and granted interim approval use within the State of New Jersey, Terre Hill will then proceed to install and monitor systems in the field for the purpose of achieving goals set by the Tier II Protocol and final certification. At that time a net environmental benefit evaluation will be completed. However, it should be noted that the Terre Kleen™ technology requires no input of raw material, has no moving parts, and therefore, uses no water or energy.

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Appendix A. Detailed Results of Sediment Removal Efficiency Tests

Sediment Removal Efficiencies at 125% (2587 gpm, 5.76 cfs, 22.5 gpm/sf)

300 mg/L

The average flow recorded for the entire test was 2587.9 gpm (5.77 cfs), with a standard deviation (SD) of 5.68. The recorded temperature for the test was 70.2 degrees F. The measured influent sample concentrations ranged from 232.7 mg/L to 317.1 mg/L, with a mean concentration of 256.9 mg/L and SD of 29.1. The effluent concentrations ranged from 233.3 mg/L to 272.2 mg/L, with a mean concentration of 256.2 mg/L and SD of 13.8. The background concentrations ranged from 5.7 mg/L to 113.2 mg/L. The resulting sediment removal efficiency for the SSC method was 0.3%. The adjusted influent concentrations ranged from 287.1 mg/L to 297.2 mg/L, with a mean concentration of 292.4 mg/L and SD of 5.62. The corresponding adjusted removal efficiency was 12.4%. The measured influent TSS concentrations ranged from 150 mg/L to 190 mg/L, with a mean concentration of 166 mg/L and SD of 15.2. The effluent concentrations ranged from 150 mg/L to 250 mg/L, with a mean concentration of 194 mg/L and SD of 40.4. The resulting sediment removal efficiency for the TSS method was -16.9%.

The following are the approximated PSD values calculated from the laser particle count data:
(d_{90} – 24.3µm), (d_{75} – 16.2µm), (d_{50} – 9.0µm), (d_{25}-4.5µm).

200 mg/L

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%.

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).

100 mg/L

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 mean concentration of 101.1 mg/L and SD of 3.06. The corresponding adjusted removal efficiency was 4.0%. The measured influent TSS concentrations ranged from 17 mg/L to 43 mg/L, with a mean concentration of 25.8 mg/L and SD of 10.4. The effluent concentrations ranged from 37 mg/L to 53 mg/L, with a mean concentration of 42.8 mg/L and SD of 6.2. The resulting sediment removal efficiency for the TSS method was -65.9%.

The following are the approximated PSD values calculated from the laser particle count data:
(d_{90} – 25.9µm), (d_{75} – 17.3µm), (d_{50} –8.8µm), (d_{25}-3.9µm).

Sediment Removal Efficiencies at 100% (2070 gpm, 4.61 cfs, 18 gpm/sf)

<u>300 mg/L</u>

The average flow recorded for the entire test was 2078.2 gpm (4.63 cfs), with a standard deviation (SD) of 5.00. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 192.7 mg/L to 234.8 mg/L, with a mean concentration of 207.1 mg/L and SD of 14.8. The effluent concentrations ranged from 202.1 mg/L to 222.5 mg/L, with a mean concentration of 213.7 mg/L and SD of 7.0. The background concentrations ranged from 13.5 mg/L to 110.6 mg/L. The resulting sediment removal efficiency for the SSC method was -3.2%. The adjusted influent concentrations ranged from 288.0 mg/L to 307.1 mg/L, with a mean concentration of 295.7 mg/L and SD of 7.69. The corresponding adjusted removal efficiency was 27.8%. The measured influent TSS concentrations ranged from 56 mg/L to 120 mg/L, with a mean concentration of 84.6 mg/L and SD of 22.9. The effluent concentrations ranged from 110 mg/L to 160 mg/L, with a mean concentration of 130 mg/L and SD of 21.1. The resulting sediment removal efficiency for the TSS method was -53.7%.

The following are the approximated PSD values calculated from the laser particle count data:
(d_{90} – 25.5µm), (d_{75} – 15.7µm), (d_{50} –7.5µm), (d_{25}-3.5µm).

<u>200 mg/L</u>

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%.

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).

<u>100 mg/L</u>

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 sediment removal efficiency for the TSS method was -50.0%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 28.2μm), (d_{75} – 20.4μm), (d_{50} –11.9μm), (d_{25}-5.6μm).

Sediment Removal Efficiencies at 75% (1552 gpm, 3.46 cfs, 13.5 gpm/sf)

<u>300 mg/L</u>

The average flow recorded for the entire test was 1543.1 gpm (3.44 cfs), with a standard deviation (SD) of 11.4. The recorded temperature for the test was 70.2 degrees F. The measured influent sample concentrations ranged from 202.1 mg/L to 315.0 mg/L, with a mean concentration of 244.6 mg/L and SD of 40.5. The effluent concentrations ranged from 146.5 mg/L to 155.8 mg/L, with a mean concentration of 150.5 mg/L and SD of 3.33. The background concentrations ranged from 6.9 mg/L to 74.0 mg/L. The resulting sediment removal efficiency for the SSC method was 38.5%. The adjusted influent concentrations ranged from 295.3 mg/L to 307.4 mg/L, with a mean concentration of 301.5 mg/L and SD of 4.44. The corresponding adjusted removal efficiency was 50.1%. The measured influent TSS concentrations ranged from 200 mg/L to 280 mg/L, with a mean concentration of 252 mg/L and SD of 30.3. The effluent concentrations ranged from 130 mg/L to 200 mg/L, with a mean concentration of 164 mg/L and SD of 27.0. The resulting sediment removal efficiency for the TSS method was 34.9%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 25.7μm), (d_{75} – 17.2μm), (d_{50} –9.6μm), (d_{25}-4.7μm).

200 mg/L

The average flow recorded for the entire test was 1535.8 gpm (3.42 cfs), with a standard deviation (SD) of 12.8. The recorded temperature for the test was 70.0 degrees F. The measured influent sample concentrations ranged from 144.6 mg/L to 282.9 mg/L, with a mean concentration of 218.2 mg/L and SD of 48.0. The effluent concentrations ranged from 100.3 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%.

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).

100 mg/L

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%.

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).

Sediment Removal Efficiencies at 50% (1035 gpm, 2.31 cfs, 9 gpm/sf)

300 mg/L

The average flow recorded for the entire test was 1033.9 gpm (2.30 cfs), with a standard deviation (SD) of 2.58. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 281.8 mg/L to 438.5 mg/L, with a mean concentration of 342.1 mg/L and SD of 51.9. The effluent concentrations ranged from 102.6 mg/L to 117.1 mg/L, with a mean concentration of 111.1 mg/L and SD of 5.68. The background concentrations ranged from 6.3 mg/L to 63.8 mg/L. The resulting sediment removal efficiency for the SSC method was 67.5%. The adjusted influent concentrations ranged from 275.1 mg/L to 311.8 mg/L, with a mean concentration of 296.4 mg/L and SD of 14.7. The corresponding adjusted removal efficiency was 62.5%. The measured influent TSS concentrations ranged from 170 mg/L to 380 mg/L, with a mean concentration of 236 mg/L and SD of 84.4. The effluent concentrations ranged from 90 mg/L to 170 mg/L, with a mean concentration of 120.6 mg/L and SD of 32.5. The resulting sediment removal efficiency for the TSS method was 48.9%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 27.3µm), (d_{75} – 18.9µm), (d_{50} –10.4µm), (d_{25}-4.8µm).

<u>200 mg/L</u>

The average flow recorded for the entire test was 1033.7 gpm (2.30 cfs), with a standard deviation (SD) of 4.41. The recorded temperature for the test was 70.1 degrees F. The measured influent sample concentrations ranged from 191.4 mg/L to 244.1 mg/L, with a mean concentration of 225.2 mg/L and SD of 19.9. The effluent concentrations ranged from 73.4 mg/L to 77.8 mg/L, with a mean concentration of 75.9 mg/L and SD of 1.71. The background concentrations ranged from 1.7 mg/L to 44.1 mg/L. The resulting sediment removal efficiency for the SSC method was 66.3%. The adjusted influent concentrations ranged from 202.2 mg/L to 207.2 mg/L, with a mean concentration of 204.9 mg/L and SD of 2.29. The corresponding adjusted removal efficiency was 63.0%. The measured influent TSS concentrations ranged from 100 mg/L to 190 mg/L, with a 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%.

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).

<u>100 mg/L</u>

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%.

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).

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 319.7 mg/L and SD of 15.6. The effluent concentrations ranged from 75.8 mg/L to 86.1 mg/L, with a mean concentration of 82.6 mg/L and SD of 3.70. The background concentrations ranged from 1.6 mg/L to 46.8 mg/L. The resulting sediment removal efficiency for the SSC method was 74.2%. The adjusted influent concentrations ranged from 296.2 mg/L to 311.8 mg/L, with a mean concentration of 302.8 mg/L and SD of 6.81. The corresponding adjusted removal efficiency was 72.7%. The measured influent TSS concentrations ranged from 200 mg/L to 240 mg/L, with a mean concentration of 220 mg/L and SD of 15.8. The effluent concentrations ranged from 94 mg/L to 200 mg/L, with a mean concentration of 128.8 mg/L and SD of 41.8. The resulting sediment removal efficiency for the TSS method was 41.5%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 26.1µm), (d_{75} – 18.1µm), (d_{50} –9.9µm), (d_{25}-4.7µm).

200 mg/L

The average flow recorded for the entire test was 517.4 gpm (1.15 cfs), with a standard deviation (SD) of 3.43. The recorded temperature for the test was 70.3 degrees F. The measured influent sample concentrations ranged from 186.6 mg/L to 235.0 mg/L, with a mean concentration of 202.6 mg/L and SD of 17.4. The effluent concentrations ranged from 52.6 mg/L to 57.8 mg/L, with a mean concentration of 55.2 mg/L and SD of 1.69. The background concentrations ranged from 2.3 mg/L to 35.4 mg/L. The resulting sediment removal efficiency for the SSC method was 72.8%. The adjusted influent concentrations ranged from 178.1 mg/L to 208.2 mg/L, with a mean concentration of 196.0 mg/L and SD of 10.7. The corresponding adjusted removal efficiency was 71.9%. The measured influent TSS concentrations ranged from 120 mg/L to 180 mg/L, with a mean concentration of 158 mg/L and SD of 23.9. The effluent concentrations ranged from 61 mg/L to 110 mg/L, with a mean concentration of 87 mg/L and SD of 22.8. The resulting sediment removal efficiency for the TSS method was 44.9%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} – 24.1µm), (d_{75} – 16.5µm), (d_{50} –8.9µm), (d_{25}-4.2µm).

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%.

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).

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.

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

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 69.5%. The adjusted influent concentrations ranged from 191 mg/L to 215 mg/L, with a mean concentration of 202.0 mg/L and SD of 8.51. The corresponding adjusted removal efficiency was 75.3%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} –27.1μm), (d_{75} –16.5μm), (d_{50} –8.6μm), (d_{25}-4.5μm).

<u>Sediment Removal Efficiency at 200 gpm, 0.45 cfs, 1.8 gpm/sf</u>

The average flow recorded for the entire test was 200.5 gpm (0.45 cfs), with a standard deviation (SD) of 0.44. The recorded temperature for the test was 76.1 degrees F. The measured influent sample concentrations ranged from 143.7 mg/L to 170.2 mg/L, with a mean concentration of 161.2 mg/L and SD of 9.05. The effluent concentrations ranged from 44.2 mg/L to 49.3 mg/L, with a mean concentration of 46.7 mg/L and SD of 2.02. The background concentrations ranged from 0.6 mg/L to 16.9 mg/L. The resulting sediment removal efficiency for the SSC method was 71.0%. The adjusted influent concentrations ranged from 196 mg/L to 225 mg/L, with a mean concentration of 203.0 mg/L and SD of 10.8. The corresponding adjusted removal efficiency was 77.0%.

The following are the approximated PSD values calculated from the laser particle count data: (d_{90} –23.4μm), (d_{75} –15.4μm), (d_{50} –8.3μm), (d_{25}-4.3μm).

Sediment Removal Efficiency at 100 gpm, 022. cfs, 0.9 gpm/sf

The average flow recorded for the entire test was 99.9 gpm (0.22 cfs), with a standard deviation (SD) of 0.22. The recorded temperature for the test was 77.8 degrees F. The measured influent sample concentrations ranged from 134.1 mg/L to 192.6 mg/L, with a mean concentration of 151.3 mg/L and SD of 24.2. The effluent concentrations ranged from 37.3 mg/L to 47.8 mg/L, with a mean concentration of 40.9 mg/L and SD of 4.08. The background concentrations ranged from 0 mg/L to 8.4 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%.

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).

NJCAT TECHNOLOGY VERIFICATION ADDENDUM REPORT

Terre Kleen™ TK18 Separator

Terre Hill Stormwater Systems

April 2011

1. Introduction

NJCAT published a Technology Verification Report on the Terre Kleen™ Hydrodynamic Separator manufactured by Terre Hill Stormwater Systems Corporation (Terre Hill) in January 2010. Terre Hill contracted with Alden Research Laboratory, Inc (Alden), 30 Shrewsbury Street, Holden, MA 01520 in October 2010 to test the Terre Kleen™ TK18 Hydrodynamic Separator for online applications in New Jersey. This test evaluated sediment retention performance for the TK18 hydrodynamic separator in laboratory testing in accordance with the specific requirements in Section F of the *Protocol for Manufactured Hydrodynamic Sedimentation Devices for Total Suspended Solids Based on Laboratory Analysis, Dated August 5, 2009*, published by the New Jersey Department of Environmental Protection last revised December 15, 2009.

2. Technical Performance Claim

Claim – The TK18 tested at 200% of the Maximum Treatment Flow Rate (MTFR), and with the sump loaded with the NJDEP scour testing particle size distribution sediment to 50% (8.25 in) of the maximum recommended maintenance sediment depth, had effluent TSS concentrations below the reporting detection limit (5 mg/l).

3. Technical System Performance

3.1 Laboratory Testing

The TK18 Hydrodynamic Separator was tested at the Alden laboratory/test facility. The TK18 is a 6-ft x 6.5 ft rectangular separating device consisting of an 18-inch diameter influent pipe discharging into a 6.5-ft long x 2-ft wide primary gravel chamber, a secondary settling/grit chamber, an internal flow-through duct, eighteen (18) inclined Lamella plates, an overflow weir and an outlet shelf chamber. The 18-inch influent pipe has an invert located 75 inches above the wetted floor. The outlet pipe is 24 inches in diameter, with an invert of approximately 72.5 inches, and contains a 3-inch rounding at the entrance. The inlet and outlet pipes are oriented with 3% slopes and the centerlines of both pipes are located 2 feet from the left wall (looking downstream). The test unit supplied by Terre Hill included five (5) 12-inch viewing windows, located approximately 30 inches above the floor, to facilitate observations and documentation of sediment movement. Figure 2 (page 12) shows a layout drawing of the TK18 test unit and Figure 3 (page 13) shows a photograph of the unit installed in Alden's test facility.

Figure 4 (page 14) shows the closed test loop which was used to test the TK18 hydrodynamic separator. Water was supplied to the unit with the use of a 20HP and a 50HP pump (combined flow capacity of approximately 10 cfs) which draw water from a 50,000-gallon laboratory sump. A calibrated 6-in orifice and a calibrated 12-in x 8-in venturi flow meter measured the flow from the 20HP and 50HP pumps respectively. The flows were connected to a 16-in diameter manifold that carried the test flow to a section of 16-in diameter piping, a 90-degree elbow and 15-ft of 18-in influent pipe. Water then passed through the test unit and a 24-in diameter effluent pipe to return to the laboratory sump. To collect the effluent sediment concentration samples an isokinetic sampling-tube array was located within the 24-in effluent piping approximately 3-ft downstream of the test unit. The array consisted of three (3) vertically adjustable sampling tubes, each containing a flow-control shut-off valve (See Figure 5 page 16).

Flow

The inflow to the test unit was measured using the calibrated 6-in orifice and 12-in x 8-in venturi flow meter in unison. The flows were recorded separately and added together to determine the total flow. Each meter was fabricated per ASME guidelines and calibrated in Alden's Calibration Department prior to the start of testing. Flows were set with butterfly valves and the differential head from each meter was measured using a Rosemount® 0 to 250-inch Differential Pressure cell, also calibrated at Alden prior to testing. The test flows were averaged and recorded approximately every 6 seconds throughout the duration of the test using a computerized data acquisition program. The accuracy of the flow measurement is estimated at ±2%.

Sample Collection

As described above, isokinetic sampling tubes were located within the effluent piping to collect the effluent sediment concentration samples. The tubes ranged from 0.50 to 1.0 inches in diameter depending on the location within the pipe. Each tube was vertically adjusted and calibrated prior to testing to match the velocities at the test flow.

Sample Concentration Analyses

Sample concentrations can be analyzed using one of two analytical methods: Suspended Sediment 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.

Suspended Sediment Analysis (SSC) Analysis

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. Additional information on sample preparation and analysis is described on page 16.

3.2 Particle Size Distribution (PSD)

In order to satisfy the particle size distribution set forth by the NJDEP testing protocol, Alden developed a sediment mix composed of NJ#00N and F110 silica sand available from US Silica. Table 1 shows the theoretical PSD of each grade of sand, as well as the mix ratios and resulting percentages. Table 2 shows the PSD required by NJDEP, as well as the PSD provided by the US Silica sand mix and the actual PSD as determined by conducting a sieve analysis on the test mix. A graphical presentation of the data is shown on Figure 1.

Table 1 Test Sediment Mix using Commercially Available US Silica Sand

Range	Target NJCAT	Mesh	Microns	NJ # 00N 20%	F-110 80%	%	%	Total 100.0%
500-1000	**10%**	30	600	45		9.0		**9.0**
250-500	**10%**	40	425	52		10.4		
		50	300	3		0.6		**11.0**
100-250	**55%**	70	212		4		3.2	
		100	150		18		14.4	
		120	125					
		140	106		44		35.2	**52.8**
50-100	**25%**	170	88					
		200	75		25		20.0	
		270	53		8		6.4	**26.4**
< 50					1		0.8	**0.8**
		Total		100	100			**100**

Table 2 Test Sediment Particle Size Distribution (PSD)

Range microns	NJDEP Target %	NJDEP Microns	NJDEP % Finer	US Silica Sieve	US Silica Microns	US Silica % Finer	Alden Sieve Sieve	Alden Sieve Microns	Alden Sieve % Finer
<50	0%	50	0%	1%	50	1%	1%	50	1%
50-100	25%	100	25%	26%	100	27%	22%	100	23%
100-250	55%	250	80%	53%	250	80%	56%	250	78%
250-500	10%	500	90%	11%	500	91%	5%	500	84%
500-1000	10%	1000	100%	9%	1000	100%	16%	1000	100%

3.3 Scour Test Procedures

The TK18 unit was tested in accordance with "Section F" of the 2009 NJCAT/NJDEP testing protocol for Manufactured Hydrodynamic Sedimentation Devices. The protocol requires that the average TSS concentration of all effluent samples be no more than 10 mg/L higher than the background TSS concentration of the clear water influent for approval for MTD online installation. In accordance with the protocol, these tests were conducted with initial sediment loading corresponding to 50% of the unit's capture capacity (8.25-in as stated by Terre Hill). Additionally, the test matrix was expanded to include Suspended Sediment Concentration (SSC) analysis.

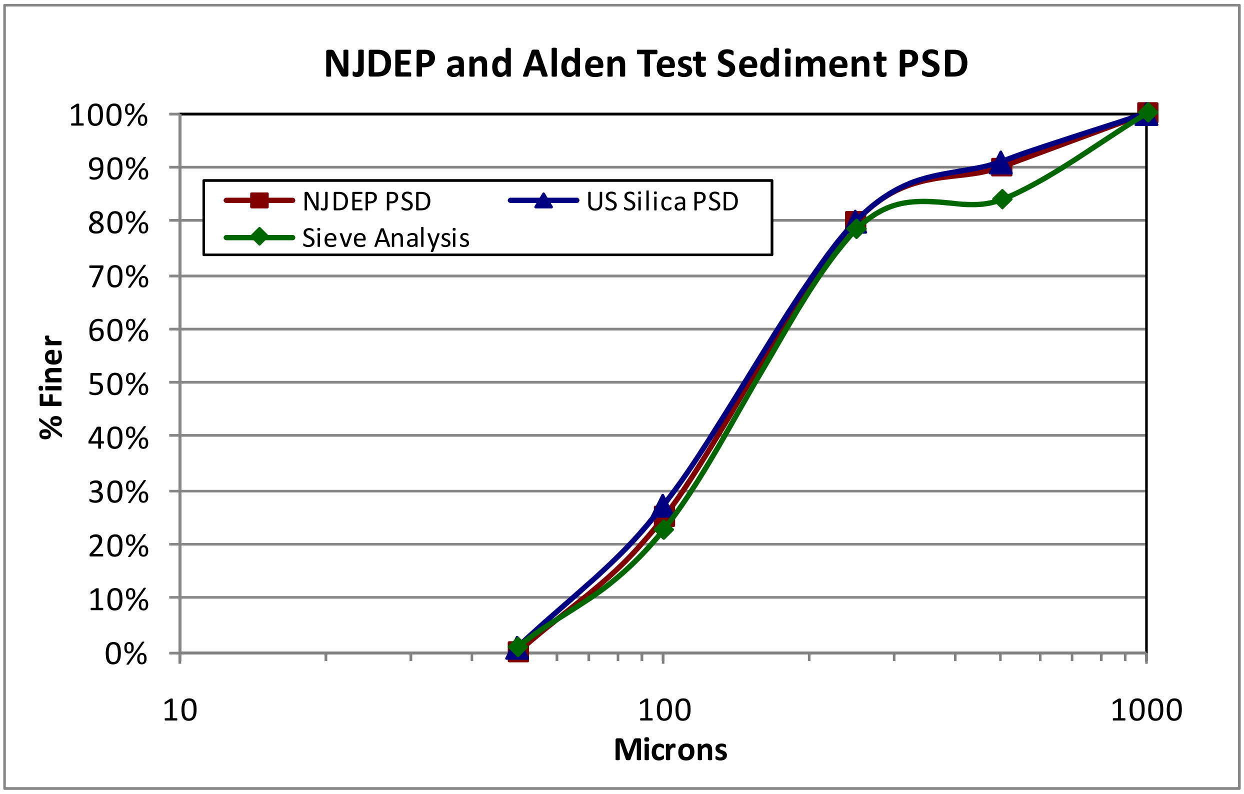

Figure 1 Test Sediment Mix PSD

Testing of the TK18 was conducted in two phases: Phase 1 testing measured the retention of particles in the sediment bed at 200% Maximum Treatment Flow Rate (MTFR); Phase 2 testing was conducted to verify the <10 mg/L net TSS effluent concentration at 200% MTFR.

Phase 1

The sedimentation chamber was pre-loaded with the test sediment to a level corresponding to 50% (15.6 ft^3, 8.25-in) of the unit's capture capacity as stated by Terre Hill. (Note: With the unit empty two (2) perimeter level lines were drawn in the collection sump. The upper level line was at 8.25-in (50%) and the lower level line at 7.43-in (~10% lower sediment level.). The unit was slowly filled to the invert of the effluent pipe and the system remained idle for a minimum of 2 hours prior to testing.

Testing was conducted by introducing a flow of clean water (no sediment) into the unit at a rate equal to 200% (9.22 cfs) of the MTFR for a period of 15 minutes, under steady-state conditions, while continuously obtaining flow data. After completion of the test run, the unit was drained and the sediment bed leveled and measured to determine the net sediment loss. If the sediment loss was less than 10% of the pre-loaded sediment, the testing proceeded to Phase 2.

Phase 2

After successful completion of Phase 1 testing, the unit was filled with clean water and a steady-state flow of 200% (9.22 cfs) of the MTFR was run through the unit for a period of 30 minutes, during which time background and effluent samples were collected at 5-minute intervals. Two samples were collected at each interval and location for SSC and TSS SM 2540D analysis.

3.4 Verification Procedures

Phase 1

The unit was preloaded with the 50-1000 micron PSD sediment to a volume equal to 50% of the chamber capacity (8.25-in). The unit was operated for the protocol required 15 minutes at a target steady state flow of 9.22 cfs (4138 gpm). The average flow recorded through the test duration was 4,096 gpm (-1%), with a Standard Deviation (SD) of 14.5 and Coefficient of Variance (COV) of 0.004. The unit was drained at the completion of the testing to about 3-in above the sediment bed and the sediment was moved away from the corners of the chamber and the water was decanted to a level just at the bed surface. The bed was then smoothed out and the distance from the bed surface to the 8.25-in line was measured with an engineer's rule. The average measurement from the line was ~ 3/8–in indicating that the loss of sediment bed volume was less than 5%, well within the 10% requirement for the units MTFR.

Phase 2

The unit was operated for 30 minutes, per the protocol requirements, at a target steady state flow of 9.22 cfs (4138 gpm). The average flow recorded through the test duration was 4,131 gpm (-0.2%), with a Standard Deviation (SD) of 14.9 and Coefficient of Variance (COV) of 0.004. Background and effluent samples were collected every 5 minutes, with the effluent sample collected 40 seconds after the background sample, which is equal to 1 residence time from the location of the background sample to effluent sample.

The TSS analysis for the background and effluent samples resulted in Non-Detected (ND) concentrations, being below the 5 mg/L reporting limit (RL) of the analytical laboratory. Assuming minimum background and maximum effluent values, the maximum net effluent concentration would be below 5 mg/L.

The SSC analysis resulted in net effluent concentrations ranging from -1.5 mg/L to 4.1 mg/L, with a mean net concentration of 1.2 mg/L (2.5 mg/L if negative values excluded). The SSC data are consistent with the TSS findings and provide additional confirmation of minimal sediment scour. The SSC data summary is shown in Table 3.

Table 3 SCC Sample Analyses

Sample	Background	Effluent	EFF - BG
	mg/L	mg/L	mg/L
1	8.1	12.2	**4.1**
2	7.5	10.3	**2.8**
3	10.8	9.8	**-1.0**
4	6.3	8.1	**1.8**
5	6.6	7.8	**1.2**
6	10.3	8.8	**-1.5**
MEAN	**8.3**	**9.5**	**1.2**

4. Verification of Performance Claim

The TK18 Hydrodynamic Separator scour test results show that the TK18 has the capability to retain collected sediments under flows that are 200% of the unit's MTFR. The measured TSS effluent concentration at this condition was < 5 mg/L (the reporting detection limit) qualifying the unit to be installed on-line.

5. References

(Alden 2011). Optional Online Installation Re-Entrainment/Scour Testing of the Terre Kleen™ TK18 Hydrodynamic Separator Stormwater Treatment Unit per NJDEP Testing Protocol of December 15, 2009.

(NJDEP (2009). Protocol for Manufactured Hydrodynamic Sedimentation Devices for Total Suspended Solids Based on Laboratory Analysis. Dated August 5, 2009, Revised December 9, 2009.