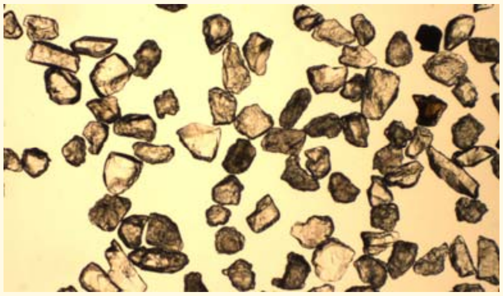
Nutrient Separating Baffle Box®

NJDEP Hydrodynamic Protocol
Evaluation with 100 μm Particles

Daniel P. Smith, Ph.D., P.E., DEE
Applied Environmental Technology
Tampa, FL 33592-2250

May 30, 2013

AET



Nutrient Separating Baffle Box®
NJDEP Hydrodynamic Protocol Evaluation with 100 um Particles
May 30, 2013
Applied Environmental Technology (AET)
Tampa, FL 33592-2250

Table of Contents

Page

Table of Contents (Continued)

Page

List of Figures

Page

List of Tables

EXECUTIVE SUMMARY

The Nutrient Separating Baffle Box® (NSBB) is a manufactured treatment device (MTD) supplied by Sun tree Technologies Inc.® for removing solids from stormwater. Performance of a full-scale NSBB was experimentally evaluated according to the removal efficiency and resuspension protocol recently published by the New Jersey Department of Environmental Protection (NJDEP) and endorsed by the Stormwater Equipment Manufacturer's Association (SWEMA). Experiments were conducted using a relatively narrow particle size distribution (PSD) centered on 100 μm, in lieu of the broader PSD specified by NJDEP. The performance evaluation was conducted using NSBB Model 3-6-73, which has a sedimentation surface area of 18 square feet. A false bottom was installed in each chamber at 6 inch depth, or 50% of the Maximum Sediment Storage Volume (MSSV). Sediment removal efficiency was evaluated by dosing at least 25 lbs. of test sediment to the NSBB, and precisely measuring the mass of sediment dosed and the mass of sediment captured. Influent Suspended Sediment Concentration (SSC) was 200 mg/L in all tests. Removal efficiency experiments were conducted for seven flow rates over a range of 0.25 to 1.75 cubic feet per second (cfs). SSC removal efficiency ranged from 68.1 to 98.2 percent, and progressively increased as flow rate decreased. A Maximum Treatment Flow Rate (MTFR) of 1.30 cfs was derived for 80% SSC removal using the NJDEP weighted removal efficiency procedure. A resuspension experiment was conducted at 2.70 cfs, or 208% of the MTFR, in which no sediment was dosed to the NSBB and bottom chambers were pre-loading with 100 μm test sediment to 6 inch depth, or 50% of MSSV. The sediment used on the NSBB resuspension test was finer than that required by the NJDEP protocol and provided a more rigorous resuspension evaluation. Effluent SSC concentrations in the resuspension test ranged from 3.2 to 6.6 mg/L and did not statistically differ from background influent levels. The SSC in NSBB effluent during the resuspension test were well below the 20 mg/L NJDEP limit that qualifies the NSBB for on-line installation. The results of the Model 3-6-72 tests were used to determine the Maximum Treatment Flow Rates for eleven additional NSBB models in the Suntree product line by applying constant surface overflow rate scaling to the MTFR of Model 3-6-72.

BACKGROUND

The Nutrient Separating Baffle Box® (NSBB) is a structural Stormwater Control Measure (SCM), or Manufactured Treatment Device (MTD), that reduces pollutant loadings by capturing sediments, gross solids, and associated pollutants. The treatment effectiveness of the NSBB can be assessed through definitive experimental evaluations that quantify the suspended sediment removal efficiency under controlled conditions (1). The New Jersey Department of Environmental Protection (NJDEP) recently issued a new revised protocol for the laboratory evaluation of hydrodynamic separation devices to determine suspended sediment removal efficiency and sediment resuspension. The new protocol, titled *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device* (2) is based on a protocol that was recommended by the Stormwater Equipment Manufacturers Association (SWEMA) to perform essentially the same evaluation (3).

The *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device* (2) presents detailed protocols for the laboratory evaluation of hydrodynamic separation devices to determine suspended sediment removal efficiency and sediment resuspension. This document requires that a full scale, commercially available MTD with a specified Effective Sedimentation Area be used in performance testing. The NJDEP protocol includes specifications for the particle size distribution (PSD) of sediment for removal efficiency and resuspension experiments, use of false bottoms in removal efficiency testing, sediment pre-loading in resuspension testing, methods of sampling and analyses, maximum water temperature and maximum background sediment levels. Qualifications of the 3rd party testing laboratory are established.

OBJECTIVE

The objective of this study was to evaluate the performance of a full-scale Nutrient Separating Baffle Box® (NSBB) for 100 μm sediment particles, using protocols for removal efficiency and resuspension established by NJDEP (2). A 100 μm test sediment is congruent with the treatment functionality of the NSBB and provides a more useful comparative basis for hydrodynamic MTD performance than wider PSDs. Many municipalities and stormwater agencies seek MTD performance data based on a 100 μm particle size sediment.

SUNTREE TECHNOLOGIES INC.®

Corporate History The stormwater treatment division of Suntree Technologies was founded by Mr. Henry Happel and Mr. Tom Happel in 1993 in response to local environmental concerns and the need to protect the Indian River Lagoon from stormwater pollutants. Initially incorporated as Suntree Isles and currently doing business as Suntree Technologies Inc.®, the company has been designing and manufacturing stormwater pollution control devices since 1993. The Nutrient Separating Baffle Box® was developed in 1998 by incorporating screen capture devices into in-line sedimentation chambers in order to capture large stormwater materials and hold them out of the water column between storm events. The first NSBB was installed in 1999, and NSBB designs have since continued to evolve and improve. Suntree has also developed an extensive line of other products for the stormwater management industry, including a variety of inlet filter systems, media filtration systems, polymer filtration systems, and advanced skimmer systems. Suntree provides both standardized BMP units and customized designs, and holds thirteen patents for innovative technologies that are related to their NSBB product line.

Organization and Management Suntree Technologies Inc.® is a privately owned Florida corporation with corporate headquarters located at 798 Clearlake Road, Cocoa, FL (PH: 321-637-7552). Suntree Technologies is currently owned and managed by Tom Happel as president and John Happel as Vice President. The product market place of Suntree Technologies has expanded beyond Florida to include all 50 states, with an extensive distributor network.

Operating Experience with Respect to the Proposed Technology To date there are approximately 1,500 installations of the Suntree Nutrient Separating Baffle Box® across the

United States, which vary in size and configuration to treat storm pipes ranging in size from 6" to 84" in diameter. In addition to 14 different standard sizes, custom NSBB configurations are manufactured to accommodate various unique treatment and site specific requirements.

The Nutrient Separating Baffle Box® (NSBB) is also referred to as the 2nd Generation Baffle Box and is a significant design improvement over previous old style baffle boxes. Key innovations have been the incorporation of a raised screen basket in line with the stormwater inlet pipe to keep organic material and debris separate from the static water between rain events, and the addition of turbulence deflectors to improve the settling of fine sediments while minimizing re-suspension. While Suntree initially developed the Nutrient Separating Baffle Box® as a gross pollutant removal device prior to stormwater outfalls, NSBB application has since been expanded to a pretreatment option prior to underground detention, exfiltration fields, filtration systems, and injection wells, as well as its general use as a component of a treatment train. A variety of media treatment systems are also available as options for the NSBB. The unique design of the Nutrient Separating Baffle Box® results in minimal head loss through the treatment structure. As a result, the NSBB can be installed in either an on-line or off-line configuration, making for an easy retrofit within existing water sheds.

Patents The proprietary technology behind the Nutrient Separating Baffle Box® and its many unique and specialized features are protected by patents issued by the U.S. Patent office, and patents pending. The trade name, Nutrient Separating Baffle Box®, is a federally registered trademark of Suntree Technologies, Inc.® Below is a list of issued utility patents for the NSBB and its features:

6,428,692	6,979,148	7,294,256	8,034,236
7,270,747	8,231,780	7,981,283	8,034,234
7,153,417	7,846,327	8,083,937	8,142,666
8,366,923			

Technical Resources, Staff and Capital Equipment Suntree Technologies Inc.® employs 30 employees which includes 2 staff engineers. In addition to in-house design work, additional engineering is often outsourced to several different firms. Specialized product testing and evaluations are performed in house and by third party testing laboratories.

Suntree Technologies Inc.® representatives oversee the assembly and installation of every Nutrient Separating Baffle Box® to ensure that installation is always perfect, and that the treatment system is quality controlled to ensure optimum treatment of the water flow. Suntree Technologies Inc.® warranties all of its products to be free from manufacturer's defects for a period of at least five (5) years from the date of purchase. Suntree Technologies Inc.® also warranties that the materials used to manufacture its products are able to withstand and remain durable to typical environmental conditions for a period of at least five (5) years from the date of purchase.

The vault that makes up the Nutrient Separating Baffle Box® is typically made of either concrete or fiberglass. Typically, the concrete is cast by an independent casting company that is located relatively local to the installation site. The interior components are manufactured in Cocoa

Florida and shipped to the casting company where the components are then installed. If a project requires a fiberglass vault, the vault with all the interior components pre-installed is shipped from Cocoa, Florida. In almost all cases, all the unique interior components are installed prior to delivery of the vault. This makes for a quick and easy install, in which the excavation, setting Nutrient Separating Baffle Box®, and restoration of the excavation often takes less than a day.

The products of Suntree Technologies Inc.® are available either directly from Suntree Technologies or through a national sales network of authorized distributors. There are no other manufacturers authorized to sell or market the Nutrient Separating Baffle Box®.

NUTRIENT SEPARATING BAFFLE BOX®

The NSBB is a subsurface rectangular vault MTD that is placed on-line in the stormwater collection system. The NSBB vault is subdivided into a series of chambers by engineered vertical baffles which influence hydrodynamics and capture suspended particles by sedimentation (Figure 1). The NSBB additionally contains a basket screen that is located above the top of the chamber baffles. The screen captures floating and suspended solids and holds them out of the water column during non-flow periods. Details of the NSBB can be found on the Suntree Technologies Inc.® website (4). The NJDEP performance evaluation of will be conducted using the commercially available NSBB Model 3-6-72. Details of NSBB 3-6-72 are summarized in Table 1.

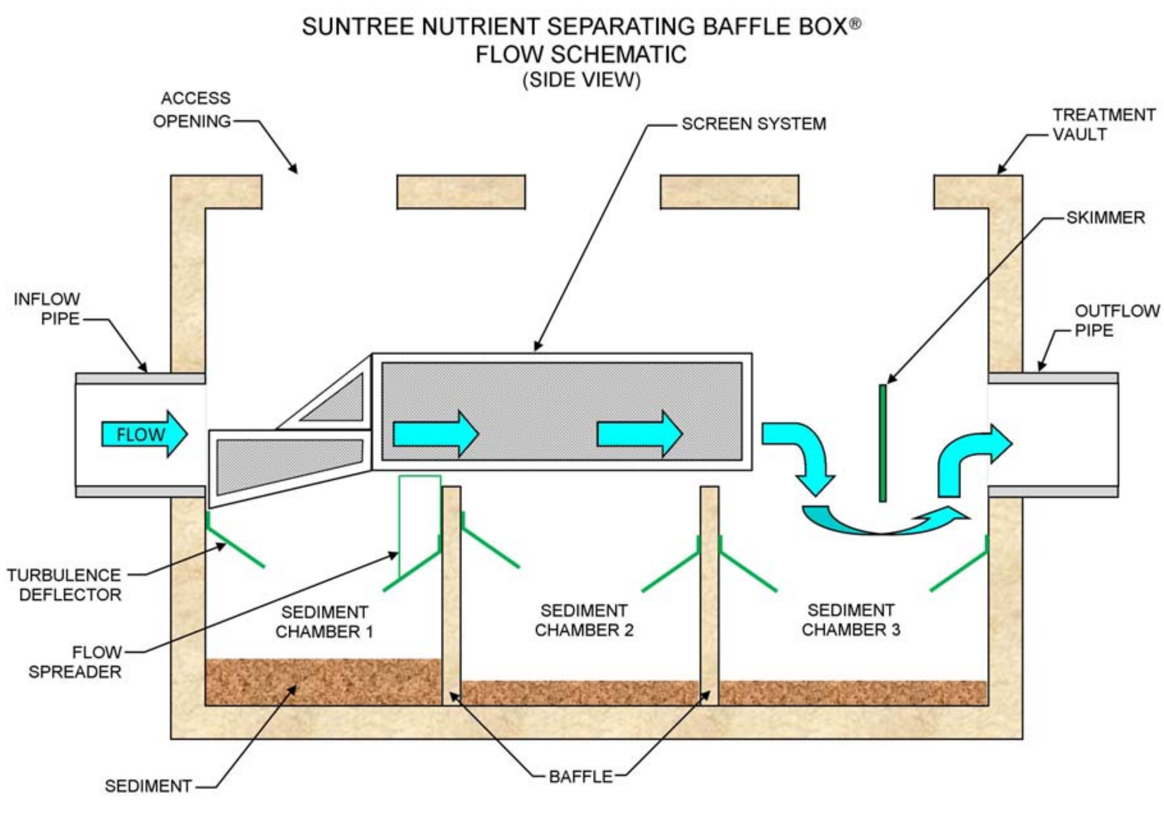


Figure 1 Nutrient Separating Baffle Box®

Table 1 NSBB 3-6-72 Specifications

Internal length, inch	72
Internal width, inch	36
Number of bottom chambers	3
Baffle height, inch	36
Effective sedimentation area, ft^2	18
Chamber empty bed volume, gallon	404
Maintenance Sediment Storage Volume, ft^3	18.0
Screen box length, inch	51
Screen box width, inch	21

Drawings of the NSBB 3-6-72 are included in Appendix A. The Maintenance Sediment Storage Volume (MSSV) of the NSBB 3-6-72 has been established as 18 ft^3, which represents an average sediment depth of 12 in. over the plan area of each of the three bottom chambers. The NJDEP protocol (2) requires a sediment pre-loading of 50% of the MSSV, which for the NSBB 3-6-72 is a uniform sediment depth of 6 inch over the bottom surface of all three chambers (9 ft^3 volume). In practice, sediment accumulation in the NSBB is typically not uniform, with the greatest accumulation of sediment in the first chamber and the least accumulation in the last. For removal efficiency testing, false bottoms were placed across the entire bottom of each chamber at 6 in. depth, i.e. at the 50% MSSV sediment depth. For the resuspension experiment, test sediment was placed to a uniform depth of 6 in. in each chamber; false bottoms were not used.

PARTICLE SIZE DISTRIBUTION

The NSBB evaluation was conducted using sediment with a relatively narrow particle size distribution (PSD) centered on 100 μm. The test sediment was a processed Best Sand 110 (Best Sand Corporation, Chardon, OH). Best Sand 110 is a high quality sub-angular grain silica sand with a purity of greater than 99% SiO_2 and a median particle size (d_{50}) in the 100 μm range. A series of sieving and decanting procedures were developed to produce a sediment with a d_{50} in the 100 μm particle size. Production steps were: remove coarser particles by dry sieving through US No. 125 sieve; remove finer particles by wet elutriation with continuous washing in a 12 in. x 18 in. slurry channel basin with water flow rate of ca. 4.4 gallon per minute; decant water; collect sand and dry at 170F, and store in sealed 5 gallon buckets until ready for use.

PSD analyses were conducted by a certified laboratory (BTL Engineering Services, Tampa, FL 33614) according to ASTM D 422 (9). A PSD of test sediment is shown in Figure 2. Results of PSD conducted on eight test sediment samples are listed in Table 2. Mean d_{50} was 97.5 μm, with a standard deviation of 3.7 μm and coefficient of variation of 0.037. The 100 μm PSD contrasts with the broader PSD specified in the NJDEP protocol (2). Results of all test sediment PSD analyses are included in Appendix E.

The 100 μm PSD contrasts with the broader PSD specified in the NJDEP protocol (2). Sediment removal in hydrodynamic devices is highly dependent on particle size and settling velocity (5,6,7). Use of sediment with a relatively narrow PSD centered on 100 μm is congruent with the treatment functionality of the NSBB and provides a more useful comparative performance basis than wider PSDs. Other than the use of a narrow PSD test sediment centered on 100 μm particles, the NSBB testing for removal efficiency and resuspension were in accordance with the NJDEP protocol for hydrodynamic separator devices (2). The sediment used in the NSBB resuspension tests was much finer than that specified in the NJDEP resuspension protocol (i.e. d_{50} of 98 versus 216 μm). According to theory, propensity for resuspension is proportional to the inverse of the particle diameter. Therefore, the NSBB experiment provided a more rigorous resuspension test than required by the NJDEP protocol.

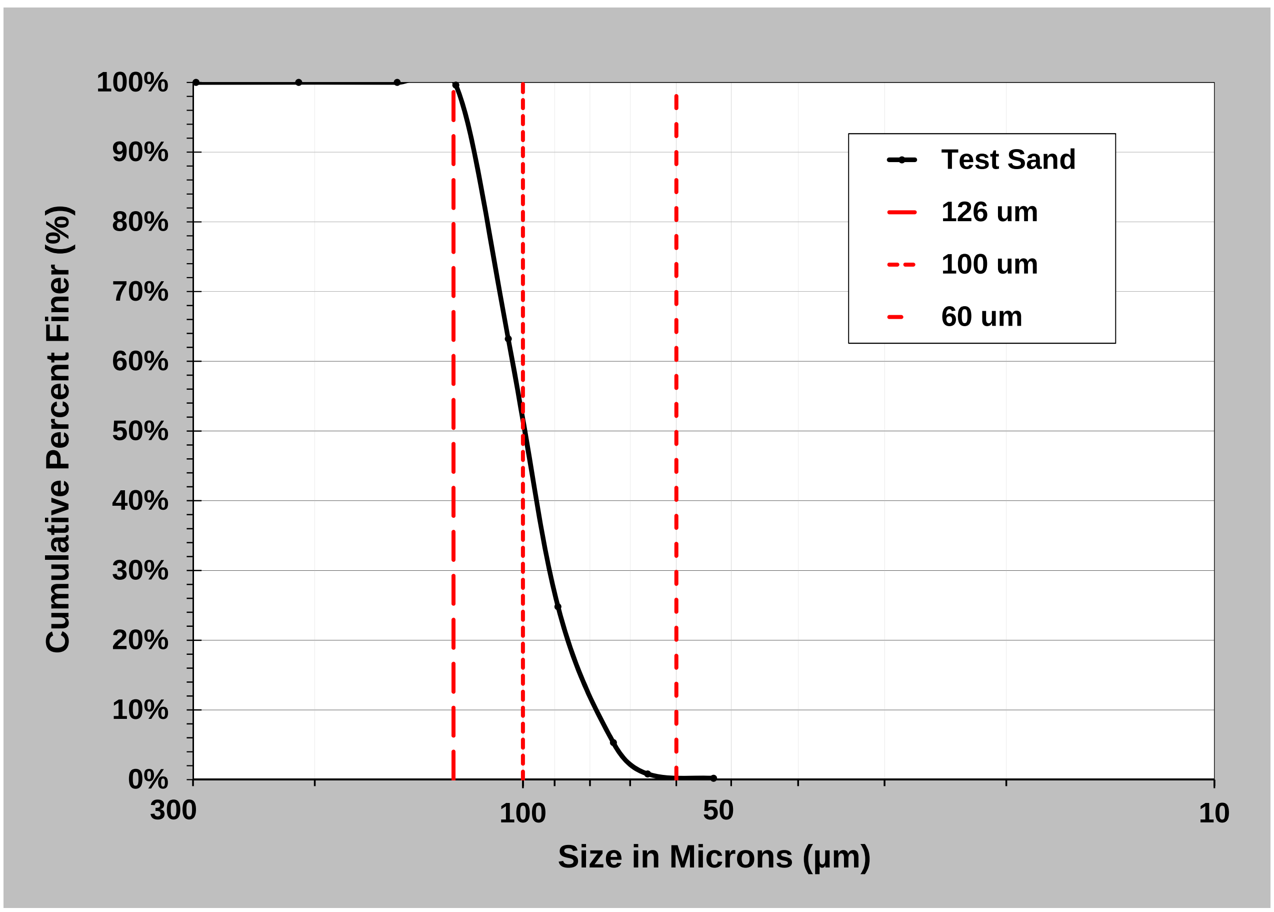


Figure 2 Particle Size Distribution of Test Sediment

Table 2 Test Sediment Particle Size Analysis

Sand Source	Date	d_{90}, um	d_{50}, um	d_{10}, um
Hopper	11/12/12	117.9	100.8	80.3
Hopper	11/16/12	118.5	101.2	78.6
Hopper	11/20/12	118.1	100.9	80.0
Hopper	11/26/12	106.5	92.5	76.3
Hopper	11/28/12	106.2	92.0	76.6
Chamber 1 Pre-Load	01/08/13	116.4	98.0	78.6
Chamber 2 Pre-Load	01/08/13	114.4	96.4	79.2
Chamber 3 Pre-Load	01/08/13	114.0	98.2	82.1
	Mean	114.0	97.5	79.0
	Standard Deviation	5.0	3.7	1.9
	Median	115.4	98.1	78.9
	Coefficient of Variation	0.044	0.037	0.024

NSBB PERFORMANCE EVALUATION WITH NJDEP PROTOCOL

The NJDEP protocol entails the following:

- Establish a Maintenance Sediment Storage Volume (MSSV), the maximum amount of sediment that can accumulate in the MTD based on a six month interval.
- Evaluate suspended sediment removal efficiency of the treatment device across a range of flow rates that encompass 25, 50, 75, 100 and 125% of the Maximum Treatment Flow Rate (MTFR). Each experiment is conducted with an influent suspended sediment concentration of 200 mg/l and with a false bottom placed at a level of 50% of the MSSV.
- Establish a Maximum Treatment Flow Rate (MTFR) for which a performance claim (i.e. percent removal efficiency) will be made for the treatment device. The performance claim is stated as a flow weighted removal efficiency of suspended solids (TSS/SSC). MTFR is derived from a continuous curve of weighted removal efficiency based on individual experiments that bracket the MTFR-scaled flow rates at 25 and 125%.
- Evaluate sediment resuspension at a flow rate of 200% of the Maximum Treatment Flow Rate (MTFR) for on-line installation, without sediment dosing into the NSBB influent, and with sediment pre-loading of 50% of the Maintenance Sediment Storage Volume (MSSV).
- Compare effluent TSS/SSC from the resuspension experiment with NJDEP on-line MTD criteria of 20 mg/L.

For the NSBB, the Maintenance Sediment Storage Volume (MSSV) is a uniform depth of 12 in. in each of the three chambers. A target SSC removal efficiency of 80% was established as the basis for the performance claim. The conducted removal efficiency experiments are listed in Table 3.

Table 3 Summary of Removal Efficiency Experiments

Flow Rate, cfs	% of MTFR[1]	Sediment Mass Flow, gram/min	Hydraulic Retention Time, min[2]	Surface Overflow Rate, gal/ft^2-min
0.25	19.2	85	3.60	6.2
0.50	38.5	170	1.80	12.5
0.75	57.7	255	1.20	18.7
1.00	76.9	340	0.90	24.9
1.25	96.2	425	0.72	31.2
1.50	115	510	0.60	37.4
1.75	135	595	0.51	43.6

[1] Maximum Treatment Flow Rate, determined in subsequent section of report
[2] Based on chamber volumes

EXPERIMENTAL SYSTEM

Configuration Experiments were conducted at the Applied Environmental Technology Test Facility (AET-TF) in Hillsborough County, Florida (8). A schematic of the system used to conduct the experiments is shown in Figure 2. The system consisted of a Screening Chamber, a Dosing Hopper System, the Nutrient Separating Baffle Box (NSBB), a Water Recycle Reservoir, influent pump, influent flow control valve, influent flow meter, and associated piping and appurtenances. Access locations were provided for background influent and effluent sampling. Through a process of adaptive development, the apparatus depicted in Figure 1 was iteratively assembled into a complete experimental system, fully capable of meeting the testing requirements of the NJDEP Protocol. The Influent Pump was the only power requiring component of the experimental system; all other flow was by gravity. Sediment was dosed from an open hopper directly into the conveyance pipe through a slot in the crown of the pipe. Test water was AET-TF groundwater supplied by pump to the Water Recycle Reservoir. The groundwater supply had circumneutral pH, was virtually free of suspended sediment, and had limited dissolved oxygen levels. Water pumped to the Water Supply Reservoir was aerated and filtered several days prior to performance of tests. All experiments were conducted at water temperatures of less than 80F.

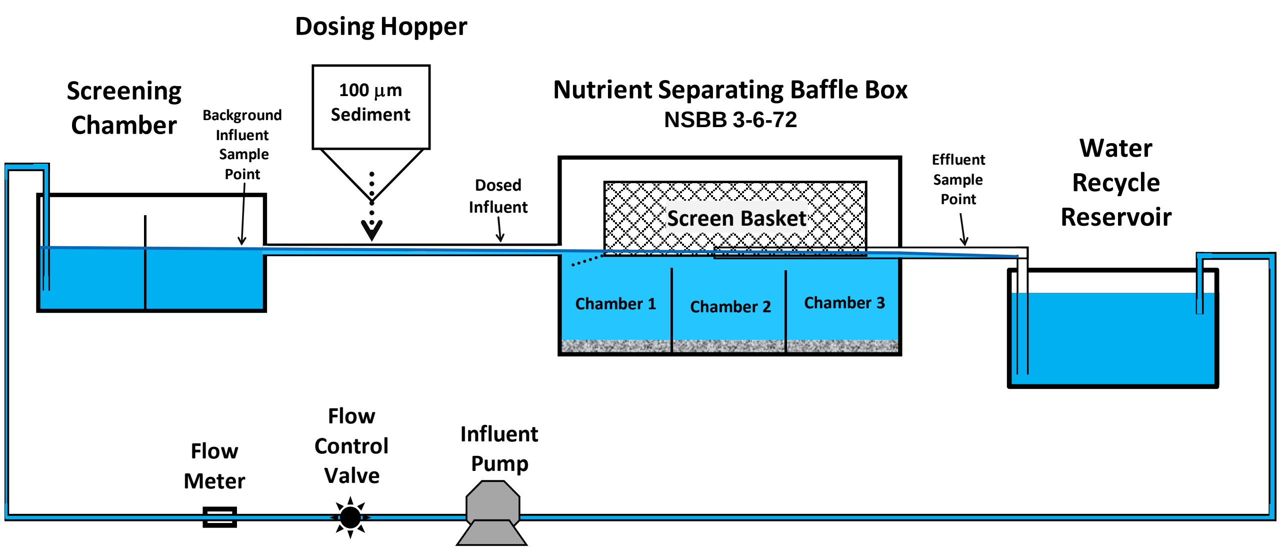


Figure 3 Schematic of Experimental System

Pump Flow to the experimental system was provided by a John Deere diesel powered vacuum well point pump (Model 6VW-DJDST-45D-M, Thompson Pump Co., Sarasota, FL). The pump was connected by 6 inch tubing to a PVC withdrawal pipe in the Water Recycle Reservoir that extended eight inches below the water surface. The pump had variable speed control to adjust the flow rate and was capable of maximum flow rates exceeding three cubic feet per second.

Flow Rate Control Valve A 6 inch knife gate valve (Thompson Pump Co., Sarasota, FL) was used for fine flow rate adjustment at test initiation and throughout the experiments as needed.

Flow Meter Flow rate was measured with a PT-500 Ultrasonic Flow Meter, Serial Number 7629 (Greyline Instruments Inc., Massena, New York). The PT-500 is a Transit Time ultrasonic flow meter that employs two sensors mounted on the outside of the pipe wall and has a manufacturer stated accuracy of ±2% (http://www.greyline.com/pt500.htm). The instrument was calibrated by Micronics Ltd. and a copy of the Certificate of Calibration is included in Appendix E. The flowmeter was positioned in close proximity to the flow valve to enable expeditious adjustment of the flow rate by a single operator.

Screening Chamber The screening chamber (3 ft. by 6 ft.) contained a coarse screen to remove any larger suspended material which inadvertently entered the experimental system. Water was pumped from the Water Supply Reservoir to the upstream end of the Screening Chamber, and all flow passed through the screen on its way to the 14 in. pipe that connected the Screening Chamber to the baffle box. An access cover was placed in the top of the Screening Chamber at the location of the outlet to enable samples to be taken for background influent Suspended Solids Concentrations.

Sediment Dosing System Sediment was dosed using a dry feed system placed directly over the crown of the 18 inch pipe that connected the Screening Chamber to the NSBB. The location of sediment dosing was 6 ft. (72 in.) from the entrance to the NSBB. Sediment dosed from the hopper passed through a slot in the crown in the pipe. The hopper had an inverted square pyramid geometry of 23.5 in. inner diameter with rounded corners, and sides at 42^{o} from horizontal. Sediment mass flow was controlled by aluminum plates placed at the bottom of the hopper. The aluminum plates contained one or two circular orifices which were calibrated to deliver target mass flow rates. Seven plates were fabricated, one for each of the seven removal efficiency experiments. Plate calibration was conducted in situ by measuring the mass of sediment collected for 60 seconds using dried and prepared test sand.

NSBB 3-6-72 The NSBB 3-6-72 was placed on-line for all testing and treated 100% of the applied flow. For removal efficiency testing, false bottoms were placed across the entire bottom of each chamber at 6 in. depth, i.e. at the 50% MSSV sediment depth. For the resuspension experiment, test sediment was placed to a uniform depth of 6 in. in each chamber; false bottoms were not used. The NSBB was connected to the Water Recycle Reservoir by 18 inch piping. Piping proceeded horizontally from the NSBB to a location just inside the wall of the Water Recycle Reservoir, where a right angle in the piping directed flow in a vertically downward direction to the bottom of the Water Recycle Reservoir.

Water Recycle Reservoir The Water Recycle Reservoir had a circular plan area of 22 ft. and mean working depth of ca. 46 in., with water capacity of ca. 10,800 gallons. Flow from the NSBB entered the reservoir at the bottom; it was directed parallel to the reservoir wall to create a circumferential flow field. Water withdrawal occurred from a location ca. 8 in. below the water surface, ca. 40 in. from the inflow pipe, but in the opposite direction from which influent flow was directed. The inflow and withdrawal locations and their orientations created a circumferential path of water flow path in the Water Recycle Reservoir.

CONDUCT OF REMOVAL EFFICIENCY EXPERIMENTS

All removal efficiency experiments followed a testing protocol that was iteratively developed to implement the NJDEP testing requirements.

System Cleaning The NSBB, Screening Chamber, and piping were covered between experiments and were completely cleaned prior to testing to remove sediment.

Sediment Preparation Several hours before each experiment, ca. 33 lbs. of sediment was removed from sealed containers, dried for 2 hours at 180°F, cooled, and sieved though a U.S. No. 80 (180 μm) screen. The sediment was loaded into the dosing hopper shortly before the experiment was initiated. Appendix D included Quality Assurance results for Constant Weight in Sediment Preparation, Constant Weight Pre-Testing.

Water Temperature Water temperature was verified to be less than 80F just before the initiation of each experiment using a NIST traceable thermometer (Traceable Calibration Control Company 281-482-1714).

Field Data Sheets Field data sheets were prepared for preparation of test sediment, temperature monitoring, flow rate target and monitoring, sediment dosing rate monitoring, total sediment dosing time, background suspended sediment concentration sample collection times, Suspended Sediment Concentration (SSC) laboratory analysis, and laboratory blank and laboratory control samples for SSC analysis. Data sheets specified and recorded time of sediment dosing initiation, time of sediment dosing termination, time of all sample events, and time of other observations.

Sample Containers Samples containers were prepared for at least eight background influent SSC samples and six sediment dosing samples. All containers has sealable tops. SSC containers were one half gallon PETE canisters with round 4 in. diameter open mouths. SSC containers and tops were rinsed at least three times with tap water and drained. SSC containers were numbered and deployed in order of increasing number with experimental time. Sediment containers were 4.5 x 6 in. open containers of 2.75 in. depth, cleaned by repeated wipings with clean paper towels. Sediment containers were lettered A though F and deployed progressively with experimental time.

Flow Initiation and Control When all experimental preparations were completed, the pump was started at an initial speed estimated to produce the target flow rate. The flow meter was then powered on and allowed to electronically stablilize. When flow readings could be discerned, the pump speed was adjusted if necessary. Further adjustment was made with the flow control valve until stable flow was achieved that was centered around the target flow rate. The pump was run for several minutes of stable flow at the target flow rate before sediment dosing was initiated. Flow rate adjustments were made as needed through out the experiments using the flow rate control valve. Flow rate was recorded on data sheets at 1 minute intervals throughout the experiments.

Sediment Dosing Initiation Sediment dosing was initiated after several minutes of stable flow had been attained which was centered at the target flow rate. Dosing was initiated by sliding the calibrated dosing plate into the dosing plate slot at the bottom of the dosing hopper, displacing the blank plate (i.e. zero dosing). The time of initiation of sediment dosing was the start of the sediment dosing period and was carefully recorded. The sediment dosing time ended when sediment dosing was terminated. The start of the sediment dosing time was the zero time point of the experiment and the basis of the time stamp for all sampling and all measurements.

Background Influent Sampling Eight backgound influent samples were collected at intervals spaced through the sediment dosing time. The sample location was in the sediment screening chamber, just in front of the entrance to the discharge pipe. Sampling was conducted by opening the cover in the top of the Screening Chamber; loosening but not removing the threaded cap on the cannister; immersing the container with the opening facing directly into the direction of water flow with the centerline of the opening ca. 6 in. below the surface of the water; removing the cap for a short time to allow water ingress; placing the cap over the opening; quickly removing the cannister from the water while simultaneously turning the cannister so the the opening was facing upward; and screwing the top closed.

Sediment Dose Sampling Six sediment dose samples were collected at intervals spaced through the sediment dosing time. Sediment dose sampling was conducted by placing a sediment collection container under the hopper dosing point for 60 seconds to collect all sediment leaving the hopper.

Sediment Dosing Termination Sediment dosing was terminated by sliding the the blank plate (i.e. zero dosing) into the dosing plate slot at the bottom of the dosing hopper, displacing the dosing plate. The time of termination of sediment dosing was the end of the sediment dosing time and was carefully recorded. The sediment dosing time was usd to calculated the total sediment dosed from the hopper. The sediment dosing time was used to calculate the total sediment dosed from the hopper. The sediment dosing time correected for the time of six hopper dose samples was used to calculate the total sediment dosed to the NSBB.

Retained Sediment Collection and Analysis The mass of sediment accumulated in the NSBB was quantified using a previously developed methodology that had been demonstrated to produce sediment mass recoveries of 99.9% (Appendix B). Following the termination of sediment dosing, the pump was turned off and water in the NSBB chambers was allowed to settle for 30 minutes. The clear water in each chamber was decanted to approximately eight inches above the surface of the accumulated sediment. The sediment slurry was then removed with a suction pipe and directed to an external sediment filtration system. The filtration system consisted of a bank of pre-tared paper filters contained in filter support screens. The filter paper was a food grade preparation paper (Bunn 20124) with a purported pore size range of 5 to 15 μm. Paper filters were dried and tare weighed to a precision of 0.01 grams before filtration. Filters and sediment were dried to constant weight (12 hours at 180^{o}C) and sediment mass was determined by subtracting the tare weight.

Analytical and Quality Assurance Procedures Analysis of Suspended Sediment Concentration (SSC) analysis was conducted according to the AET SSC protocol contained in Appendix C. SSC Quality Assurance results are included in Appendix E. A 2 hour drying time for filtered samples was verified to be sufficient by weight changes of 0.05 mg and less for 250 mg/L equivalent SSC concentrations (Table D-1, App. E; Table E-2, App. E). For all removal efficiency experiment analyses events, Method Blanks were less than the established Reporting Limit of 2.07 mg/L (Table E-3, App. E). For all removal efficiency experiment analyses events, Lab Control Sample recoveries were within the established tolerance of 15% (Table E-6, App. E). Initial Demonstration of Capability samples in the low SSC range of ca. 10 mg/L were all within the 30%

Recovery Criteria (Table E-5, App. E). Demonstration of Capability samples in the high SSC range of ca. 100 mg/L were all within 15% Recovery Criteria (Table E-5, App. E).

Data Management Data sheets were assembled and a complete file maintained at AET for each experiment. All data was placed in electronic format by entering into Excel spreadsheets which are maintained at several locations.

REMOVAL EFFICIENCY EXPERIMENT RESULTS

This section summarizes measured temperature, flow rate, sediment dosing rate and background sediment concentrations, presents the removal efficiency results of seven flow rate experiments, and derives weighted removal efficiencies using the NJDEP weighing factors. Full results of the removal efficiency experiments are presented in Appendix F.

Water Temperature The water temperatures was verified to be less 80F just prior to the start of each of the seven removal efficiency experiments and remained less than 80F during testing.

Flow Rate Measured and target flow rates are shown in Figure 4 and summarized in Table 4. Mean flow rates were all within 1% of target flow rates, which was well within the ±10% criteria in the NJDEP protocol (2). Monitored flow rates for the 1.00 cfs experiment is shown in Figure 5, which illustrates that flow rates was well within the the NJDEP-permitted tolerance.

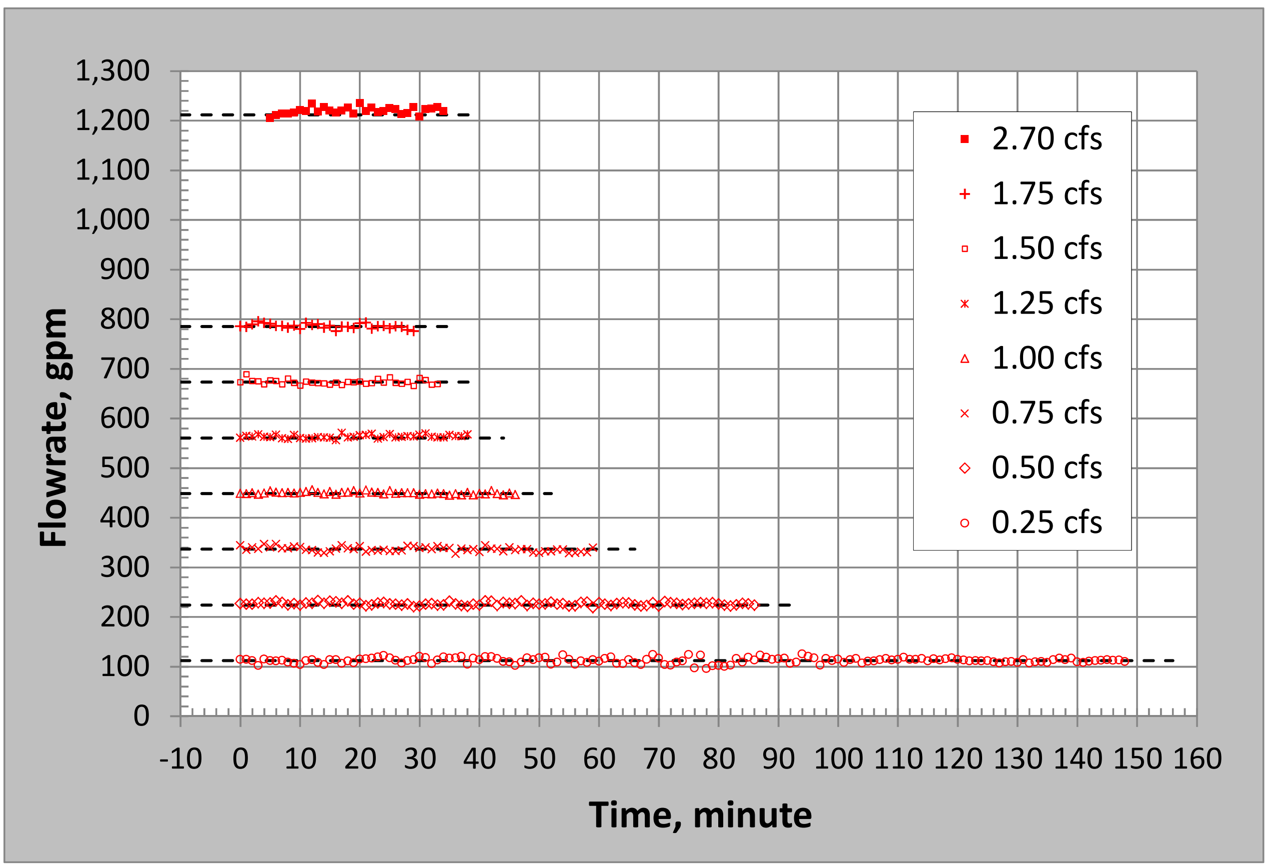


Figure 4 Monitored Flow Rates in Removal Efficiency Experiments

Table 4 Measured Flow Rates in Removal Efficiency Experiments

Target Flow Rate		Measured Flow Rate				
cfs	gpm	Mean, gpm	SD, gpm[1]	CV[2]	% RE[3]	Median, gpm
0.25	112.2	112.3	5.54	0.049	0.06	112.9
0.50	224.4	226.6	3.03	0.013	0.98	226.7
0.75	336.6	336.4	4.82	0.014	-0.05	336.4
1.00	448.8	449.9	2.65	0.006	0.25	449.7
1.25	561.0	563.6	3.40	0.006	0.47	563.1
1.50	673.2	673.3	5.11	0.008	0.02	672.5
1.75	785.4	785.7	4.89	0.006	0.04	785.8

[1] Standard Deviation
[2] Coefficient of Variation = Standard Deviation / Mean x 100
[3] % Relative Error = (Measured Mean - Target) / Target x 100

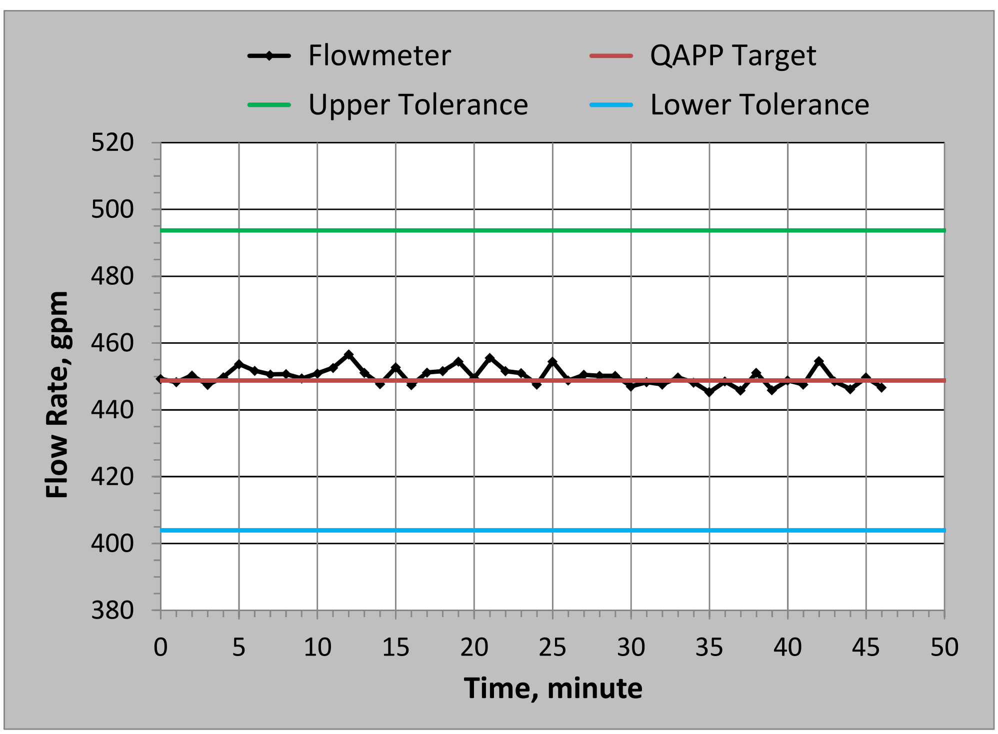


Figure 5 Monitored Flow Rate in 1.00 cfs Experiment

Sediment Dosing Measured and target sediment dosing rates are shown in Figure 6 and summarized in Table 5. Mean dosing rates were all within 5% of target flow rates, which was well within the ±10% criteria in the NJDEP protocol. Monitored sediment dosing rates for the 1.00 cfs experiment is shown in Figure 7, which illustrates that dosing rates were well within the NJDEP-permitted tolerance. Mean influent SSC to the NSBB were estimated by dividing the mean sediment dosing rate by the mean flow rate. Mean influent SSC are compared to the target influent SSC of 200 mg/L in Figure 8. Estimated mean influent SSC were well within the ±10% NJDEP-permitted tolerance (i.e. 180 to 220 mg/L).

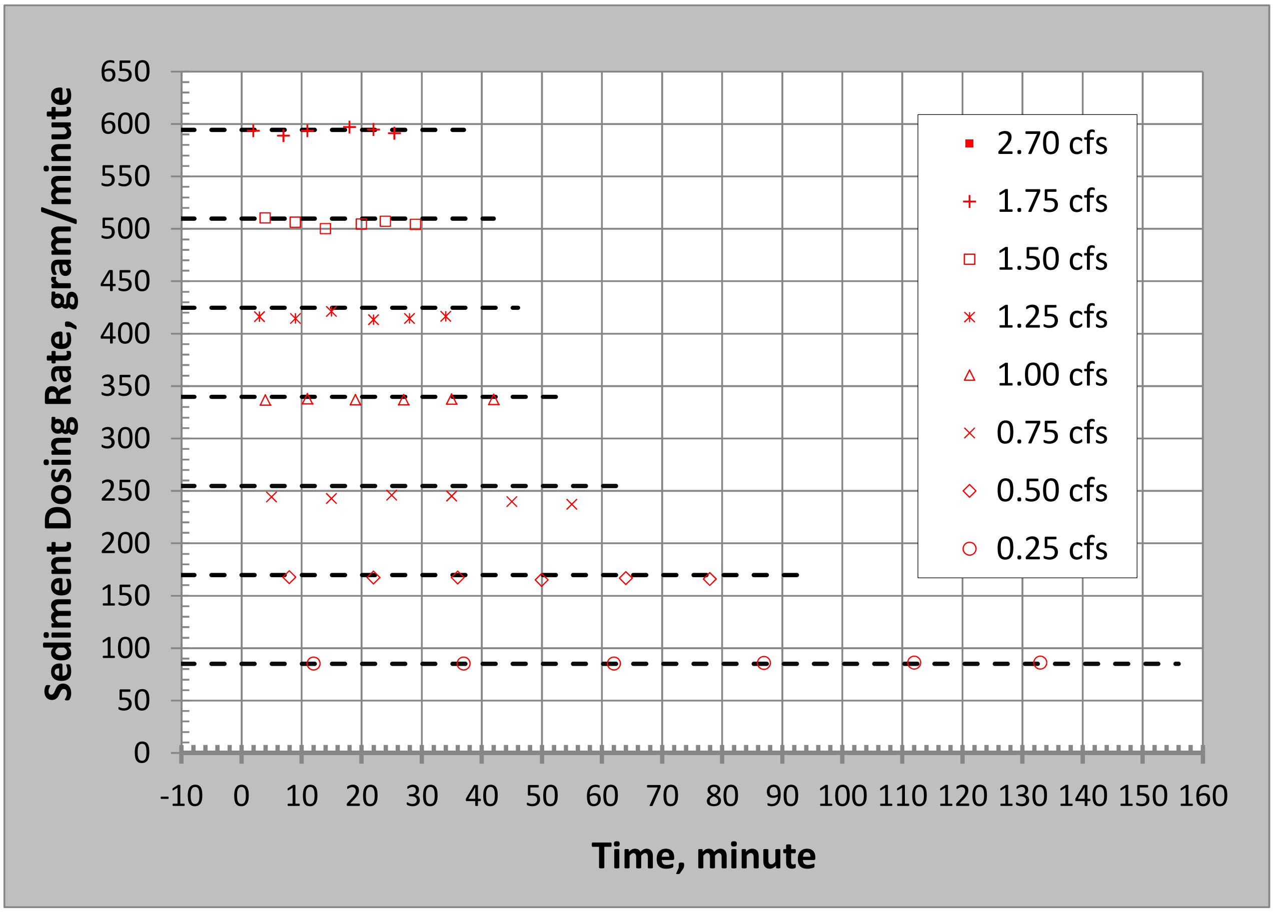


Figure 6 Sediment Dosing Rates in Removal Efficiency Experiments

Table 5 Measured Sediment Dosing Rates

Target Flow Rate	Target Dosing Rate	Measured Dosing Rate				
cfs	gram/min	Mean, gram/min.	SD, gram/min.[1]	CV[2]	% RE[3]	Median, gram/min.
0.25	84.9	85.6	0.4	0.004	0.76	85.6
0.50	169.9	166.9	1.0	0.006	-1.8	167.2
0.75	254.8	242.4	3.4	0.014	-4.9	243.4
1.00	339.7	337.2	0.5	0.001	-0.74	337.1
1.25	424.7	415.9	2.8	0.007	-2.1	415.2
1.50	509.6	505.2	3.4	0.007	-0.86	505.2
1.75	594.5	593.3	2.8	0.005	-0.20	593.8

[1] Standard Deviation

[2] Coefficient of Variation = Standard Deviation / Mean x 100

[3] % Relative Error = (Measured Mean - Target) / Target x 100

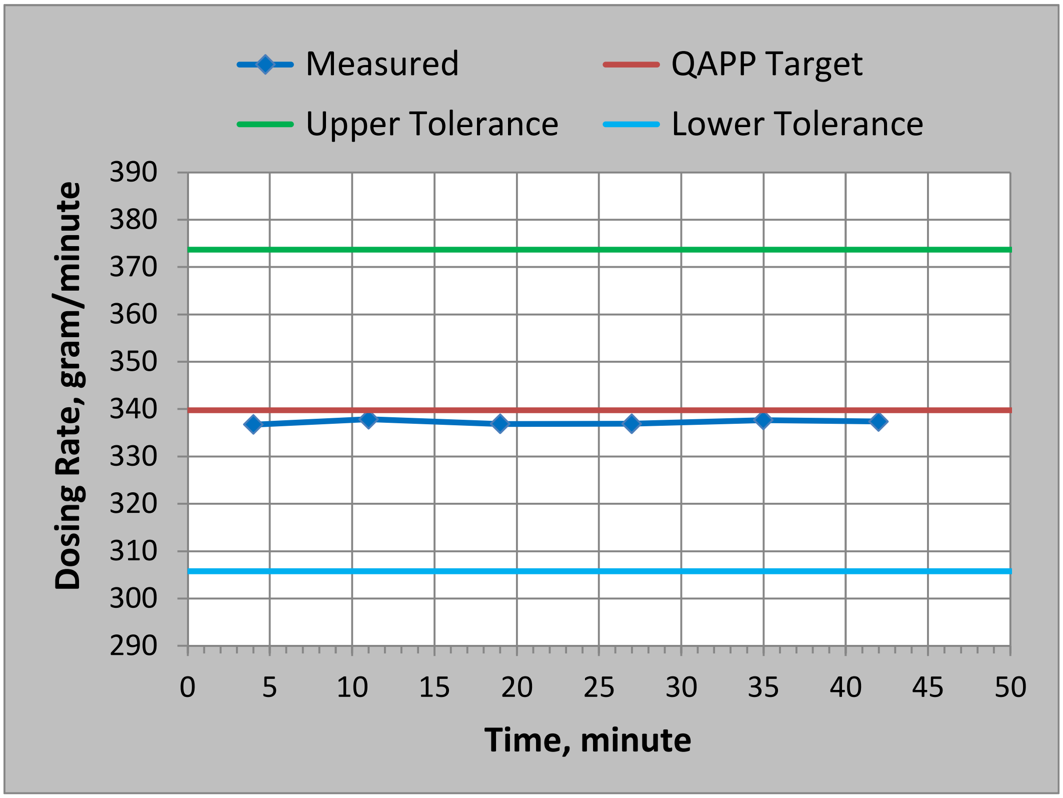


Figure 7 Sediment Dosing Rate in 1.00 cfs Experiment

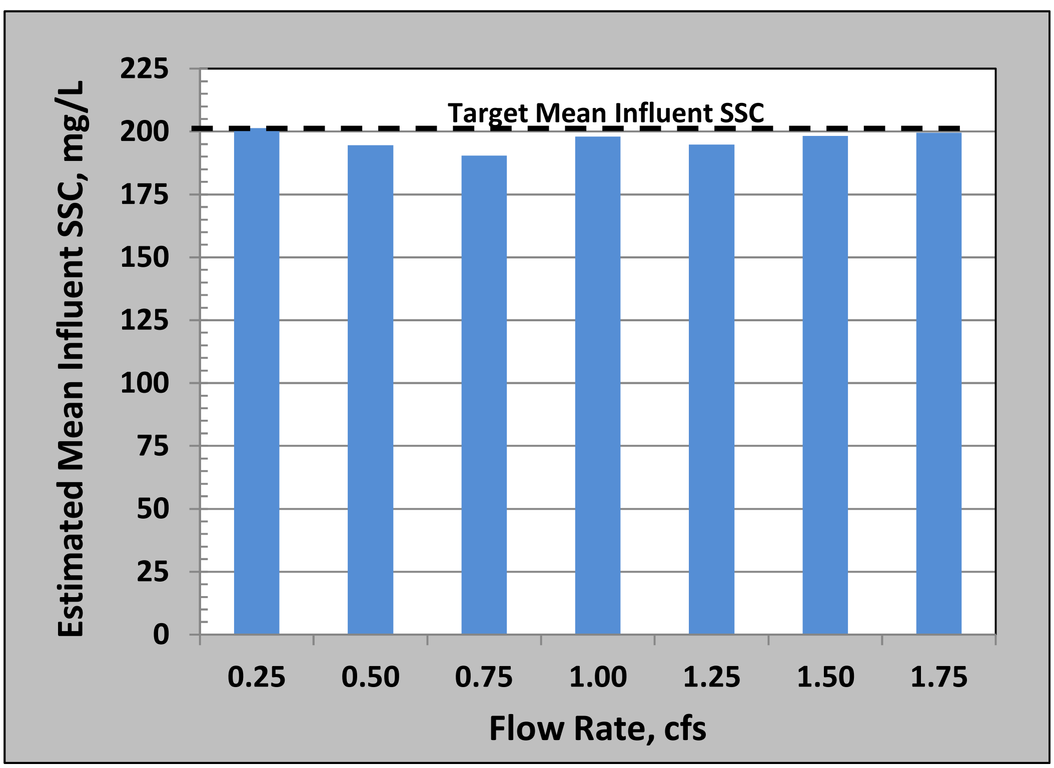


Figure 8 Estimated Mean Influent SSC in Removal Efficiency Experiments

Background Sediment Concentration Background SSC in the removal efficiency tests are summarized in a box plot in Figure 9 and in Table 6. Mean background SSC ranged from 2.2 to 13.4 mg/L (n=8). Figure 9 shows that all background SSC distributions were well within the 20 mg/L criteria in the NJDEP protocol (Figure 9). Background SSC generally increased with increasing flow rate, with the exception of the 1.25 cfs experiment. All measured background SSC were less than 20 mg/L except for one level of 24.4 mg/L the 1.25 cfs experiment.

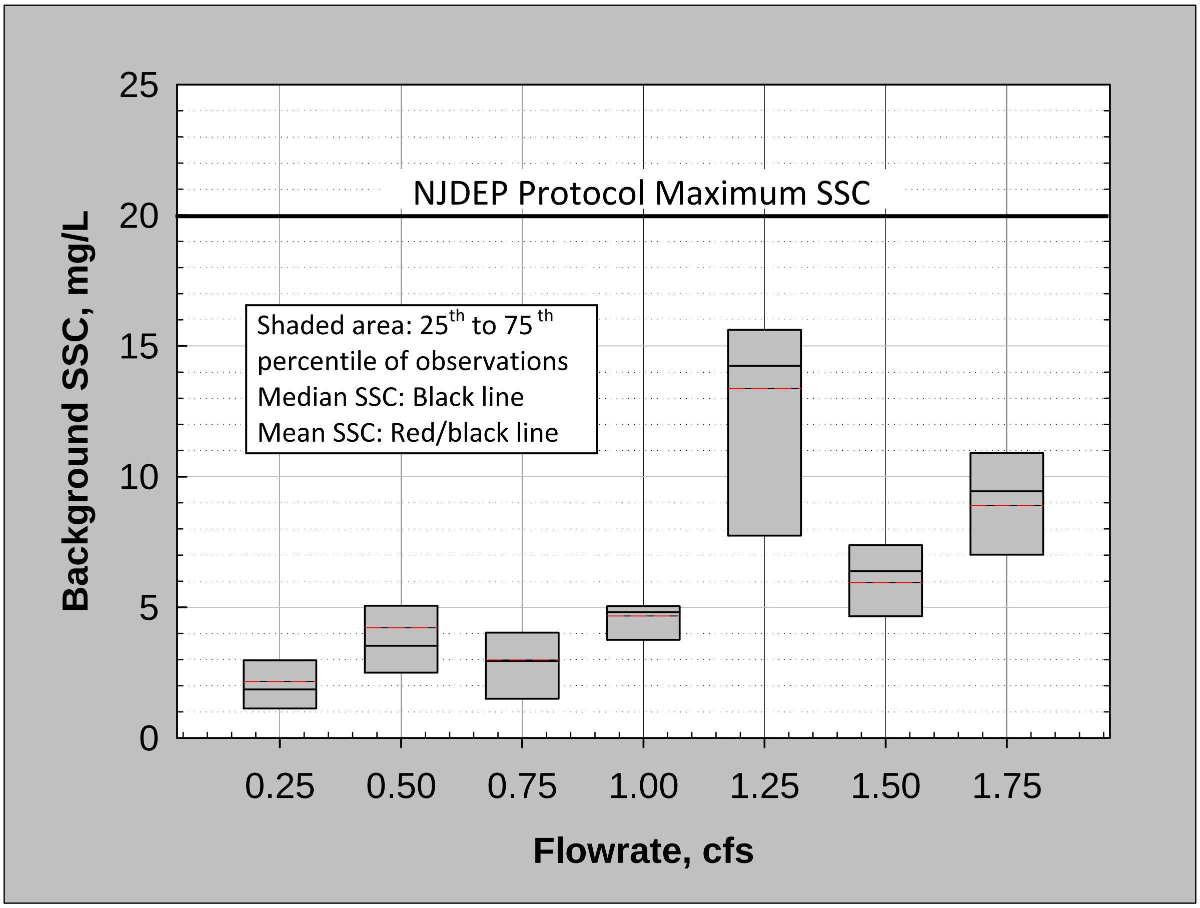


Figure 9 Background Sediment Concentration in Removal Efficiency Experiments

Table 6 Measured Background Suspended Sediment Concentrations

Target Flow Rate	Measured Background Suspended Sediment Concentration			
cfs	**Mean, mg/L**	**SD, mg/L[1]**	**CV[2]**	**Median, mg/L**
0.25	2.16	1.4	0.659	1.86
0.50	4.22	2.4	0.574	3.53
0.75	2.98	1.5	0.500	2.94
1.00	4.67	1.2	0.260	4.81
1.25	13.4	6.3	0.471	14.2
1.50	5.95	2.0	0.332	6.38
1.75	8.89	2.7	0.302	9.44

[1] Standard Deviation

[2] Coefficient of Variation = Standard Deviation / Mean x 100

[3] % Relative Error = (Measured Mean - Target) / Target x 100

Sediment Mass Removal Efficiency The masses of sediment dosed to NSBB 3-6-72 and captured in bottom chambers are listed in Table 7 for the seven removal efficient experiments. The dosed mass ranged from 26.8 to 30 lbs., and satisfied the 25 lb. minimum dosing mass in the NJDEP protocol. Sediment removal efficiencies ranged from 98.2% at 0.25 cfs to 68.1% at 1.75 cfs, and progressively increased as flow rate decreased (Figure 10). A third order polynomial equation was fit to the removal efficiency data (n=7) and provided an acceptable fit to experimental data ($R^2 > 0.99$) as shown in Figure 10.

Table 7 Sediment Mass Removal Efficiency

Target Flow Rate, cfs	Sediment Mass Dosed, lbs.	Sediment Mass Captured, lbs.	Removal Efficiency, %
0.25	26.81	26.32	98.20
0.50	29.38	26.61	90.60
0.75	28.28	21.04	74.40
1.00	29.69	21.49	72.40
1.25	29.29	20.80	71.00
1.50	30.03	20.70	68.90
1.75	30.04	20.47	68.10

[1] Standard Deviation
[2] Coefficient of Variation = Standard Deviation / Mean x 100
[3] % Relative Error = (Measured Mean - Target) / Target x 100

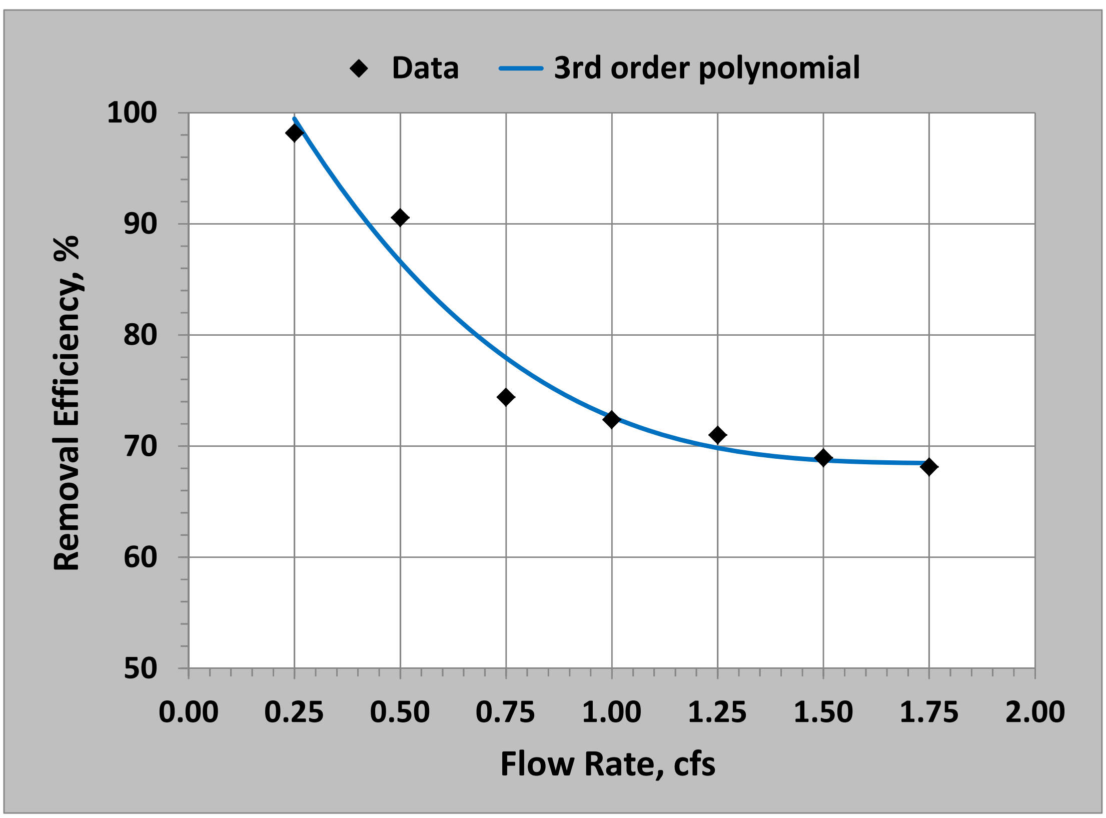


Figure 10 Removal Efficiency versus Flow Rate

Flow-Weighted Removal Efficiency The NJDEP protocol establishes the Maximum Treatment Flow Rate (MTFR) as a flow weighted removal efficiency, with weighing factors 0.25, 0.30, 0.20, 0.15 and 0.10 for flow rates of 25, 50, 75, 100 and 125% of MTFR, respectively. To derive MTFR for the NSBB 3-6-72, a continuous function was developed of the weighted removal efficiency versus flow rate. The weighted removal efficiency function was based on the third order polynomial describing removal efficiency as a function of single flow rate presented in Figure 10. For any flow rate, the removal efficiencies at the 25, 50, 75, 100 and 125% flow rates were calculated and the NJDEP weighing factors were applied. Weighted removal efficiencies are shown in Figure 11. With increasing flow rate (Figure 11, X axis), the flow weighted removal efficiency decreases (Figure 11, Y axis). The permissible flow range of the weighted removal efficiency calculation is 1.00 to 1.40 cfs and is constrained by the range of flow rates used in the removal efficiency experiments (Figure 11). Calculations of the flow weighted removal efficiency for 1.00 and 1.30 cfs are shown in Table 8.

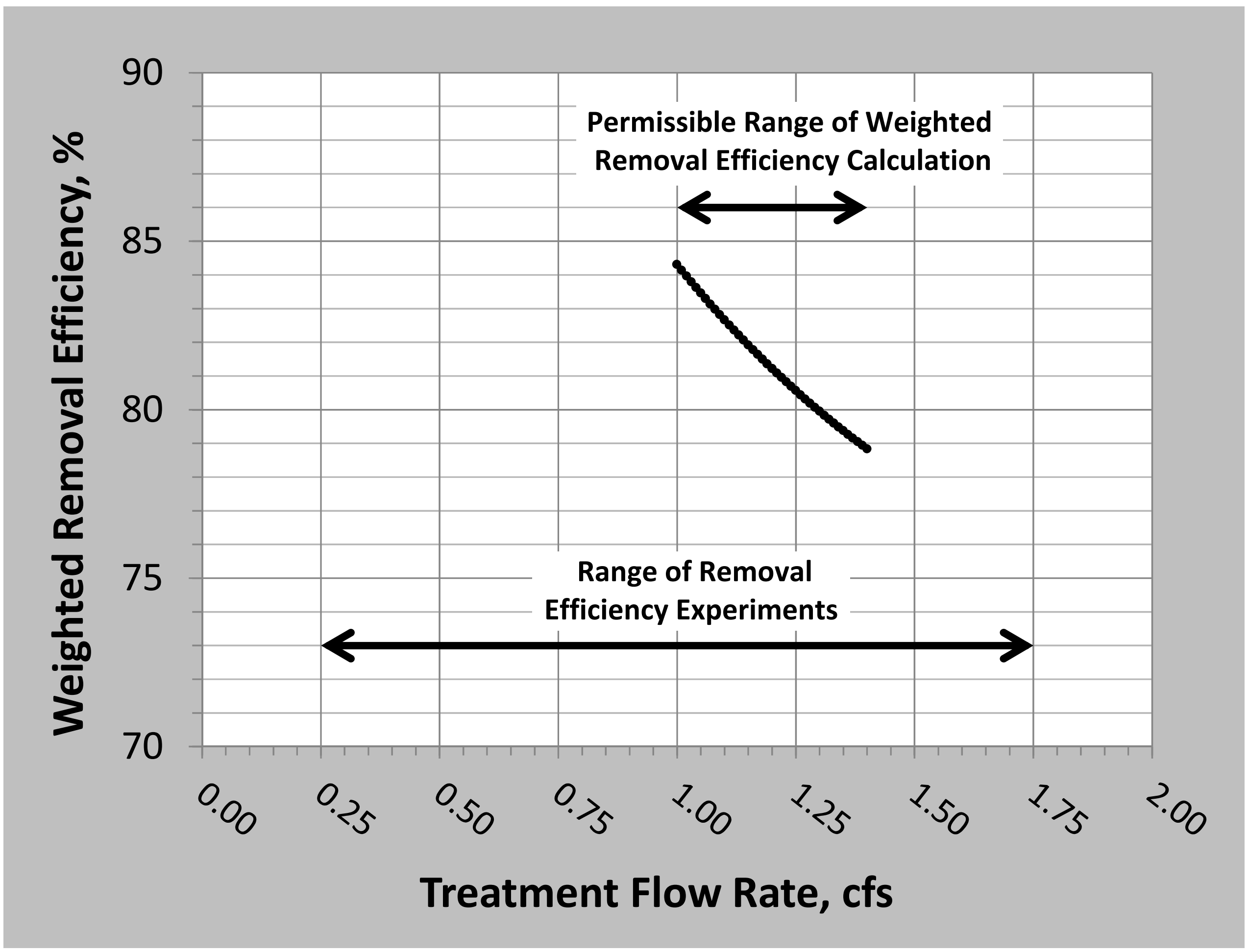


Figure 11 Flow Weighted Removal Efficiencies

Table 8 Flow Weighted Removal Efficiency Calculations

Maximum Treatment Flow Rate, cfs		% of Maximum Treatment Flow Rate					Flow Weighted Removal Efficiency, %
		25%	50%	75%	100%	125%	
1.00	Flow Rate, cfs	0.250	0.500	0.750	1.000	1.250	84.3
	Removal Efficiency, %	99.4	86.6	77.9	72.6	69.8	
1.30	Flow Rate, cfs	0.325	0.650	0.975	1.300	1.625	80.0
	Removal Efficiency, %	95.1	81.0	73.0	69.5	68.6	

Maximum Treatment Flow Rate (MTFR) A target weighted removal efficiency of 80% was established as the basis of the performance claim for NSBB 3-6-72. For 80% SSC removal of 100 μm sediment by NSBB 3-6-72, a Maximum Treatment Flow Rate of 1.30 cfs was derived as illustrated in Figure 12.

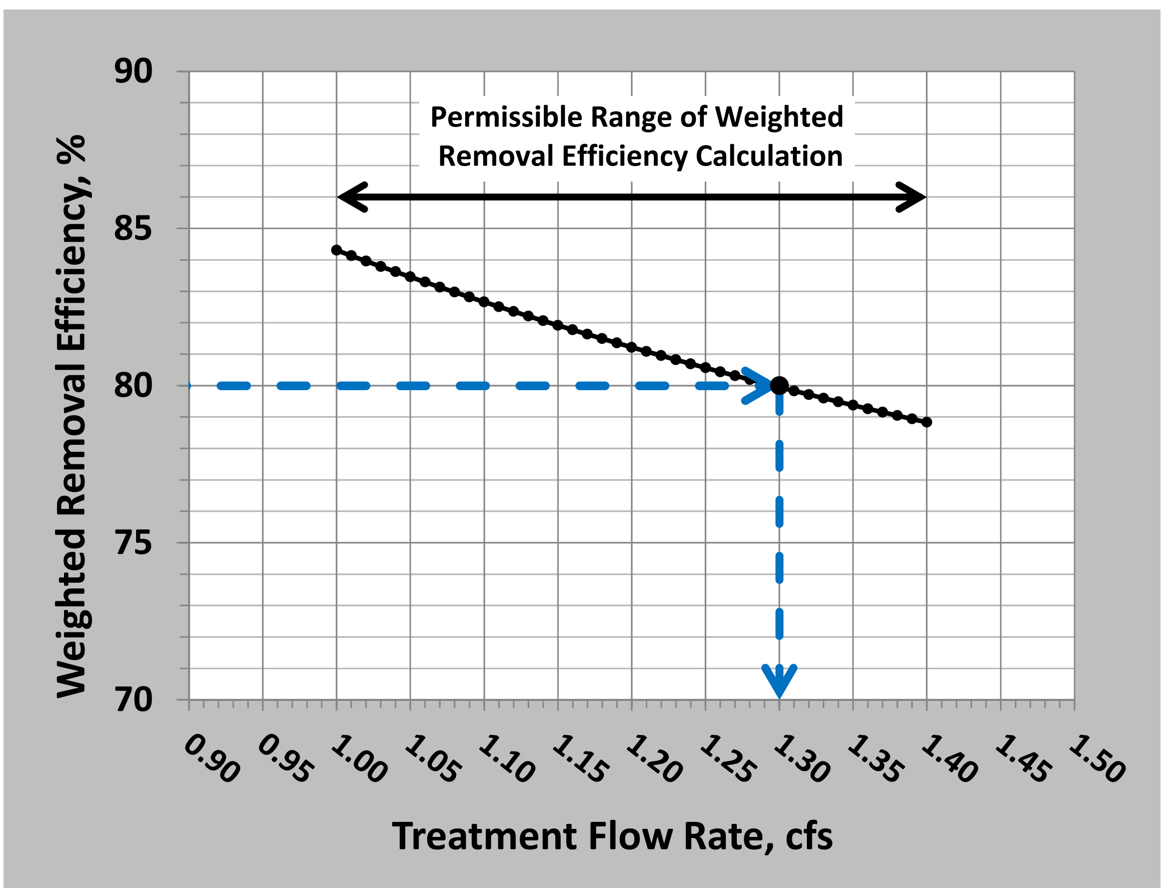


Figure 12 Maximum Treatment Flow Rate Determination

CONDUCT OF RESUSPENSION EXPERIMENT

The resuspension experiment followed a testing protocol that was iteratively developed to implement the NJDEP testing requirements.

Comparison of NSBB and NJDEP Resuspension PSDs The NSBB resuspension experiment was conducted using the same sediment that was employed in the removal efficiency tests. The NSBB resuspension sediment had a relatively narrow PSD centered on 100 μm and was finer than the NJDEP protocol resuspension sediment. The PSDs of the NSBB resuspension test and NJDEP resuspension protocol are compared in Figure 14. The NSBB resuspension test provided a more rigourous resuspension evaluation than if the NJDEP protocol sediment had been used.

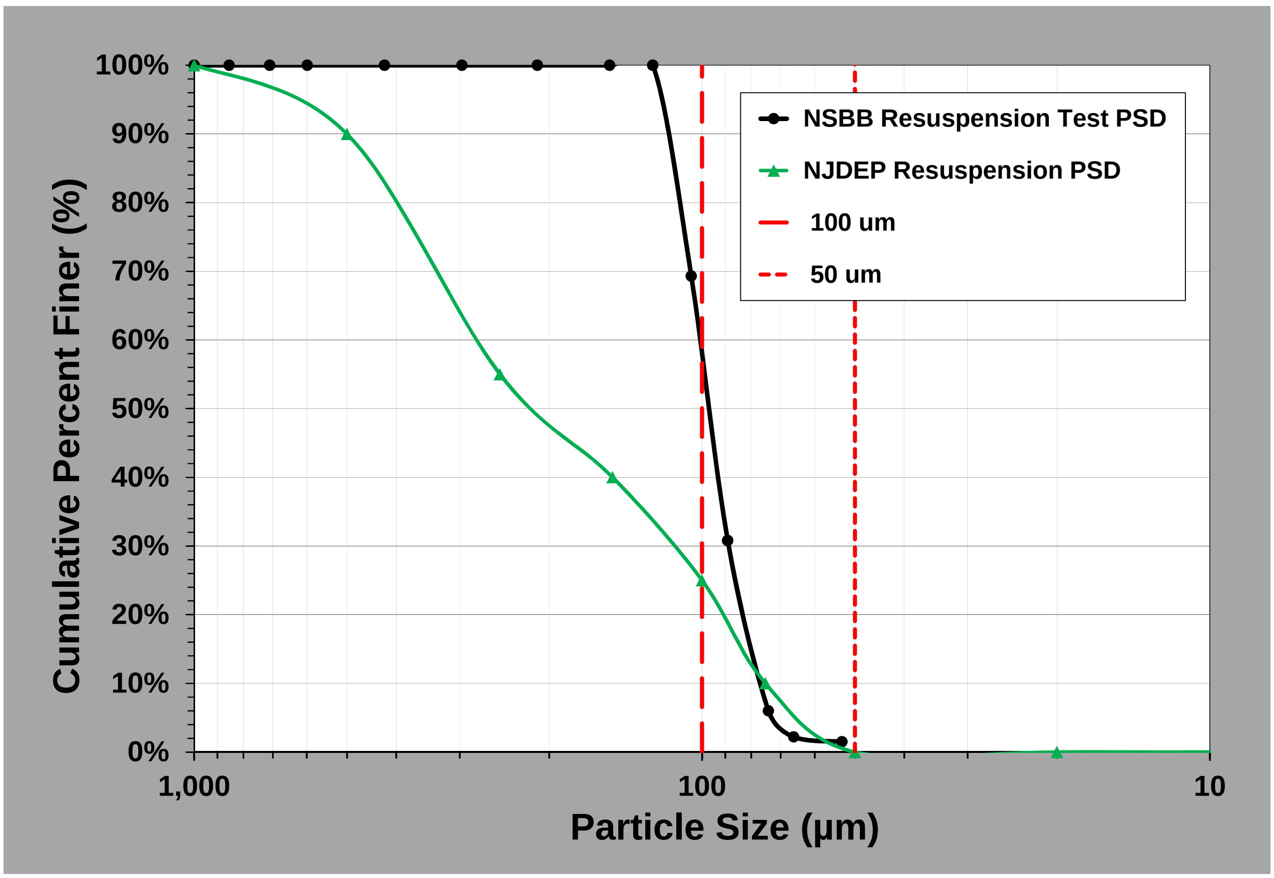


Figure 13 Comparison of PSD used in Resuspension Experiment with NJDEP PSD

Sediment Pre-Loading Test sediment was preloaded into each NSBB chamber to a uniform six inch depth on 1 4 2013. Sediment was added from sealed containers and water added to a level just above the sediment surface. Stirring and releveling of sand was conducted to insure absence of air from the system. The resuspenison test was conducted in 1 8 2013. Water was pumped slowly to fill the NSBB to the top of the baffles.

Water Temperature Water temperature was verified to be less than 80F just before the initiation of the experiment using a NIST traceable thermometer (Traceable Calibration Control Company 281-482-1714).

Field Data Sheets Field data sheets were prepared for temperature monitoring, flow rate target and monitoring, , total experimental time at target flow rate, background suspended sediment concentration sample collection times, effluent suspended sediment concentration sample collection times, Suspended Sediment Concentration (SSC) laboratory analysis, and laboratory blank and laboratory control samples for SSC analysis. Data sheets specified and recorded the times of all sample events of other observations.

Sample Containers Samples containers were prepared for at least eight background influent SSC samples and fifteen effluent SSC samples. All containers has sealable tops. SSC containers with one half gallon PETE canisters with round 4 in. diameter open mouths. SSC containers and tops were rinsed at least three times with tap water and drained. SSC containers were numbered and deployed in increasing number with experimental time.

Flow Initiation and Control The pump and flow control valve were pre-set to achieve the target resuspension flow rate of 2.70 cfs (i.e. 208% of MTFR). When all experimental preparations were completed, the pump was started at the pre-settings. The flow meter was then powered on and allowed to electronically stablilize. When flow readings could be discerned, a the zero time was stamped, and checking of flow rate and adjustment of flow rate with the flow control valve were initiated. Flow rate adjustments were made as needed through out the experiments using the flow rate control valve. Flow rate was recorded on data sheets at 1 minute intervals throughout the experiment. The target 2.70 cfs flow rate was reached within 4 minutes of pump startup and maintained at that flow rate for the remaining 30 minutes of the test. Background influent and NSBB effluent samples were collected though the 30 minute constant flow rate period.

Background Influent Sampling Backgound influent samples were collected at intervals spaced through the 30 min. resuspension test time. The sample location was in the sediment screening chamber, just in front of the entrance to the discharge pipe. Backgound influent sampling was conducted by opening the cover in the top of the Screening Chamber; loosening but not removing the threaded cap on the cannister; immersing the container with the opening facing directly into the direction of water flow with the centerline of the opening ca. 6 in. below the surface of the water; removing the cap for a short time to allow water ingress; placing the cap over the opening,; quickly removing the cannister from the water while simultaneously turning the cannister so the the opening was facing upward; and screwing the top closed.

Effluent Sampling Effluent samples were collected at intervals spaced through the 30 min. resuspension test time. Samples were collected though a slot in the top of the pipe connecting the NSBB to the Water Supply Reservoir at ca. 4 ft. downstream of the NSBB exit. Sampling was conducted by loosening but not removing the threaded cap on the cannister; immersing the container with the opening facing directly into the direction of water flow with the centerline of the opening ca. 4 in. below the surface of the water; removing the cap for a short time to allow water ingress; placing the cap over the opening,; quickly removing the cannister from the water while simultaneously turning the cannister so the the opening was facing upward; and screwing the top closed.

Analytical and Quality Assurance Procedures The Method Blank for the resuspension test analysis event was within the established Reporting Limit of 2.07 mg/L (Table E-3, App. E). Recovery of the Lab Control Sample for the resuspension test analysis event was 103.3%, and was within the established tolerance of 15% (Table E-6, App. E).

Data Management Data sheets were assembled and a complete file maintained at AET for each experiment. All data was placed in electronic format by entering into Excel spreadsheets which are maintained at several locations.

RESUSPENSION EXPERIMENT RESULTS

This section summarizes measured temperature, flow rate, background and effluent sediment concentrations in the resuspension experiment, and compares the data sets for background and effluent SSC to each other and to the NJDEP criteria for on-line installation of 20 mg/L SSC. Full results of the removal efficiency experiments are presented in Appendix F.

Water Temperature The water temperature just prior to the start of the resuspension experiment was less than 80F and remained less than 80F during testing.

Flow Rate Measured and target flow rates are plotted in Figure 14 and summarized in Table 9. Mean flow rate was within 1% of target flow rate, which was well within the ±10% the NJDEP-permitted tolerance (Figure 14), with a coefficient of variation of less than 0.01.

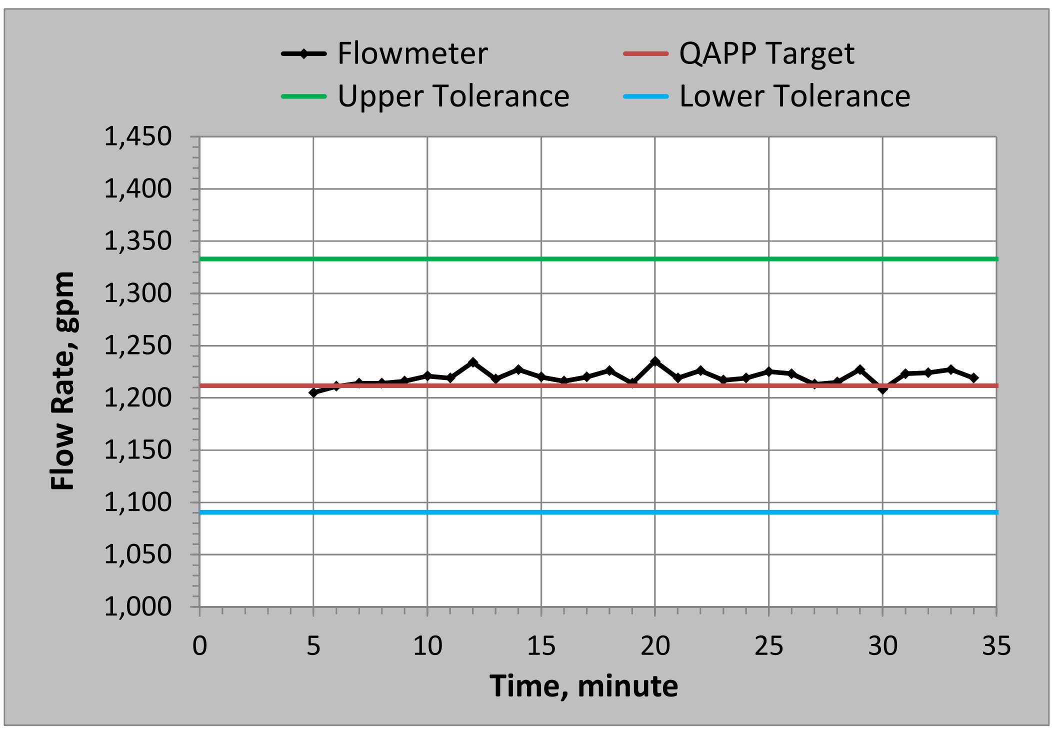


Figure 14 Flow Rate in Resuspension Experiment

Table 9 Measured Flow Rates in Resuspension Experiment

Target Flow Rate		Measured Flow Rate				
cfs	gpm	Mean, gpm	SD, gpm[1]	CV[2]	% RE[3]	Median, gpm
2.70	1,211.8	1,219.8	6.90	0.006	0.67	1,219.0

[1] Standard Deviation
[2] Coefficient of Variation = Standard Deviation / Mean x 100
[3] % Relative Error = (Measured Mean - Target) / Target x 100

Background and Effluent Suspended Sediment Concentrations The SSC concentrations in the resusopension experiment are plotted in Figure 15 and listed in Table 10.

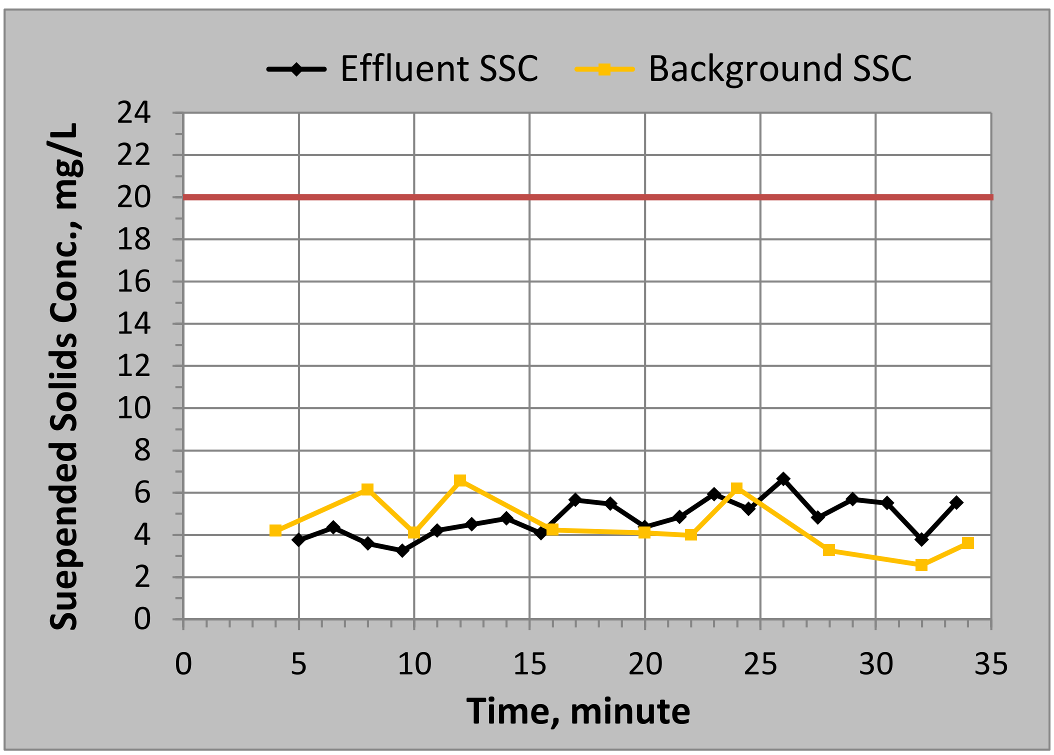


Figure 15 Suspended Sediment Concentrations in Resuspension Test

Table 10 Suspended Sediment Concentrations in Resuspension Experiment

Sample	Measured Suspended Sediment Concentration/ mg/L				
	Mean	SD[1]	CV[2]	Median	Maximum
Background (Influent)	4.44	1.3	0.290	4.10	6.56
Effluent	4.79	0.9	0.187	4.79	6.64

[1] Standard Deviation
[2] Coefficient of Variation = Standard Deviation / Mean x 100

Mean SSC in NSBB effluent was 4.79 mg/L and ranged from 3.2 to 6.6 mg/L. Mean background SSC in NSBB influent was 4.44 mg/L and ranged from 2.6 to 6.6 mg/L. Statistical analysis indicated that the effluent SSC data set (n = 20) and the influent SSC data set (n = 11) were both normally distributed (Shapiro-Wilk test) and passed an equal variance test (Figure 16). A t-test (95% confidence level for difference of means) indicated that the difference in the mean values of influent and effluent data was not great enough to reject the possibility that the difference was due to random sampling variability. There was not a statistically significant difference between the influent and effluent SSC data sets. All SSC values in NSBB effluent were well below 20 mg/L. The NSBB 3-6-72 fully met the NJDEP resuspension criteria for on-line installation at 1.30 cfs Maximum Treatment Flow Rate. The sediment used in the NSBB resuspension tests was much finer than that specified in the NJDEP resuspension protocol (i.e. d_{50} of 98 versus 216 μm) and provided a more rigorous resuspension test than the NJDEP protocol. Therefore, the results of the NSBB resuspension test confirm that the NSBB meets the NJDEP protocol criteria for on-line installation. The NJDEP protocol includes a procedure to correct effluent SSC for

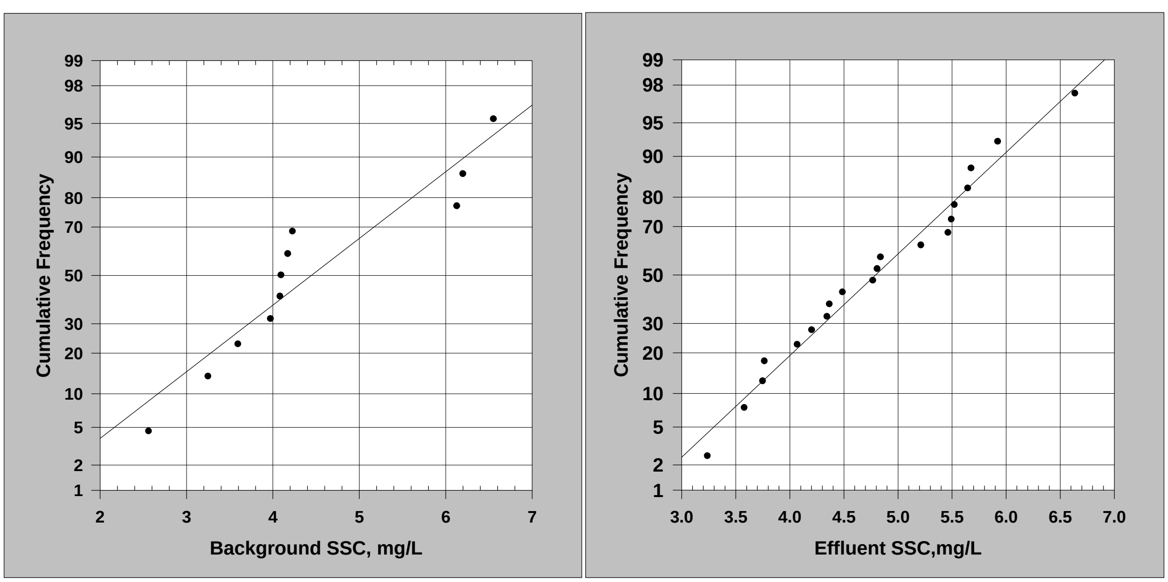


Figure 16 Resuspension SSC Normal Probability Plots

background levels by creating a curve of the background SSC and subtracting each effluent SSC for background at the time of sampling. Application of this technique resulted in a high percentage of negative values for background-corrected effluent SSC and was considered to be not appropriate.

SURFACE OVERFLOW RATE SCALING

The Nutrient Separating Baffle Box® (NSBB) is supplied in a range of models and sizes. The Maximum Treatment Flow Rate (MTFR) of NSBB models were derived by constant surface overflow rate scaling. Surface overflow rate is widely used for comparative performance assessment of hydrodynamic stormwater treatment devices, and equals the applied flow rate per surface area available for sedimentation. The basis for scaling was the 1.30 cfs MTFR of the NSBB 3-6-72 that was developed in this report. Dimensions of NSBB models and their scaled MTFR are listed in Table 11.

Table 11 Maximum Treatment Flow Rate of NSBB® Models*

NSBB Model #	Inside Width, ft.	Inside Length, ft.	Baffle Height, in.	Sedimentation Area, ft^2	Maximum Treatment Flow Rate, cfs
2-4-60	2	4	24	8.0	0.58
3-6-72	3	6	36	18.0	1.30
4-8-84	4	8	36	32.0	2.31
5-10-84	5	10	36	50.0	3.61
6-12-84	6	12	36	72.0	5.20
8-12-84	8	12	36	96.0	6.93
8-14-100	8	14	40	112	8.09
10-14-100	10	14	40	140	10.1
10-16-125	10	16	46	160	11.6
10-20-125	10	20	48	200	14.4
12-20-132	12	20	48	240	17.3
12-24-132	12	24	60	288	20.8

*80% SSC Removal Efficiency

SUMMARY

A full-scale Nutrient Separation Baffle Box® Model 3-6-72 was experimentally evaluated using removal efficiency and resuspension protocols published by the New Jersey Department of Environmental Protection (NJDEP) and endorsed by the Stormwater Equipment Manufacturer's Association (SWEMA). Experiments employed a relatively narrow particle size distribution (PSD) centered on 100 μm, in lieu of the broader NJDEP PSD. Seven removal efficiency experiments were conducted at flow rates ranging from 0.25 to 1.75 cubic feet per second (cfs), each at influent Suspended Sediment Concentration (SSC) of 200 mg/L. SSC removal efficiencies ranged from 68.1 to 98.2 percent and progressively increased as flow rate decreased. A Maximum Treatment Flow Rate (MTFR) of 1.30 cfs was derived for 80% SSC removal by the NSBB 3-6-72, based on the NJDEP weighted removal efficiency procedure. In a resuspension experiment conducted at 208% of MTFR (2.70 cfs), sediment resuspension was not significant; the mean SSC in NSBB discharge was only 0.35 mg/L greater than the mean influent SSC. The maximum SSC in NSBB discharge (6.6 mg/L) was well below the limit of 20 mg/L that is allowed by NJDEP for on-line installation. The Maximum Treatment Flow Rates of fourteen NSBB models were determined by applying constant surface overflow rate scaling to the Maximum Treatment Flow Rate of Model 3-6-72 that was determined in this study.

REFERENCES

1 Smith, D. (2009) A New Approach to Evaluating Pollutant Removal by Storm Water Treatment Devices, Journal of Environmental Engineering, Volume 136, 4, 371-380.

2 New Jersey Department of Environmental Protection (2013) New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device, January 25, 2013.

3 Stormwater Equipment Manufacturer's Association (2012). Protocol for Manufactured Treatment Devices that Utilize Sedimentation for Total Suspended Solids Removal. Submitted to New Jersey Department of Environmental Protection and New Jersey Corporation for Advanced Technology, February 7, 2012.

4 Suntree Technologies Inc.® (2012) *http://www.suntreetech.com/Products/Nutrient+Separating+Baffle+Box/default.aspx*

5 Wilson, M., Mohseni, O. , Gulliver, J., Hozalski, R. and Stefan, H. (2009) Assessment of Hydrodynamic Separators for Storm-Water Treatment. J. Hydraulic Engineering, 135, 5, 383.

6 Prandit and Gopalakrishnan (1996) Physical Modeling of a Stormwater Sediment Removal Box Final Report submitted to Brevard County, Florida and the National Estuary Program, Civil Engineering Program, Florida Institute of Technology, Melbourne, FL, June 1996.

7 Fluid Mechanics With Engineering Applications 9th Edition, Franzini and Finnemore, WCB/McGraw Hill, New York.

8 Smith, D. (2012) Nutrient Separating Baffle Box: SWEMA Hydrodynamic Protocol Evaluation with 100 μm Sediment Particles Quality Assurance Project Plan, July 11, 2012.

9 American Society for Testing and Materials (2007) Standard Test Method for Particle Size Analysis of Soils. ASTM D 422-63 (Reapproved 2007). ASTM, Philadelphia, PA.

10 American Society for Testing and Materials (2007) Standard Test Methods for Determining Sediment Concentrations in Water Samples. D3977-97 (Reapproved 2007), ASTM, Philadelphia, PA.

APPENDIX A

Nutrient Separating Baffle Box® No. 3-6-72

SUNTREE TECHNOLOGIES INC.® NUTRIENT SEPARATING BAFFLE BOX®
MODEL NO: NSBB-3-6-72

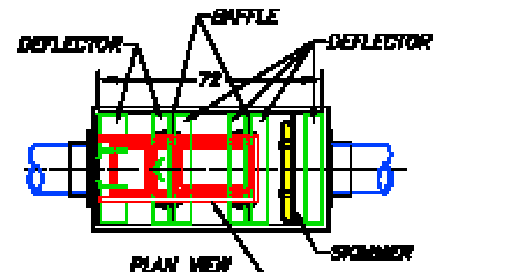
FLOW & BY-PASS SPECIFICATIONS FOR THE BIOMASS SEPARATING SCREEN SYSTEM, SEDIMENT STORAGE, AND SKIMMER SPECIFICATIONS.

1. Inflow Pipe Area (15" PVC AS SHOWN) ——— 1.33 sq.ft.

SCREEN SPECIFICATIONS:
2. Open orifice area in screen system ——— 5.10 sq.ft.
3. Open orifice area in screen system with 50% blockage ——— 4.5 sq.ft.
4. Open orifice area in screen system with 75% blockage ——— 2.58 sq.ft.
5. By-pass through screen system below the ceiling of the pipe. ——— 1.83 sq.ft.
6. Minimum by-pass around screen system below the ceiling of the pipe. ——— 1.88 sq.ft.
7. Screen system storage volume ——— 8.5 cu.ft.

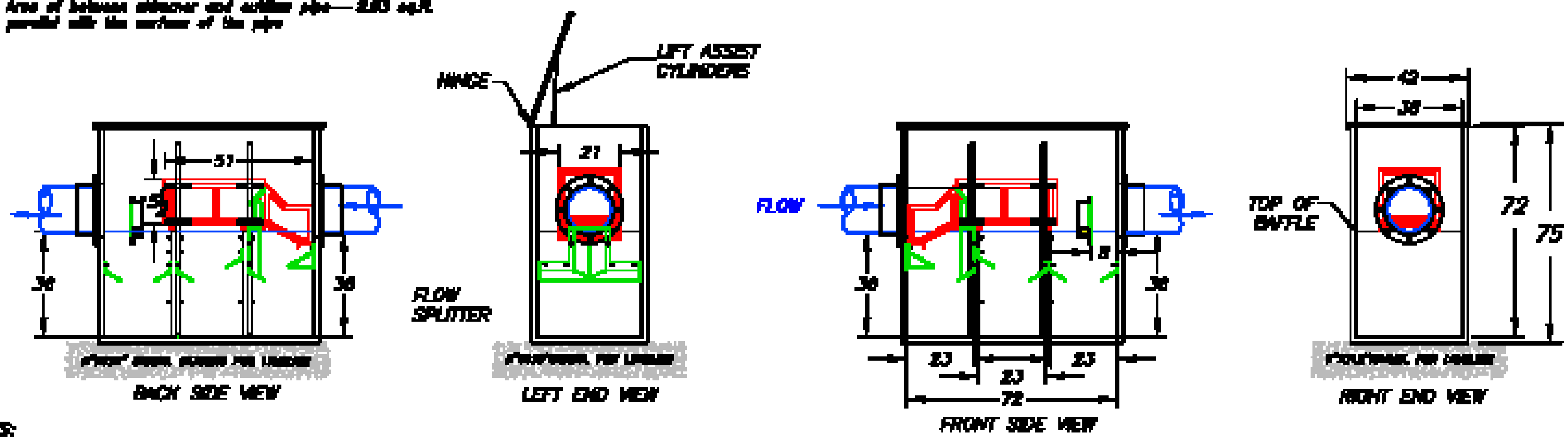
SEDIMENT STORAGE:
8. Volume of first chamber ——— 18.00 cu.ft.
9. Volume of second chamber ——— 18.50 cu.ft.
10. Volume of third chamber ——— 16.00 cu.ft.
11. Volume of total sediment storage ——— 52.50 cu.ft.

SKIMMER SPECIFICATIONS:
12. Flow area under skimmer ——— 2.65 sq.ft.
13. Area of pipe in line with skimmer ——— 1.88 sq.ft.
14. Area of between skimmer and outflow pipe parallel with the surface of the pipe ——— 2.83 sq.ft.



PATENTED
AND PATENTS PENDING

INSTALLATION NOTES:
1. INFLOW AND OUTFLOW PIPES ARE TO BE FLUSH WITH THE INSIDE SURFACE OF THE CONCRETE STRUCTURE. (CAN NOT INTRUDE BEYOND FLUSH)
2. INVERT OF OUTFLOW PIPE SHOULD BE EVEN WITH THE TOP OF THE BAFFLES.
4. THE BOTTOM OF THE SKIMMER SHOULD BE 4" BELOW THE INVERT OF THE OUTFLOW PIPE.
5. INVERT OF THE INFLOW PIPE SHOULD BE BELOW THE INVERT OF THE OUTFLOW PIPE.



FRONT VIEW

NOTES:

1. VAULT SUPPORTS PEDESTRIAN LOADING.
2. ALL WALLS, TOP, AND BOTTOM ARE LAMINATED FIBERGLASS WITH PVC STRUCTURAL FOAM CORE.
3. INFLOW AND OUTFLOW PIPES ARE TO BE FLUSH WITH THE INSIDE SURFACE OF THE VAULT. PIPES CAN NOT INTRUDE INTO THE VAULT.
4. TOP OF VAULT TO BE HINGED WITH STAINLESS STEEL PIANO HINGE ALONG ONE LONG SIDE OF THE VAULT.
5. LIFT SUPPORT CYLINDER TO INCORPORATED TO HELP WITH HOLDING UP THE TOP COVER OF THE VAULT.
6. PYLON AND PIVOTING PANEL TO BE INCORPORATED AS SHOWN INTO THE BODY OF THE SCREEN SYSTEM.
7. TURBULENCE DEFLECTORS TO BE INCORPORATED AS SHOW TO REDUCE TURBULENCE INSIDE SETTLING CHAMBERS.
8. RECOMMENDED PIPE SIZE TO RANGE FROM 12" TO 18".

SUNTREE TECHNOLOGIES, INC. 798 CLEARLAKE RD. SUITE #2 COCOA, FL 32922		2-01-31-13-01
NUTRIENT SEPARATING BAFFLE BOX® MODEL NO: NSBB-3-6-72		NSBB-3-6-72
DATE: 05/25/05	SCALE: = 57.6	
DRAFTER: T.H.H.	UNITS =INCHES	

APPENDIX B

PARTICLE SIZE DISTRIBUTION ANALYSIS

Particle Size Distribution Analyses
ASTM D 422-63

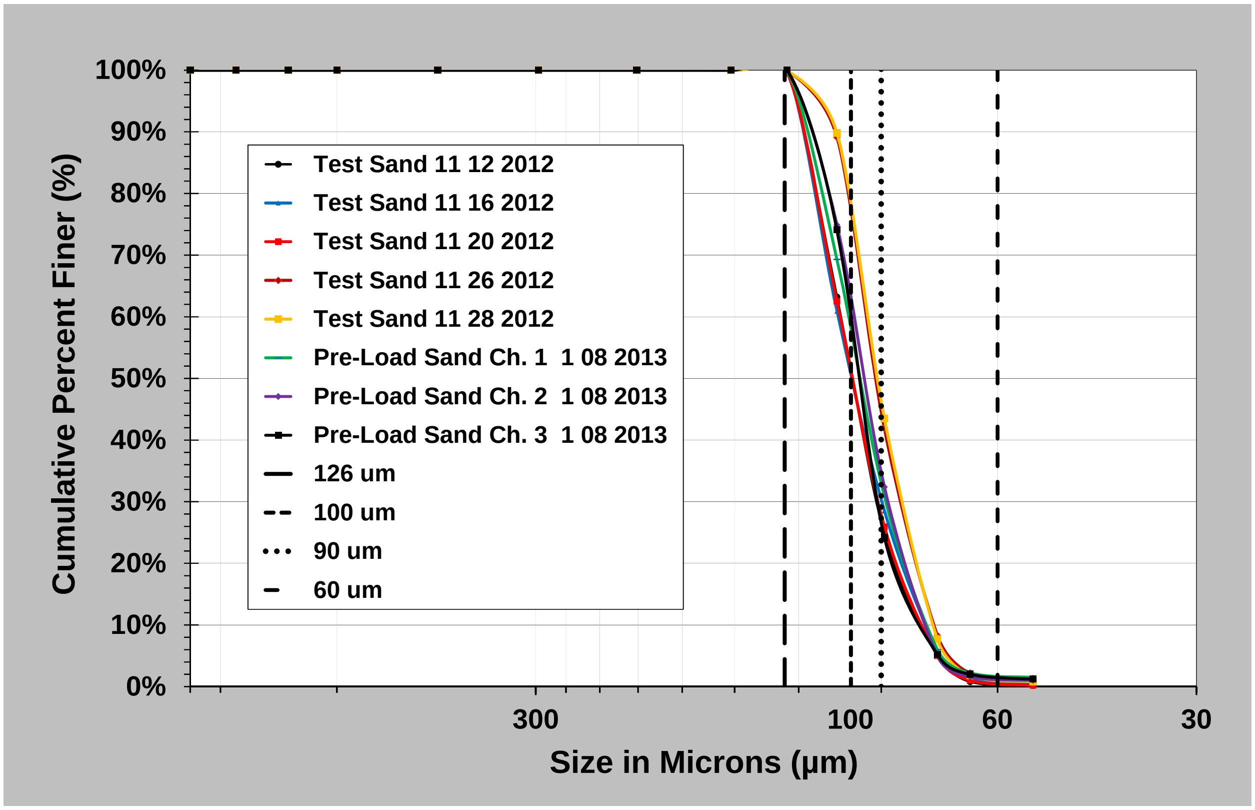
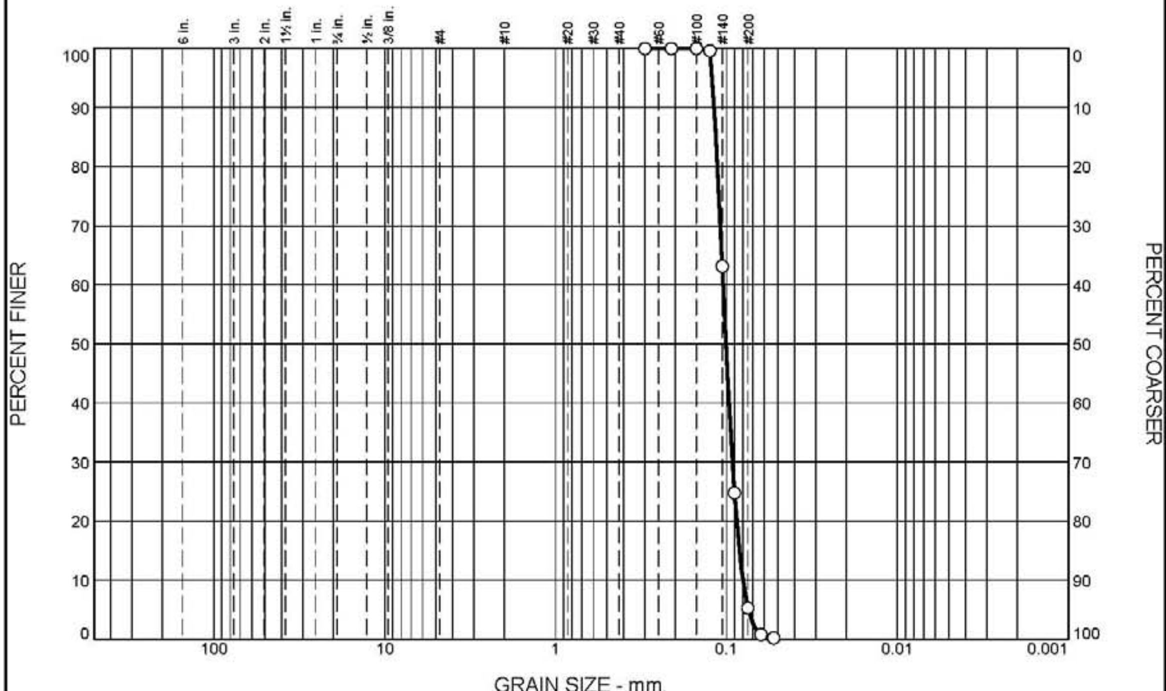


Figure B-1 Particle Size Distributions of Eight Test Sediment Samples

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	94.7	5.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	99.6		
#140	63.2		
#170	24.8		
#200	5.3		
#230	0.8		
#270	0.2		

* (no specification provided)

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.1179 D_{85}= 0.1153 D_{60}= 0.1048
D_{50}= 0.1008 D_{30}= 0.0925 D_{15}= 0.0843
D_{10}= 0.0803 C_u= 1.30 C_c= 1.02

Classification

USCS= AASHTO=

Remarks

Location: Baffle Box

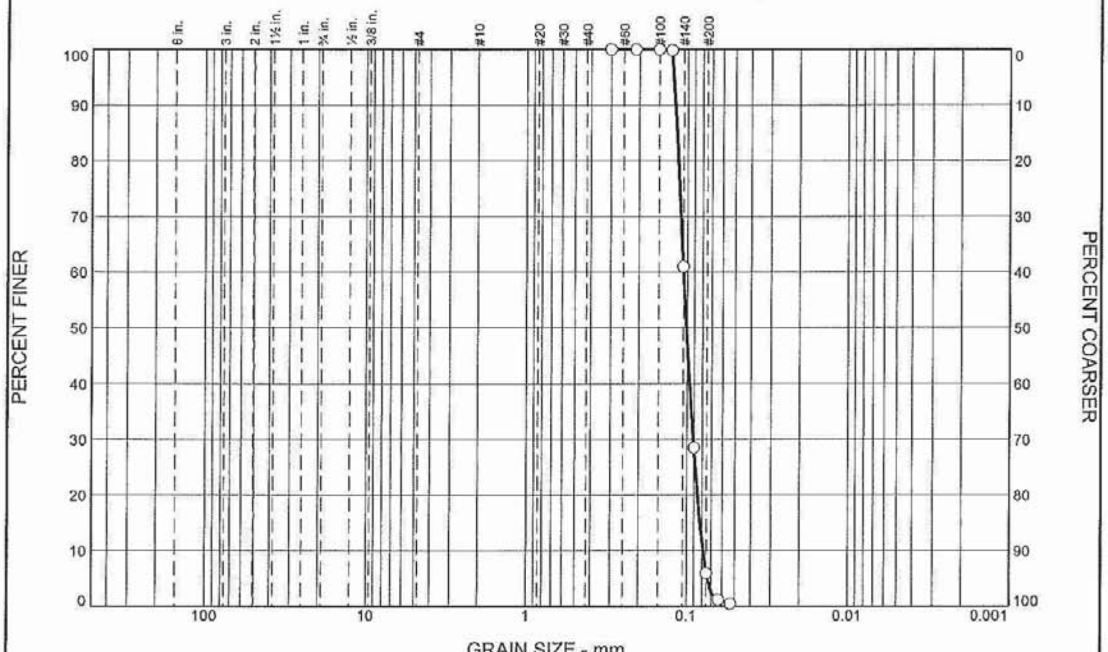
Date: 11/20/2012

BTL Engineering, Inc. **Tampa, FL**	**Client:** Applied Enviromental Technologies **Project:** Nutrients Separating Baffle Box **Project No:** 5241-12-1062 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-2 11/12/2012 Test Sediment PSD

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	94.1	5.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	99.9		
#140	60.9		
#170	28.5		
#200	5.9		
#230	1.2		
#270	0.4		

* (no specification provided)

Soil Description

Very Pale Brown Very Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1185 D_{85}= 0.1161 D_{60}= 0.1056
D_{50}= 0.1012 D_{30}= 0.0908 D_{15}= 0.0820
D_{10}= 0.0786 C_u= 1.34 C_c= 0.99

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Location: PSD2
Sample Number: 1085

Date: 11/26/2012

BTL Engineering, Inc.

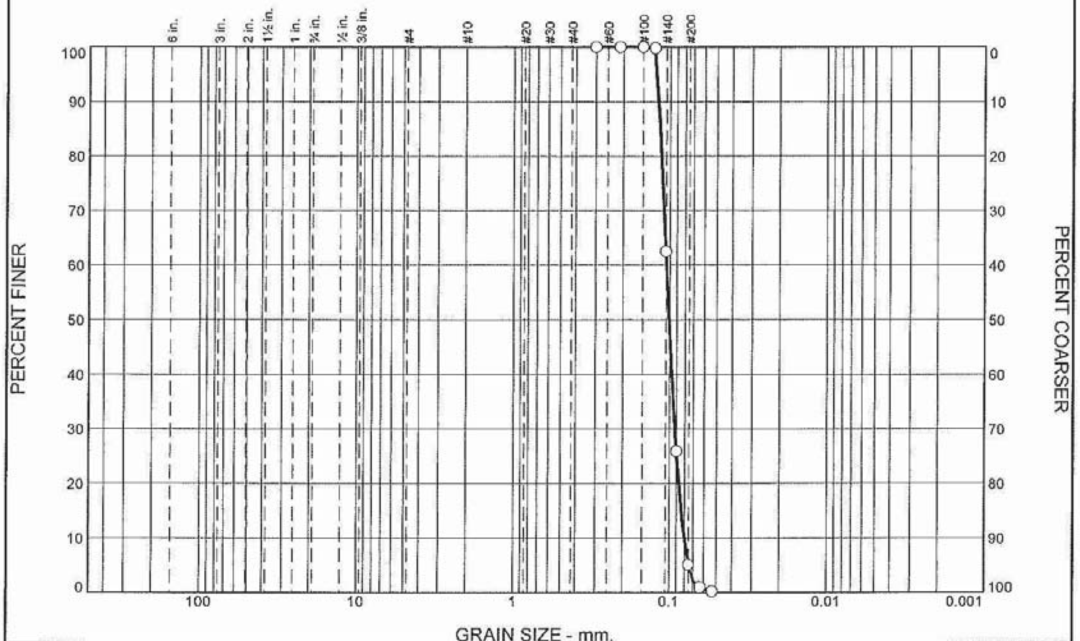
Tampa, FL

Client: Applied Environmental Technologies
Project: Nutrients Separating Baffle Box
Project No: 5241-12
Figure

Tested By: T. Hannum **Checked By:** S. West

Figure B-3 11/16/2012 Test Sediment PSD

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	95.0	5.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	99.8		
#140	62.5		
#170	25.9		
#200	5.0		
#230	1.0		
#270	0.2		

* (no specification provided)

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1181 D_{85}= 0.1155 D_{60}= 0.1050
D_{50}= 0.1009 D_{30}= 0.0920 D_{15}= 0.0837
D_{10}= 0.0800 C_u= 1.31 C_c= 1.01

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Location: PSD3
Sample Number: 1084

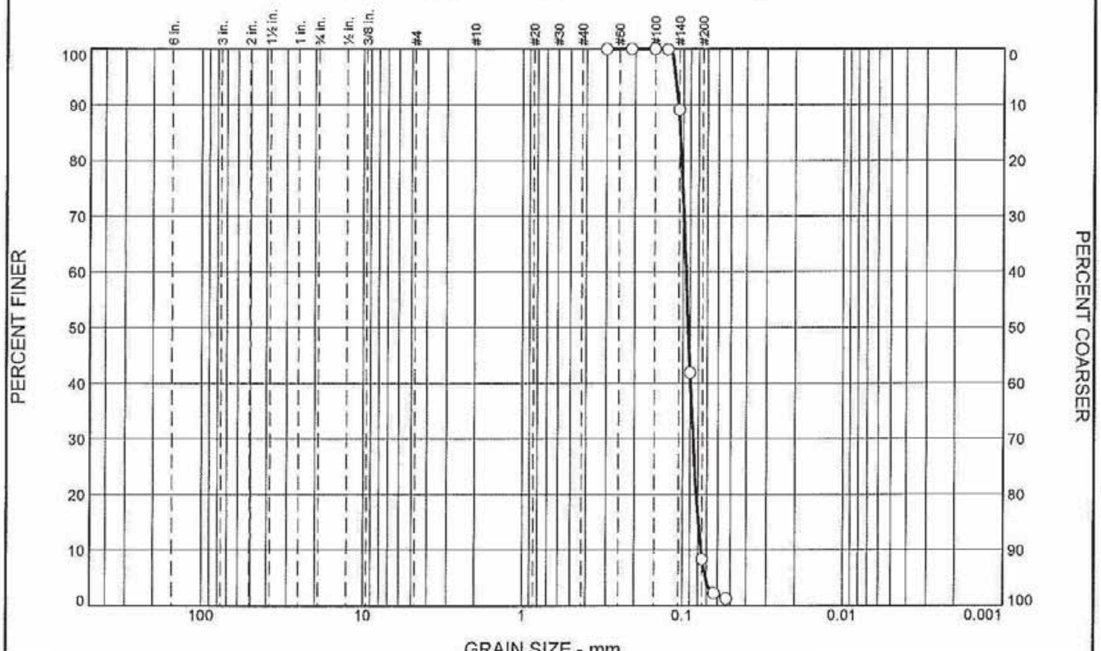
Date: 11/26/2012

BTL Engineering, Inc.	**Client:** Applied Enviromental Technologies
	Project: Nutrients Separating Baffle Box
Tampa, FL	**Project No:** 5241-12 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-4 11/20/2012 Test Sediment PSD

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	91.7	8.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	99.9		
#140	89.1		
#170	41.9		
#200	8.3		
#230	2.2		
#270	1.3		

* (no specification provided)

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1065 D_{85}= 0.1040 D_{60}= 0.0954
D_{50}= 0.0925 D_{30}= 0.0860 D_{15}= 0.0794
D_{10}= 0.0763 C_u= 1.25 C_c= 1.01

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Location: PSD-5
Sample Number: 1112-1

Date: 12/04/2012

BTL Engineering, Inc.

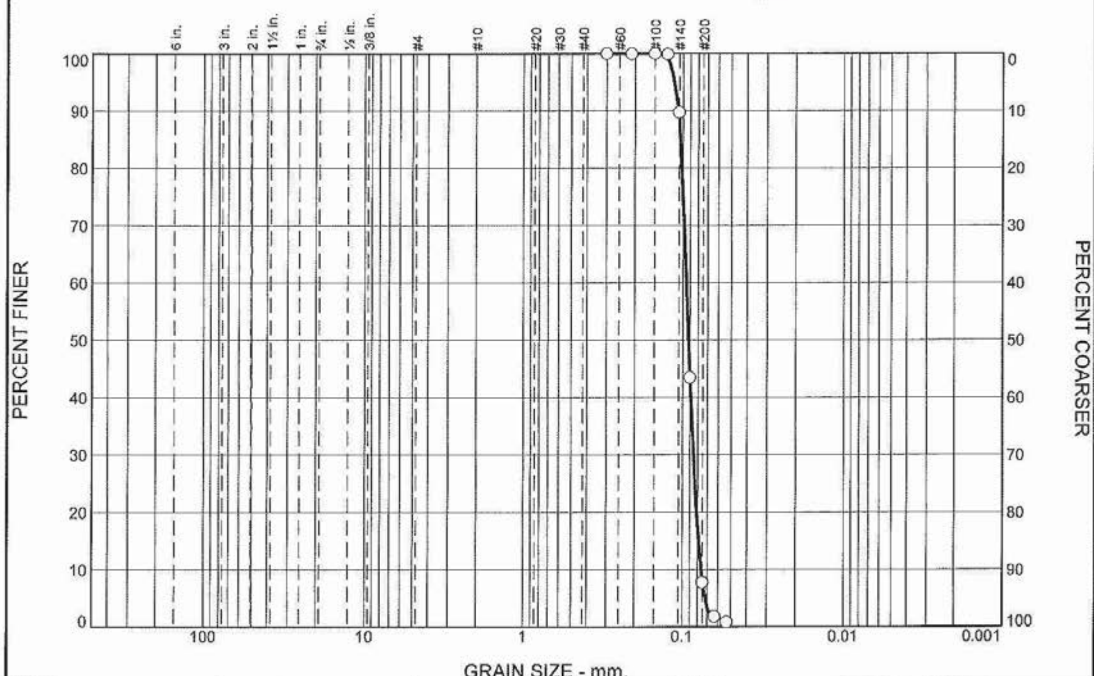
Tampa, FL

Client: Applied Enviromental Technologies
Project: Nutrients Separating Baffle Box
Project No: 5241-12 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-5 11/26/2012 Test Sediment PSD

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	92.3	7.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	99.9		
#140	89.8		
#170	43.5		
#200	7.7		
#230	1.8		
#270	0.8		

* (no specification provided)

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1062 D_{85}= 0.1036 D_{60}= 0.0950
D_{50}= 0.0920 D_{30}= 0.0855 D_{15}= 0.0793
D_{10}= 0.0766 C_u= 1.24 C_c= 1.01

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Location: PSD-7
Sample Number: 1112-3
Date: 12-4-2012

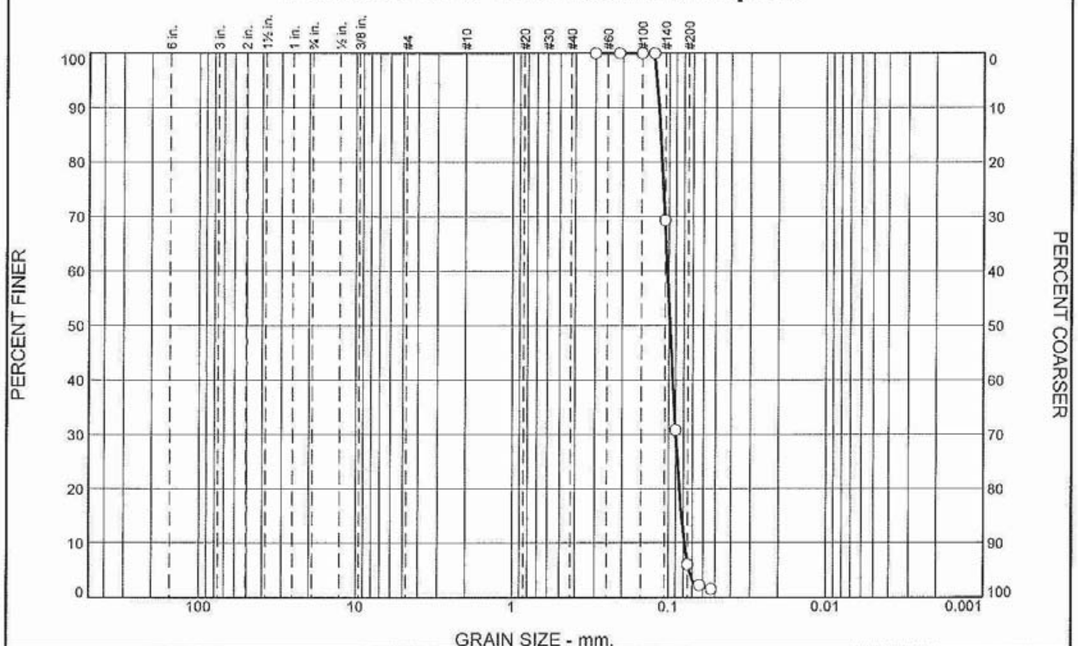
BTL Engineering, Inc.
Tampa, FL

Client: Applied Enviromental Technologies
Project: Nutrients Separating Baffle Box
Project No: 5241-12 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-6 11/28/2012 Test Sediment PSD

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	94.0	6.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	100.0		
#140	69.3		
#170	30.8		
#200	6.0		
#230	2.2		
#270	1.5		

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1164 D_{85}= 0.1135 D_{60}= 0.1020
D_{50}= 0.0980 D_{30}= 0.0896 D_{15}= 0.0820
D_{10}= 0.0786 C_u= 1.30 C_c= 1.00

Classification

USCS= SP-SM AASHTO= A-3

Remarks

* (no specification provided)

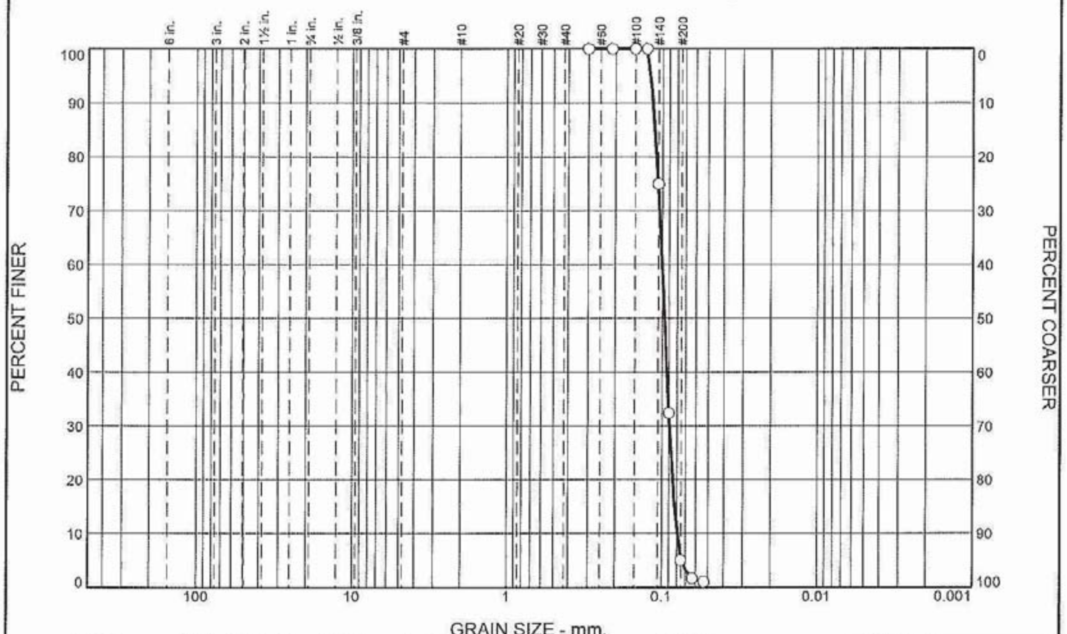
Location: A
Sample Number: 0014-1 **Date:** 1/09/2013

BTL Engineering, Inc. Tampa, FL	**Client:** Applied Enviromental Technologies **Project:** Baffle Box **Project No:** 5241-13 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-7 1/8/2013 Pre-Load Sediment PSD: Chamber 1

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	95.0	5.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	100.0		
#140	74.9		
#170	32.4		
#200	5.0		
#230	1.6		
#270	1.0		

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1144 D_{85}= 0.1111 D_{60}= 0.1000
D_{50}= 0.0964 D_{30}= 0.0891 D_{15}= 0.0822
D_{10}= 0.0792 C_u= 1.26 C_c= 1.00

Classification

USCS= SP-SM AASHTO= A-3

Remarks

* (no specification provided)

Location: B
Sample Number: 0014-2

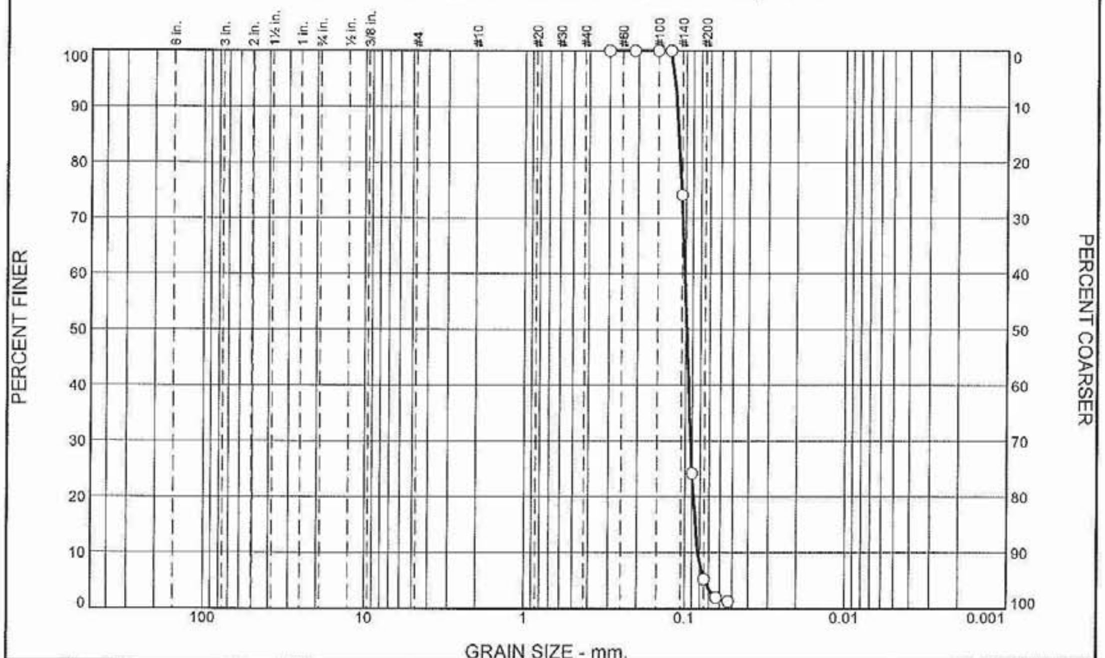
Date: 1/09/2013

BTL Engineering, Inc. Tampa, FL	**Client:** Applied Enviromental Technologies **Project:** Baffle Box **Project No:** 5241-13 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-8 1/8/2013 Pre-Load Sediment PSD: Chamber 2

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	0.0	94.8	5.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#50	100.0		
#70	100.0		
#100	100.0		
#120	100.0		
#140	74.1		
#170	24.2		
#200	5.2		
#230	2.0		
#270	1.3		

* (no specification provided)

Soil Description

Very Pale Brown Fine Sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{90}= 0.1140 D_{85}= 0.1110 D_{60}= 0.1012
D_{50}= 0.0982 D_{30}= 0.0921 D_{15}= 0.0857
D_{10}= 0.0821 C_u= 1.23 C_c= 1.02

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Location: C
Sample Number: 0014-3
Date: 1/09/2013

BTL Engineering, Inc.

Tampa, FL

Client: Applied Enviromental Technologies
Project: Baffle Box
Project No: 5241-13 **Figure**

Tested By: T. Hannum **Checked By:** S. West

Figure B-9 1/8/2013 Pre-Load Sediment PSD: Chamber 3

APPENDIX C

SEDIMENT RECOVERY EVALUATION

Sediment Recovery Evaluation
Nutrient Separating Baffle Box

9/28/12 to 9/30/12

Procedure

Baffle box model (NSBB 12x24X12 in.) with elevated false bottom 1st and 2nd chambers
NSBB was completely cleaned and free of sediment
Test sand was baked until there was no moisture and perfectly dry
Baffle box chambers were filled with water to top of baffles
1000 grams of test sand was wieghed and added to each chamber
Tare weights were measured for tray + filter
Sand was siphoned from the chambers individually and filtered and deposited in tray
Trays + filter were baked until the sand had no moisture and was perfectly dry
Weight of sand + tray + filter was measured
Sand removed from each chamber was calculated as mass of sand + tray + filter minus tare weight

Sediment Recovery Evaluation
Nutrient Separating Baffle Box

9/28/12 to 9/30/12

Results

Test	**1**
Date	**9/28/2011**

Baffle chamber	Mass tray + filter	Mass sand + tray + filter	Mass sand	Percent Recovery	Average Percent Recovery	Average Percent Loss
1	500.48	1,499.57	999.09	99.9090		
2	501.21	1,497.79	996.58	99.6580		
3	502.06	1,501.51	999.45	99.9450	99.8373	0.1627

Test	**2**
Date	**9/29/2011**

Baffle chamber	Mass tray + filter	Mass sand + tray + filter	Mass sand	Percent Recovery	Average Percent Recovery	Average Percent Loss
1	500.48	1,499.79	999.31	99.9310		
2	501.06	1,500.03	998.97	99.8970		
3	502.04	1,501.93	999.89	99.9890	99.9390	0.0610

Test	**3**
Date	**9/30/2011**

Baffle chamber	Mass tray + filter	Mass sand + tray + filter	Mass sand	Percent Recovery	Average Percent Recovery	Average Percent Loss
1	500.44	1,500.09	999.65	99.9650		
2	500.85	1,500.52	999.67	99.9670		
3	501.9	1,501.60	999.70	99.9700	99.9673	0.0327

Average Percent Recovery (3 tests)	Average Percent Loss (3 tests)
99.9	0.09

APPENDIX D

SUSPENDED SEDIMENT CONCENTRATION ANALYSIS PROTOCOL

Standard Operating Procedure

Analysis for Determining Suspended Sediment Concentration (SSC) in Water Samples

Purpose This Standard Operating Procedure (SOP) describes the procedures used to determine Suspended Sediment Concentration (SSC) as described in ASTM method D3977-97 B

Scope and Application

- This method is applicable to water samples collected from a Nutrient Separating Baffle Box (NSBB) for SWEMA/NJCAT evaluation
- The minimum reporting limit (RL) is 2.07 mg/L
- Water samples to be tested will have SSC generally in the range of 10 to 250 mg/L
- This SOP was prepared for method-compliant use by AET

Summary of Method:
A glass fiber filter is placed into an aluminum pan and dried to constant weight at 104^{o} C. A well-mixed sample of known volume is passed through the filter. The filter/pan and residue retained on the filter are dried to constant weight at 104^{o} C. The difference in weight (mass) is divided by the volume of the filtered sample to determine SSC.

Interferences

- Critical to this analyses are well mixing of the sample, preparation of the filter and filtration apparatus, rinsing of the sample container and filtration apparatus to capture all residual sediment, and drying time and temperature
- Only well characterized sand in a well characterized matrix will be present in test samples leading to relatively limited interferences

Safety

- It is mandatory to wear personal safety equipment while working with samples, glassware, and apparatus
- Sound judgment and good laboratory procedures are always recommended

Equipment and Supplies

- Glass fiber filter discs, 15.0 cm, without organic binder, Whatman type 934-AH
- Buchner funnel
- Filtration flask, 2000 mL
- Vacuum pump
- Drying oven, 103-105^{o}C
- Desiccator
- Analytical balance capable of weighing to 0.1 mg
- Graduated cylinders
- Aluminum pans
- Indelible marker, Sharpie or equivalent

Sample Collection, Preservation, and Handling

- Samples are collected in plastic containers and preserved and stored at >0 to 6^{o} C (32 to 43 ^{o} F). There is no specific holding time defined for this analysis.

Reagents and Standards

- Suspended Solid Standards, 40 to 250 mg/L, prepared by adding known mass of test sediment to a known volume of distilled water

Calibration and Standardization

- The analytical balance is calibrated annually to NIST Traceable standards
- Calibration verification: calibration verifications are performed with NIST traceable standards and documented

Procedure

Preparation of glass fiber filters/aluminum pans

- Assemble filter and aluminum pans for projected number of samples for SSC analyses
- Including at two additional filter/pans for Lab Control Sample and Method Blank
- In each filter/pan, include a small piece of additional filter material (wipe filter) for post filtration cleaning of the interior surfaces of the Buchner funnel to remove any remaining sediment
- Number all filter pans sequentially with an indelible marker
- Place first filter in the Buchner funnel apparatus with the wrinkled side up
- Apply vacuum to the funnel
- While vacuum is applied, wash the disc with approximately 50 mL distilled water
- Continue vacuum to remove as much water as possible
- Discontinue vacuum
- Remove filter from apparatus and place in aluminum pan along with wipe filter
- Place pan in drying oven at 103-105^{o}C and dry for two hours
- Remove filter/pan/wipe filter assemblage from oven and place in a desiccator for two hours
- Place filter/pan/wipe filter assemblage onto analytical balance and weigh (tare weight)
- Record tare weight = A (gram)

Filtration

- Prepare the Lab Control Sample (LCS) by adding a known mass of test sediment to a known volume of distilled water in a standard sample container, where the volume of distilled water volume is within the range of volume of samples being analyzed and the added sediment mass provides SSC of 40 to 200 mg/L
- A Method Blank (MB) is prepared by adding a known volume of distilled water to a standard sample container, where added distilled water volume is within the range of volume of samples being analyzed
- Mark the level of water sample on the side of the sample container
- Place filter into Buchner funnel

- Shake the unknown sample vigorously, pour initial sample volume into Buchner funnel, quickly start the vacuum pump
- Continue to pour remainder of sample into Buchner funnel as sample water is filtered
- Rinse the filter with copious amounts of distilled water and continue vacuum to remove as much water as possible, trying to bring the sand to the middle of the filter
- Remove the filter from apparatus and place it in the aluminum pan
- Wipe the inside of the Buchner funnel with the wipe filter to remove any remaining sediment
- Maintain the filter order for all filters to provide more orderly analyses process
- Fill the sample container to the marked level
- Measure it water volume in the container using a graduated cylinder
- Record sample volume = C (ml)

Drying

- Place the filter/pan/wipe filter assemblage into the drying oven at 103-105°C for at least 2 hours
- Remove the filter/pan/wipe filter assemblage from the oven and place immediately in desiccator

Final Weighing

- Place filter/pan/wipe filter assemblage onto analytical balance and weigh (filtered weight)
- Record filtered weight = B (gram)

Data Analysis and Reporting

- Calculate SSC in mg/L as SSC = (B – A) / C x 1,000,000, where:
  - A = Weight of filter assemblage before filtration, gram
  - B = Weight of filter assemblage after filtration, gram
  - C = Volume of sample filtered, mL

Method Performance

- Demonstration of Capability (DOC) DOC for this method is based on the analyst experience with Total Suspended Solids, SM 2540 D and the SSC method itself
- An Initial Demonstration of Capabilities (IDOC) Study will be performed prior to evaluation of SWEMA/NJCAT verification test samples
- The IDOC will entail analysis of at least 4 consecutive prepped LCSs. The recovery of the LCSs must be 70%-130% in the low SSC range (ca. 10 mg/L) and 85%-115% in the high SSC range (ca. 100 mg/L) to pass

Quality Control

- A Lab Control Sample (LCS) is prepared by adding a known mass of test sediment to a known volume of distilled water in a standard sample container, where the volume of distilled water is within the range of volume of samples being analyzed and the added sediment mass provides SSC of 10 to 50 mg/L

- A Method Blank (MB) is prepared by adding a known volume of distilled water to a standard sample container, where added distilled water volume is within the range of volume of samples being analyzed
- SSC procedure uses entire sample volume and duplicate analyses cannot be performed
- Any deviations from the norm encountered while conducting this analysis must be noted in the bench sheet and corrected
- An analysis event is performance of SSC analyses on multiple samples in one analytical campaign, such as analyses of samples resulting from one or more flow rate tests
- Quality Control (QC) specifications are:

QC Check	Minimum	Frequency	Acceptance Criteria	Corrective Action
Constant weight	None	Once at initiation of SWEMA/ NJCAT	Weight change of less than 0.5 mg for a sample with SSC > 250 mg/L	Longer duration drying time
Method Blank (MB)	1	Per analyses event	< Reporting Limit	Repeat analyses; identify problems
Lab Control Sample (LCS)	1	Per analyses event	85 - 115% recovery	Repeat analyses; flag data
Demonstration of Capability	4	Once for each analyst	High Range recovery: 85 - 115% (ca. 100 mg/L) Low Range recovery: 70 - 130% (ca. 10 mg/L)	Identify problem(s), repeat analyses

References

- American Society for Testing and Materials, Standard Test Methods for Determining Sediment Concentration in Water Samples, Method D3977 – 97 part B., 1997
- Standard Methods for the Examination of Water and Wastewater, Method 2540D

APPENDIX E

QUALITY ASSURANCE DOCUMENTATION

SWEMA/NJCAT-100 μm Protocol
Quality Assurance Documentation

Constant Weight in Suspended Solids Concentration (SSC) Tests

The SSC procedure requires verification that the sample drying time is long enough to achieve a constant sample weight. Verification tests were performed on 11/27/2012 and 11/28/2012 using SSC background influent samples collected in NSBB pre-testing runs. On each date, the complete SSC test procedure was performed on eight background influent samples. At the completion of the SSC tests, samples were dried for an additional 2 hours and re-weighed. Using the analytical SSC, the difference in mass of tare + solids was scaled to a 250 mg/L SSC concentration. Results are shown in Tables A-1 and A-2. The weight change of all samples was well below 0.5 mg for all samples, satisfying the constant weight criteria.

Table E-1 SSC Constant Weight Demonstration (11/27/2012)

Dry 12 hours					Dry additional 2 hours		
Tare, g	Tare + solids, g	Volume, ml	Solids, g	SSC, mg/L	Tare + solids, g	Difference in mass of (tare + solids), g	Absolute value of difference in (tare + solids), normalized to 250 mg/L SSC, mg
9.6016	9.6034	1,453	0.0018	1.24	9.6031	0.0003	0.0015
9.5767	9.5794	1,467	0.0027	1.84	9.5799	-0.0005	0.0037
14.5078	14.5132	1,785	0.0054	3.03	14.5127	0.0005	0.0061
14.3000	14.3041	1,429	0.0041	2.87	14.3041	0.0000	0.0000
9.4165	9.4210	1,591	0.0045	2.83	9.4205	0.0005	0.0057
14.5313	14.5358	1,612	0.0045	2.79	14.5355	0.0003	0.0033
9.6842	9.6885	1,590	0.0043	2.70	9.6875	0.0010	0.0108
9.5537	9.5593	1,498	0.0056	3.74	9.5593	0.0000	0.0000

Table E-2 SSC Constant Weight Demonstration (11/28/2012)

Sample Time, minute	Dry 12 hours					Dry additional 2 hours		
	Tare, g	Tare + solids, g	Volume, ml	Solids, g	SSC, mg/L	Tare + solids, g	Difference in mass of (tare + solids), g	Absolute value of difference in (tare + solids), normalized to 250 mg/L SSC, mg
2	9.6874	9.6908	1,598	0.0034	2.13	9.6906	0.0002	0.0017
10	9.5927	9.5960	1,660	0.0033	1.99	9.5962	-0.0002	0.0016
17	14.5347	14.5389	1,662	0.0042	2.53	14.5339	0.0050	0.0503
23	14.5105	14.5154	1,375	0.0049	3.56	14.5152	0.0002	0.0029
33	9.6349	9.6368	1,392	0.0019	1.36	9.6368	0.0000	0.0000
41	9.6063	9.6092	1,207	0.0029	2.40	9.6086	0.0006	0.0058
49	9.5734	9.5774	1,843	0.0040	2.17	9.5772	0.0002	0.0017
57	9.6546	9.6596	1,595	0.0050	3.13	9.6594	0.0002	0.0025

Suspended Solids Concentration Method Detection Limit (MDL)

The Method Detection Limit (MDL) is the lowest quantity of suspended sediment that can be distinguished from that absence of suspended sediment in the sample. The MDL for SSC was established by performing SSC analyses on a series of laboratory blanks and performing statistical analyses. Ten laboratory blanks were prepared by adding a known volume of distilled water to clean sample containers (zero suspended sediment). The complete SSC analyses procedure was performed on each laboratory blank. The results are listed in Table A-3 and plotted in Figure A-1. A statistical summary of the laboratory blank SSC data set is shown in Table A-4. Mean and standard deviation were -0.139 and 0.977 mg/L, respectively. The data set passed the Shapiro-Wilk test for normal distribution (P=0.05). A cumulative probability plot of SSC data is shown in Figure A-2.

The MDL for SSC was established by applying one-sided t-distribution for nine degrees of freedom at a 97.5% confidence level ($\nu = 9$, $\alpha = .025$), for which the critical value is 2.262. The MDL was established as:

$MDL = Mean_{SSC} + 2.262 * \text{Standard Deviation}_{SSC}$
$MDL = -0.139 + 2.262 * 0.977$
$MDL = 2.07$ mg/L

For an analytical SSC result greater than 2.07 mg/L, there is 97.5% confidence that suspended sediment is actually present in the sample.

Table E-3 Laboratory Blank SSC Determination

Date	Tare, g	Tare + solids, g	Volume, ml	Solids, g	SSC, mg/L
11/27/12	9.6629	9.6621	1,010	-0.0008	-0.79
12/06/12	9.3926	9.3927	1,000	0.0001	0.10
12/07/12	14.3451	14.3441	1,010	-0.0010	-0.99
12/10/12	9.5629	9.5659	1,984	0.0030	1.51
12/11/12	14.4411	14.4415	1,000	0.0004	0.40
12/12/12	14.2313	14.2322	1,000	0.0009	0.90
12/18/12	13.1760	13.1757	1,025	-0.0003	-0.29
12/19/12	9.5476	9.5456	1,035	-0.0020	-1.93
12/20/12	9.3645	9.3642	1,017	-0.0003	-0.29
01/08/13	9.5710	9.5710	1,000	0.0000	0.00

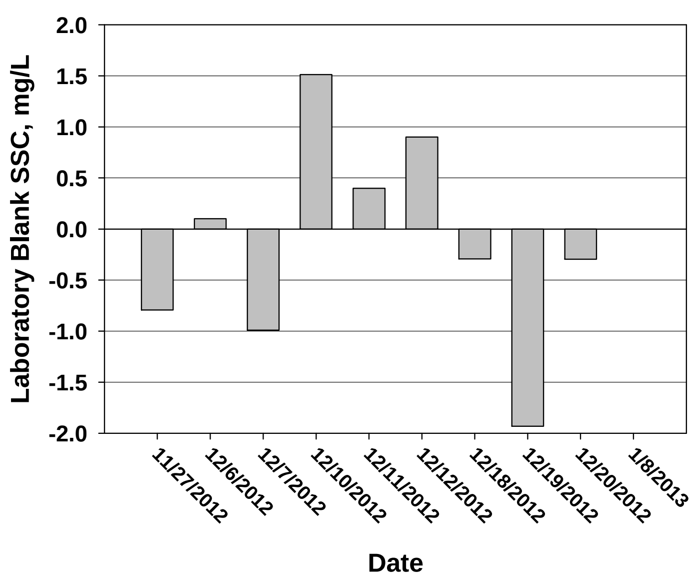


Figure D-1 SSC of Laboratory Blanks (n=10)

Table E-4 Statistical Parameters for Data Set of Laboratory Blank SSC

Count	10
Mean	-0.139
Median	-0.146
Minimum	-1.93
Maximum	1.51
Range	3.44
Standard Deviation	0.977
Variance	0.954
Kurtosis	0.392
Skewness	-0.130

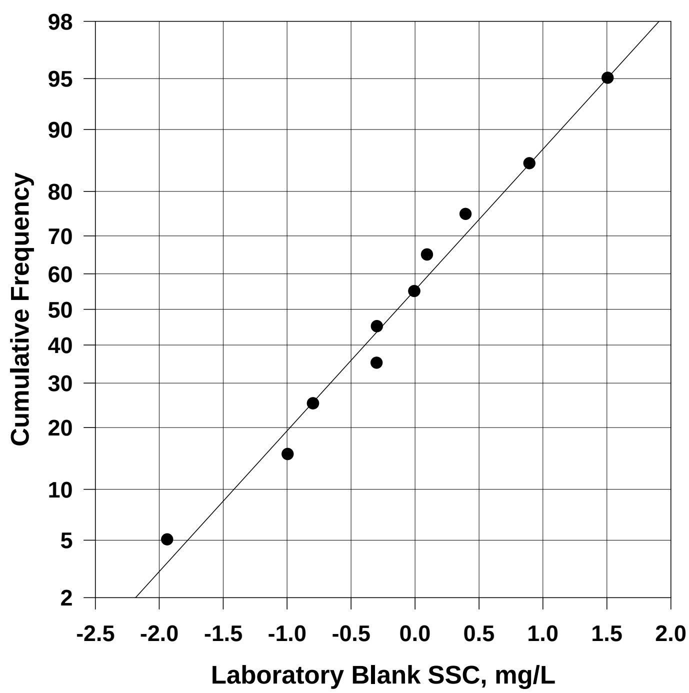


Figure E-2 Cumulative Frequency of Laboratory Blank SSC

Suspended Solids Concentration Reporting Limit (RL)

In NSBB verification testing, SSC analyses are used to:

- Verify that background SSC in NSBB influent do not exceed 20 mg/L in either sediment removal efficiency testing and resuspension testing
- In resuspension testing, verify that SSC in NSBB discharge do not increase by more than 20 mg/L over the influent background SSC.

The main purpose of SSC analyses is therefore to verify that SSC levels remain below 20 mg/L, rather than to precisely quantify the SSC levels that obtain during testing. Therefore, the SSC Reporting Limit was established as the MDL (2.07 mg/L). Furthermore, all SSC analytical results were included in the verification report, even if the SSC values are less than the Reporting Limit. In reviewing the verification report, it should be kept in mind that SSC values less than the MDL of 2.07 mg/L cannot be distinguished from background.

Suspended Solids Concentration Method Demonstration of Capability

The initial Demonstration of Capability for the Suspended Solids Concentration Method was performed on 11/28-30/2010 using three SSC standards in the low range (ca. 10 mg/L) and three SSC standards in the high range (ca. 100 mg/L). Results are shown in Table A-5. Mean recovery of low and high range samples were 100.7 and 95.4%, respectively. All low range samples met the 40% recovery criteria and all high range samples met the 15% recovery criteria. The maximum absolute errors were 2.8 and 10.0 mg/L in low and high SSC ranges, respectively.

The low and high range data sets for SSC recovery both passed the Shapiro-Wilk test for normality. Confidence intervals were established for SSC recovery using t-distribution analysis of Demonstration of Capability data sets. For the low SSC range, a one way analysis was applied

Table E-5 Demonstration of Capability

SSC Range	SSC, mg/L			% Recovery							
	Standard Solution	Standard Solution Mean	Analytical Result	%	Mean	Standard Deviation	Minimum	Maximum	Coefficient of Variation	Within 40% Criteria?	Within 15% Criteria?
Low	11.7	10.7	10.0	85.5	100.7	22.5	85.5	126.6	0.22	Yes	-
	10.7		13.5	126.6						Yes	-
	9.8		8.8	90.0						Yes	-
High	103.3	101.9	96.4	93.3	95.4	1.9	93.3	97.0	0.020	-	Yes
	101.1		96.9	95.8						-	Yes
	101.2		98.1	97.0						-	Yes

based on the primary need of SSC in the verification testing which is to demonstrate that SSC levels are less than 20 mg/L. For the low SSC range, one sided t-distribution analysis (ν = 2, α = .2, critical value = 1.886) provides a lower recovery limit of 100.7 - 1.886*22.5, or 58.1%. Using the limited low SSC range dataset (n=3), it is predicted that there is a 90% probability that actual SSC is less than 20 mg/L for any analytical SSC result of 11.6 mg/L or less. For the high SSC range, two sided t-distribution analysis (ν = 2, α = .1, critical value = 2.920) provides lower and upper recovery limits (90% confidence) of 89.9 and 100.8%. The analysis of SSC recoveries based on the Demonstration of Capability results is limited due to the small number of samples in each SSC range (n=3). Additional insight into SSC recoveries is provided in Laboratory Control Samples section that follows.

Laboratory Control Samples (LCS)

A summary of Laboratory Control Sample (LCS) analyses is presented in Table A-6 and Figure A-3. Mean LCS recovery was 95.64%, with a standard deviation of 7.65, minimum of 86.2, and maximum of 107.3%. Shapiro-Wilk test indicated that the LC SSC recovery data set was normally distributed (Figure A-4). Lower and upper recovery limits were derived using a two sided t-distribution analysis at 90% confidence (ν = 7, α = .1, critical value = 1.895). Lower and upper recovery limits of LC SSC recoveries were 81.1 and 110.1%, respectively.

Table E-6 Laboratory Control Sample SSC Determination

Date	Test Flow	SSC Standard Solution, mg/L (Lab Control)	SSC Analytical Result, mg/L	% Recovery	Recovery Within ±10%?	Recovery Within ±15%?
12/06/12	0.75	28.9	28.4	98.3	Yes	Yes
12/10/12	1.25	17.8	17.7	99.2	Yes	Yes
12/11/12	0.50	20.3	17.5	86.2	No	Yes
12/12/12	0.25	20.6	22.1	107.3	Yes	Yes
12/18/12	1.00	20.8	19.1	91.9	Yes	Yes
12/19/12	1.50	23.0	19.9	86.5	No	Yes
12/20/12	1.75	31.3	28.9	92.4	Yes	Yes
01/08/13	2.70	18.3	18.9	103.3	Yes	Yes

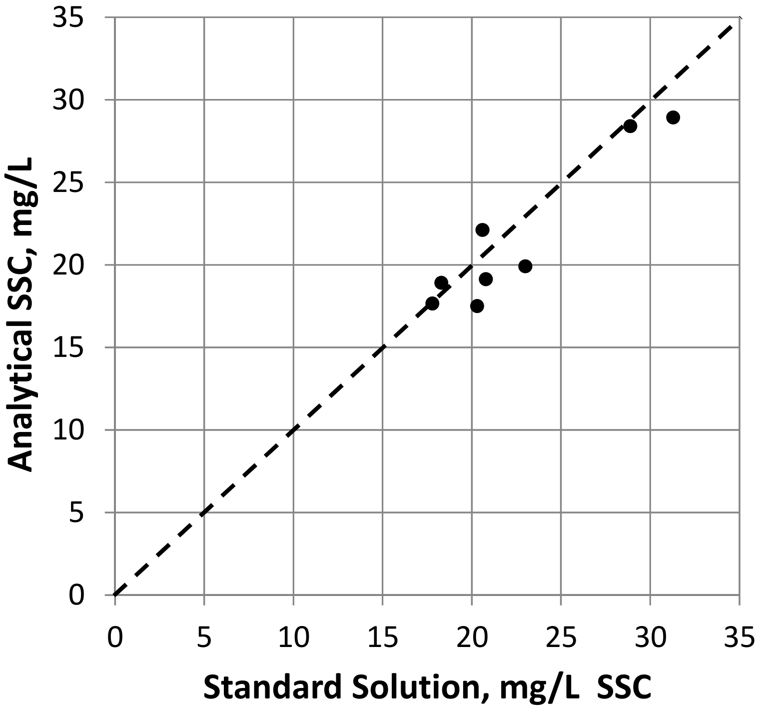


Figure E-3 Laboratory Control Sample SSC

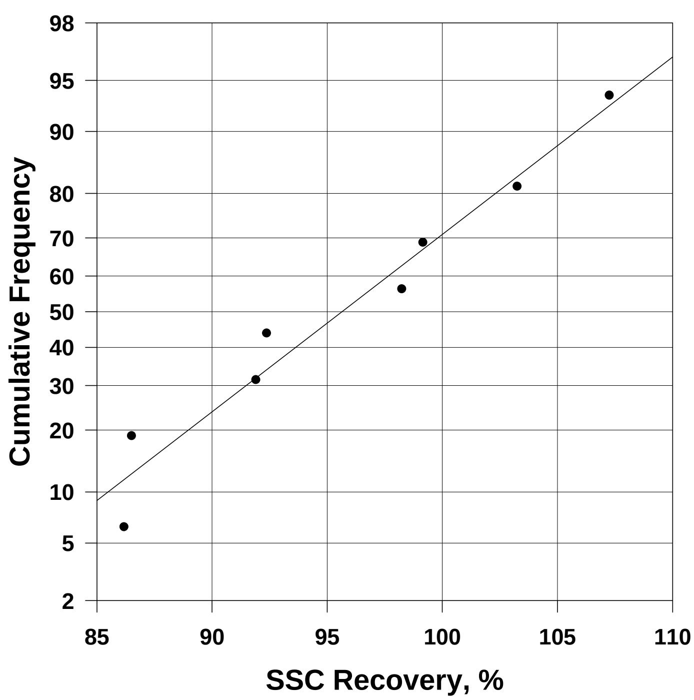


Figure E-4 Cumulative Frequency of Laboratory Control Sample SSC Recovery

Constant Weight in Sediment Preparation Constant Weight Pre-Testing

Each sediment removal efficiency test required preparation of sediment. The starting sediment had been previously dried and stored in sealed containers. Approximately 35 lbs. of sediment was sieved through a US No. 80 sieve, placed in aluminum pans, heated for 2 hours at 170F, cooled, and placed in the dosing hopper just prior to performance of the test. A test was performed on 11/28/2012 to verify that the procedure resulted in sediment of constant dryness. A subsample of cooled sediment was weighed, dried at 103C for 2 hours, cooled, and reweighed. The results are shown in Table A-7. The relative difference in mass was negligible after the second drying step (2 hour at 103C), indicating that acceptable dryness was achieved by the drying procedure.

Table E-7 Sediment Preparation Constant Weight Demonstration

	gram
Tare Weight	29.77
Weight Sediment + Tare	
After 2 hours at 170F	112.18
After 2 hours at 103C	112.16
Weight Sediment	
After 2 hours at 170F	82.41
After 2 hours at 103C	82.39
Fractional change	-2.43E-04

Certificate of Calibration

Flow rate was measured with a PT-500 Ultrasonic Flow Meter, Serial Number 7629 (Greyline Instruments Inc., Massena, New York). The PT-500 is a Transit Time ultrasonic flow meter that employs two sensors mounted on the outside of the pipe wall and has a manufacturer stated accuracy of ±2% (http://www.greyline.com/pt500.htm). The instrument was calibrated by Micronics Ltd. and a copy of the Certificate of Calibration is included on Page E-9.

micronics

Certificate of Calibration

Micronics Ltd certifies that, at the time of manufacture, the instrument detailed below was calibrated and verified using an Electromagnetic Flow Meter of known accuracy, which is traceable to National and International Standards in accordance with Micronics Ltd calibration procedures (Doc 780-1001-007-TP). These procedures are in compliance with the relevant clauses of ISO 9001.

Description of Instrument Calibrated

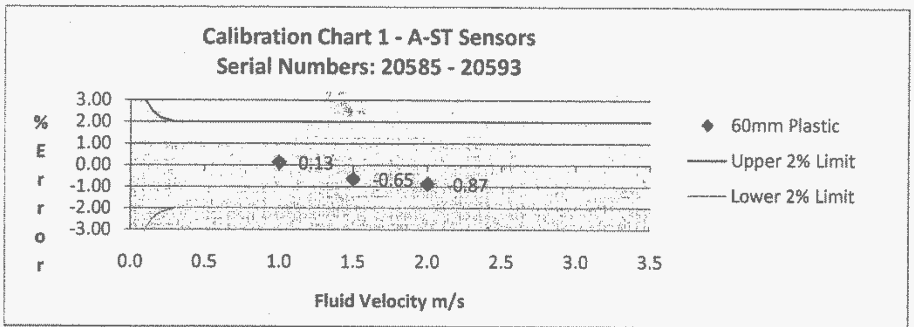
These are ultrasonic 'clamp-on' flowmeters, designed for measuring flow in 'clean' liquids.

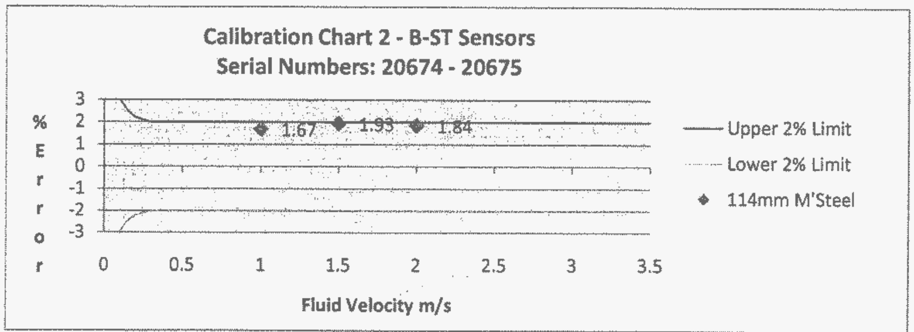
Uncertainty in Reference Measurement Equipment

Flowmeter ±0.2%; DMM ±0.005%; Pulse Counter ±0.005%

Unit Under Test	
Model:	PT500
Serial No:	7629
Condition:	New
Software Version:	02.07.002

Environmental Conditions	
Ambient Temperature (°C)	23.1
Fluid Temperature (°C)	27.3
Relative Humidity %RH	52





4-20mA Current Output Calibration

Load (c)	Set *I* (mA)	DAC Value	Measured *I* (mA)	Deviation (%)
620	4.000	8144	4.0045	0.1125
620	20.000	40896	20.0045	0.0225

Tested by:- F.C.C.

Pulse Output Check

Vol/Pulse (litres)	Measured Vol (litres)	Expected No Pulses	Measured No Pulses	Deviation (%)
10.00	1075.7	108	107	-0.53

Date Tested:- 22.07.10

Registered Office: Micronics Limited, Knaves Beech Business Centre, Davies Way, Loudwater, Buckinghamshire, HP10 9QR
Web site: www.micronicsltd.co.uk Tel: +44 (1628) 810456 Fax: +44 (1628) 531540
Directors: E.J. Farmon, M.A. Farmon

APPENDIX F

EXPERIMENTAL DATA AND RESULTS

Experimental Data and Results

Table F-1 List of Experiments

Experiment	Test Date	Flowrate, cfs
Removal Efficiency	12/12/12	0.25
	12/11/12	0.50
	12/06/12	0.75
	12/18/12	1.00
	12/10/12	1.25
	12/19/12	1.50
	12/20/12	1.75
Resuspension	01/08/13	2.70

Table F-2 Summary of Results for 0.25 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	112.2	112.3	0.0494	96.1	125.4	0.06
NSBB Sediment Dosing Time, min	142.33					
Sediment Dosing Rate, gram/min	84.9	85.6	0.004	85.2	86.0	0.76
Mean Influent SSC, mg/L	201.4					
Background SSC, mg/L	20 mg/L max.	2.2	0.66	0.5	5.0	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed to NSBB	12,182	26.81		
Sediment Captured				
Chamber 1	10,723	23.60	89.7	88.0
Chamber 2	819	1.80	6.9	56.2
Chamber 3	415	0.91	3.5	64.9
Total	11,957	26.32	100.0	98.2

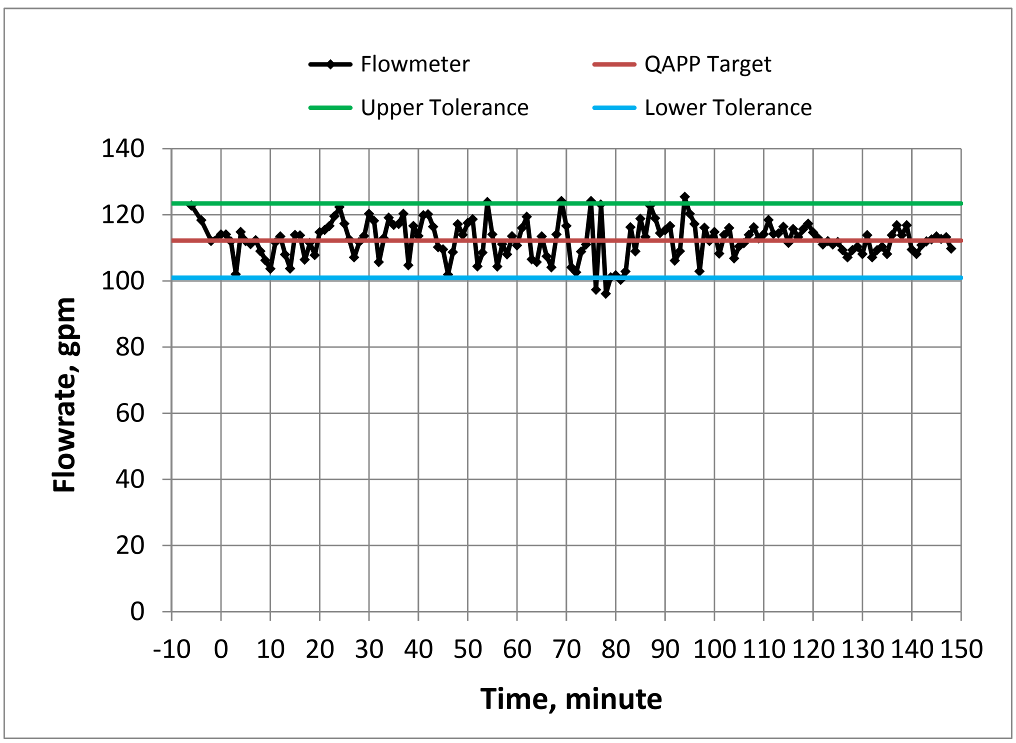


Figure F-1 Monitored Flow Rate for 0.25 cfs Experiment

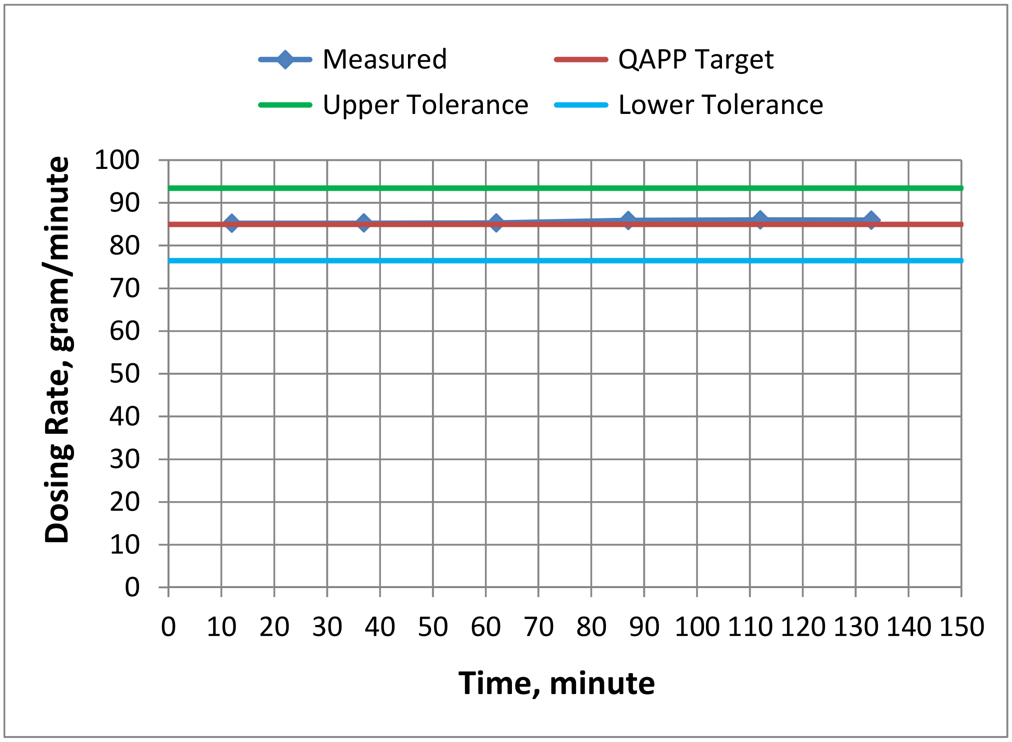


Figure F-2 Monitored Sediment Dosing Rate for 0.25 cfs Experiment

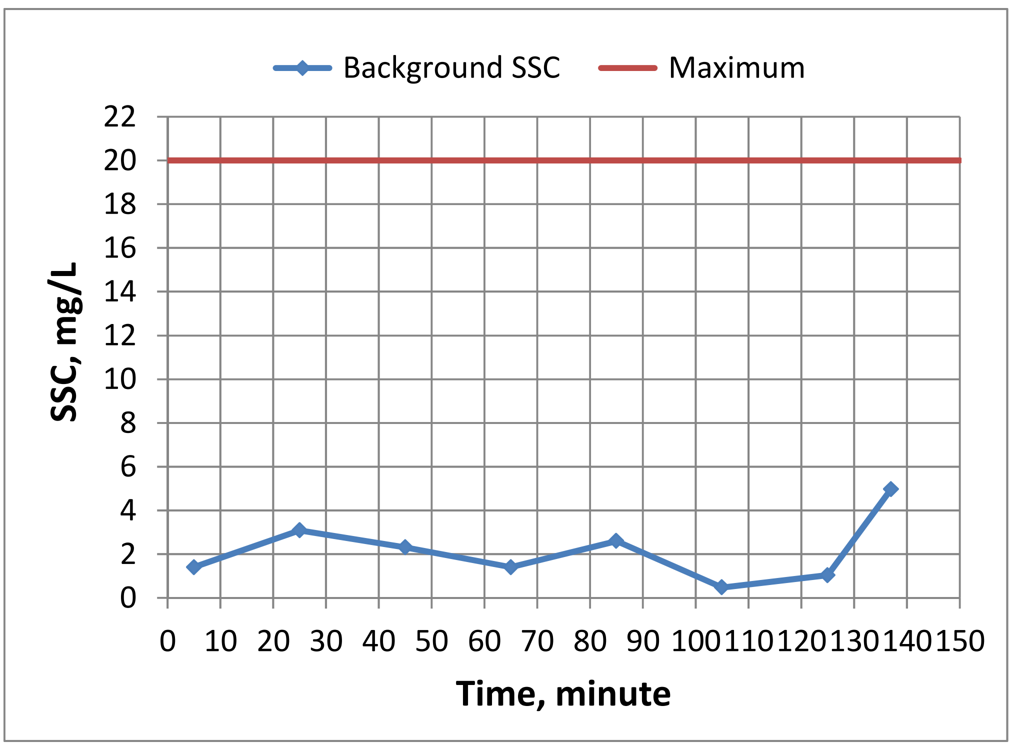


Figure F-3 Monitored Background SSC for 0.25 cfs Experiment

Table F-3 Summary of Results for 0.50 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	224.4	226.6	0.0134	218.8	232.9	0.98
NSBB Sediment Dosing Time, min	80.0					
Sediment Dosing Rate, gram/min	169.9	166.9	0.006	165.2	167.8	-1.77
Mean Influent SSC, mg/L	194.6					
Background SSC, mg/L	20 mg/L max.	4.2	0.57	2.0	9.6	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed	13,349	29.38		
Sediment Captured				
Chamber 1	10,650	23.44	88.1	79.8
Chamber 2	842	1.85	7.0	31.2
Chamber 3	596	1.31	4.9	32.1
Total	12,088	26.61	100.0	90.6

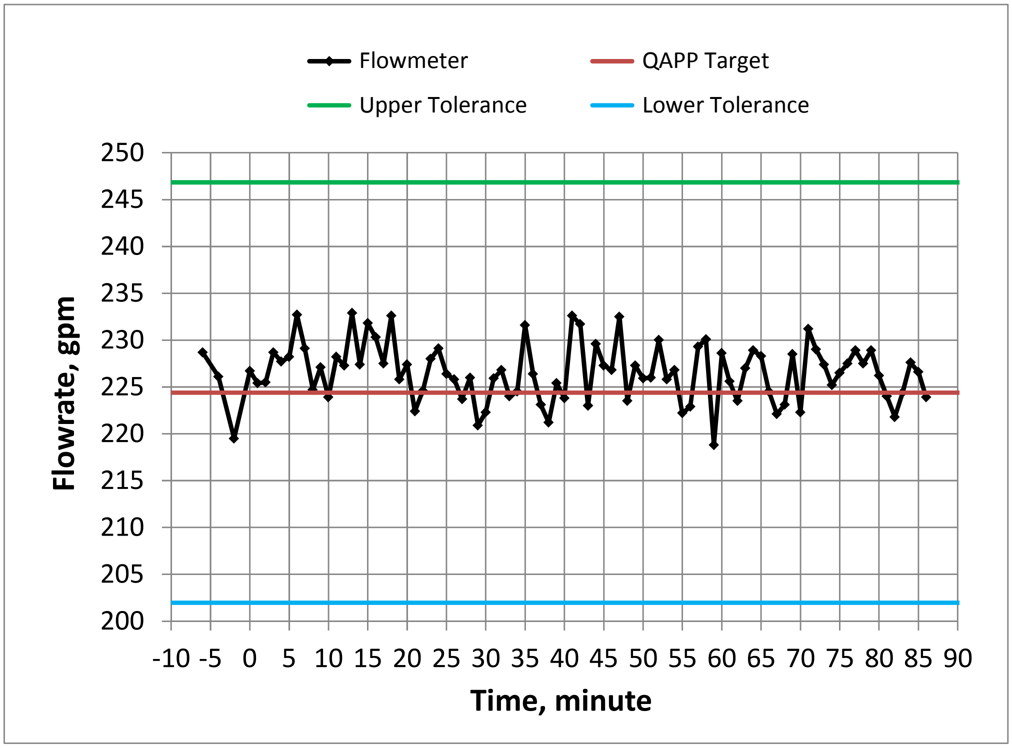


Figure F-4 Monitored Flow Rate for 0.50 cfs Experiment

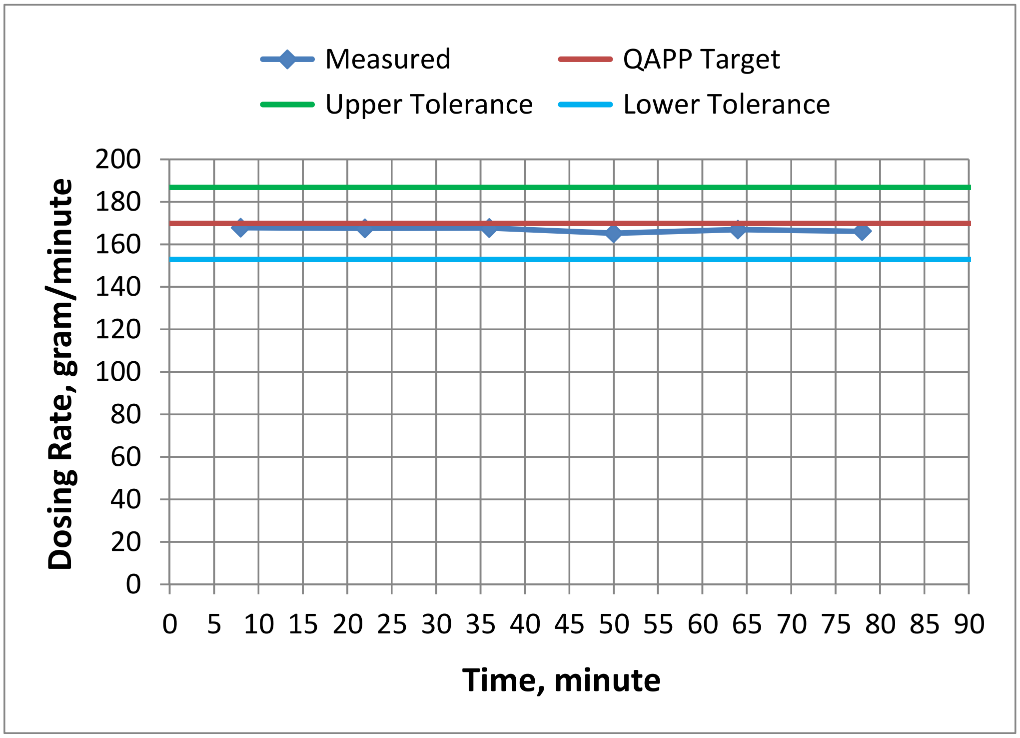


Figure F-5 Monitored Sediment Dosing Rate for 0.50 cfs Experiment

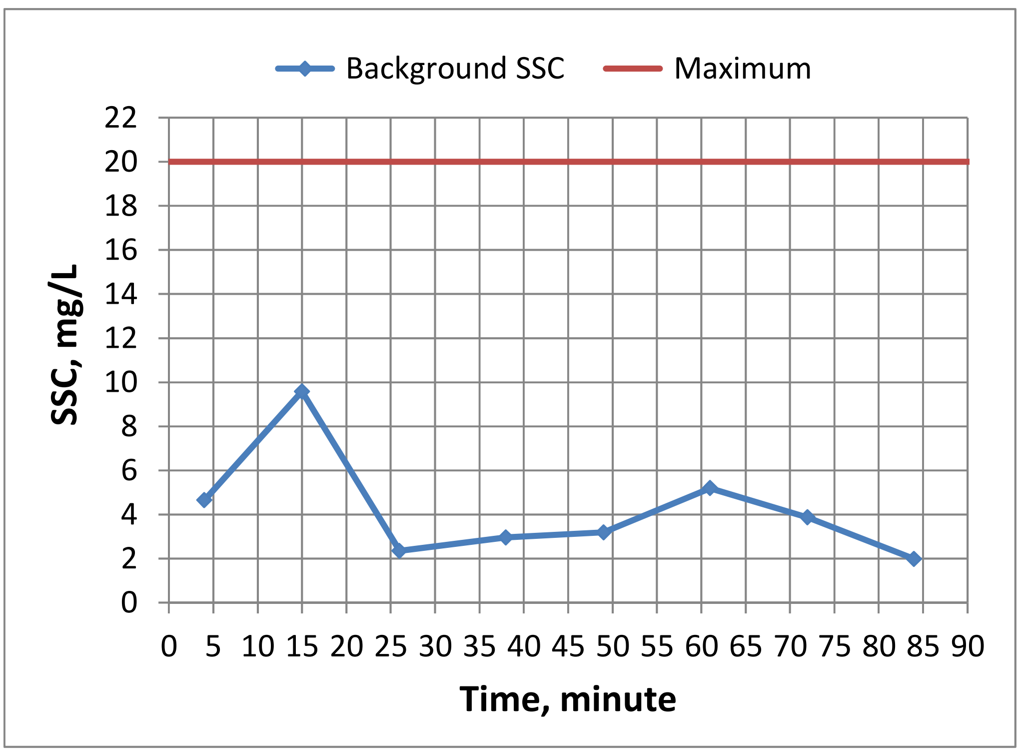


Figure F-6 Monitored Background SSC for 0.50 cfs Experiment

Table F-4 Summary of Results for 0.75 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	336.6	336.4	0.0143	327.5	346.8	-0.05
NSBB Sediment Dosing Time, min	53.0					
Sediment Dosing Rate, gram/min	254.8	242.4	0.014	237.1	245.9	-4.87
Mean Influent SSC, mg/L	190.4					
Background SSC, mg/L	20 mg/L max.	3.0	0.50	0.9	5.3	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed	12,847	28.28		
Sediment Captured				
Chamber 1	8,192	18.03	85.7	63.8
Chamber 2	849	1.87	8.9	18.2
Chamber 3	517	1.14	5.4	13.6
Total	9,559	21.04	100.0	74.4

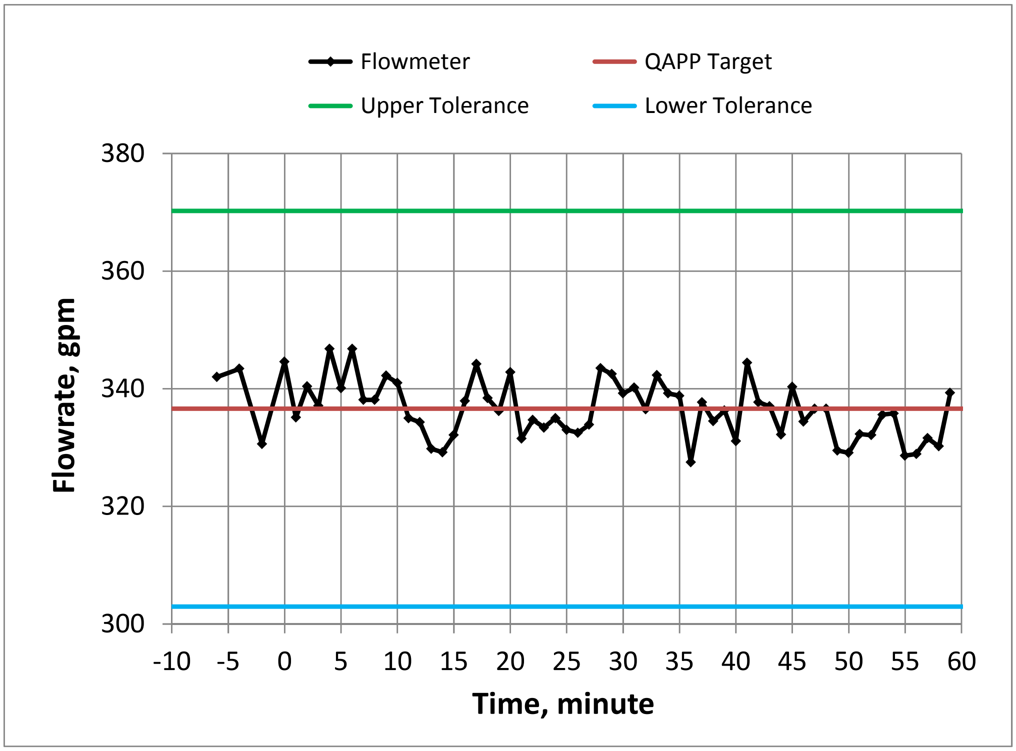


Figure F-7 Monitored Flow Rate for 0.75 cfs Experiment

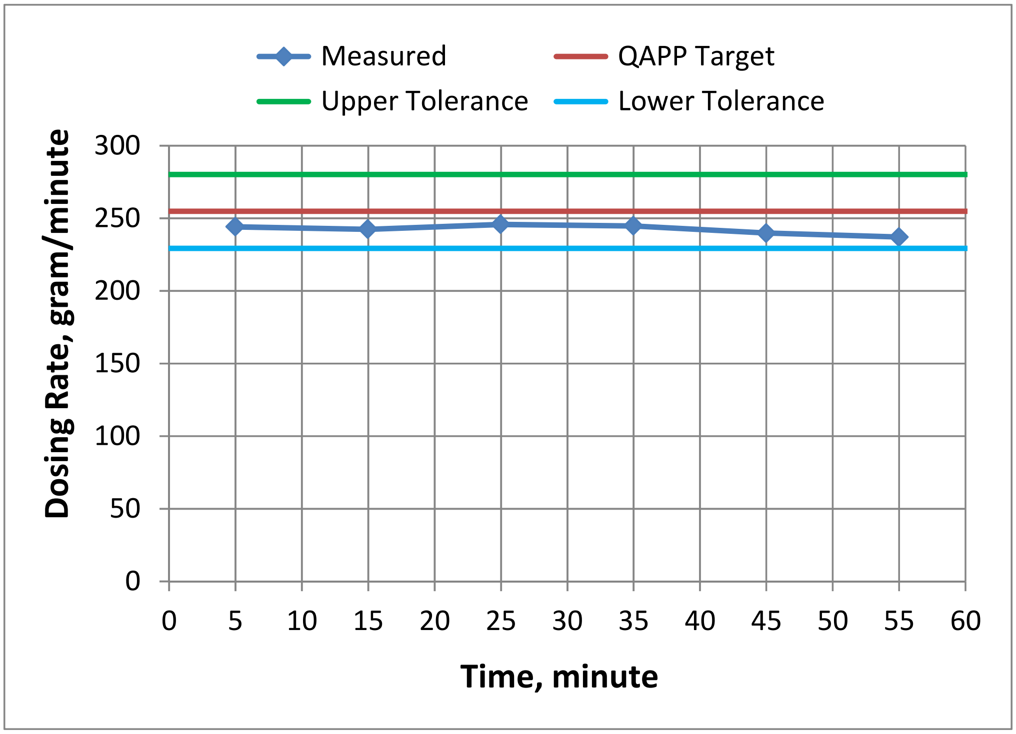


Figure F-8 Monitored Sediment Dosing Rate for 0.75 cfs Experiment

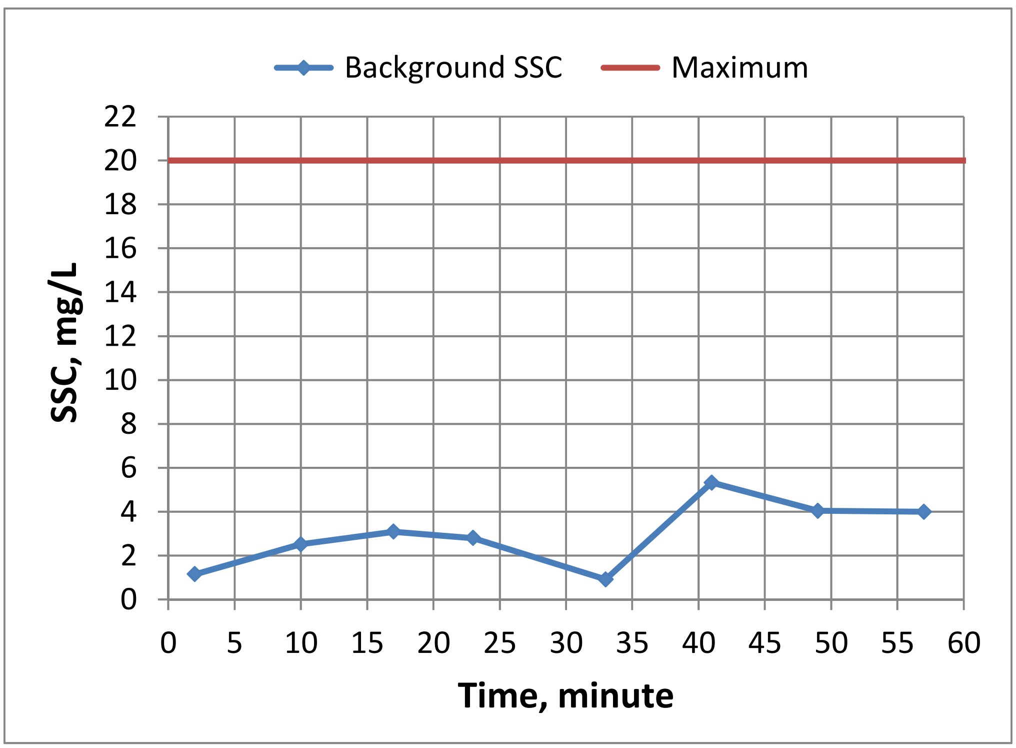


Figure F-9 Monitored Background SSC for 0.75 cfs Experiment

Table F-5 Summary of Results for 1.00 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	448.8	449.9	0.0059	445.3	456.6	0.25
NSBB Sediment Dosing Time, min	40.0					
Sediment Dosing Rate, gram/min	339.7	337.2	0.001	336.7	337.9	-0.74
Mean Influent SSC, mg/L	198.0					
Background SSC, mg/L	20 mg/L max.	4.7	0.26	3.0	7.0	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed	13,489	29.69		
Sediment Captured				
Chamber 1	7,943	17.49	81.4	58.9
Chamber 2	1,404	3.09	14.4	25.3
Chamber 3	416	0.91	4.3	10.0
Total	9,763	21.49	100.0	72.4

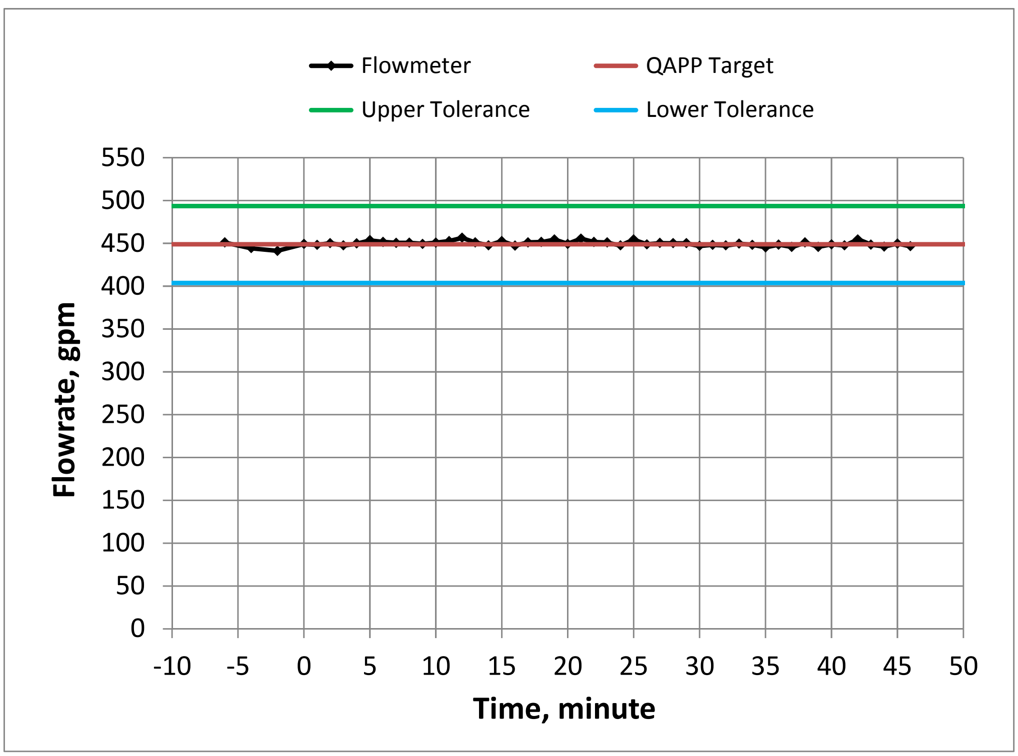


Figure F-10 Monitored Flow Rate for 1.00 cfs Experiment

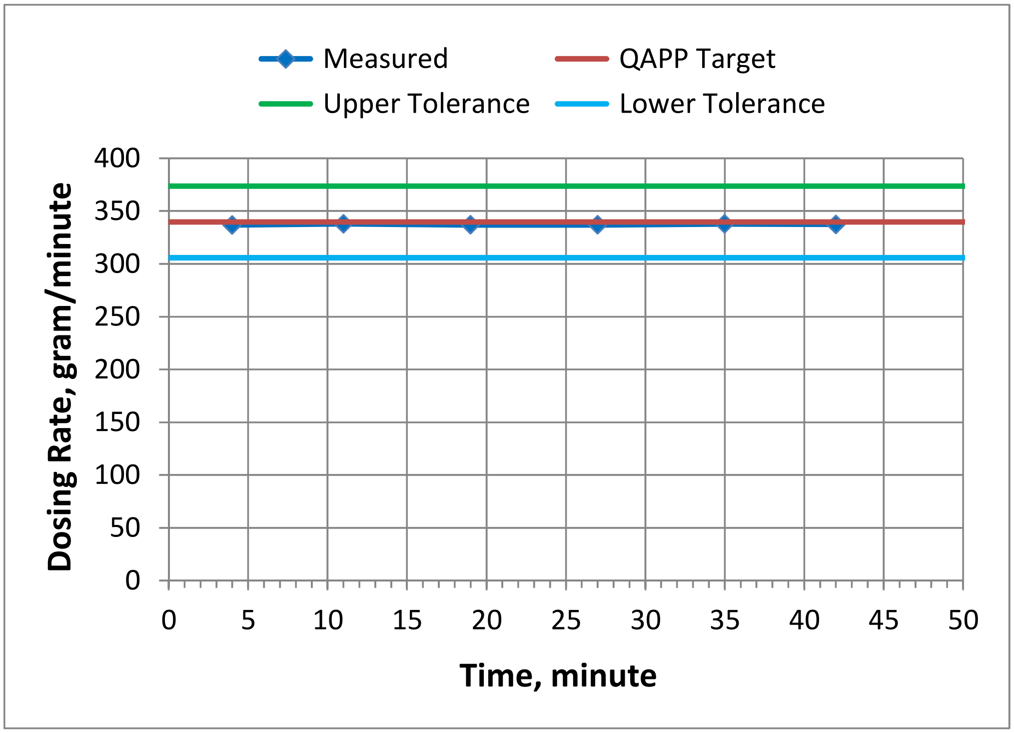


Figure F-11 Monitored Sediment Dosing Rate for 1.00 cfs Experiment

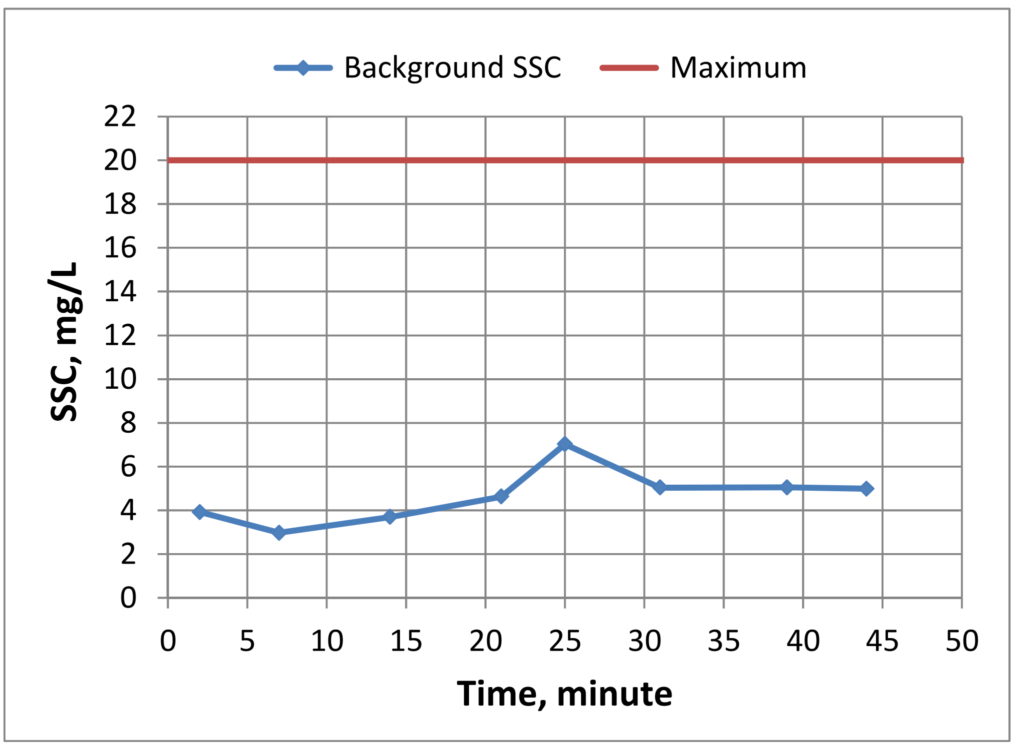


Figure F-12 Monitored Background SSC for 1.00 cfs Experiment

Table F-6 Summary of Results for 1.25 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	561	563.6	0.0060	556.4	570.8	0.47
NSBB Sediment Dosing Time, min	32.0					
Sediment Dosing Rate, gram/min	424.7	415.9	0.007	413.2	421.0	-2.07
Mean Influent SSC, mg/L	194.9					
Background SSC, mg/L	20 mg/L max.	13.4	0.47	4.0	24.4	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed	13,308	29.29		
Sediment Captured				
Chamber 1	7,277	16.02	77.0	54.7
Chamber 2	1,716	3.78	18.2	28.5
Chamber 3	456	1.00	4.8	10.6
Total	9,449	20.80	100.0	71.0

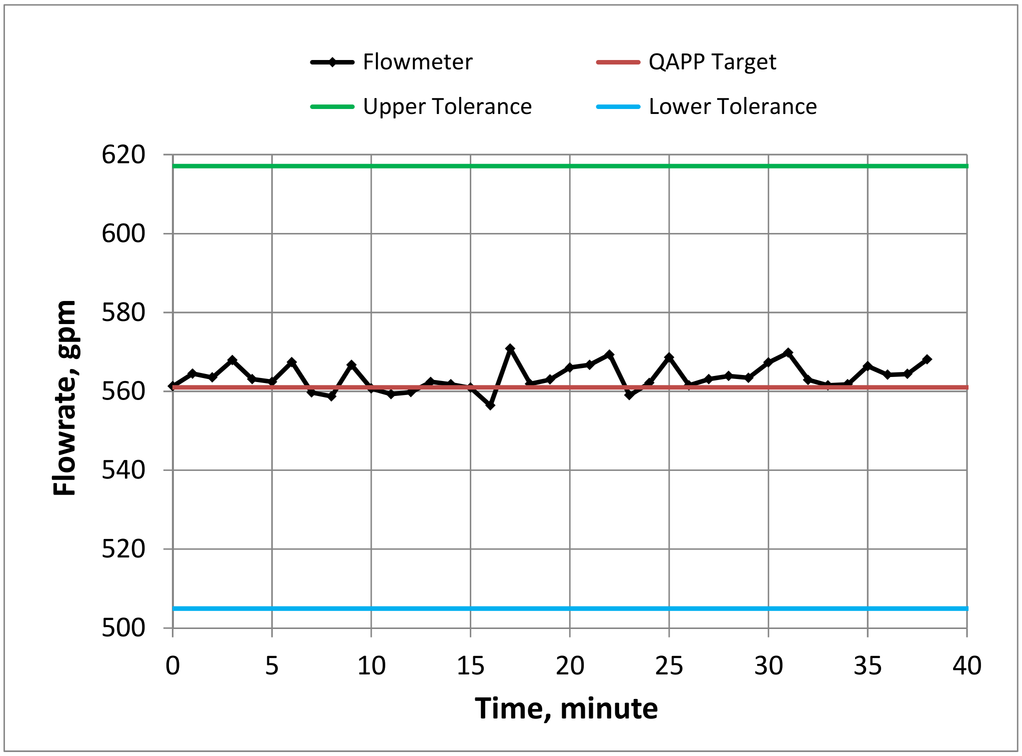


Figure F-13 Monitored Flow Rate for 1.25 cfs Experiment

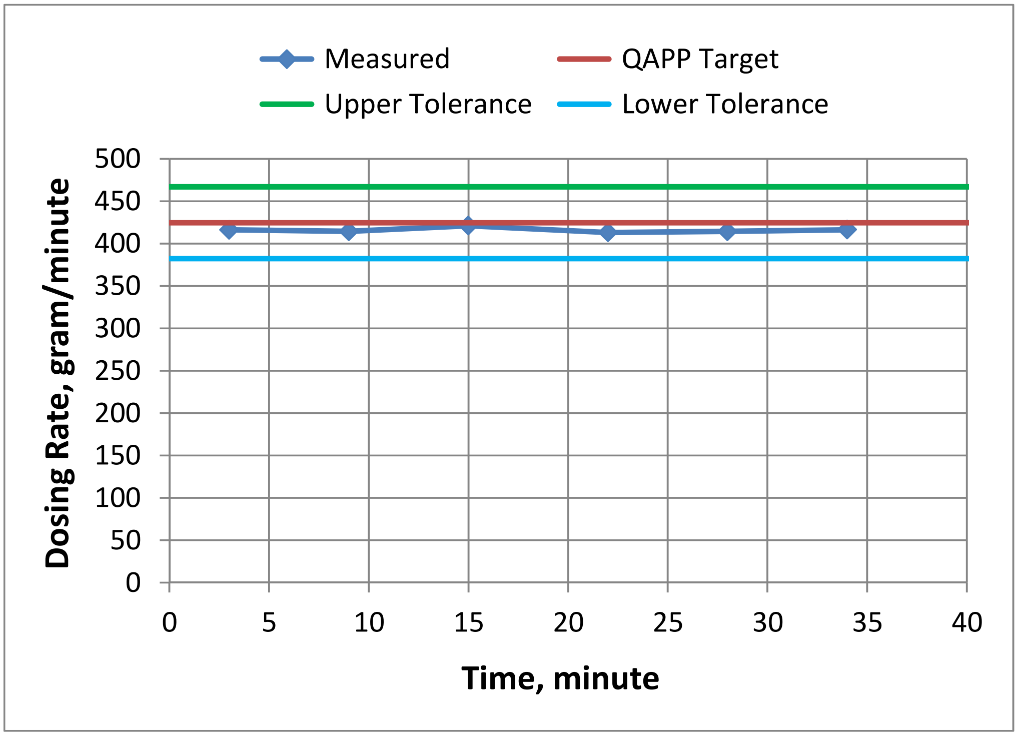


Figure F-14 Monitored Sediment Dosing Rate for 1.25 cfs Experiment

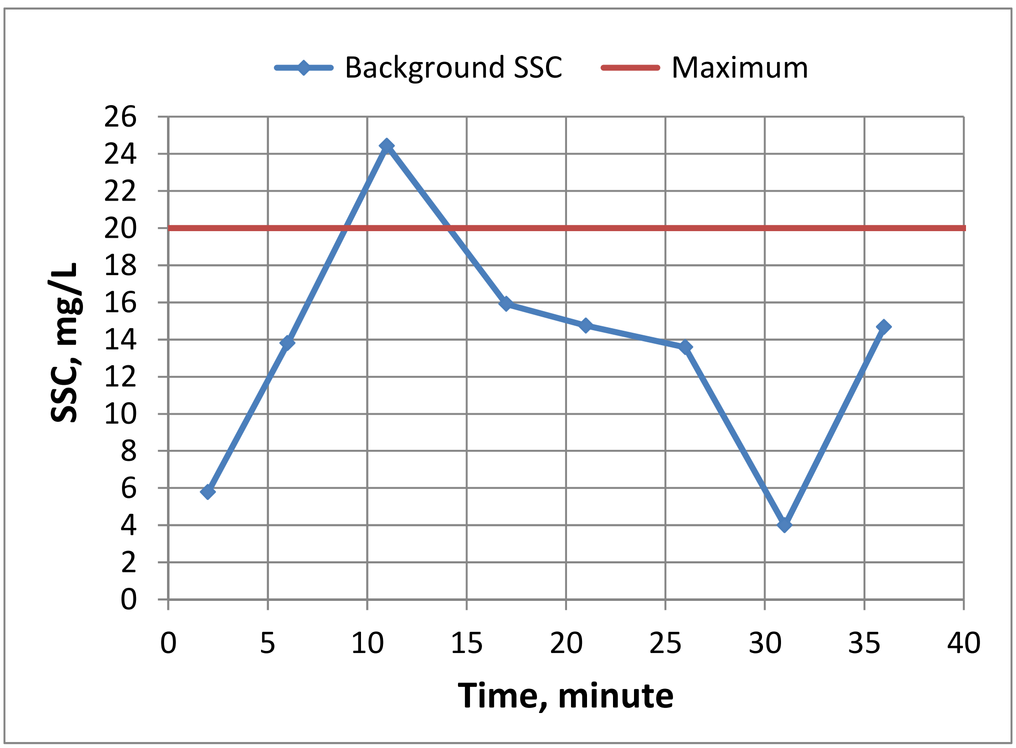


Figure F-15 Monitored Background SSC for 1.25 cfs Experiment

Table F-7 Summary of Results for 1.50 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	673.2	673.3	0.0076	665.7	689.3	0.02
NSBB Sediment Dosing Time, min	27.0					
Sediment Dosing Rate, gram/min	509.6	505.2	0.007	500.1	510.1	-0.86
Mean Influent SSC, mg/L	198.2					
Background SSC, mg/L	20 mg/L max.	5.9	0.33	2.1	8.2	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed	13,641	30.03		
Sediment Captured				
Chamber 1	7,206	15.86	76.6	52.8217613
Chamber 2	1,823	4.01	19.4	28.3261936
Chamber 3	376	0.83	4.0	8.15320012
Total	9,405	20.70	100.0	68.9

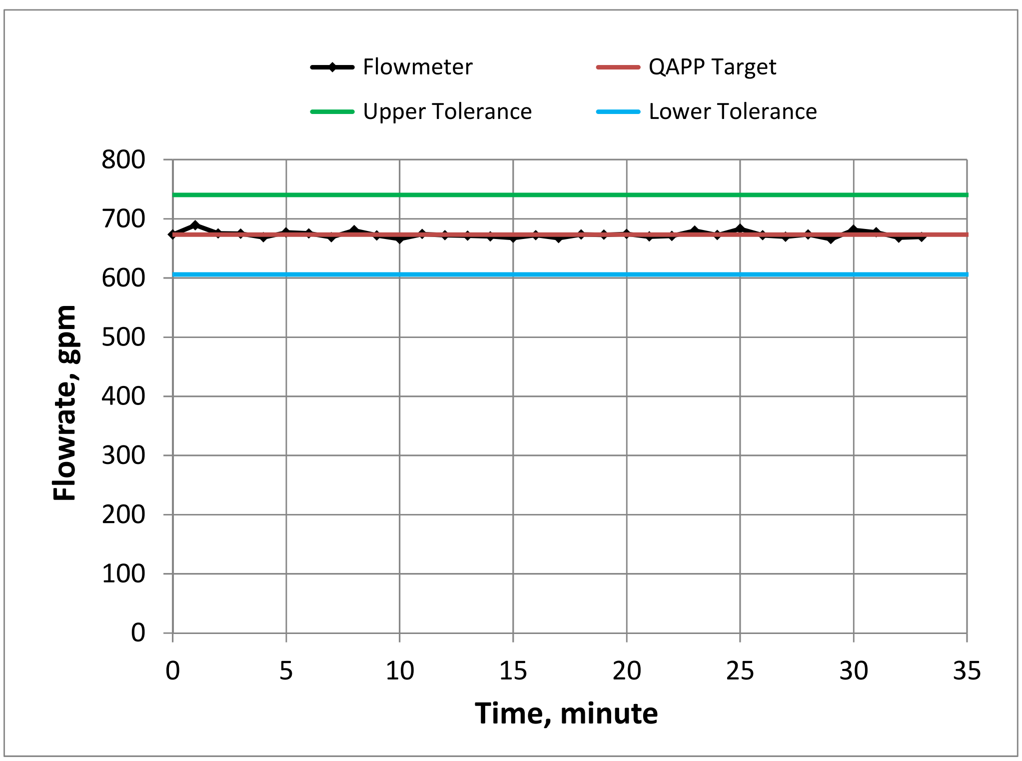


Figure F-16 Monitored Flow Rate for 1.50 cfs Experiment

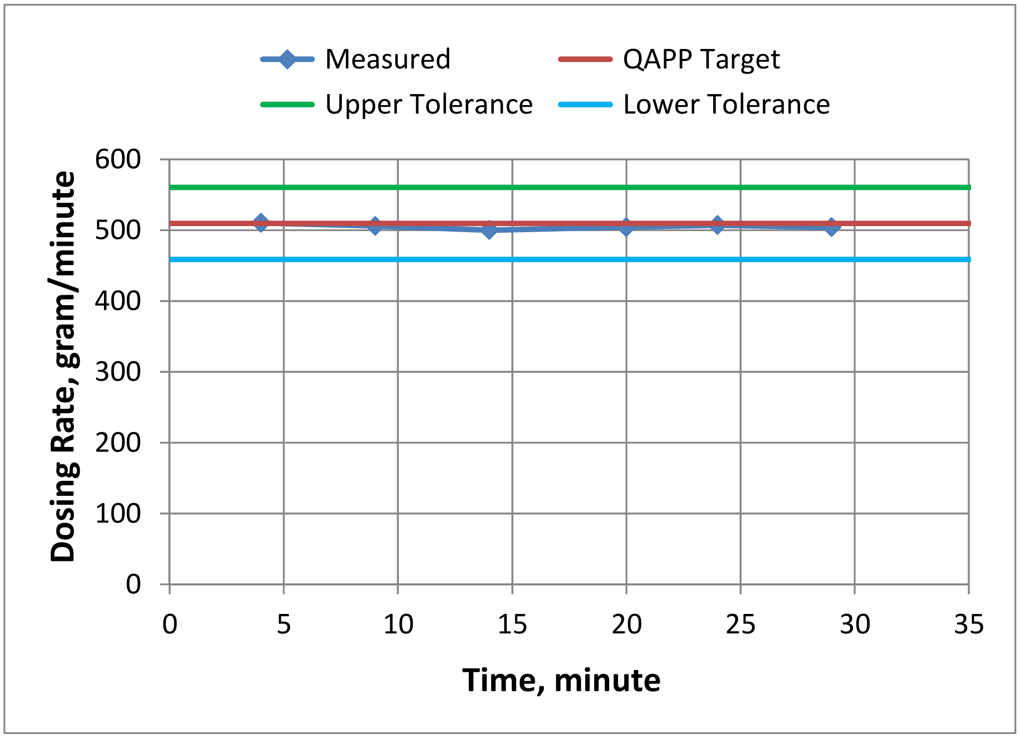


Figure F-17 Monitored Sediment Dosing Rate for 1.50 cfs Experiment

Figure F-18 Monitored Background SSC for 1.50 cfs Experiment

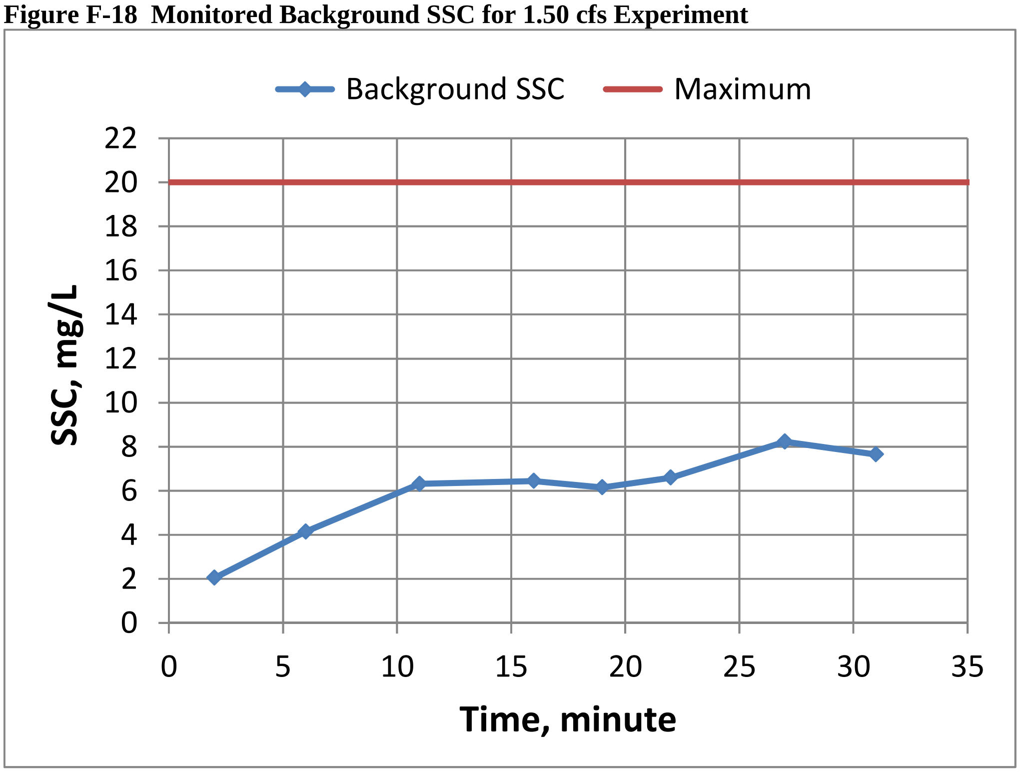


Table F-8 Summary of Results for 1.75 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	785.4	785.7	0.0062	775.9	795.4	0.04
NSBB Sediment Dosing Time, min	23.0					
Sediment Dosing Rate, gram/min	594.5	593.3	0.005	589.1	597.2	-0.20
Mean Influent SSC, mg/L	199.5					
Background SSC, mg/L	20 mg/L max.	8.9	0.30	3.7	12.0	

	gram	lbs.	% in chamber	% Removal Efficiency
Total Sediment Dosed to NSBB	13,647	30.04		
Sediment Captured				
Chamber 1	7,045	15.51	75.8	51.6
Chamber 2	1,883	4.14	20.2	28.5
Chamber 3	371	0.82	4.0	7.9
Total	9,299	20.47	100.0	68.1

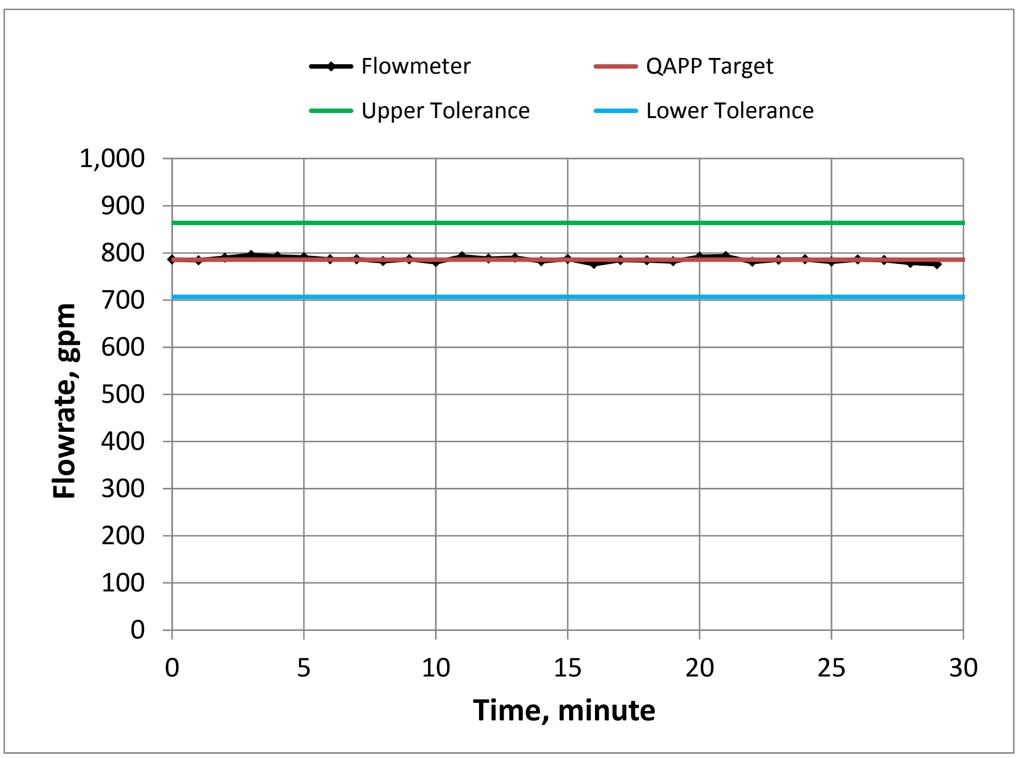


Figure F-19 Monitored Flow Rate for 1.75 cfs Experiment

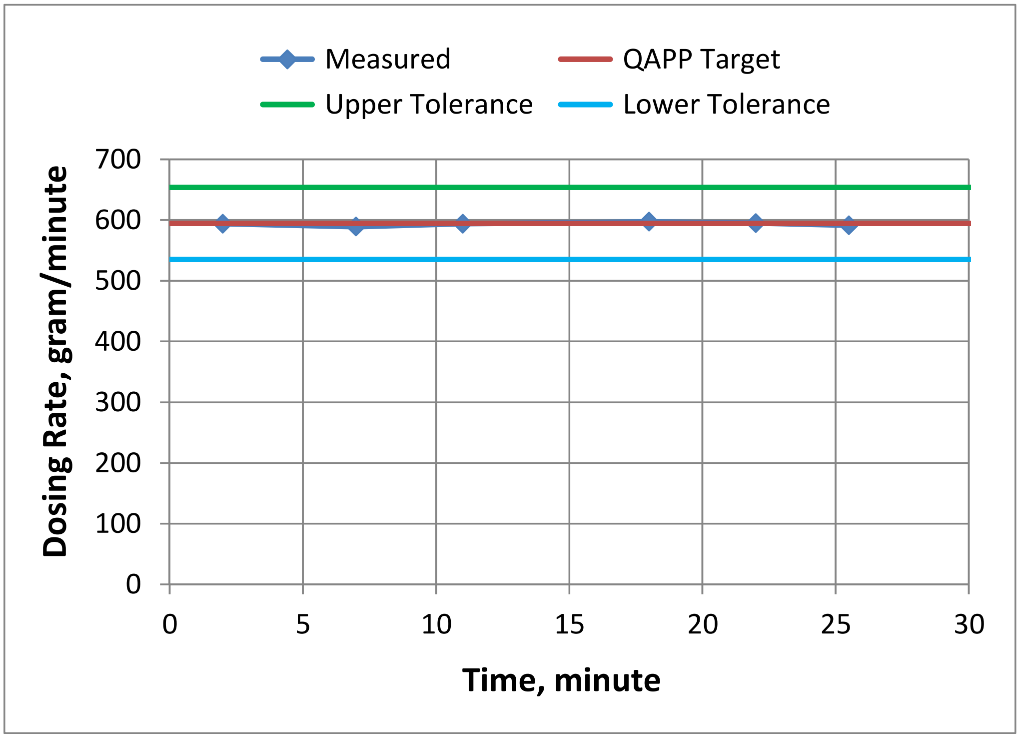


Figure F-20 Monitored Sediment Dosing Rate for 1.75 cfs Experiment

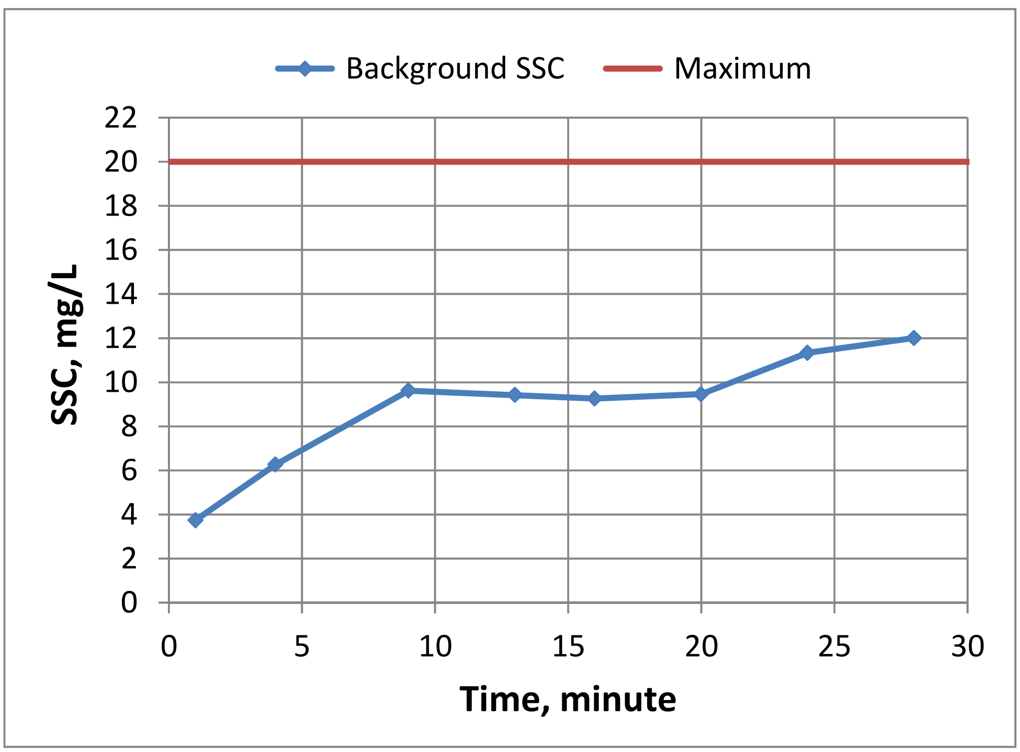


Figure F-21 Monitored Background SSC for 1.75 cfs Experiment

Table F-9 Summary of Results for 2.70 cfs Flow Rate Experiment

	Target	Experiment				Relative Error, %
		Mean	C.V.	Minimum	Maximum	
Flowrate, gpm	1211.8	1219.8	0.0057	1205.0	1235.0	0.67
Sediment Dosing Rate, gram/min	0.0					
Effluent SSC, mg/L	20 mg/L max.	4.8	0.19	3.2	6.6	
Background SSC, mg/L	-	4.4	0.29	2.6	6.6	

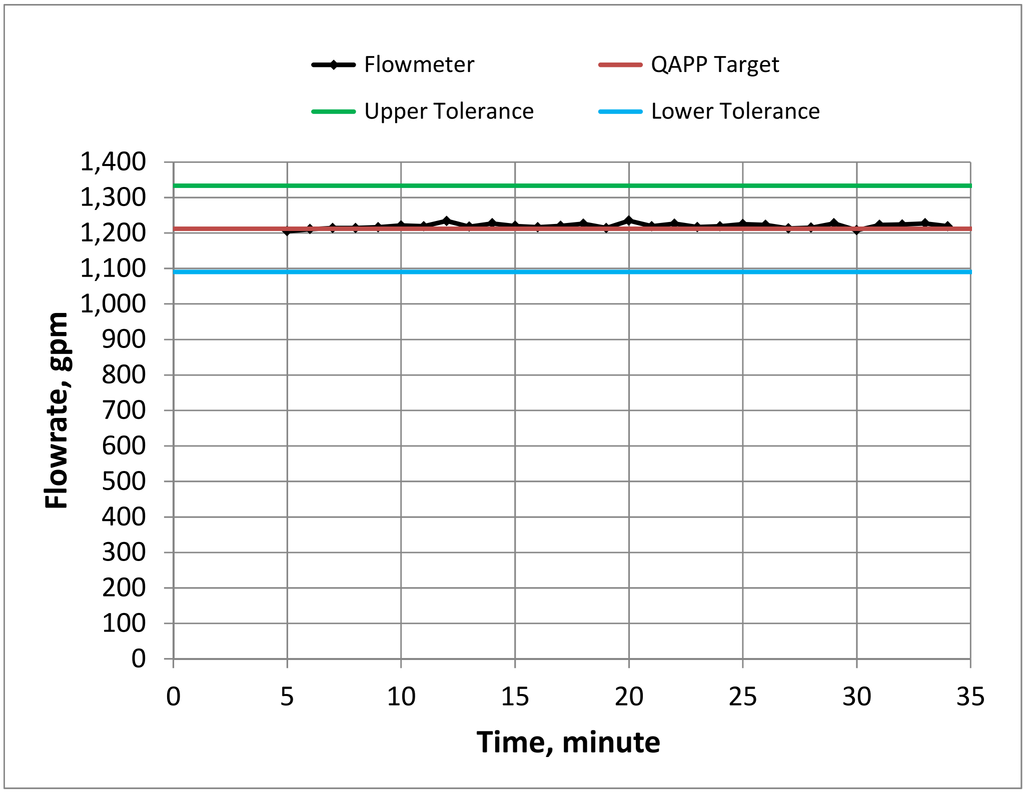


Figure F-22 Monitored Flow Rate for 2.70 cfs Experiment

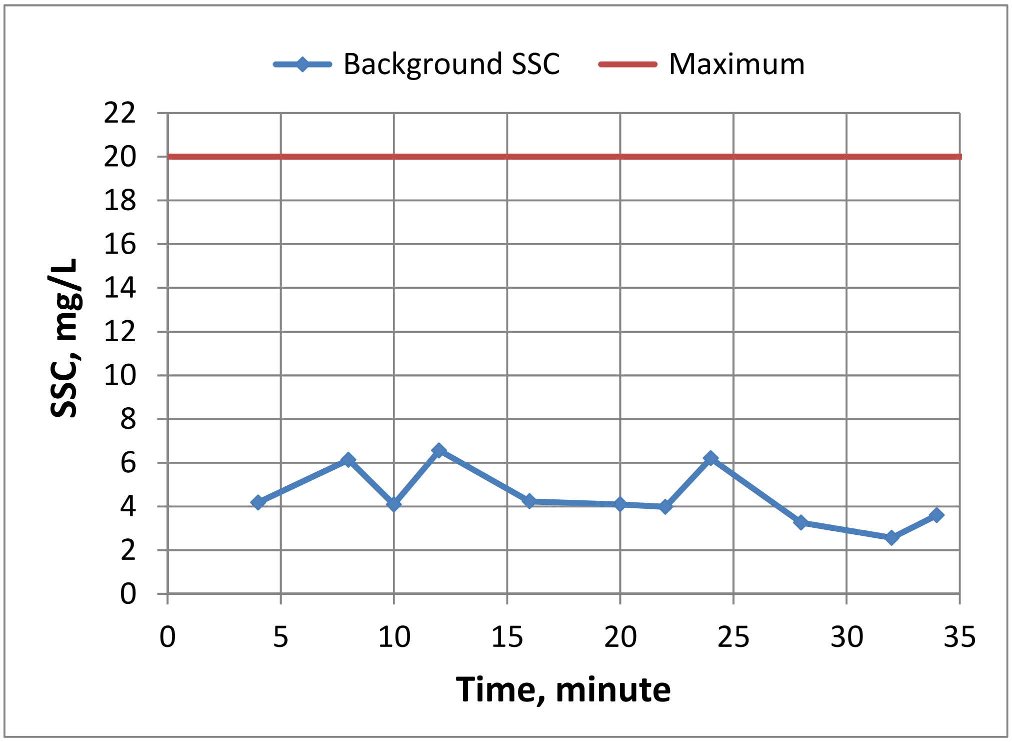


Figure F-23 Monitored Background SSC for 2.70 cfs Experiment

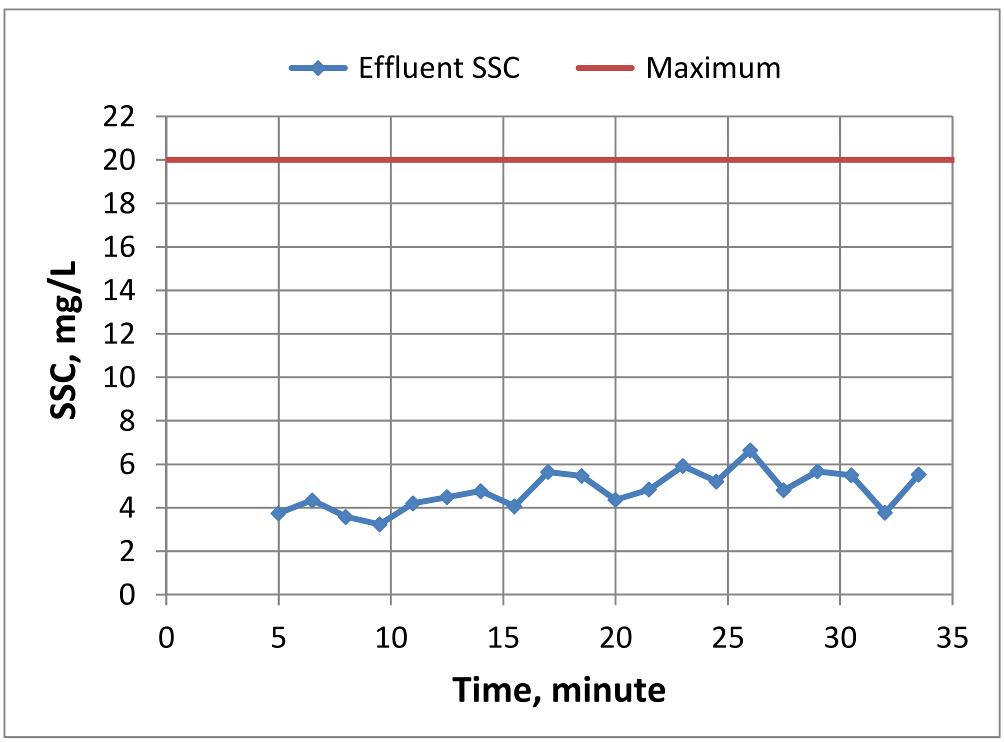


Figure F-24 Monitored Effluent SSC for 2.70 cfs Experiment