NJCAT TECHNOLOGY VERIFICATION

BaySaver Barracuda™ Hydrodynamic Separator

BaySaver Technologies, LLC

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1. Description of Technology

The BaySaver Barracuda Hydrodynamic Separator (BaySaver Barracuda) is a manufactured stormwater treatment device that removes suspended solids from stormwater runoff. The device is an insert that can be installed in either a polypropylene plastic pipe or concrete vault, and consists of a cone (vortex separator) and a sump apparatus with protrusions (extending horizontally into the sump area) which are referred to as "teeth".

Stormwater is directed to a cone-shaped (vortex) device inside the unit, which allows denser particles (greater density than the surrounding water) to move to the center of the device where they settle to the bottom. A weir prevents inflowing water from bypassing the vortex separator. Once water has flowed through the vortex and a majority of sediment has settled out into the sump, the effluent water rises to the outlet pipe, which is at virtually the same elevation as the inlet pipe. The "teeth" affixed to the inside walls of the sump reduce the velocity of the water in the vortex flow pattern below the cone and effectively reduce re-suspension of sediment in the sump, allowing the accumulated sediment to be retained within the unit. (**Figure 1**)

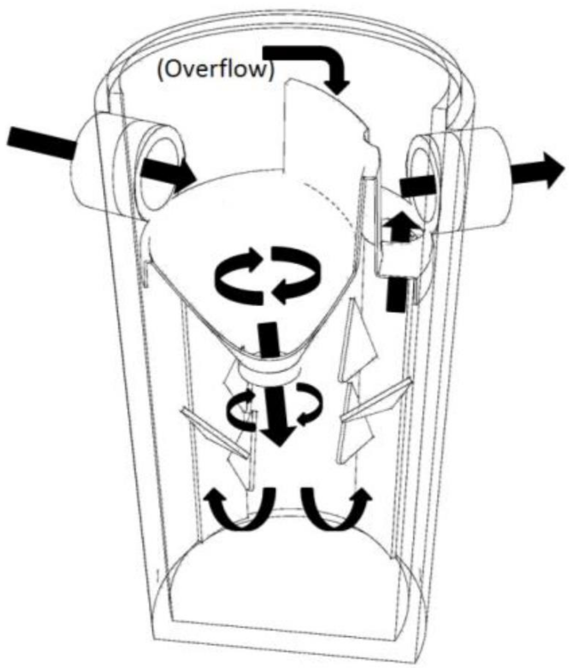

Figure 1 BaySaver Barracuda Flow Path Diagram

2. Laboratory Testing

The BaySaver Barracuda was installed at the Mid-Atlantic Stormwater Research Center (MASWRC, a subsidiary of BaySaver) in Mount Airy, Maryland, to test the removal efficiency of total suspended solids (TSS) and the ability to retain, i.e., inhibit scour, of collected sediment. All testing and data collection procedures including sediment blending, were supervised by Boggs Environmental Consultants, Inc. (BEC), and in accordance with the *New Jersey*

Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (January 2013) (NJDEP HDS Protocol). BEC is an independent environmental and engineering consulting company located in Middletown, Maryland. All water quality samples collected during the test program were analyzed by Fredericktowne Labs, which is an independent environmental testing laboratory. All sediment PSD samples were analyzed by ECS Mid-Atlantic, LLC, which is an independent geotechnical and environmental testing facility. Prior to the start of testing, a Quality Assurance Project Plan (QAPP) was submitted to and approved by the New Jersey Corporation for Advanced Technology (NJCAT).

2.1 Test Setup

The test unit was a full-scale commercially available BaySaver Barracuda consisting of a vortex separator, sedimentation sump, and teeth. The unit was measured at approximately 121 inches in height and 48 inches in diameter. Influent and effluent piping to the unit were 12 inches in diameter and at approximately the same inlet/outlet elevations. The total sedimentation area of this unit was 12.57 ft^2.

The test setup is shown in **Figure 2** below. The setup consisted of reservoir tanks, feed basin, pumps, flow control valves, discharge tank, BaySaver Barracuda, flow meter and temperature probe. The maximum water storage capacity of the reservoir tanks was approximately 7,000 ft^3.

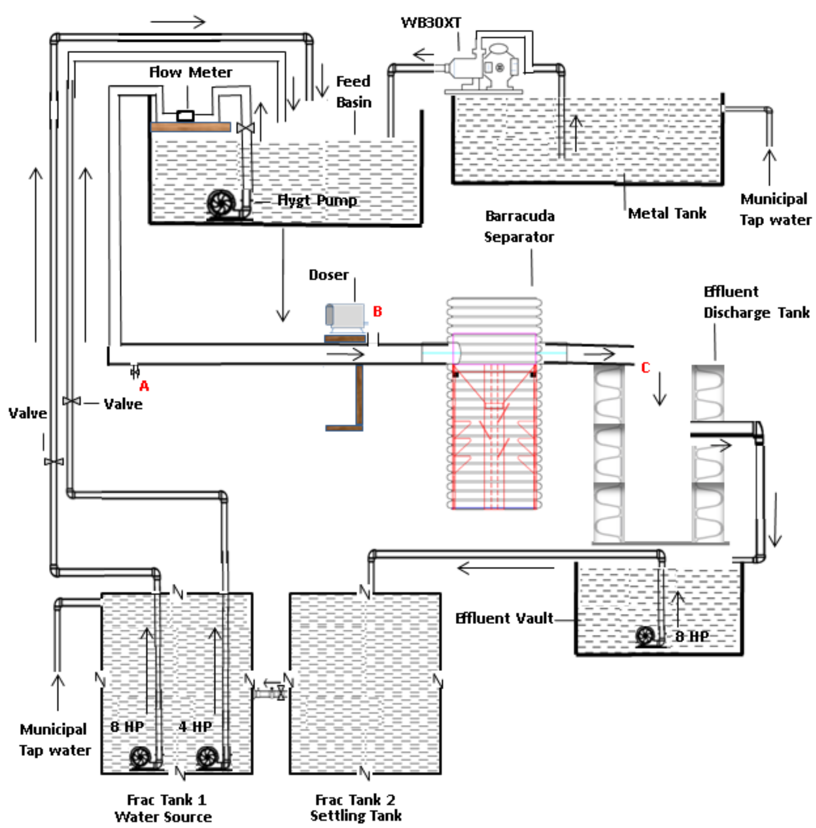

Figure 2 Diagram of the Test Facility for Scour, and 125%, and 100% MTFR Tests

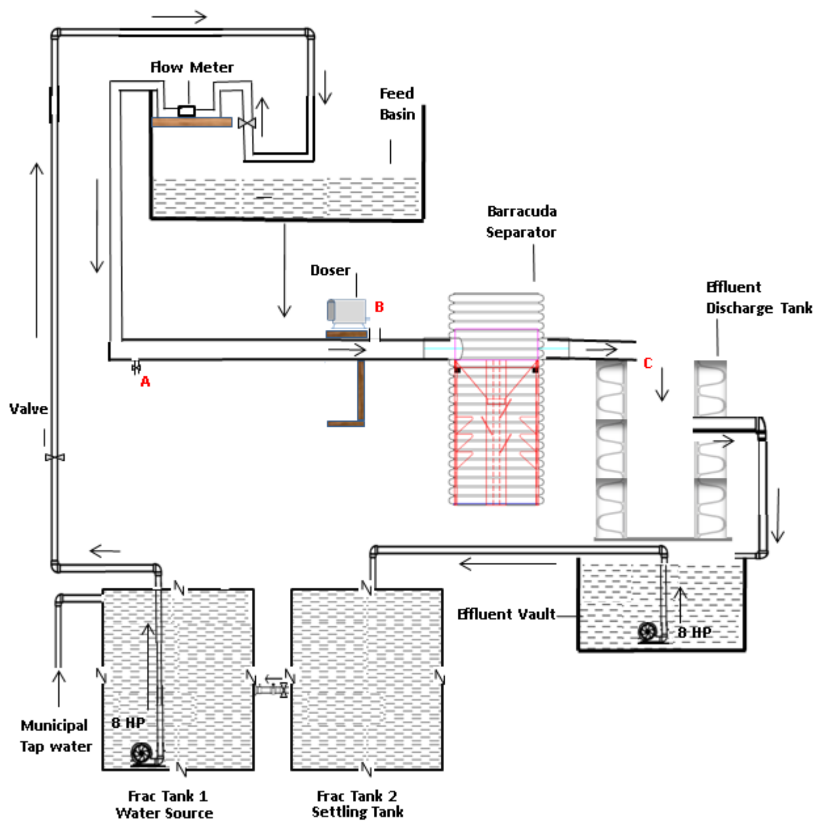

Figure 3 Diagram of the Test Facility for 75%, 50%, and 25% MTFR Tests

The letters **A**, **B**, and **C** indicate the locations where background, influent and effluent samples were collected, respectively.

Reservoir tanks, including two 18,000-gallon Frac Tanks and a 16,000-gallon metal tank, were filled with municipal tap water prior to each test run, and a PVC flow system, various flow control valves, and pumps were used to achieve each flow rate. For the higher flow rate runs (>200% MTFR scour run, 125% MTFR run and 100% MTFR run), water was pumped from the Frac Tanks and metal tank to the feed basin and a Flygt pump (27 hp) pumped water from the feed basin to the influent pipe 18 ft. upstream of the test unit. For the low flow rate runs (75% MTFR, 50% MTFR, and 25% MTFR test runs), a Godwin 8 hp pump pumped water from the Frac Tank to the same flow line as shown in **Figure 3**. Flow rates were controlled using throttling valves located on the discharge side of the pumps. Test sediment was dry fed through a 6-in. port at the crown of the 12-in. inlet pipe at a distance of 5 ft. upstream of the test unit. For all testing, flow rate was measured using a FloCat MFE electromagnetic flow meter and recorded once per minute by a SeaMetrics DL76 data logger. The flow meter was installed approximately 33 feet upstream of the BaySaver Barracuda in a "U" configuration according to manufacturer recommendations to ensure pipe-full condition. For all testing, flow exited the BaySaver Barracuda into the Effluent Discharge Tank. For water conservation purposes during the scour test (>200%) and 125% MTFR removal efficiency test (after clean water from Frac Tank 2 was diverted to Frac Tank 1 for use during the run) the water from the Effluent Discharge Tank was pumped to Frac Tank 2 and allowed to settle overnight before being used for testing the next day. For all other flow rates, water from the Effluent Discharge Tank was discharged into the sewer.

A HOBO temperature probe and data logger were located in the feed basin for 200%, 125%, and 100% MTFR testing and located in Frac Tank 1 for 75%, 50%, and 25% MTFR testing. Temperature measurements were recorded once per minute during each test run.

Background samples were collected in a 1000-mL bottle from a sampling port (Letter **A**) approximately 12 feet upstream from the sediment injection port. The port was controlled by a 1.5-inch ball valve with a 1.5-inch PVS pipe extending downward 4 ft below the bottom of the inlet pipe and purged several seconds before sample collection.

Effluent water flowed freely into the Effluent Discharge Tank (Letter **C**) at which point effluent samples were grabbed by hand by sweeping a 1000-mL bottle through the flow stream.

Sediment was added to the system via an Acrison volumetric screw auger through the crown of the 12-inch diameter inlet pipe (Letter **B**) approximately 5-feet upstream from the BaySaver Barracuda. Sediment feed samples were collected for an interval timed to the nearest second in 1000-mL plastic containers and then weighed on an analytical balance.

2.2 Test Sediment

Test Sediment for Removal Efficiency Testing

The test sediment used for removal efficiency testing was a blend of high purity commercially available silica sediment. The blend ratio was determined such that the particle size distribution of the blended sediment would meet the specifications outlined in the NJDEP HDS protocol. Prior to the start of testing, a surplus of test sediment was blended in one batch to be used for all five removal efficiency test runs. Six random samples from the batch were collected and composited under the direct supervision of BEC, and then three sub-samples were collected from the composite sample to be sent to ECS Mid-Atlantic, LLC, for PSD analysis using method ASTM D422-63. The PSD test results are summarized below in **Table 1** and **Figure 4**.

Table 1 Particle Size Distribution of Removal Efficiency Test Sediment

Particle Size (um)	Test Blend % Finer by Mass				
	NJDEP Target	Sample A	Sample B	Sample C	Average
1000	100	99.0	100.0	100.0	**99.7**
500	95	93.7	94.4	94.4	**94.2**
250	90	89.7	89.8	89.9	**89.8**
150	75	81.1	81.2	81.0	**81.1**
100	60	63.0	62.8	62.8	**62.9**
75	50	54.6	54.5	54.7	**54.6**
50	45	51.8	52.2	52.5	**52.2**
20	35	37.7	37.6	37.5	**37.6**
8	20	20.5	20.4	20.4	**20.4**
5	10	13.4	13.3	13.4	**13.4**
2	5	4.8	4.7	4.7	**4.7**

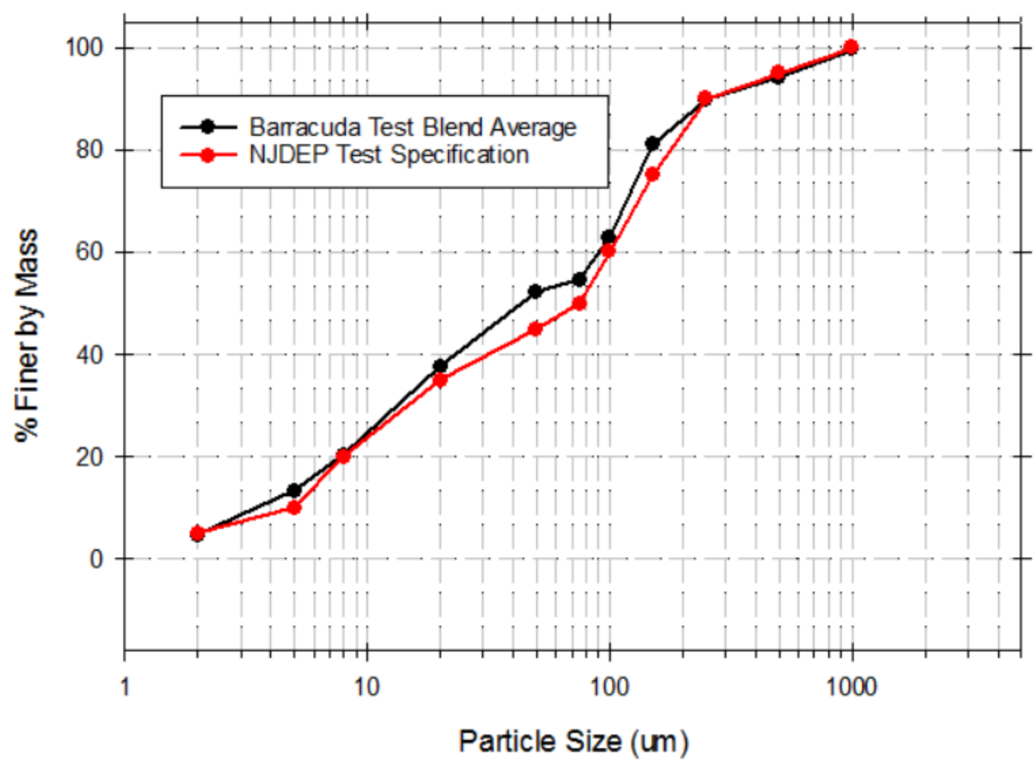

Figure 4 Average Removal Efficiency Test Sediment PSD vs. NJDEP HDS Protocol Specification

The removal efficiency test sediment was verified to be in compliance with the NJDEP HDS Protocol specification. The d_{50} of the sediment was found to be 42 μm and the sediment was finer than that required by the protocol, thus acceptable for use.

Scour Test Sediment

The test sediment used for scour testing was a blend of high purity commercially available silica sediment. The blend ratio was determined such that the particle size distribution of the blended sediment would meet the specifications outlined in the NJDEP HDS protocol. One batch of sediment was blended before the start of testing and six random samples from the batch were collected and composited under the direct supervision of BEC. Three sub-samples were then collected from the composite sample and sent to ECS Mid-Atlantic, LLC, for PSD analysis using method ASTM D422-63. The PSD results for the scour test sediment are summarized below in **Table 2** and **Figure 5**. The scour test sediment was found to be finer than the sediment required by NJDEP HDS Protocol specification and acceptable for use.

Table 2 Particle Size Distribution of Scour Test Sediment

Particle Size (um)	**Test Blend % Finer by Mass**				
	NJDEP Target	**Sample A**	**Sample B**	**Sample C**	**Average**
1000	100	99.9	99.9	99.9	**99.9**
500	90	88.6	88.9	88.2	**88.6**
250	55	72.6	72.2	72.8	**72.5**
150	40	55.9	55.3	56.0	**55.7**
100	25	26.0	26.3	26.2	**26.2**
75	10	11.8	11.5	11.8	**11.7**
50	0	5	4.8	4.9	**4.9**

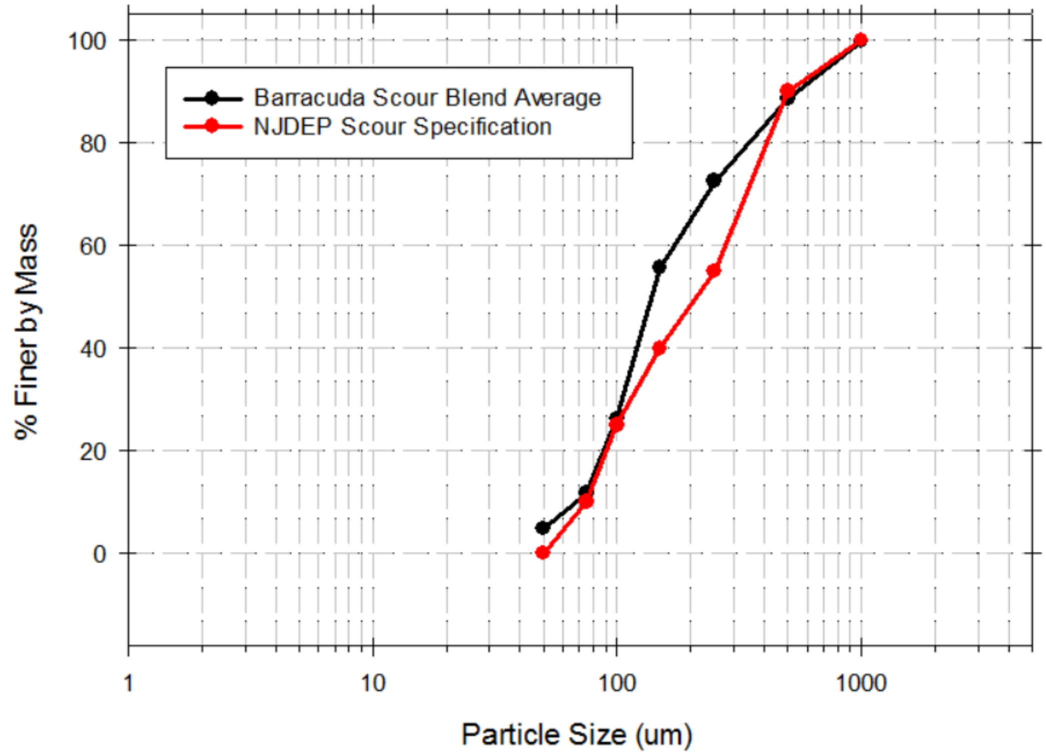

Figure 5 Average Scour Test Sediment PSD vs. NJDEP HDS Protocol Specification

2.3 Removal Efficiency Testing

Removal efficiency testing was conducted in accordance with Section 5 of the NJDEP Laboratory Protocol for HDS MTDs. A false floor was installed in the clean unit at the 50% sediment storage depth of 10-inches above the device floor. Testing was conducted at five flow rates: 25%, 50%, 75%, 100%, and 125% Maximum Treatment Flow Rate (MTFR) (142 gpm – 720 gpm) and at a target influent sediment concentration of 200 mg/L.

Test sediment was introduced to the flow stream via a volumetric screw auger within 10% of the target concentration of 200 mg/L and was sampled six times over the course of each flow rate test. Each sediment sample was collected over an interval timed to the nearest second using a Sportline P176 stopwatch in a 1000 mL plastic container for a sample volume of 100 mL or a collection time of one minute (whichever came first). Sediment feed samples were weighed on a Cole-Parmer Symmetry PR410 analytical balance (under the supervision of BEC).

The first effluent grab sample was collected following a minimum of three MTD detention times after flow rate was established and the first sediment sample was collected. Sequential effluent samples were collected every minute. When sediment feed was interrupted for measurement, the next series of sequential effluent samples were collected after three MTD detention times had passed. Fifteen effluent samples were collected during each flow test run, and eight background samples were collected with the odd-numbered effluent samples.

2.4 Scour Testing

Before testing began, a false floor was installed 6 inches above the floor of the unit and then pre-loaded with 4 inches of leveled scour test sediment. Measurements were taken by BEC to verify that the final height of the leveled sediment simulated a 50% maximum sediment storage volume. The unit was filled with clear water to the invert of the inlet pipe, and testing began within 96 hours of pre-loading the sediment.

Testing was performed at a flow rate of 1128 gpm (2.51 cfs), slightly greater than two times the MTFR. Target flow rate was achieved within three minutes after commencement of testing, at which time the first background sample was collected. Effluent grab samples were collected every two minutes for a total of fifteen effluent samples. Eight background samples were collected at evenly time spaced intervals throughout the test.

3. Performance Claims

Per the NJDEP verification procedure and based on the laboratory testing conducted for the BaySaver Barracuda S4, the following are the performance claims made by BaySaver Technologies, LLC.

Total Suspended Solids (TSS) Removal Efficiency

For the particle size distribution and weighted calculation method required by the NJDEP HDS Protocol, the BaySaver Barracuda achieved a weighted TSS removal efficiency of at least 50% for an MTFR of 1.25 cfs (561 gpm).

Maximum Treatment Flow Rate (MTFR)

The MTFR for the BaySaver Barracuda S4 model was demonstrated to be 1.25 cfs (561 gpm) with a total sedimentation area of 12.57 ft^2, which corresponds to a surface loading rate of 44.6 gpm/ft^2 of sedimentation area.

Maximum Sediment Storage Depth and Volume

The maximum sediment storage depth is 20 inches which corresponds to 20.94 ft^3 of sediment storage volume for the BaySaver Barracuda S4 model. A sediment storage depth of 10 inches corresponds to 50% full sediment storage capacity (10.47 ft^3).

Effective Treatment and Sedimentation Area

The effective treatment and sedimentation area of the BaySaver Barracuda varies with model size, as it is dependent upon the surface area of the model diameter. The effective treatment and sedimentation area of the BaySaver Barracuda S4 model is 12.57 ft^2.

Detention Time and Volume

The BaySaver Barracuda detention time depends on flow rate and model size. The Barracuda S4 model tested had a detention time of approximately 61 seconds for a flow rate of 1.25 cfs (561 gpm). Detention time is calculated by dividing the treatment chamber wet volume by the MTFR.

On-line Installation

Based on the results of the scour testing, the BaySaver Barracuda qualifies for on-line installation.

4. Supporting Documentation

The NJDEP Procedure (NJDEP, 2013) for obtaining verification of a stormwater manufactured treatment device (MTD) from the New Jersey Corporation for Advanced Technology (NJCAT) requires that "copies of the laboratory test reports, including all collected and measured data; all data from performance evaluation test runs; spreadsheets containing original data from all performance test runs; all pertinent calculations; etc." be included in this section. This was discussed with NJDEP and it was agreed that as long as such documentation could be made available by NJCAT upon request that it would not be prudent or necessary to include all this information in this verification report. This information was provided to NJCAT and is available upon request.

4.1 Removal Efficiency Testing

Removal efficiency test runs were completed on the BaySaver Barracuda S4 at flow rates of 25%, 50%, 75%, 100%, and 125% MTFR at a target influent concentration of 200 mg/L in accordance with the NJDEP HDS protocol. The results from the five test runs were used to calculate the overall annualized weighted removal efficiency.

Average flow rate was determined from the data collected from the flow data logger in one-minute intervals. Six sediment feed rate samples were used to calculate the average influent concentration for each run. The samples were required to meet a COV of <0.10, as specified by the NJDEP HDS Protocol. Average influent concentration for each run was calculated by using the total mass of the test sediment added during dosing divided by the volume of water that flowed through the MTD during dosing.

The average effluent concentration was adjusted by subtracting the measured background concentration. All background concentrations were less than the 20 mg/L maximum allowable concentration specified by the NJDEP HDS Protocol. The removal efficiency for each run was calculated using the following formula:

$$\textbf{Removal Efficiency (\%)} = \left(\frac{\text{Average Influent Concentration} - \text{Adjusted Average Effluent Concentration}}{\text{Average Influent Concentration}} \right) \times 100$$

Removal Efficiency Test Results for 25% MTFR

The 25% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.31 cfs. A summary of test readings, measurements and calculations is shown in **Table 3** below. **Figure 6** portrays water flow and temperature data and sediment feed results are shown in **Table 4**. Background and effluent sampling measurements are presented in **Table 5**. The BaySaver Barracuda S4 test unit removed 56.6% of the test sediment at a flow rate of 0.32 cfs. QA/QC results for flow rate, feed rate and influent, effluent and background concentrations were within the allowable parameters specified by the protocol as shown below in **Table 6**.

Table 3 Summary of Barracuda S4 25% MTFR

Test Date	Target Flow Rate	Detention Time	Target Sediment Concentration	Target Sediment Feed Rate	Test Duration
	(cfs/gpm)	(sec)	(mg/L)	(mg/min)	(min)
6/22/2017	0.31/139	243	200	106,190	75
Measured Values					
Average Flow Rate	**Average Influent Concentration***	**Maximum Water Temp.**	**Average Adjusted Effluent Concentration**	**Average Removal Efficiency**	**QA/QC Compliance**
(cfs/gpm)	**(mg/L)**	**(°F)**	**(mg/L)**	**(%)**	Yes
0.32/142	191.4	71.5	83.1	56.6	

*Average influent concentration reported was calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test by the total flow volume during the injection of test sediment.

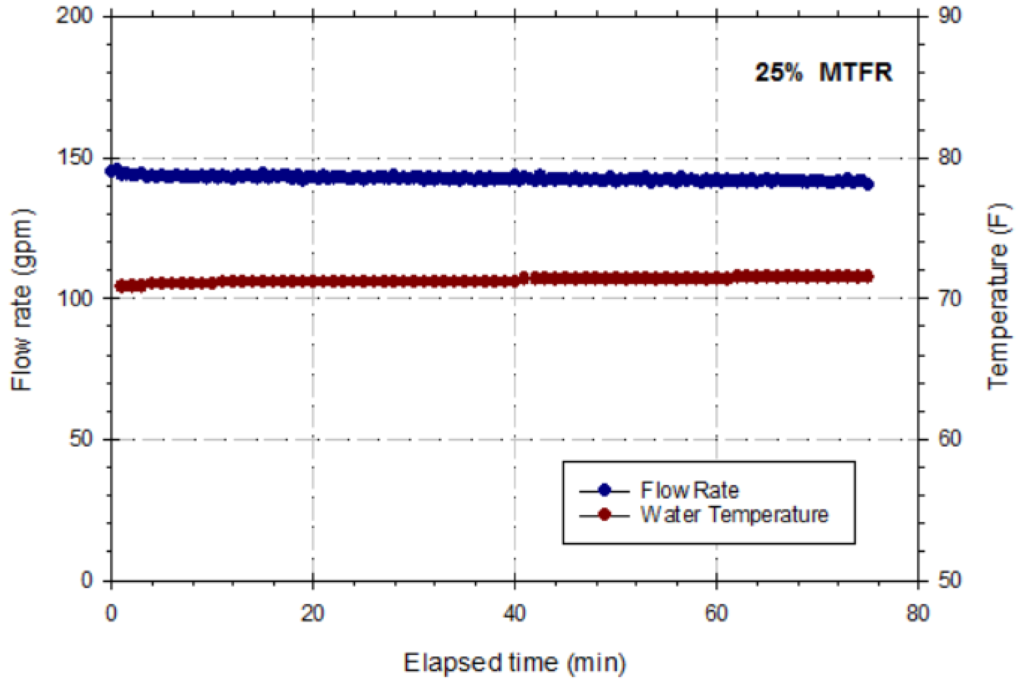

Figure 6 Water Flow and Temperature for 25% MTFR

Table 4 Sediment Feed Summary 25% MTFR

Target Concentration		200 mg/L	Target Feed Rate		106,190 mg/min	
Sample ID	Run Time	Sample Mass	Sample Duration	Feed Rate	Flow rate	Calculated Influent Concentration*
	(min)	(g)	(sec)	(mg/min)	(gpm)	(mg/L)
Sediment 1	0	105.539	60	105,539	144.98	192.31
Sediment 2	15	109.043	60	109,043	143.88	200.21
Sediment 3	30	103.496	60	103,496	142.47	191.91
Sediment 4	45	105.28	60	105,280	142.18	195.61
Sediment 5	60	97.593	60	97,593	142.18	181.33
Sediment 6	75	96.429	60	96,429	140.38	181.46
			Average	102,897	142.68	190.47

*Calculated influent concentrations were calculated using the measured flow rate corresponding to the time sediment sample was collected.

Table 5 Background and Effluent Measurements 25% MTFR

Sample ID	Time (min)	Concentration (mg/L)
Background 1	13	1*
Background 2	15	1*
Background 3	29	1*
Background 4	43	1*
Background 5	45	1*
Background 6	59	1*
Background 7	73	1*
Background 8	75	1*

Sample #	Time (min)	Effluent Concentration (mg/L)	Background Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
1	13	80	1*	79
2	14	89		88
3	15	85	1*	84
4	28	91		90
5	29	77	1*	76
6	30	87		86
7	43	85	1*	84
8	44	84		83
9	45	89	1*	88
10	58	81		80
11	59	82	1*	81
12	60	81		80
13	73	79	1*	78
14	74	96		95
15	75	76	1*	75
Removal Efficiency		**56.6%**	**Average Adjusted Effluent Concentration**	**83.1 mg/L**

*Background concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, 1 mg/L was used for calculations.

Table 6 QA/QC Results 25% MTFR

Flow Rate (cfs/gpm)				
Run Parameters	Target	Actual	Difference	COV
	0.31/139	0.32/142	+2.2%	0.006
QA/QC Limit			± 10% PASS	0.03 PASS
Sediment Feed Rate (mg/min)				
Run Parameters	Target	Actual	Difference	COV
	106,190	102,897	-3.1%	0.048
QA/QC Limit			± 10% PASS	0.10 PASS
Influent Concentration (mg/L)				
Run Parameters	Target	Actual	Difference	COV
	200	191.4	-4.3%	0.048
QA/QC Limit			± 10% PASS	0.10 PASS
Background Concentration (mg/L)				
Run Parameters	Low	High	Average	Acceptable Threshold
	1	1	1	
QA/QC Limit				<20 mg/L PASS

Removal Efficiency Test Results for 50% MTFR

The 50% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.63 cfs. A summary of test readings, measurements and calculations is shown in **Table 7** below. **Figure 7** shows the water flow and temperature data, and sediment feed results are shown in **Table 8**. Background and effluent sampling measurements are presented in **Table 9**. The Barracuda S4 test unit removed 54.1% of the test sediment at a flow rate of 0.61 cfs. QA/QC results for flow rate, feed rate and influent, effluent and background concentrations were within the allowable parameters specified by the protocol as shown below in **Table 10**.

Table 7 Summary of Barracuda S4 50% MTFR

Test Date	Target Flow Rate	Detention Time	Target Sediment Concentration	Target Sediment Feed Rate	Test Duration
	(cfs/gpm)	(sec)	(mg/L)	(mg/min)	(min)
6/19/2017	0.63/281	122	200	212,380	45
Measured Values					
Average Flow Rate	Average Influent Concentration*	Maximum Water Temp.	Average Adjusted Effluent Concentration	Average Removal Efficiency	QA/QC Compliance
(cfs/gpm)	(mg/L)	(°F)	(mg/L)	(%)	Yes
0.61/275	200.0	74.6	91.8	54.1	

*Average influent concentration reported was calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test by the total flow volume during the injection of test sediment.

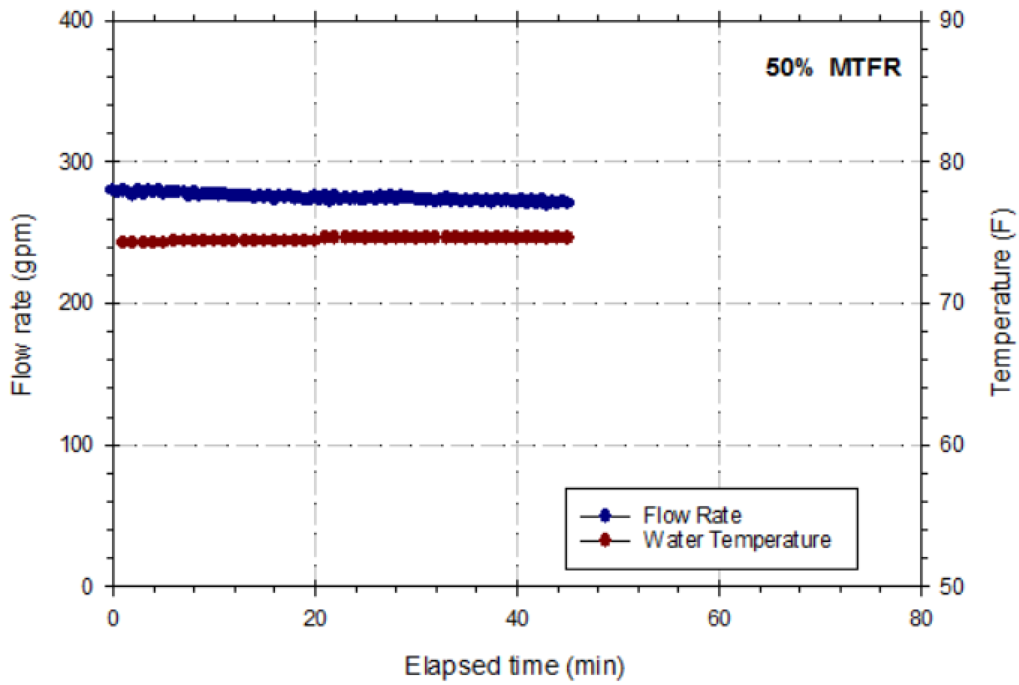

Figure 7 Water Flow and Temperature for 50% MTFR

Table 8 Sediment Feed Summary 50% MTFR

Target Concentration		**200 mg/L**	**Target Feed Rate**		**212,380 mg/min**	
Sample ID	**Run Time**	**Sample Mass**	**Sample Duration**	**Feed Rate**	**Flow rate**	**Calculated Influent Concentration***
	(min)	**(g)**	**(sec)**	**(mg/min)**	**(gpm)**	**(mg/L)**
Sediment 1	0	119.888	35	205,522	279.76	194.07
Sediment 2	9	116.814	35	200,253	277.47	190.66
Sediment 3	18	120.320	35	206,263	274.24	198.69
Sediment 4	27	125.003	35	214,291	273.20	207.21
Sediment 5	36	123.988	35	212,551	273.51	205.29
Sediment 6	45	122.843	35	210,588	270.90	205.36
			Average	208,245	274.85	200.21

*Calculated influent concentrations were calculated using the measured flow rate corresponding to the time sediment sample was collected.

Table 9 Background and Effluent Measurements 50% MTFR

Sample ID	Time (min)	Concentration (mg/L)
Background 1	7	1*
Background 2	9	1*
Background 3	17	1*
Background 4	25	1*
Background 5	27	1*
Background 6	35	1*
Background 7	43	1*
Background 8	45	1*

Sample #	Time (min)	Effluent Concentration (mg/L)	Background Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
1	7	88	1*	87
2	8	98		97
3	9	93	1*	92
4	16	77		76
5	17	99	1*	98
6	18	95		94
7	25	95	1*	94
8	26	98		97
9	27	96	1*	95
10	34	98		97
11	35	98	1*	97
12	36	89		88
13	43	96	1*	95
14	44	82		81
15	45	90	1*	89
Removal Efficiency		**54.1%**	**Average Adjusted Effluent Concentration**	**91.8 mg/L**

*Background concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, 1 mg/L was used for calculations.

Table 10 QA/QC Results 50% MTFR

Flow Rate (cfs/gpm)				
Run Parameters	Target	Actual	Difference	COV
	0.63/281	0.61/275	-2.1%	0.009
QA/QC Limit			± 10% PASS	0.03 PASS
Sediment Feed Rate (mg/min)				
Run Parameters	Target	Actual	Difference	COV
	212,380	208,245	-1.9%	0.025
QA/QC Limit			± 10% PASS	0.10 PASS
Influent Concentration (mg/L)				
Run Parameters	Target	Actual	Difference	COV
	200	200.0	+0.0%	0.025
QA/QC Limit			± 10% PASS	0.10 PASS
Background Concentration (mg/L)				
Run Parameters	Low	High	Average	Acceptable Threshold
	1	1	1	
QA/QC Limit				<20 mg/L PASS

Removal Efficiency Test Results for 75% MTFR

The 75% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 0.94 cfs. A summary of test readings, measurements and calculations is shown in **Table 11** below. **Figure 8** shows the water flow and temperature data, and sediment feed results are shown in **Table 12**. Background and effluent sampling measurements are presented in **Table 13**. The BaySaver Barracuda S4 test unit removed 49.8% of the test sediment at a flow rate of 0.94 cfs. QA/QC results for flow rate, feed rate and influent, effluent and background concentrations were within the allowable parameters specified by the protocol as shown below in **Table 14**.

Table 11 Summary of Barracuda S4 75% MTFR

Test Date	Target Flow Rate	Detention Time	Target Sediment Concentration	Target Sediment Feed Rate	Test Duration
	(cfs/gpm)	(sec)	(mg/L)	(mg/min)	(min)
6/15/2017	0.94/421	81	200	318,730	35
Measured Values					
Average Flow Rate	**Average Influent Concentration***	**Maximum Water Temp.**	**Average Adjusted Effluent Concentration**	**Average Removal Efficiency**	**QA/QC Compliance**
(cfs/gpm)	(mg/L)	(°F)	(mg/L)	(%)	Yes
0.94/419	213.9	70.5	107.3	49.8	

*Average influent concentration reported was calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test by the total flow volume during the injection of test sediment.

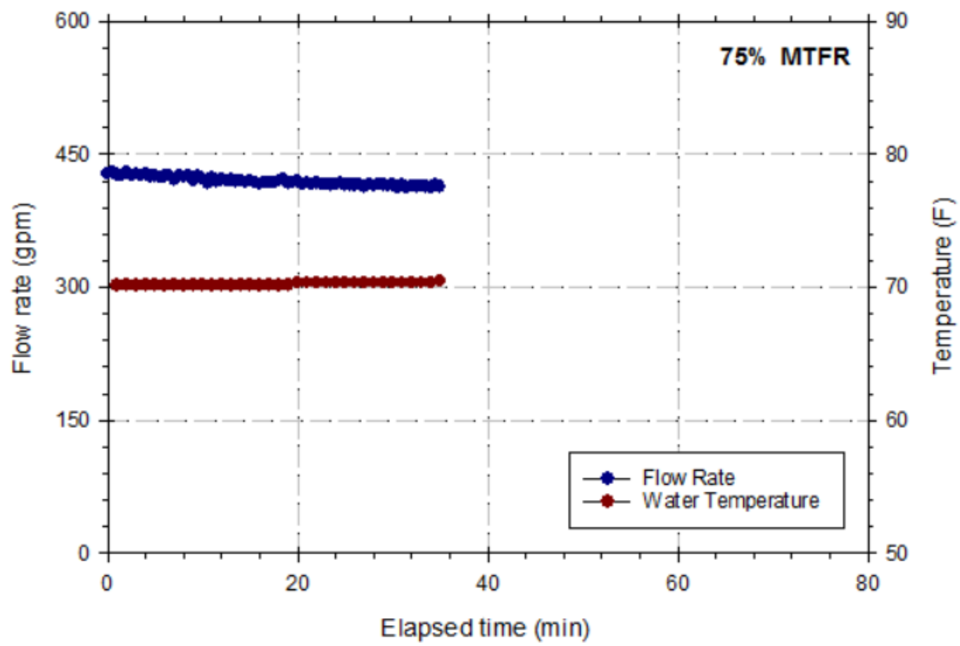

Figure 8 Water Flow and Temperature for 75% MTFR

Table 12 Sediment Feed Summary 75% MTFR

Target Concentration		200 mg/L	Target Feed Rate		318,730 mg/min	
Sample ID	Run Time	Sample Mass	Sample Duration	Feed Rate	Flow rate	Calculated Influent Concentration*
	(min)	(g)	(sec)	(mg/min)	(gpm)	(mg/L)
Sediment 1	0	142.987	25	343,169	428.71	211.46
Sediment 2	7	142.154	25	341,170	421.53	213.81
Sediment 3	14	142.365	25	341,676	420.59	214.61
Sediment 4	21	144.156	25	345,974	418.71	218.28
Sediment 5	28	138.538	25	332,491	414.34	211.99
Sediment 6	35	138.021	25	331,250	412.98	211.89
			Average	339,288	419.48	213.67

*Calculated influent concentrations were calculated using the measured flow rate corresponding to the time sediment sample was collected.

Table 13 Background and Effluent Measurements 75% MTFR

Sample ID	Time (min)	Concentration (mg/L)		
Background 1	5	4		
Background 2	7	1		
Background 3	13	1*		
Background 4	19	1*		
Background 5	21	1*		
Background 6	27	1*		
Background 7	33	1		
Background 8	35	1*		
Sample #	**Time (min)**	**Effluent Concentration (mg/L)**	**Background Concentration (mg/L)**	**Adjusted Effluent Concentration (mg/L)**
1	5	99	4	95
2	6	120		118
3	7	100	1	99
4	12	110		109
5	13	100	1*	99
6	14	110		109
7	19	110	1*	109
8	20	110		109
9	21	110	1*	109
10	26	110		109
11	27	100	1*	99
12	28	110		109
13	33	120	1	119
14	34	100		99
15	35	120	1*	119
Removal Efficiency		**49.8%**	**Average Adjusted Effluent Concentration**	**107.3 mg/L**

*Background concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, 1 mg/L was used for calculations.

Table 14 QA/QC Results 75% MTFR

Flow Rate (cfs/gpm)				
Run Parameters	Target	Actual	Difference	COV
	0.94/421	0.94/419	-0.5%	0.012
QA/QC Limit			± 10% PASS	0.03 PASS
Sediment Feed Rate (mg/min)				
Run Parameters	Target	Actual	Difference	COV
	318,730	339,288	+6.4%	0.018
QA/QC Limit			± 10% PASS	0.10 PASS
Influent Concentration (mg/L)				
Run Parameters	Target	Actual	Difference	COV
	200	213.9	+6.95%	0.018
QA/QC Limit			± 10% PASS	0.10 PASS
Background Concentration (mg/L)				
Run Parameters	Low	High	Average	Acceptable Threshold
	1	4	1.4	
QA/QC Limit				<20 mg/L PASS

Removal Efficiency Test Results for 100% MTFR

The 100% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 1.25 cfs. A summary of test readings, measurements and calculations is shown in **Table 15** below. **Figure 9** shows the water flow and temperature data, and sediment feed results are shown in **Table 16**. Background and effluent sampling measurements are presented in **Table 17**. The Barracuda S4 test unit removed 48.5% of the test sediment at a flow rate of 1.25 cfs. QA/QC results for flow rate, feed rate and influent and effluent background concentrations were within the allowable parameters specified by the protocol as shown below in **Table 18**.

Table 15 Summary of Barracuda S4 100% MTFR

Test Date	Target Flow Rate	Detention Time	Target Sediment Concentration	Target Sediment Feed Rate	Test Duration
	(cfs/gpm)	(sec)	(mg/L)	(mg/min)	(min)
6/12/2017	1.25/561	61	200	424,750	30
Measured Values					
Average Flow Rate	**Average Influent Concentration***	**Maximum Water Temp.**	**Average Adjusted Effluent Concentration**	**Average Removal Efficiency**	**QA/QC Compliance**
(cfs/gpm)	(mg/L)	(°F)	(mg/L)	(%)	Yes
1.25/559	201.8	72.4	104.0	48.5	

*Average influent concentration reported was calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test by the total flow volume during the injection of test sediment.

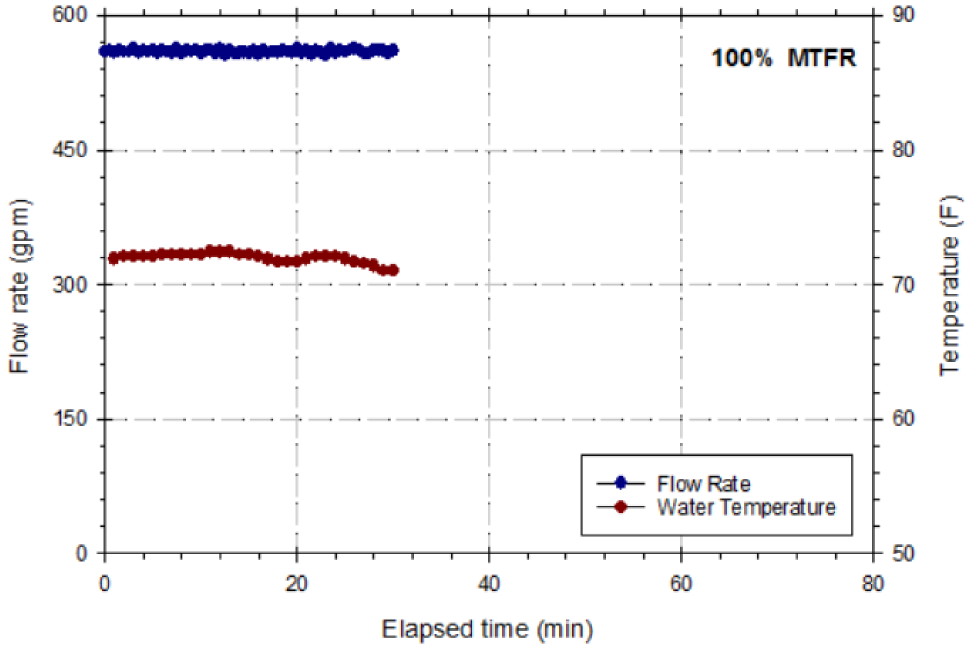

Figure 9 Water Flow and Temperature for 100% MTFR

Table 16 Sediment Feed Summary 100% MTFR

Target Concentration		200 mg/L	Target Feed Rate		424,750 mg/min	
Sample ID	Run Time	Sample Mass	Sample Duration	Feed Rate	Flow rate	Calculated Influent Concentration*
	(min)	(g)	(sec)	(mg/min)	(gpm)	(mg/L)
Sediment 1	0	144.997	20	434,991	559.46	205.40
Sediment 2	6	151.714	20	455,142	561.44	214.16
Sediment 3	12	142.895	20	428,685	561.85	201.56
Sediment 4	18	135.247	20	405,741	558.21	192.02
Sediment 5	24	143.448	20	430,344	556.33	204.35
Sediment 6	30	135.835	20	407,505	560.19	192.17
			Average	427,068	559.58	201.61

*Calculated influent concentrations were calculated using the measured flow rate corresponding to the time sediment sample was collected.

Table 17 Background and Effluent Measurements 100% MTFR

Sample ID	Time (min)	Concentration (mg/L)		
Background 1	4	1		
Background 2	6	1*		
Background 3	11	1*		
Background 4	16	2		
Background 5	18	1		
Background 6	23	1		
Background 7	28	1		
Background 8	30	1		
Sample #	**Time (min)**	**Effluent Concentration (mg/L)**	**Background Concentration (mg/L)**	**Adjusted Effluent Concentration (mg/L)**
1	4	110	1	109
2	5	110		109
3	6	110	1*	109
4	10	110		109
5	11	94	1*	93
6	12	96		95
7	16	100	2	98
8	17	120		119
9	18	110	1	109
10	22	120		119
11	23	100	1	99
12	24	110		109
13	28	100	1	99
14	29	91		90
15	30	95	1	94
Removal Efficiency		**48.5%**	**Average Adjusted Effluent Concentration**	**104.0 mg/L**

*Background concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, 1 mg/L was used for calculations.

Table 18 QA/QC Results 100% MTFR

Flow Rate (cfs/gpm)				
Run Parameters	Target	Actual	Difference	COV
	1.25/561	1.25/559	-0.4%	0.003
QA/QC Limit			± 10% PASS	0.03 PASS
Sediment Feed Rate (mg/min)				
Run Parameters	Target	Actual	Difference	COV
	424,750	427,068	+0.5%	0.043
QA/QC Limit			± 10% PASS	0.10 PASS
Influent Concentration (mg/L)				
Run Parameters	Target	Actual	Difference	COV
	200	201.8	+0.9%	0.043
QA/QC Limit			± 10% PASS	0.10 PASS
Background Concentration (mg/L)				
Run Parameters	Low	High	Average	Acceptable Threshold
	1	2	1.1	
QA/QC Limit				<20 mg/L PASS

Removal Efficiency Test Results for 125% MTFR

The 125% MTFR test was conducted in accordance with the NJDEP HDS Protocol at a target flow rate of 1.56 cfs. A summary of test readings, measurements and calculations is shown in **Table 19** below. **Figure 10** shows the water flow and temperature data, and sediment feed results are shown in **Table 20**. Background and effluent sampling measurements are presented in **Table 21**. The Barracuda S4 test unit removed 43.8% of the test sediment at a flow rate of 1.60 cfs. QA/QC results for flow rate, feed rate and influent, effluent and background concentrations were within the allowable parameters specified by the protocol as shown below in **Table 22**.

Table 19 Summary of Barracuda S4 125% MTFR

Test Date	Target Flow Rate	Detention Time	Target Sediment Concentration	Target Sediment Feed Rate	Test Duration
	(cfs/gpm)	(sec)	(mg/L)	(mg/min)	(min)
6/8/2017	1.56/701	49	200	530,710	25
Measured Values					
Average Flow Rate	**Average Influent Concentration***	**Maximum Water Temp.**	**Average Adjusted Effluent Concentration**	**Average Removal Efficiency**	**QA/QC Compliance**
(cfs/gpm)	**(mg/L)**	**(°F)**	**(mg/L)**	**(%)**	
1.60/720	188.7	65.3	106.1	43.8	Yes

*Average influent concentration reported was calculated by dividing the entire mass of test sediment injected into the flow stream over the duration of the test by the total flow volume during the injection of test sediment.

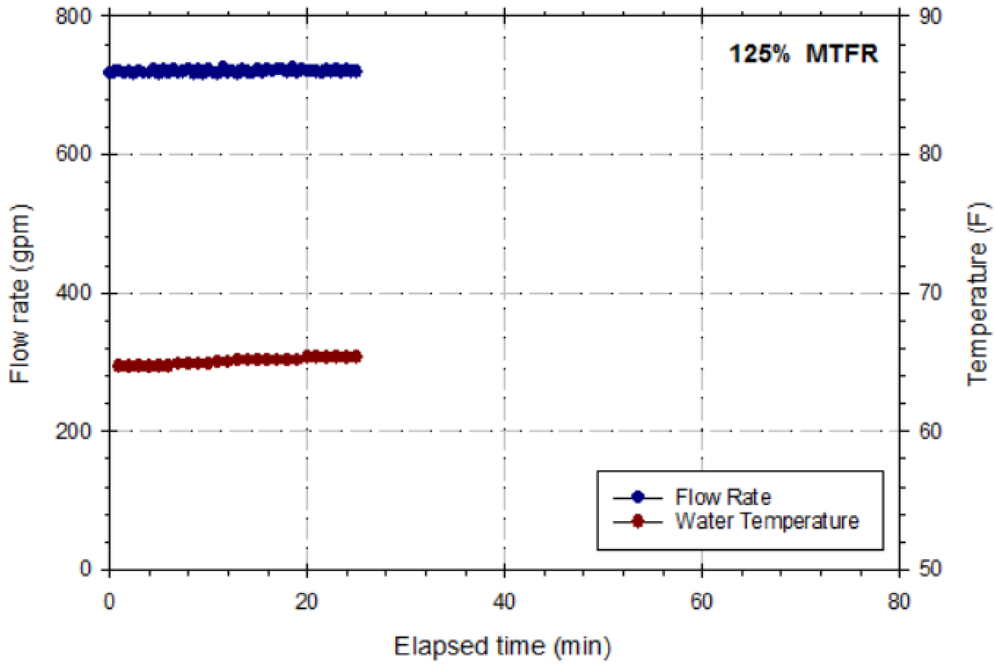

Figure 10 Water Flow and Temperature for 125% MTFR

Table 20 Sediment Feed Summary 125% MTFR

Target Concentration		200 mg/L	Target Feed Rate		530,710 mg/min	
Sample ID	Run Time	Sample Mass	Sample Duration	Feed Rate	Flow rate	Calculated Influent Concentration*
	(min)	(g)	(sec)	(mg/min)	(gpm)	(mg/L)
Sediment 1	0	129.382	15	517,528	718.33	190.33
Sediment 2	5	123.383	15	493,532	716.67	181.92
Sediment 3	10	123.833	15	495,332	721.98	181.24
Sediment 4	15	137.213	15	548,852	723.23	200.48
Sediment 5	20	129.834	15	519,336	720.73	190.35
Sediment 6	25	127.839	15	511,356	718.96	187.89
			Average	514,323	719.98	188.70

*Calculated influent concentrations were calculated using the measured flow rate corresponding to the time sediment sample was collected.

Table 21 Background and Effluent Measurements 125% MTFR

Sample ID	Time (min)	Concentration (mg/L)
Background 1	3	1*
Background 2	5	1*
Background 3	9	3
Background 4	13	3
Background 5	15	2
Background 6	19	4
Background 7	23	5
Background 8	25	6

Sample #	Time (min)	Effluent Concentration (mg/L)	Background Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
1	3	110	1*	109
2	4	110		109
3	5	120	1*	119
4	8	120		118
5	9	110	3	107
6	10	120		117
7	13	74	3	71
8	14	110		108
9	15	110	2	108
10	18	77		74
11	19	110	4	106
12	20	95		91
13	23	120	5	115
14	24	140		135
15	25	110	6	104
Removal Efficiency		**43.8%**	**Average Adjusted Effluent Concentration**	**106.1 mg/L**

*Background concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, 1 mg/L was used for calculations.

Table 22 QA/QC Results 125% MTFR

Flow Rate (cfs/gpm)				
Run Parameters	Target	Actual	Difference	COV
	1.56/701	1.60/720	+2.7%	0.003
QA/QC Limit			± 10% PASS	0.03 PASS
Sediment Feed Rate (mg/min)				
Run Parameters	Target	Actual	Difference	COV
	530,710	514,323	-3.1%	0.039
QA/QC Limit			± 10% PASS	0.10 PASS
Influent Concentration (mg/L)				
Run Parameters	Target	Actual	Difference	COV
	200	188.7	-5.7%	0.039
QA/QC Limit			± 10% PASS	0.10 PASS
Background Concentration (mg/L)				
Run Parameters	Low	High	Average	Acceptable Threshold
	1	6	3.1	
QA/QC Limit				<20 mg/L PASS

Annualized Weighted TSS Removal Efficiency

The annualized weighted TSS removal efficiency has been calculated using the weighting factors provided in the NJDEP HDS protocol. As shown in **Table 23** below, the BaySaver Barracuda S4 achieved a 52.0% annualized weighted TSS removal for an MTFR of 1.25 cfs (561 gpm). This testing demonstrates that the BaySaver Barracuda meets the NJDEP requirement that HDS devices achieve at least a 50% weighted annualized TSS removal efficiency.

Table 23 Annualized Weighted TSS Removal Efficiency for BaySaver Barracuda S4

% MTFR	Removal Efficiency (%)	Annual Weighting Factor	Weighted Removal Efficiency (%)
25	56.6	0.25	14.2
50	54.1	0.3	16.2
75	49.8	0.2	10.0
100	48.5	0.15	7.3
125	43.8	0.1	4.4
Annualized Weighted TSS Removal Efficiency			**52.0%**

4.2 Scour Testing

Scour testing was conducted on the BaySaver Barracuda S4 in accordance with Section 4 of the NJDEP HDS Protocol at a flow rate of 2.51 cfs or 1128 gpm (slightly greater than 200% of the MTFR) to verify that the unit is suitable for on-line installation.

Water flow and temperature data for scour testing is shown in **Figure 11,** and effluent and background concentration results are shown in **Table 24** below. The adjusted effluent concentration was calculated by subtracting the background concentration from the recorded effluent concentration. All background and effluent concentrations were less than or equal to 1 mg/L. The average adjusted effluent concentration was less than 1mg/L when tested at greater than 200% of the MTFR. Based on these results, the BaySaver Barracuda is suitable for on-line installation.

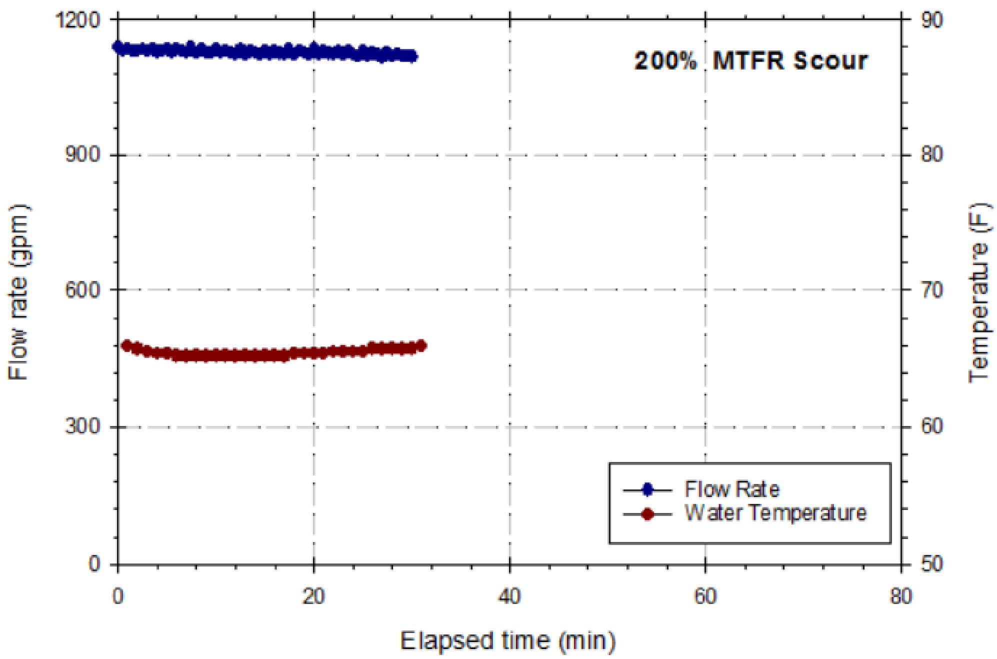

Figure 11 Water Flow and Temperature for >200% MTFR Scour Test

Table 24 Background and Effluent Measurements for Scour Testing

Date	5/30/2017	Average Flow Rate	2.51 cfs/1128 gpm
Maximum Temperature	65.9 °F	Flow Rate COV	0.005
Sample ID	Time (min)	Concentration (mg/L)	
Background 1	0	1*	
Background 2	4.5	1*	
Background 3	9	1*	
Background 4	13.5	1*	
Background 5	18	1*	
Background 6	22.5	1	
Background 7	27	1	
Background 8	30	1	
Sample #	Time (min)	Effluent Concentration (mg/L)	Adjusted Effluent Concentration (mg/L)
1	2	1	<1
2	4	1*	<1
3	6	1	<1
4	8	1	<1
5	10	1	<1
6	12	1	<1
7	14	1	<1
8	16	1*	<1
9	18	1	<1
10	20	1	<1
11	22	1*	<1
12	24	1	<1
13	26	1*	<1
14	28	1	<1
15	30	1*	<1

*Concentrations marked with an asterisk were reported by the laboratory as below detection limit (1 mg/L). In these cases, a value of 1 mg/L was used for calculations.

5. Design Limitations

BaySaver Technologies, LLC, provides engineering support to all clients. Each system is designed and sized according to anticipated flow rate, load rating, and system depth at the installation site. All site and design constraints are discussed during the design and manufacturing process.

Required Soil Characteristics

The BaySaver Barracuda is delivered to the job site to be housed in a pre-cast concrete structure or an ADS polypropylene manhole. During the pre-casting design process, soil characteristics including corrosiveness, top and lateral loading, and ground water must be addressed. The BaySaver Barracuda can be installed and will function in all soil types. A copy of the geotechnical report along with surface loading requirements, and groundwater situation must be reviewed and verified during the design process (see below for buoyancy situations).

Slope

The BaySaver Barracuda is typically installed on a 0% slope or flat installation grade across the unit (invert in to invert out). In general, it is recommended that the pipe slope into the system not exceed 10%. Slopes in excess of 10% could cause increased velocities which could affect the turbulence into the system. The BaySaver engineering team will evaluate the design prior to specification for application on sites with steep slopes.

Maximum Flow Rate

The maximum treatment flow rate of the BaySaver Barracuda is dependent upon model size and performance specifications. The hydraulic loading rate is 44.6 gpm/ft^2 for all models. BaySaver Engineering staff can assist site design engineers to ensure an appropriate model.

Maintenance Requirements

The lifespan and maintenance needs of the BaySaver Barracuda depend on the sediment load and individual site conditions. The system must be inspected at regular intervals and maintained when necessary to ensure the optimal performance. Detailed requirements can be found in **Section 6**.

Driving Head

Driving head will vary depending on the site specific configuration. Design support is given by BaySaver for each project, and site-specific drawings (cut sheets) will be provided that show pipe inverts, finish surface elevation, and peak treatment and maximum flow rates through the BaySaver Barracuda to ensure no adverse impact on the hydraulic grade-line.

Installation Limitations

BaySaver provides contractors with instructions prior to delivery, and onsite assistance is available from the installation technician during delivery and installations. Pick weights and lifting details are also provided prior to delivery to ensure that the contractor is able to prepare the appropriate equipment on site.

Configurations

The BaySaver Barracuda is available in various configurations and can be installed on- or off-line, although this verification pertains to on-line installations. An internal bypass weir removes the need for any external high-flow diversion structure in the on-line system. When bypass occurs, flow is routed directly from the treatment chamber to the outlet chamber, thus preventing any scour or loss of captured pollutants. In some cases, inlet/outlet pipes with varying pipe angles can be accommodated. Contact BaySaver for design assistance on this.

Structural Load Limitations

BaySaver Barracudas are typically designed for HS-20 loading. If a depth greater than 15 feet is required from final grade, the manhole structural design must be reviewed by the manufacturer. Contact the BaySaver team if increasing load is expected.

Pre-treatment Requirements

The BaySaver Barracuda has no pre-treatment requirements.

Limitations in Tailwater

Site-specific tailwater conditions will be assessed on each individual project. Tailwater conditions increase the amount of driving head required for optimal system operation. The manufacturer's internal protocols require that these conditions are discussed with the engineer of record and that a solution be implemented to adjust for any design variations caused by tailwater conditions at both treatment and bypass flow rates.

Depth to Seasonal High Water Table

Groundwater conditions do not affect BaySaver Barracuda function and treatment performance. High groundwater may cause buoyancy, and an anti-floatation ballast can be added to the structure to counteract this. If high groundwater is anticipated, the BaySaver engineering team will evaluate the need for anti-buoyance measures and provide the guidance to address the concerns.

6. Maintenance Plans

The BaySaver Barracuda requires periodic maintenance to continue operating at design efficiency. The maintenance process is comprised of the cleaning of the manhole with a vacuum truck. The system needs to be cleaned, when necessary, to ensure optimum performance, typically every 12-18 months. The rate at which the system collects pollutants will depend more upon site activities than the size of the unit. Since storm water solids loads can be variable, it is possible that the maintenance cycle could be more or less than the projected duration for a given O&M cycle.

Inspection

Inspection is the key to effective maintenance, and it is easily performed. BaySaver recommends the BaySaver Barracuda be inspected every six (6) months for the first year and then on an annual basis. Sediment accumulation may be especially variable during the first year after installation as construction disturbances and landscaping stabilizes. Inspections may need to be performed more often in the winter months in climates where sanding operations may lead to rapid accumulations or in other areas with heavy sediment loading. It is very useful to keep a record of each inspection. NJDEP requires that sediment be removed when the sediment depth reaches 50% of the MTD's maximum sediment storage capacity. The BaySaver Barracuda should be cleaned when inspection reveals that 10 inches or more of sediment is accumulated at the bottom of manhole or when visual inspection shows a large accumulation of debris or oil. This determination of sediment depth can be made by lowering a stadia rod into the manhole until it hits the sediment and measuring the distance from the bottom of the pole to the water line mark on the stadia rod. Note: To avoid underestimating the volume of sediment in the manholes, the measuring device must be lowered to the top of the sediment pile carefully. Finer, silty particles at the top of the pile may offer less resistance to the end of the rod than larger particles toward the bottom of the pile. Maintenance frequency can be determined by adhering to the initial sizing frequency given by the initial sizing of the system. Once actual sediment loading on-site is determined, a modified maintenance frequency can be proposed to the site owner. Please contact the ADS/BaySaver Technologies Engineering Department for maintenance cycle estimations or assistance at 1.800.229.7283.

Maintenance Procedures

1. Remove the manhole cover to provide access to the pollutant storage. Pollutants are stored in the sump, below the cone assembly visible from the surface. You'll access this area through the 10" diameter access cylinder.
2. Use a vacuum truck or other similar equipment to remove all water, debris, oils and sediment from both the top cone area and the bottom sump compartment area of the Barracuda unit.
3. Use a high-pressure hose to clean the manhole of all remaining sediment and debris (recommended but optional). Then, use the vacuum truck to remove this water.
4. Fill the cleaned Barracuda unit with water to the invert of the outlet pipe.
5. Replace the manhole cover/close the hatch (if applicable).
6. Dispose of polluted water, oils, sediment and trash at an approved facility.

- Local regulations prohibit the discharge of solid material into the sanitary system. Check with the local sewer authority for authority to discharge the liquid.
- Many places treat the pollutants as leachate. Check with local regulators about disposal requirements. Important: Additional local regulations may apply to the maintenance procedure.

7. Statements

The following signed statements from the manufacturer (BaySaver Technologies, LLC), third-party observer (Boggs Environmental Consultants, Inc.) and NJCAT are required to complete the NJCAT verification process.

In addition, it should be noted that this report has been subjected to public review (e.g. stormwater industry) and all comments and concerns have been satisfactorily addressed.

Date: 07-12-2017

To: Dr. Richard Magee, Sc.D., P.E. BCEE
Executive Director
New Jersey Corporation for Advanced Technology
c/o Center for Environmental Systems
Stevens Institute of Technology
One Castle Point on Hudson
Hoboken, NJ 07030

Subject: Submittal of the laboratory verification report for the Barracuda Separator S4

Dr. Magee,

We are providing this letter as our statement certifying that the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device (January 2013)* has been strictly followed. In addition, we certify that all requirements and criteria were met and exceeded during testing of the BaySaver Barracuda S4 Separator.

If you have any questions, please contact us at your convenience.

Sincerely,

Daniel J. Figola, P.E.
General Manager,
BaySaver Technologies, LLC

Signature: Daniel J Figola Date: 7/12/17

BOGGS ENVIRONMENTAL CONSULTANTS

Middletown, MD & Morgantown, WV

Administrative Office:
200 W Main Street
Middletown, Maryland 21769
Office (301) 694-5687
Fax (301) 694-9799

July 25, 2017

BaySaver Technologies, LLC
1030 Deer Hollow Drive
Mount Airy, MD 21771
(301) 679-0640
dfigola@ads-pipe.com

ATTENTION: Daniel Figola, General Manager

REFERENCE: Third Party Review of Testing Procedures for Baysaver Barracuda S4 Separator at the Mid Atlantic Storm Water Research Center (MASWRC), 1207 Park Ridge Drive, Mount Airy, MD 21771

BOGGS ENVIRONMENTAL CONSULTANTS, INC. (BEC) provided Third Party Review services for the testing of the Baysaver Barracuda S4 Separator, conducted from May 26, 2017, through June 29, 2017, to evaluate if the required testing meets certification standards established by the New Jersey Department of Environmental Protection (NJDEP).

LABORATORY TESTING PROCEDURES & METHODOLOGIES

The following procedures and requirements were followed during the testing of the Baysaver Barracuda S4 Separator.

- NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology.* Trenton, NJ. January 25, 2013.
- NJDEP 2013b. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device.* Trenton, NJ. January 25, 2013.
- BaySaver Technologies, LLC 2017. *Quality Assurance Project Plan for BaySaver Barracuda Separator.* Prepared by BaySaver Technologies. May, 2017.

ONSITE OBSERVATION OF TESTING PROCEDURES

BEC was physically present at MASWRC, at 1207 Park Ridge Drive, in Mount Airy, MD 21771, to observe that the following adhered to the required set forth by the documentation listed above:

- Setup of the testing equipment, including all calibrations;
- Mixing and establishment of sediment blends meeting PSD's specified and approved by NJDEP;
- Establishment of a Procedure Checklist (by BEC), which was used during each run (May 30, 2017 through June 22, 2017) to ensure and document all details of procedures and to personally witness sample collection;
- Mass measurement verification (solid samples), and chain of custody for liquid samples sent to an outside lab;
- Data collection, calculations, and conclusions as reported in BaySaver Technologies, LLC's report entitled, *NJCAT TECHNOLOGY VERIFICATION BaySaver Barracuda™ Hydrodynamic Separator*, July, 2017.

THIRD PARTY VERIFICATION & OPINIONS

Based on observations during the runs and the analysis of all data, BEC verified the following:

- That the testing of the Baysaver Barracuda S4 Separator at the Mid-Atlantic Storm Water Research Center was conducted in accordance with the NJDEP protocols specified above.
- For the particle size distribution and weighted calculation method required by the NJDEP HDS Protocol, the Baysaver Barracuda Separator achieved a weighted TSS removal efficiency of at least 50% for an MTFR of 1.25 cfs (559 gpm).

Should you have any questions, contact our office at your earliest convenience.

Sincerely,
BOGGS ENVIRONMENTAL CONSULTANTS, INC.

William R. Warfel
Principal Environmental Scientist

Robin J. Maliszewskyj
Chemical Engineer

ENVIRONMENTAL SCIENCE, ENGINEERING & INDUSTRIAL HYGIENE SERVICES

BOGGS
ENVIRONMENTAL CONSULTANTS

Middletown, MD & Morgantown, WV

Administrative Office:
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Office (301) 694-5687
Fax (301) 694-9799

September 11, 2017

Dr. Richard Magee
Technical Director
New Jersey Corporation for Advanced Technology
c/o Center for Environmental Systems
Stevens Institute of Technology
One Castle Point on Hudson
Hoboken, NJ 07030
rsmagee@rcn.com

REFERENCE: No Conflict of Interest Statement for Third Party Review of BaySaver S-4 Separator Testing Procedures at the Mid Atlantic Stormwater Research Center, 1207 Park Ridge Drive Mount Airy, MD 21771

Dr. Magee

BOGGS ENVIRONMENTAL CONSULTANTS, INC. (BEC) was hired by BaySaver Technologies, LLC to provide Third Party Review Services for the testing of the BaySaver S-4 Separator.

I want to ensure you that there is no conflict of interest between BEC and BaySaver Technologies, LLC for the following reasons:

- BEC has no ownership stake in BaySaver Technologies, LLC.
- BEC receives no commission for selling a manufactured treatment device for BaySaver Technologies, LLC.
- BEC has no licensing agreement with BaySaver Technologies, LLC, and,
- BEC receives no funding or grants associated with the testing program from BaySaver Technologies, LLC.

Please give me a call if you have any questions.

Sincerely,
BOGGS ENVIRONMENTAL CONSULTANTS, INC.

William R. Warfel

William R. Warfel
Principal Environmental Scientist

ENVIRONMENTAL SCIENCE, ENGINEERING & INDUSTRIAL HYGIENE SERVICES

Center for Environmental Systems
Stevens Institute of Technology
One Castle Point
Hoboken, NJ 07030-0000

July 25, 2017

Shashi Nayak
NJDEP
Division of Water Quality
Bureau of Non-Point Pollution Control
401-02B
PO Box 420
Trenton, NJ 08625-0420

Dear Mr. Nayak,

Based on my review, evaluation and assessment of the testing conducted on the BaySaver Barracuda™ Hydrodynamic Separator (commercial unit model Barracuda S4) at the Mid-Atlantic Storm Water Research Center (MASWRC, a subsidiary of BaySaver), supervised by Boggs Environmental Consultants, Inc.,, the test protocol requirements contained in the "New Jersey Laboratory Testing Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device" (NJDEP HDS Protocol) were met or exceeded. Specifically:

Test Sediment Feed

The mean PSD of the test sediments comply with the PSD criteria established by the NJDEP HDS protocol. The BaySaver removal efficiency test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification. The test sediment was shown to be finer than the sediment blend specified by the protocol (<75µ); the test sediment d_{50} was 42 microns. The scour test sediment PSD analysis was plotted against the NJDEP removal efficiency test PSD specification and shown to be finer than specified by the protocol.

Removal Efficiency Testing

In accordance with the NJDEP HDS Protocol, removal efficiency testing was executed on the BaySaver Barracuda S4, a 4 ft. diameter commercially available unit, in order to establish the ability of the BaySaver Barracuda to remove the specified test sediment at 25%, 50%, 75%, 100% and 125% of the target MTFR. The BaySaver Barracuda S4 demonstrated 52.0% annualized weighted solids removal as defined in the NJDEP HDS Protocol. The flow rates, feed rates and influent concentration all met the NJDEP HDS test protocol's coefficient of variance requirements and the background concentration for all five test runs never exceeded 20 mg/L (maximum of 6 mg/L).

Scour Testing

In order to demonstrate the ability of the BaySaver Barracuda to be used as an on-line treatment device scour testing was conducted at greater than 200% of MTFR in accordance with the NJDEP HDS Protocol. The average flow rate during the online scour test was 2.51 cfs, which represents 202% of the MTFR (MTFR = 1.25 cfs). Background concentrations were 1 mg/L or non-detect throughout the scour testing, which complies with the 20 mg/L maximum background concentration specified by the test protocol. Unadjusted effluent concentrations ranged from 1 mg/L to non-detect. When adjusted for background concentrations, the effluent concentrations were <1mg/L. These results confirm that the BaySaver Barracuda S4 did not scour at 202% MTFR and meets the criteria for on-line use.

Maintenance Frequency

The predicted maintenance frequency for all BaySaver Barracuda models is essentially 60 months.

Sincerely,

Richard S. Magee, Sc.D., P.E., BCEE
Executive Director

8. References

ASTM D422-63. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D3977-97. *Standard Test Methods for Determining Concentrations in Water Samples*.

BaySaver Technologies, LLC 2017. *Quality Assurance Project Plan for BaySaver Barracuda Separator.* Prepared by BaySaver Technologies. May 2017.

BaySaver Technologies, LLC 2017. *NJCAT Technology Verification: BayFilter™.* Prepared by BaySaver Technologies. May 2017.

NJDEP 2013a. *New Jersey Department of Environmental Protection Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation for Advanced Technology*. Trenton, NJ. January 25, 2013.

NJDEP 2013b. *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Hydrodynamic Sedimentation Manufactured Treatment Device.* Trenton, NJ. January 25, 2013.

VERIFICATION APPENDIX

Introduction

- Manufacturer – BaySaver Technologies, LLC, 1030 Deer Hollow Drive, Mt. Airy, MD 21771. Website: http://www.BaySaver.com Phone: 800-229-7283.
- Barracuda MTD – BaySaver Barracuda verified models are shown in **Table A-1** and **Table A-2**.
- TSS Removal Rate – 50%
- On-line installation

Detailed Specification

- NJDEP sizing tables and physical dimensions of the BaySaver Barracuda verified models are attached (**Table A-1** and **Table A-2**).
- New Jersey requires that the peak flow rate of the NJWQ Design Storm event of 1.25 inch in 2 hours shall be used to determine the appropriate size for the MTD. The BaySaver Barracuda S4 model has a maximum treatment flow rate (MTFR) of 1.25 cfs (561 gpm), which corresponds to a surface loading rate of 44.6 gpm/ft^2 of sedimentation area.
- Pick weights and installation procedures vary slightly with model size. Design support is given by BaySaver for each project and pick weights and installation procedures will be provided prior to delivery.
- Maximum recommended sediment depth prior to cleanout is 10 inches for all model sizes.
- Maintenance Guide is at: http://www.ads-pipe.com/pdf/en/Barracuda_Maintenance_07_17.pdf
- Maintenance frequency for the BaySaver Barracuda models is 60 months.
- Under N.J.A.C. 7:8-5.5, NJDEP stormwater design requirements do not allow a hydrodynamic separator such as the BaySaver Barracuda to be used in series with another hydrodynamic separator to achieve an enhanced TSS removal rate.

Table A-1 MTFRs and Sediment Removal Intervals for BaySaver Barracuda Models

Model[1]	Manhole Diameter[1] (ft)	NJDEP 50% TSS Maximum Treatment Flow Rate (cfs)	Treatment Area (ft^2)	Hydraulic Loading rate (gpm/ft^2)	50% Maximum Sediment Storage[3] (ft^3)	Sediment Removal Interval[2] (months)
Barracuda S3	3	0.70	7.07	44.6	5.89	60
Barracuda S4	4	1.25	12.57	44.6	10.47	60
Barracuda S5	5	1.95	19.63	44.6	16.36	60
Barracuda S6	6	2.80	28.27	44.6	23.56	60
Barracuda S8	8	5.00	50.27	44.6	41.89	60
Barracuda S10	10	7.80	78.54	44.6	65.45	60

Notes:

1. In some areas Barracuda units are available in additional diameters. Units not listed here are sized not to exceed 44.6 gpm/ft^2 of effective treatment during the peak water quality flow.
2. Sediment Removal Interval (months) = (50% HDS MTD Max Sediment Storage Volume * 3.57) / (MTFR * TSS Removal Efficiency) calculated using equation in Appendix B, Part B of the NJDEP HDS Protocol.
3. 50% Sediment Storage Capacity is equal to manhole diameter x 10 inches of sediment depth. Each Barracuda unit has a 20 inches deep sediment sump.

Table A-2 Standard Dimensions for BaySaver Barracuda Models

Model	Manhole Diameter (ft)	NJDEP 50% TSS MTFR (cfs)	Total Chamber Depth (ft)	Treatment Chamber Depth[1] (ft)	Treatment Chamber Wet Volume[4] (ft^3)	Aspect Ratio[2] (Depth/Dia.)	Sediment Sump Depth (in)	Maximum Pipe Diameter (in)
Barracuda S3	3	0.70	4.83	4.00	28.3	1.33	20.0	12.0
Barracuda S4	4	1.25	6.83	6.00	75.4	1.50	20.0	12.0
Barracuda S5	5	1.95	6.83	6.00[3]	117.8	1.20	20.0	18.0
Barracuda S6	6	2.80	6.83	6.00[3]	169.7	1.00	20.0	18.0
Barracuda S8	8	5.00	11.03	10.20	512.7	1.275	20.0	24.0
Barracuda S10	10	7.80	13.59	12.76	1002	1.276	20.0	30.0

Notes:

1. Treatment chamber depth is defined as the total chamber depth minus ½ the sediment storage depth.
2. The aspect ratio is the unit's treatment chamber depth/diameter. The aspect ratio for the tested unit is 1.5. Larger models (>250% MTFR of the tested unit, > 3.125 cfs) must be geometrically proportionate to the tested unit. A variance of 15% is allowable (1.275 to 1.725).
3. For units < 250% MTFR (5 and 6 ft models), the depth must be equal or greater than the depth of the unit treated.
4. Referred to as Treatment Chamber Capacity in the BaySaver Barracuda Maintenance Guide

July 2019

GENERAL USE LEVEL DESIGNATION FOR PRETREATMENT (TSS)

For

BaySaver Technologies™ BaySeparator

Ecology's Decision:

Based on BaySaver Technologies™ application submissions Ecology hereby issues the following use level designation:

1. **General Use Level Designation (GULD) for the BaySeparator System pretreatment use (a) ahead of infiltration treatment, or (b) to protect and extend the maintenance cycle of a basic or enhanced treatment device (e.g., sand or media filter). This GULD applies to BaySeparator units sized at an operating rate of no more than 35.4 gpm/ft² of manhole area (primary plus storage). Base the size of the BaySeparator unit on the water quality design flow rate as determined below.**

2. **Calculate the water quality design flow rate using the following procedures:**

   - **Western Washington: for treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using the latest version of the Western Washington Hydrology Model or other Ecology-approved continuous runoff model.**

   - **Eastern Washington: For treatment installed upstream of detention or retention, the water quality design flow rate is the peak 15-minute flow rate as calculated using one of the three methods described in Chapter 2.2.5 of the Stormwater Management Manual for Eastern Washington (SWMMEW) or local manual.**

   - **Entire State: For treatment installed downstream of detention, the water quality design flow rate is the full 2-year release rate of the detention facility.**

3. **The GULD designation has no expiration date but may be amended or revoked by Ecology and is subject to the conditions specified below.**

<u>Ecology's Conditions of Use:</u>

1. **Design, assemble, install, operate, and maintain BaySeparators in accordance with BaySaver Technologies™ applicable manuals and documents and the Ecology decision and conditions specified herein.**

2. **Maintenance: The required inspection/maintenance interval for stormwater treatment devices is often dependent on the efficiency of the device and the degree of pollutant loading from a particular drainage basin. Therefore, Ecology does not endorse or recommend a "one size fits all" maintenance cycle for a particular model/size of manufactured filter treatment device.**
    - **Owners/operators must inspect the BaySeparator System for a minimum of twelve months from the start of the post-construction operation to determine site-specific maintenance schedules and requirements. You must conduct inspections monthly during the wet season, and every other month during the dry season. (According to the SWMMWW, the wet season in western Washington is October 1 to April 30. According to the SWMMEW, the wet season in eastern Washington is October 1 to June 30). After the first year of operation, owners/operators must conduct inspections based on the findings during the first year of inspections.**
    - **Conduct inspections by qualified personnel, follow manufacturer's guidelines, and use methods capable of determining either a decrease in treated effluent flow rate and/or a decrease in pollutant removal ability.**
    - **When inspections are performed, the following findings typically serve as maintenance triggers:**
        - **Maintenance of the BaySeparator System is recommended when inspection reveals that 2 feet (1.5 feet for the 1/2K model) of sediment has accumulated on the bottom of either manhole or when visual inspection shows a large accumulation of debris or oil.**

3. **Discharges from the BaySeparator unit shall not cause or contribute to water quality standards violations in receiving waters.**

Applicant: Advanced Drainage Systems - BaySaver

Applicant's Address: 4640 Truman Blvd
Hilliard, Ohio 43065

Application Documents:

- BaySaver Technologies, Inc. Technical Evaluation Report, BaySeparator™ System, Woodinville Sammamish River Outfall, Woodinville Washington. August 2018
- BaySaver Technologies, Inc. Technical Evaluation Engineering Report, BaySaver Technologies Inc., Revised 2008
- BaySaver Technologies, Inc. Technical Evaluation Engineering Report, BaySaver Technologies Inc., August 2006

- BaySaver Technologies, Inc. Technical Evaluation Engineering Report, BaySaver Technologies Inc., June 2005
- BaySaver Technologies™ Separation System Technical and Design Manual, BaySaver Technologies Inc.", March 2004
- Estimating the Maximum Treatment Rate and the Maximum Hydraulic Rate of the BaySaver Units, Omid Mohensi, September 2005
- List of Units Sold and Units Installed in Washington State, June, 2005

You may obtain a CD-ROM of the submittal reports by request from BaySaver Technologies™.

Applicant's Use Level Requests:

General use level designation (GULD) for pretreatment.

Applicant's Performance Claims:

Based on field studies, the BaySeparator System will achieve 50% removal of total suspended solids at 100% design flow rate with an average influent of 127 mg/L and a mean d50 of 54 microns.

Ecology Recommendations:

Ecology finds that:

- BaySaver Technologies, Inc. has shown Ecology, through laboratory and field testing, that the BaySeparator System is capable of attaining Ecology's Pretreatment goals.

Findings of Fact:

- BaySaver conducted field testing on a 5K BaySeparator unit in Woodinville, Washington between November 2013 and January 2017. Terracon Consultants, Inc. collected flow-weighted influent and effluent composite samples during 12 storm events. The median d50 for the influent PSD was 52 microns. Influent TSS concentrations ranged from 54 to 250 mg/L, with an average concentration of 127 mg/L. For all samples (influent concentrations above and below 100 mg/L) the bootstrap estimate of the lower 95 percent confidence limit (LCL 95) of the mean TSS reduction was 56%. For samples with influent concentrations between 50 to 100 mg/L the bootstrap estimate for the upper 95 percent confidence limit (UCL 95) of the mean TSS effluent concentration was 33 mg/L.
- BaySaver conducted three series of full-scale laboratory on tests. They conducted the first series of tests on a 24" separator unit with two 72" manholes. On average, at 25% of the maximum treatment rate the unit can achieve 84% TSS removal of F-95 sand. They conducted the second series of tests on a 24" separator unit with a 48" primary manhole and a 72" storage manhole. On average at 15% of the maximum treatment rate, the unit can achieve 94% removal of F-95 sand. They conducted the third series of tests on a 24" separator unit with a 48" primary manhole and a 72" storage manhole with water at 20° Celsius (BaySaver conducted the first two series with water at near-freezing temperatures). On average at 25% of the maximum treatment rate, the unit can achieve 89.5% removal of F-95 sand.

Technology Description:

Reviewers can download the Design Manual and technical bulletins from the company's web site: https://baysaver.com/products/bayseparator/

Recommended Research and Development:

Ecology encourages BaySaver Technologies™ to pursue continuous improvements to the BaySeparator unit. To that end, we recommend the following actions:

- Conduct field-testing to reliably ascertain the BaySaver's ability to remove the finer particles (based on the TAPE criteria) comprising TSS found on local highways, parking lots, and other high-use areas.
- Conduct field-testing to verify the appropriate maintenance practices.
- Conduct testing on various sized BaySeparator units to verify that the sizing technique is appropriate.
- Conduct testing to determine the flowrates that trigger maximum treatment operation and bypass operation.
- Conduct testing to determine the flowrate at which resuspension occurs.

Contact Information:

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Advanced Drainage Systems – BaySaver
4640 Trueman Blvd
Hilliard, Ohio 43065
(866) 405-9292
brian.rustia@ads-pipe.com

Applicant website: http://www.baysaver.com/

Ecology web link: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Ecology Contact: Douglas C. Howie, P.E.
Department of Ecology
Water Quality Program
douglas.howie@ecy.wa.gov
(360) 407-6444

Revision History

Date	**Revision**
April 2008	Original Draft use-level-designation document: CULD for pretreatment.
September 2008	Modified dates for QAPP, TER, and expiration
December 2012	Modified Design Storm Description, added Revision Table
December 2014	Revised QAPP, TER, and expiration dates
January 2016	Revised Manufacturer contact information
September 2018	GULD for Pretreatment granted
December 2018	Revised design flow rate based on field tests
July 2019	Revised Applicant contact Information

PERFORMANCE EVALUATION OF SEDIMENT REMOVAL EFFICIENCY

STORMTECH® ISOLATOR™ ROW

Prepared for:
NJDEP/NJCAT

Via:
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StormTech, LLC
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Prepared by:

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October 20, 2006

EXECUTIVE SUMMARY:

This report details the experimental set up, testing protocols, results and findings of a full scale laboratory study conducted at Tennessee Tech University to determine the sediment removal efficiency of the StormTech® Isolator™ Row for two different silica-water slurry influent streams; one influent stream consisting of SIL-CO-SIL 106, with a median particle size of approximately 22 microns, and the other consisting of SIL-CO-SIL 250, with a median particle size of 45 microns. Both silica materials are used as surrogates in laboratory testing and verification protocols as a representation of very fine sediments contained in storm water runoff. Both influent streams were tested at a hydraulic loading rate of 3.2 gpm/sqft of filter area (179.6 gpm divided by 55.6 sqft of filter area). The SIL-CO-SIL 250 influent stream was also tested at 1.7 gpm/sqft.

Over the period of several test runs, it was observed that extremely fine particles accumulated in the flow stream tending to skew the average particle size of the distributions downward. This resulted in a particle size distribution with an approximate average particle size of 10 microns. The ability of a stormwater treatment system to remove such very fine particles is noteworthy. This report includes a limited analysis of the impact on TSS removal efficiency due to the fine particle accumulation.

Following is a brief synopsis of the results:

- 60% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 106 with accumulated fines (D_{50} = 10 microns)
- 66% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 106 (D_{50} = 22 microns)
- 71% TSS Removal at 3.2 gpm/sqft for SIL-CO-SIL 250 with accumulated fines (D_{50} < 45 microns)
- 88% TSS Removal at 1.7 gpm/sqft for SIL-CO-SIL 250 with accumulated fines (D_{50} < 45 microns)

METHODS AND MATERIALS:

The main components of the laboratory set-up are shown in the design drawings (Figure 1). Two (2) SC-740 chambers are secured to a wooden frame and lay over a 12-in. bed of No. 3 angular stone (AASHTO M43 #3) contained in a wooden flume with interior W x L x H dimensions, 6.25-ft x 16.22-ft x 3-ft. The physical properties of the No. 3 stone are given in *Appendix 1.*

The chambers are covered with GEOTEX® 601 non-woven geotextile fabric with specifications given in *Appendix 2.* Two layers of GEOTEX® 315 ST woven geotextile fabric, with specifications given in *Appendix 3*, are placed at the bottom of the chamber to stabilize the stone foundation and to prevent scouring of the stone base. Both the nonwoven fabric covering the chamber and the woven fabric placed at the bottom provide filtration media for the Isolator Row.

An 8-inch pipe feeds the silica-water mixture through an expansion into the 12-inch inlet pipe of the isolator row. A 1.5 lb /gal silica-water slurry is introduced to the 8-inch pipe from a 35-gallon mixing tank using a Watson-Marlow323S/RL (220 rpm) pump. The silica–water slurry enters a 3/8" feed tap located 10 inches upstream of a butterfly valve, which introduces turbulence and promotes uniform mixing of the influent stream. The Isolator™ Row resides in the recirculating flume, which collects and drains water discharged by the chamber to the stone substrate through an 8-inch drain that discharges to the laboratory trench and sump. The water is recirculated with a 25 horsepower Allis Chalmers (model AC7V) variable speed pump. A 1-micron filter, designed for flows up to 1.5 cfs, is placed at the end of the outlet, which was intended to trap all sediment that is not removed by the chambers.

Flow rates are measured with a Thermo Electron Corporation Polysonic DCT7088 portable digital correlation transit time flow meter placed on the 8" aluminum water line. The DCT 7088 was factory calibrated by the manufacturer and is guaranteed accurate to ±0.5%. Specifications for the DCT-7088 flow meter and certificate of factory calibration are attached as *Appendix 4.*

The detailed testing protocol is provided in *Appendix 5*, including calibration details for the peristaltic pumps, detailed sediment loading rate calculations, which are used to determine the sediment loading rate required to achieve the target influent concentration of 200 mg/L, and an example of the laboratory data sheets completed for each experiment.

The product specification sheets for SIL-CO-SIL 106 and 250 are provided in Appendix 6. These sheets include size distributions, but particle sizes are only broadly classified. Calvert and Ritter (2004) recently obtained a more exact size distribution for a SIL-CO-SIL 106 sample taken directly from the material supplied by U.S. Silica. They found that more than 80% of the material is below 50 microns in size, indicating a silt-clay texture. In addition, they show that the SIL-CO-SIL 106 material size distribution is significantly less than the particle size distribution ranges recommended by Portland BES (2001) and APWA (1999) for the laboratory evaluation of stormwater BMPs. Particle size analyses by Micromeritics Analytical Services, which was conducted as part of this study, indicated that 80% of the SIL-CO-SIL 106 material was below 43 microns using the electrical sensing zone (ESZ) method; i.e. a smaller size compared to that reported by Calvert and Ritter (2004). For the SIL-CO-SIL 250, 80% was below 81 microns. The detailed reports of these analyses by Micromeritics are given in Appendix 7.

The removal efficiency η for the isolator row is calculated as

$$\eta = \frac{SSC_{Influent} - SSC_{Effluent}}{SSC_{Influent}} \times 100$$

where SSC is the suspended sediment concentration of the influent and the effluent grab samples, which are staggered by one detention time.

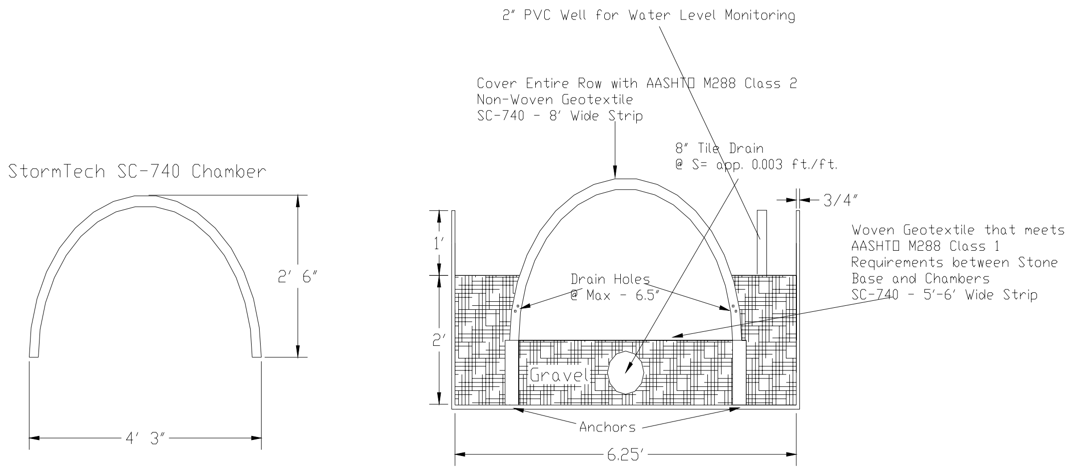


Figure 1.1: Section View of StormTech® Isolator™ Row as Installed in Lab

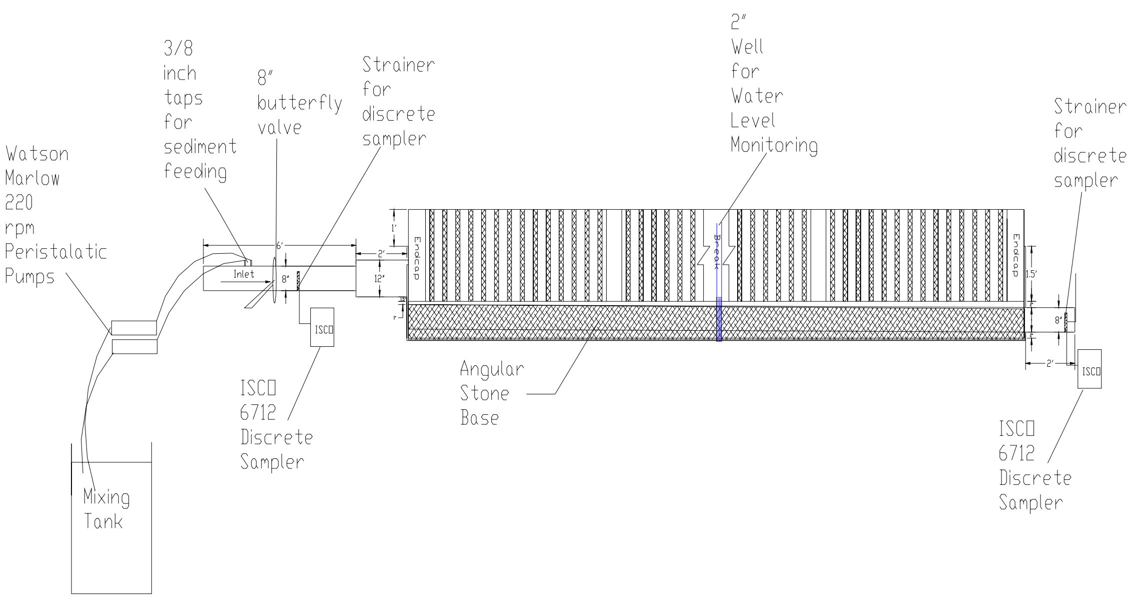


Figure 1. 2: Profile View of StormTech® Isolator™ Row as Installed in Lab.
Flow left to right.

RESULTS:

Test runs for both SIL-CO-SIL 106 and SIL-CO-SIL 250 were completed at a treatment flow rate of 180 gpm (0.4 cfs), which corresponds to a hydraulic loading rate of 3.2 gpm/sqft. Five (5) test runs were completed with SIL-CO-SIL 106 silica slurry. One (1) test run was completed with a SIL-CO—SIL 250 silica-water slurry. Additionally one (1) test run was completed with a SIL-CO-SIL 250 silica-water slurry at a treatment flow rate of 94 gpm (0.21 cfs) which corresponds to a hydraulic loading rate of 1.7 gpm/sqft. All tests lasted fifteen detention times.

<u>SIL-CO-SIL 106 Results</u>

Table 1 includes the results for the SIL-CO-SIL 106 test runs. Sample 3, 17-July (italicized) was rejected because the sample volume collected was below 200 mL due to a mechanical failure by the discrete sampler. Influent and Effluent Samples 5, 28-August, were replaced with a duplicate Influent-Effluent sample pair, which was taken to determine the size distribution of the influent sediments (see discussion below). The influent concentrations were generally above the target concentration of 200 mg/L, which indicates that the one-micron filter sock at the outlet was only partially effective at trapping the finer SIL-CO-SIL 106 particles. This was supported by visual observations, which noted that the trench went from clear to cloudy in less than one detention time. The effects of recirculating these finer particles on the size distribution of the influent silica particles are discussed below.

Chauvenet's criterion (Taylor 1982) was used to reject two influent concentrations (Sample 5, 17-July, and Sample 3, 25-July), italicized, which are lower than the mean value by more than two standard deviations. Sample 4, 25-July, was retained even though it was well below the target influent concentration of 200 mg/L; over two-standard deviations after eliminating the aforementioned outliers. After removing the two influent-effluent pairs corresponding to these outliers, the average removal efficiency for all test runs was 60±9%, with a minimum value of 44% and a maximum value of 75%. The average influent concentration was 270±59 mg/L, with a minimum value of 139 mg/L and a maximum value of 361 mg/L. The average effluent concentration was 109±35 mg/L, with a minimum value of 66 mg/L and a maximum value of 182 mg/L. These results are summarized in Table 2.

Table 1. Results SIL-CO-SIL 106 Tests

Date	Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
9-Jul	1	180	81	55
9-Jul	2	177	100	44
9-Jul	3	292	122	58
9-Jul	4	315	147	53
9-Jul	5	318	162	49
17-Jul	1	212	72	66
17-Jul	2	266	95	64
17-Jul	*3*	*189*	*124*	*34*
17-Jul	4	278	135	51
17-Jul	*5*	*70*	*170*	*-143*
25-Jul	1	236	77	67
25-Jul	2	229	66	71
25-Jul	*3*	*87*	*104*	*-20*
25-Jul	4	139	74	47
25-Jul	5	293	87	70
1-Aug	1	240	70	71
1-Aug	2	290	124	57
1-Aug	3	294	144	51
1-Aug	4	341	146	57
1-Aug	5	361	132	63
28-Aug	1	227	74	67
28-Aug	2	266	67	75
28-Aug	3	328	137	58
28-Aug	4	308	100	68
28-Aug	5	353	182	48
	Average	252	112	56
	Std. Dev.	78	35	44

Table 2. Results SIL-CO-SIL 106 Tests after Removing Outliers.

Date	Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
9-Jul	1	180	81	55
9-Jul	2	177	100	44
9-Jul	3	292	122	58
9-Jul	4	315	147	53
9-Jul	5	318	162	49
17-Jul	1	212	72	66
17-Jul	2	266	95	64
17-Jul	4	278	135	51
25-Jul	1	236	77	67
25-Jul	2	229	66	71
25-Jul	4	139	74	47
25-Jul	5	293	87	70
1-Aug	1	240	70	71
1-Aug	2	290	124	57
1-Aug	3	294	144	51
1-Aug	4	341	146	57
1-Aug	5	361	132	63
28-Aug	1	227	74	67
28-Aug	2	266	67	75
28-Aug	3	328	137	58
28-Aug	4	308	100	68
28-Aug	5	353	182	48
	Average	270	109	60
	Std. Dev.	59	35	9
	Max	361	182	75
	min	139	66	44

The observed variability in the influent and effluent concentrations was mainly due to the recirculation of fine grained particles not trapped by the filter sock. It was apparent starting with the first test (9-July) that the filter sock was not effective at trapping the fine effluent sediments and preventing their recirculation. As a result, there is a clear trend of increasing influent and effluent SSC concentrations with increasing detention time during each test run, as shown in Figures 2 and 3.

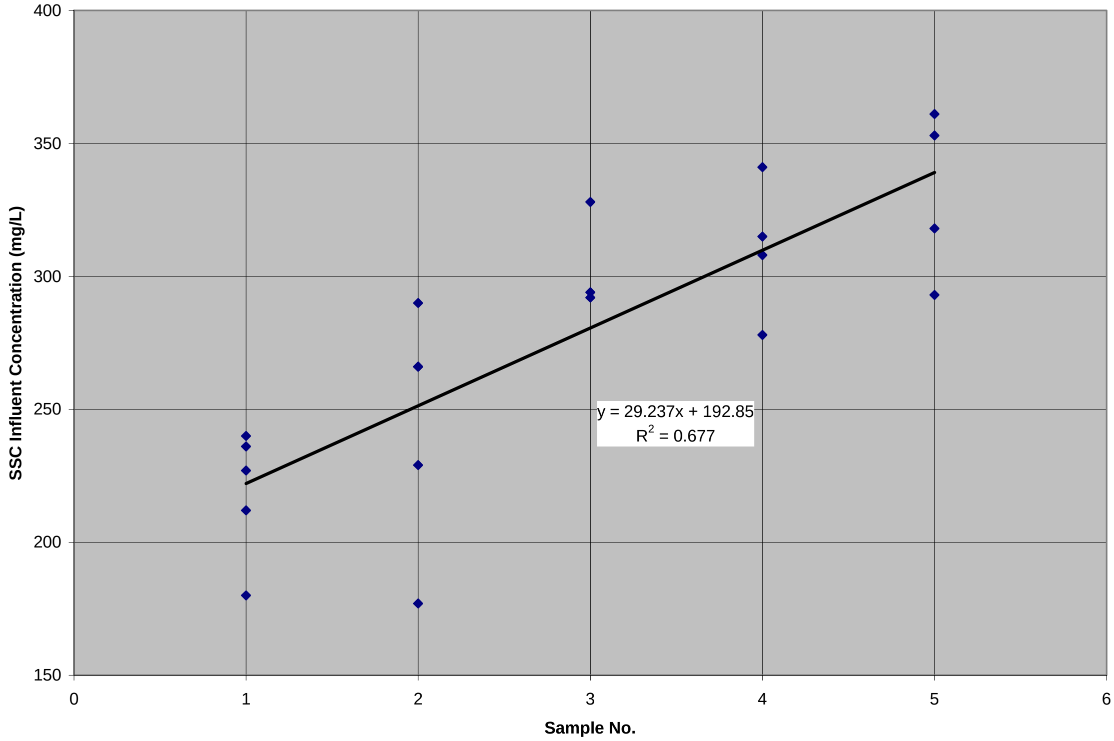


Figure 2. Average increase in influent concentrations over each test (15 detention times).

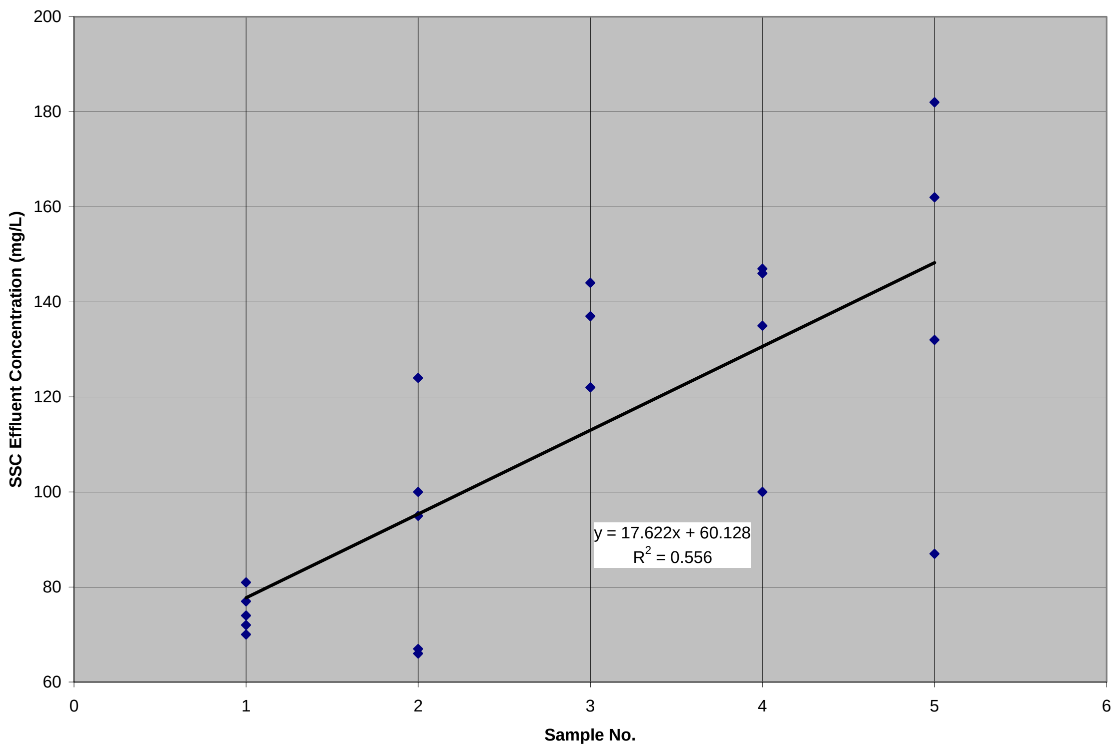


Figure 3. Average increase in effluent concentrations over each test (15 detention times).

Table 3 shows how the average removal efficiency decreased on average with detention time during each test run as a result of recirculation. The removal efficiencies are calculated by averaging all influent and effluent samples with the same sample number, respectively (e.g. all influent samples with sample number 1 and all effluent samples with sample number 2). The results indicate that at the beginning of the test recirculation has not significantly increased influent concentrations above the target level of 200 mg/L. The average influent concentration for sample one was 219 mg/L. In addition, as discussed below, one can speculate that the recirculation of predominantly fine particles has not reduced the particle size distribution of the influent significantly. Under these conditions, the average removal efficiency (based solely on the first samples of each test run) is 66%. However, as the test progresses and recirculation of fines increases, the removal efficiency is reduced.

Table 3. Reduction of removal efficiency with detention time.

Sample No.	No. of Det. Times	Avg. Influent SSC mg/L	Avg. Effluent SSC mg/L	Removal Eff. %
1	3	219	75	66
2	6	246	90	63
3	9	305	134	56
4	12	311	132	57
5	15	331	141	58

It was hypothesized that the lower removal efficiencies observed later in the test were a result of smaller size distributions due to increased recirculation of effluent as the test progressed. To confirm this hypothesis grab samples of influent were sent to Micromeritics Analytical Services, along with a composite dry sample of the SIL-CO-SIL 106 taken from five different 50-lbs. bags. In addition, corresponding grab samples of effluent were also sent for analysis. The detailed results of Micromeritics analyses are provided in Appendix 7. These results, summarized in Table 4, show a clear reduction in the particle size distribution of the influent sediments as a result of recirculation, with 16%, 50% (median), and 84% finer particle sizes of the composite influent samples approximately half the values of the composite dry sample. In addition, the effluent sediments consist mainly of very fine particles, 84% of which are 10 microns or smaller, 50% of which are only 4 microns and smaller.

Table 4. SIL-CO-SIL 106 size distribution summaries.

Sample	16% Finer Diameter (μm)	50% Finer Diameter (μm)	84% Finer Diameter (μm)
Dry Sample (5 Bags)	6.1	21.5	44.5
Composite Influent Grab	3.4	9.8	24.1
Composite Effluent Grab	2.0	4.0	10.0

Sediments occluded within the woven fabric and trapped in the gravel cannot be removed between each test run. As a result the initial condition cannot be reestablished once testing has begun, and the sediments trapped in previous test runs may washout, raising effluent and influent SSC concentrations at latter test runs. This condition is supported by the trends shown in Figures 4 and 5, which show an increase in influent and effluent SSC concentrations as the experiments progressed. One potential benefit of sediment occlusion and deposition over time may be increased removal efficiency as the geotextile fabric clogs and a filter cake develops on the isolator row bottom. Indeed there was a noticeable build up of sediments within the isolator row as the experiments progressed. Photos shown in Figure 6, which were taken after the completion of all tests, show increased sediment deposition from upstream to downstream, with accretion depths up to 4 mm in thickness. Figure 7, a plot of removal efficiency vs. the sample order number for all the experiments does indicate a subtle trend towards greater removal efficiencies, but more experiments are needed to verify this; and whether some threshold (optimal) removal efficiency would be reached.

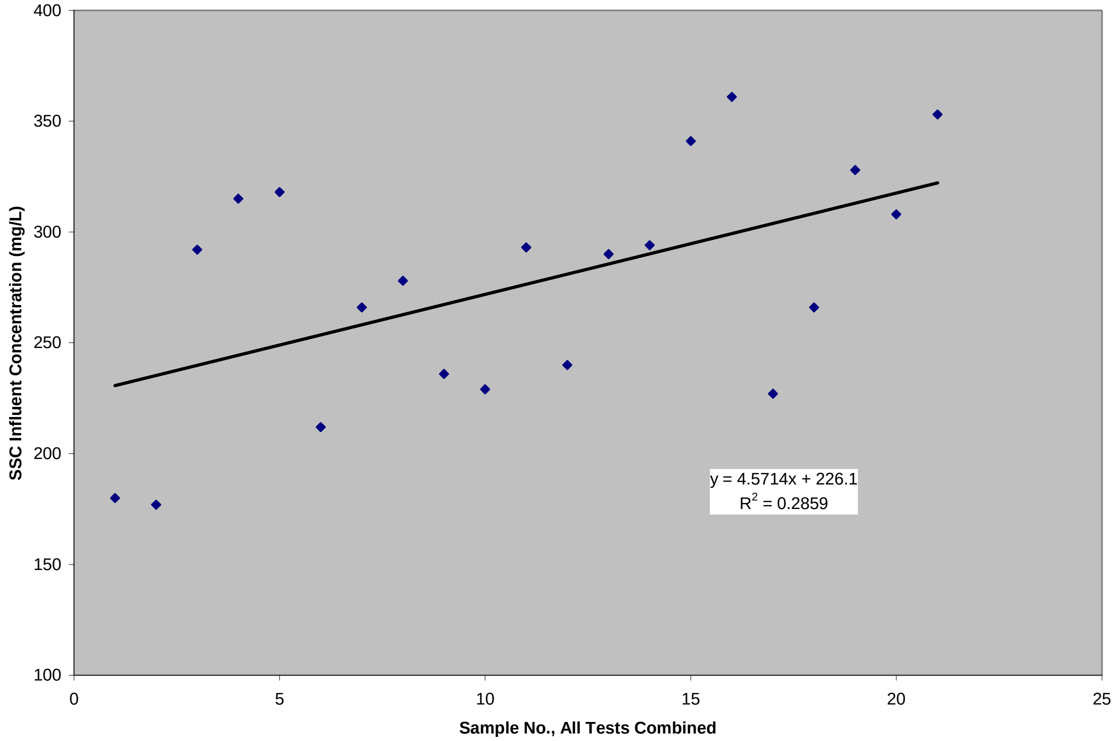


Figure 4. Average increase in influent concentration over entire test period.

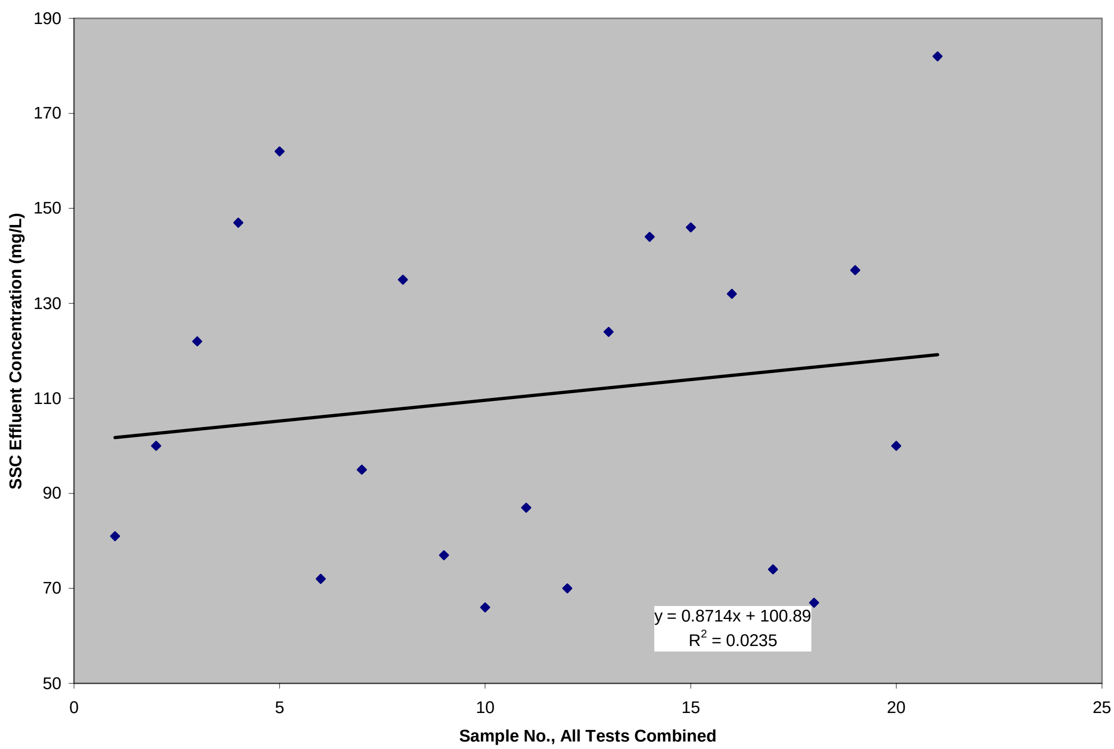
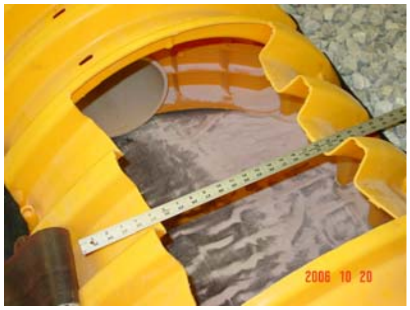


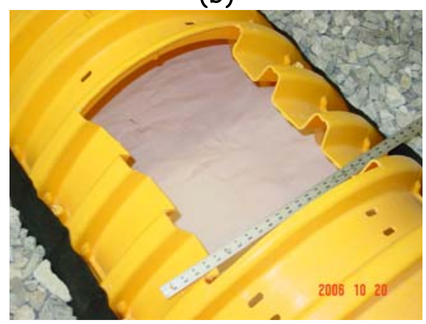
Figure 5. Average increase in effluent concentration over entire test period.



(a)

(b)

(c)



(d)

Figure 6. Photos of sediment accretion after the completion of all tests: (a) upstream-inlet; (b) mid-upstream; (c) mid-downstream; (d) downstream-outlet (October 20, 2006)

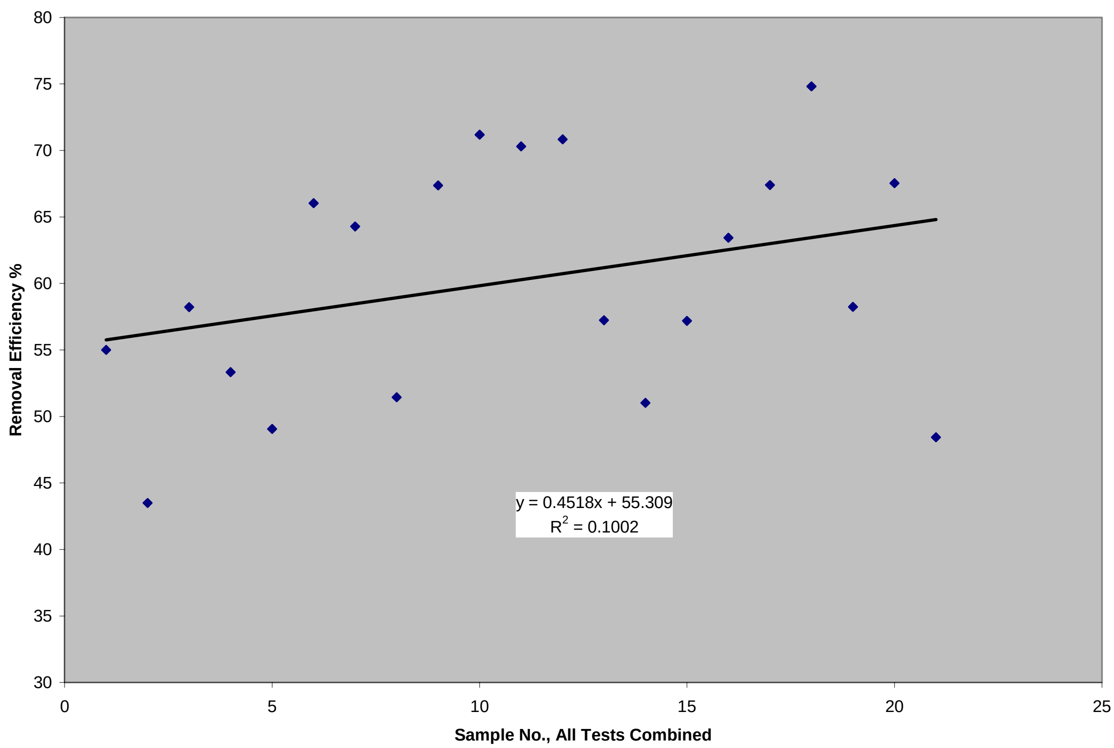


Figure 7. Average increase in removal efficiency over entire test period.

Sil-Co-Sil 250 Results

Results for the one SIL-CO-SIL 250 test are summarized in Tables 5 and 6. Although the influent concentration for Sample 5 (Table 5) is well below the target concentration of 200 mg/L, it was within two standard deviations and was retained. Recirculation of fine sediments was observed and would have reduced the particle size distribution of the influent concentrations below the mean particle size of D_{50}=45 microns. However, particle size analyses of influent sediments were not obtained as was done for the SIL-CO-SIL 106 experiment. Therefore, the following performance claims for SIL-CO-SIL 250 are for D_{50}<45 microns. The average removal efficiency was 71±14%, with a minimum value of 47% and a maximum value of 82%. Compared to the results for the SIL-CO-SIL 106, these values appear reasonable since one would expect higher removal efficiencies when the particle size distribution is greater.

Table 5. Results SIL-CO-SIL 250 Test at 3.2 gpm/sqft (July 19, 2006)

Sample	Influent SSC mg/L	Effluent SSC mg/L	Removal Eff. %
1	226	40	82
2	169	47	72
3	244	53	78
4	288	67	77
5	129	68	47
Average	211	55	71
Std. Dev.	63	12	14
Max.	288	68	82
Min.	129	40	47

The influent concentrations in Table 6 are above the target concentrations of 200 mg/l. Effluent grab samples by hand were taken in lieu of automated samples due to the reduced stage in the effluent pipe.

Table 6. Results SIL-CO-SIL 250 Test at 1.7 gpm/sqft (July 19, 2006)
(effluent grab samples)

Sample	Influent SSC mg/L	Effluent grab SSC mg/L	Removal Eff. %
1	416	27	89
2	407	44	88
3	441	48	87
4	417	56	89
5	441	61	87
Average	424	47	88
Std. Dev.	16	13	1
Max.	441	61	89
Min.	407	27	87

CONCLUSIONS:

Sediment removal efficiencies were successfully estimated for the StormTech® Isolator™ Row despite problems associated with recirculation of fine sediments, which substantially reduced the particle size distribution of the influent sediments.

The average removal efficiency of the Isolator Row for influent sediments approximately half as coarse as SIL-CO-SIL 106 is 60%, indicating that the isolator row performs well. Based on the first samples, before recirculation is thought to significantly reduce the influent particle size distribution, removal efficiencies of 66% were obtained.

A less detailed study of sediment removal performance was conducted for the coarser grained SIL-CO-SIL 250, but an average removal efficiency of 71% at 3.2 gpm/sqft seems reasonable compared to SIL-CO-SIL 106 results and indicates good performance as well. At 1.7 gpm/sqft for SIL-CO-SIL 250, an average removal efficiency of 88% was demonstrated.

The study observed a slight trend of improved removal efficiencies as the testing progressed, which supports the hypothesis of improved removal efficiencies with progressively greater sediment occlusion and accretion (i.e. filter cake development).

REFERENCES:

Christensen, A. (2005) "Hydraulic Performance and Sediment Trap Efficiency of StormTech® SC-740 Isolator™ Row." M.S. Thesis, In Partial Fulfillment of M.S. Degree, Tennessee Tech University, December 2005, 132 pages including appendices. V.S. Neary, Advisor.

Taylor, J. R., (1982). An Introduction to Error Analysis: The Study of Uncertainty in Physical Measurements. University Science Books, Mill Valley, CA.

APPENDICES

APPENDIX 1

ANGULAR STONE BACKFILL SPECIFICATIONS

LOCATION: Ahgood DATE: 6/25/03 SIZE: #3's 2" mi.

SAMPLE #1

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	5.93	20.1	79.9	35-70
1"	25.35	85.9	14.1	0-15
3/4"	28.46	96.5	3.5	-
5/8"				-
1/2"	29.11	98.7	1.3	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2	—	—	100	100

ORIGINAL DRY WEIGHT 29.50
WEIGHT AFTER WASH ______
WASH LOSS ______
PERCENT LOSS ______

SAMPLE #2

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"	—	—	100	90-100
1 1/2"	6.43	24.1	75.9	35-70
1"	23.33	87.6	12.4	0-15
3/4"	25.91	97.3	2.7	-
5/8"				-
1/2"	26.33	98.9	1.1	0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2	—		100	100

ORIGINAL DRY WEIGHT 26.63
WEIGHT AFTER WASH ______
WASH LOSS ______
PERCENT LOSS ______

SAMPLE #3

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2				100

ORIGINAL DRY WEIGHT ______
WEIGHT AFTER WASH ______
WASH LOSS ______
PERCENT LOSS ______

AVERAGE

SIEVE SIZE	WEIGHT RETAINED	PERCENT RETAINED	PERCENT PASSING	SPECS
2"				90-100
1 1/2"				35-70
1"				0-15
3/4"				-
5/8"				-
1/2"				0-5
3/8"				-
NO. 4				-
NO. 8				-
NO.16				-
NO.30				-
NO. 50				-
NO. 100				-
NO. 200				-
PAN 2 1/2				100

ORIGINAL DRY WEIGHT ______
WEIGHT AFTER WASH ______
WASH LOSS ______
PERCENT LOSS ______

Figure A.1. 1: Gravel Backfill Specifications

APPENDIX 2

GEOTEX® 601 non-woven geotextile fabric specifications

SI® Geosolutions

Product Data Sheet

GEOTEX® 601

GEOTEX 601 is a polypropylene, staple fiber, needlepunched nonwoven geotextile manufactured at one of SI Geosolutions' facilities that has achieved ISO-9002 certification for its systematic approach to quality. The fibers are needled to form a stable network that retains dimensional stability relative to each other. The geotextile is resistant to ultraviolet degradation and to biological and chemical environments normally found in soils. **GEOTEX 601** conforms to the property values listed below[1] which have been derived from quality control testing performed by one of SI Geosolutions' GAI-LAP accredited laboratories:

		MARV[2]	
PROPERTY	**TEST METHOD**	**ENGLISH**	**METRIC**
Physical			
Mass/Unit Area	ASTM D5261	5.0 oz/yd^2	170 g/m^2
Thickness	ASTM D5199	60 mils	1.5 mm
Mechanical			
Grab Tensile Strength	ASTM D4632	160 lbs	712 N
Grab Elongation	ASTM D4632	50%	50%
Puncture Strength	ASTM D4833	85 lbs	378 N
Mullen Burst	ASTM D3786	280 psi	1930 kPa
Trapezoidal Tear	ASTM D4533	60 lbs	267 N
Wide Width Tensile	ASTM D4595	720 lbs/ft	10.5 kN/m
Endurance			
UV Resistance @ 500 hrs	ASTM D4355	70%	70%
Hydraulic			
Apparent Opening Size (AOS)[3]	ASTM D4751	70 US Std. Sieve	0.212 mm
Permittivity	ASTM D4491	1.30 sec^{-1}	1.30 sec^{-1}
Permeability	ASTM D4491	0.24 cm/sec	0.24 cm/sec
Water Flow Rate	ASTM D4491	110 gpm/ft^2	4480 l/min/m^2
Typical Roll Sizes		150 in x 100 yds	3.81 m x 91.5 m
		180 in x 100 yds	4.57 m x 91.5 m

NOTES:

1 **The property values listed below are effective 12/2003 are subject to change without notice.**

2 Values shown are in weaker principal direction. Minimum average roll values are calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported.

3 Maximum average roll value. Statistically, it yields a 97.7% degree of confidence that samples taken from quality assurance testing will be below the value reported.

4019 Industry Dr. • Chattanooga, Tennessee 37416 USA • (423) 899-0444 or (800) 621-0444 • FAX (423) 553-2900 • www.fixsoil.com

Figure A.2. 1: GEOTEX® 601 non-woven geotextile fabric specifications

APPENDIX 3

GEOTEX® 315 ST woven geotextile fabric specifications

SI® Geosolutions

Product Data Sheet

GEOTEX® 315 ST

GEOTEX 315ST is a woven slit film geotextile manufactured at one of SI Corporations' facilities. The individual slit films are woven together in such a manner as to provide dimensional stability relative to each other. The construction of the geotextile makes **GEOTEX 315ST** ideal for soil separation and stabilization. The geotextile is resistant to ultraviolet degradation and to biological and chemical environments for normally found in soils. **GEOTEX 315ST** conforms to the property values listed below[1] which have been derived from quality control testing performed by one of SI Corporations' GAI-LAP accredited laboratories:

		MARV[2]	
PROPERTY	TEST METHOD	ENGLISH	METRIC
Physical			
Mass/Unit Area	ASTM D5261	6.5 oz/yd^2	220 g/m^2
Thickness	ASTM D5199	20 mils	.5 mm
Mechanical			
Tensile Strength (Grab)	ASTM D4632	315 x 315 lbs	1,400 x 1,400 N
Elongation	ASTM D4632	15 x 15%	15 x 15%
Wide Width Tensile	ASTM D4595	175 x 200 lbs/in	30.6 x 35.0 kN/m
Wide Width Elongation	ASTM D4595	10 x 8%	10 x 8%
Puncture	ASTM D4833	125 lbs	555 N
Mullen Burst	ASTM D3786	650 psi	4475 kPa
Trapezoidal Tear	ASTM D4533	120 x 120 lbs	530 x 530 N
CBR Burst	GRI-GSI	1075 lbs	4780 N
Endurance			
UV Resistance	ASTM D4355	90%	90%
Hydraulic			
Apparent Opening Size (AOS)	ASTM D4751	70 US Std. Sieve	0.212 mm
Permittivity	ASTM D4491	0.05 sec^{-1}	0.05 sec^{-1}
Permeability	ASTM D4491	.003 cm/sec	.003 cm/sec
Water Flow Rate	ASTM D4491	4 gpm/ft^2	161 l/min/m^2
Roll Sizes		12.5 ft x 360 ft 15.0 ft x 300 ft 17.5 ft x 258 ft	3.81 m x 109.73 m 4.57 m x 91.44 m 5.33 m x 78.64 m

NOTES:

1. **The property values listed above are effective 03/24/2006 and are subject to change without notice.**
2. Values for machine (warp) and cross-machine (fill), respectively, under dry or saturated conditions. Minimum average roll values (MARV) are calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported.

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Figure A.3.1: GEOTEX® 315 ST woven geotextile fabric specifications

APPENDIX 4

THERMO-ELECTRON DCT-7088 FLOW METER SPECIFICATIONS

AND CALIBRATION

Thermo
ELECTRON CORPORATION

Process Instruments

9303 W. Sam Houston Pkwy.
Houston, TX 77099 USA
(713) 272-0404
(713) 272-2273 fax

Polysonics DCT7088 Portable Digital Transit Time Flowmeter Recommended Procurement Specification

1. The instrument will utilize ultrasonic, digital, and transit time correlation technologies to provide indication, totalization, and signal transmission of liquid flow rate in full pipes.

2. The instrument will measure flow rates of clean liquids with a velocity range from +/-0 to 40 ft/s (+/-0 to 12 m/s).

   2a. Accuracy will be +/-0.5% of velocity or +/-0.05 ft/s (+/-0.0152 m/s), typical, digital output.
   2b. Flow sensitivity will be 0.01 ft/s (0.003 m/s) at any flow rate including zero.
   2c. Linearity will be 0.1% of scale, digital output.

3. The instrument will be housed in a NEMA 6 (IP67) environmentally sealed enclosure and will be waterproof against accidental immersion and splashproof with lid open.

4. Two transducers will be supplied with the instrument and will be suitable for pipe sizes from 1 to 200 in (25mm to 5m).

   4a. Transducers will be of encapsulated design and suitable for operation from -40º to +212º F (-40º to +100º C).

   4b. They will attach to the outside of the pipe using a slide-track mounting method.

   4c. The standard transducer cable length will be 16 ft (5 m).

   4d. Optional high temp transducers suitable for operation from -40 to 392 deg F (-40 to 200 deg C)

5. The analog output will be an isolated, 4-20 mA (into 1K to 5K ohms) direct currentproportional to flow. Output current limiting circuitry will be incorporated in the instrument electronics. The instrument will have an RS232 serial interface.

6. The instrument will be powered by a rechargeable, internal battery suitable for 8 hours of continuous operation. An internal battery providing 16 hours of continuous operation will optionally be available. The battery must be fully recharged within a maximum of 8 hours.

7. The display will be a 40-character, 2-line, backlit, high resolution LCD.

8. Configuration will be via a front panel, 19-key keypad with tactile action. Input parameters will be password protected. The nonvolatile memory shall retain totalizer and user parameters for up to five years. Diagnostics will be accessible via the keypad.

9. The instrument electronics will be designed to operate at temperatures between -5º to +140º F (-20º to +60º C). All electronic circuits will be interchangeable with other instruments having the same model number. All circuit boards will be conformally coated with an anti-fungus compound.

9303 W. Sam Houston Pkwy.
Houston, TX 77099 USA
(713) 272-0404
(713) 272-2273 fax

10. A 40,000-point data logger programmable in intervals of 1 s will be included as standard in the instrument. The *UltraScan* signal analysis and configuration software program for Windows® will be supplied with the instrument. The software will incorporate pull-down menus and pop-up windows to provide access to an extensive range of graphical diagnostic information. Low flow cutoff, bi-directional totalization with selectable resolution, automatic sound speed calculation of measured fluid, and adjustable damping will be standard with the software.

11. The instrument will have a built-in microprocessor to provide for adapting instrument hardware to existing piping and flow conditions. It will automatically calculate transducer spacing and read English or metric units.

12. The instrument enclosure will provide a facility for the attachment of a padlock to prevent unauthorized access to the display and front panel.

13. A test block will be supplied for instrument diagnostic testing.

14. The manufacturer will provide as an option a certified calibration in accordance with ANSI specification Z540.1.

15. The instrument will be manufactured in the USA at an ISO 9001 certified facility. The manufacturer will be Thermo Electron Corporation.

16. The instrument will be Thermo Electron Corporation's Polysonics DCT7088 Portable Digital Correlation Transit Time Flowmeter.

Windows® is a registered trademark of Microsoft Corporation in the United States and/or other countries.

Thermo
ELECTRON CORPORATION

Process Instruments
9303 W. Sam Houston Parkway S.
Houston, TX 77099-5298

713) 272-0404
Fax (713) 272-2272
www.thermo.com

CERTIFICATE OF CALIBRATION

Thermo Electron Corporation, Process Instruments certifies that the below listed instrument has been calibrated to meet or exceed published specifications using standards whose accuracies are traceable to the National Institute of Standards and Technology

PRODUCT INFORMATION

Customer:	TENNESSEE TECHNICAL	Device Serial Number:	53376
	UNIVERSITY WATER RESOU	Scale Factor:	1
	1020 STADIUM DRIVE	Full Scale Value (GPM):	900
	COOKEVILLE, TN 38505	Ambient Temperature:	75
Sales Order:	2142292	Relative Humidity	44%
Device Model:	DCT7088	Procedure Used:	1-0561-002 (A)

CALIBRATION DATA

FLOW RATE (GPM)	INSTRUMENT READING (GPM)	DIFFERENCE IN GPM	PERCENT ERROR	WITHIN SPECIFICATION?
650.35	648.76	1.59	0.24%	YES
449.62	448.52	1.10	0.24%	YES
368.97	367.25	1.72	0.47%	YES

Calibration Date: April 7, 2006

Recommended Calibration Due Date: April 7, 2007

Calibration Performed by:

Thermo Electron, Process Instruments Representative

Form FM1601(C)

APPENDIX 5

Lab Protocol, Sub-Appendices 5-a through 5-g

STORMTECH
REMOVAL EFFICIENCY EXPERIMENT
March 21, 2006

LAB PROTOCOL

1. Set up the slurry mixture in the mixing tank and make sure that the suction line of the peristaltic pump is midway between the propellers and also check for any constrictions. Also check if the direction of flow in the peristaltic pump is proper. (See **APPENDICES 5-a and 5-b**). NOTE: Two peristaltic pumps will be required when flow rates are above Q=0.6 cfs because the pump speed is limited to 220 rpm (See **APPENDIX 6-c**). To accommodate two peristaltic pumps, two taps are installed in the pipe upstream of the flume and butterfly valve.
2. Fill out test run information on laboratory test form (See **APPENDIX 5-d**).
3. See Stage-Discharge-Detention Time Calculation Table (**APPENDIX 5-e**) to determine the duration of the test run for each flow based on fifteen detention times.
4. Turn the Allis Chalmers pumps on, record the time on the test data sheet and set the flow rate. For setting the pumps refer to **APPENDIX 5-f**.
5. Slowly increase the flow rate until a steady flow condition is established. Record the time when this is established. For the flow meter setting refer to **APPENDIX 5-g.**
6. Measure and record water temperature with standard thermometer.
7. Record the time for the blank automated discrete samples at inlet and outlet and label the bottle with the test run code and I-B (influent blank), E-B (effluent blank).
8. Start and note the time the peristaltic pump is turned on. Refer to **APPENDIX 5-c** for setting the specified concentration as per required mg/L of sediment.
9. Wait 3 detention times before beginning sampling.
10. Start stopwatch to record the exact time of the test run.
11. Measure 3 lb of sediment and 2 gallon of water.
12. Monitor the level of the mixture in the mixer tank and make sure it is not dropping below the top propeller. If the slurry level in the mixing tank reaches the top propeller, pour contents into the mixing tank. Be sure to pour as far away as possible from the suction line of the peristaltic pump. Also, do not pour in to mixing tank just prior to a grab sample, as to avoid high concentrations of sediment.
13. Collect grab sample and label the bottle with the test run code and I-1.
14. Wait one (1) detention time and collect grab sample of effluent and label the bottle with the test run code and E-1.
15. Continue influent and effluent sampling at intervals of 3 detention times.
16. After fifteen (15) detention times the peristaltic pump, the stopwatch, and the main pumps are shut off at the same time.

APPENDIX-5-a

SETTING UP THE MIXER TANK

- Weigh 45 lb of the sediment and carefully transfer it into the mixer tank.
- Fill the mixer tank with 30 gal of water.
- Now the concentration of the mixture is 1.5 lb/gal.
- Set the angle of the mixer shaft according to the schematic below.
- Turn the motor driving the propellers ON.

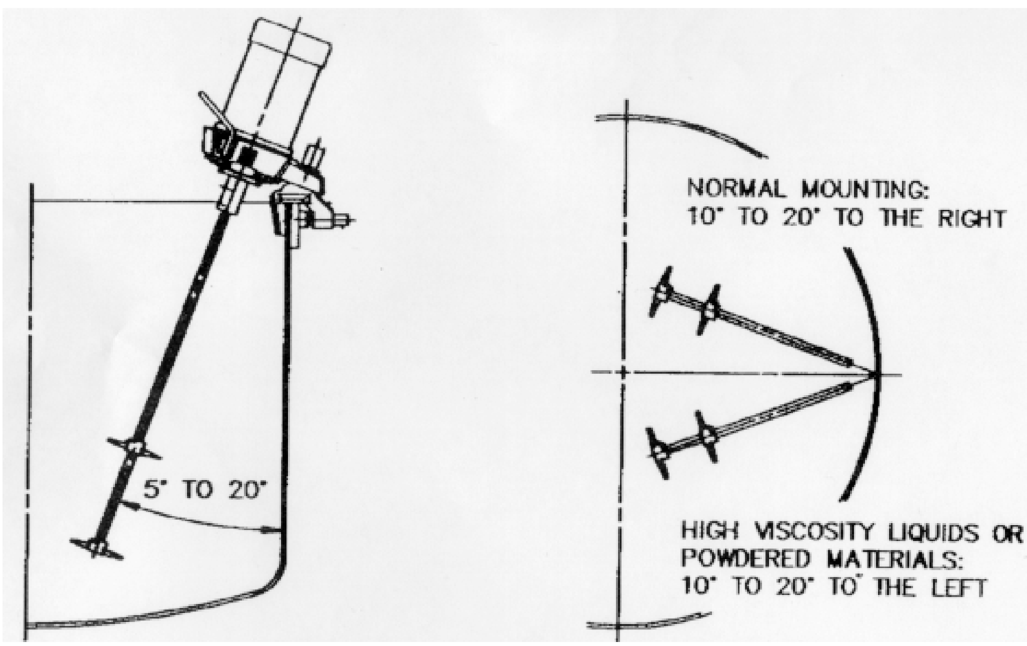


Figure A.5.1: Mixer Mounting Angle and Eccentric Angle.

APPENDIX 5-b

WATSON-MARLOW PERISTALTIC PUMP

1. Place the suction line in the mixer tank and the effluent line in the pipes that run to the concentrator. Make sure that the center screw of the pump is tight.
2. Turn the power ON and set the pump at the required rpm by using the arrow keys on the pump.
3. Before turning the pump ON, make sure that the propellers in the mixer tank are rotating properly and then give it sufficient time to ensure proper mixing.
4. Turn the pump on and simultaneously turn the stopwatch ON.
5. After the required time interval has elapsed, turn off the stopwatch and stop the pump simultaneously. Now the peristaltic pump can be turned OFF.
6. Carefully remove the suction line from the mixer tank and let the mixer tank drain.
7. For high flows two peristaltic pumps may be needed to attain required influent concentrations. The procedure remains the same for both pumps.

APPENDIX 5-c

SEDIMENT METERING CALCULATIONS AND PERISTALTIC PUMP CALIBRATION DETAILS

The loading rate calculations for the peristaltic pump to yield a target sediment concentration of 200 mg/L are based on the following equations:

$$Q_{sp} \div (Q_{wp} + Q_w) = 200 mg / L \qquad \text{A.5.1}$$

$$Q_{sp} \div Q_{sw} = 179{,}810\ mg / L \qquad \text{A.5.2}$$

where Q_{sp} is the discharge of sediment from the peristaltic pump, Q_{wp} is the discharge of water from peristaltic pump, and Q_w is the discharge of water from the inlet upstream of the sediment feed tap. *Equation A.5.1* expresses the target concentration and *Equation A5.2* expresses the sediment slurry concentration (1.5 lbs./gal. or 179,810 mg/L).

EXAMPLE

For 0.1 cfs, Q_w = 0.1*28.37 L/s = 2.837 L/s

$$179{,}810\frac{Q_{sp}}{(Q_{wp}+2.837)} = 200\frac{mg}{lit}$$

$$\frac{Q_{sp}}{Q_{wp}} = 179{,}810\frac{mg}{lit} \Rightarrow Q_{sp} = 179{,}810\frac{mg}{lit}\times Q_{wp}$$

Solving for Q_{sp} and Q_{wp}:

$$Q_{wp} = \frac{200\,\frac{mg}{s}}{179{,}810\,\frac{mg}{lit}} = 0.00316\,\frac{lit}{s}$$

And

$$Q_{sp} = 179{,}810\frac{mg}{lit}\times 0.00316\frac{lit}{s} = 568.032\frac{mg}{s}$$

Extending these calculations for the rest of the flow rates, *Table A.5.1* is developed.

Table A.5.1: Sediment metering calculations

Q exper cfs	Q exper L/s	Target C mg/L	Mix C lbs/gal	Mix C mg/L	Q peristaltic L/s	Q sediment mg/s	Pump Spd rpm
0	0.00	200	1.5	179810	0.0000	0	0.0
0.1	2.84	200	1.5	179810	0.0032	568	33.6
0.2	5.67	200	1.5	179810	0.0063	1136	67.2
0.3	8.51	200	1.5	179810	0.0095	1704	100.8
0.4	11.35	200	1.5	179810	0.0126	2272	134.4
0.5	14.19	200	1.5	179810	0.0158	2840	168.0
0.6	17.02	200	1.5	179810	0.0190	**3408**	**201.6**
0.7	19.86	200	1.5	179810	0.0221	3976	235.2
0.8	22.70	200	1.5	179810	0.0253	4544	268.8
0.9	25.53	200	1.5	179810	0.0284	5112	302.4
1	28.37	200	1.5	179810	0.0316	5680	336.0
1.1	31.21	200	1.5	179810	0.0347	6248	369.6
1.2	34.04	200	1.5	179810	0.0379	6816	403.2

DETAILS OF PERISTALTIC PUMP CALIBRATION

A Watson-Marlow Model 323ES peristaltic pump meters the sediment-water slurry mixture to the inlet pipe. The pump was calibrated to determine the loading rate (mg/s) vs. pump speed (rpm) relationship. The pump operates in a range of 1-220 rpm.

Table A.5. 2: Calibration data of the peristaltic pump

rpm	Time (sec)	Sediment mixed (lb)	Mixture collected (lb)	Sediment collected (lb)	Sediment Left (lb)	Concentration (lb/gal)	Q sediment (lb/s)	Q sediment (mg/s)
20	7853	45	36.5	5.8	39.2	1.59	0.00073	335
50	3288	45	35.3	4.7	40.3	1.29	0.00142	649
90	1889	45	45.1	6.3	38.7	1.36	0.00333	1513
140	1223	45	39.9	6	39	1.49	0.00490	2226
180	619	45	28.5	4.3	40.7	1.49	0.00694	3152
220	564	45	32.3	5	40	1.54	0.00886	4022

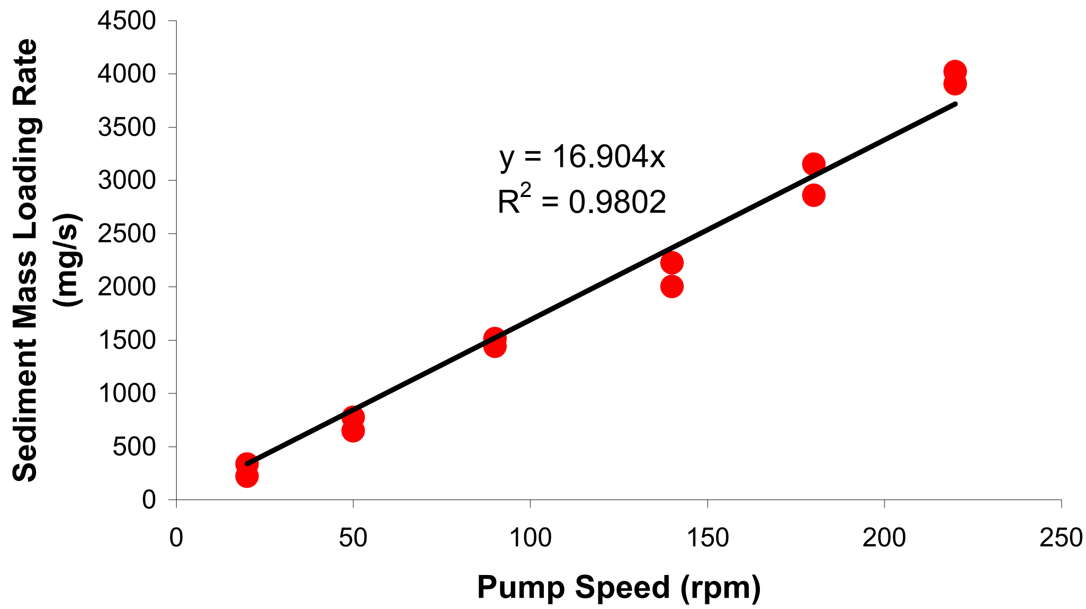


Figure A.5. 2: Calibration curve for the Watson-Marlow peristaltic pump

APPENDIX 5-d

LABORATORY DATA SHEET

TENNESSEE TECH UNIVERSITY: LABORATORY DATA SHEET **Lab_Test_Form.xls**

PROJECT: STORMTECH SC-740 CHAMBER SOLIDS REMOVAL EFFICIENCY

PERFORMED BY: **DATE:**

RUN INFO:

Test Name			
Q_{water}		cfs	gpm
$Q_{sediment}$		mg/s	
Max Stage		ft	
Volume		cu.ft.	
Detention Time		minutes	
START Sediment Wt. (lb)			
START Water (gal.)			
Mixture Concentration	1.5	lb/gal.	mg/L
Speed Peristaltic Pump		rpm	
Target $C_{influent}$	200	mg/L	

RECORD TIMES:

PRESTART		
FLOW STABILIZED		
WATER TEMPERATURE 1		
BLANK SAMPLE	^{o}C	
PERISTALTIC PUMP START		
THREE DETENTION TIMES		
GRAB SAMPLES	INFLUENT 1	EFFLUENT 1
Start sampling after 3	INFLUENT 2	EFFLUENT 2
detention times.	INFLUENT 3	EFFLUENT 3
Record times collected.	INFLUENT 4	EFFLUENT 4
Sample Effluent 1 detention	INFLUENT 5	EFFLUENT 5
time after Influent.		
FINISH		
WATER TEMPERATURE 2	^{o}C	

3*DETENTION TIME

45*DETENTION TIME

PHOTOS: Take photos at same exact place within chamber for each test run after test complete

OTHER OBSERVATIONS: sediment in trench, sump, etc.

APPENDIX 5-e

STAGE-DISCHARGE-DETENTION RELATIONS FOR RANGE OF FLOWS

Table A.5.3: Stage Discharge Results

Flow (cfs)	Stage Relative to Invert of Outlet (ft)	Depth of Water Inside Chamber (ft)	Volume of Water in All 4 Chambers (ft^3)*	Volume of Water in Gravel Beneath All Chambers (ft^3)	Total Volume (ft^3)	Detention Time, θ (min)	**15 X θ (min)**	Total Sediment Injected for 15 X θ (lbs) **	45 X θ (min)	Total Sediment Infected for 45 X θ (lbs) **	
0.10	0.70	0.00	0.00	33.52	33.52	5.59	**83.80**	6.30	251.40	18.89	
0.20	0.95	0.00	0.00	45.49	45.49	3.79	**56.86**	8.54	170.59	25.63	
0.40	1.11	0.13	13.77	46.92	60.69	2.53	**37.93**	11.40	113.79	34.20	***
0.50	1.23	0.25	26.32	46.92	73.24	2.44	**36.62**	13.76	109.86	41.27	
0.60	1.30	0.32	33.58	46.92	80.50	2.24	**33.54**	15.12	100.63	45.36	***
0.70	1.43	0.45	46.84	46.92	93.76	2.23	**33.49**	17.61	100.46	52.83	
0.80	1.53	0.55	56.85	46.92	103.77	2.16	**32.43**	19.49	97.28	58.47	
0.90	1.63	0.65	66.69	46.92	113.61	2.10	**31.56**	21.34	94.68	64.02	
1.00	1.67	0.69	70.57	46.92	117.49	1.96	**29.37**	22.07	88.12	66.20	
1.10	1.76	0.78	79.20	46.92	126.12	1.91	**28.66**	23.69	85.99	71.07	
1.20	1.84	0.86	86.70	46.92	133.62	1.86	**27.84**	25.10	83.51	75.29	

Volumes calculated using depth of water inside chamber and Table 6-SC740 of the StormTech Design Manual

Calculated using Table 7.1: Sediment metering Calculations of the StormTech Removal Efficiency Experiment Lab Protocol

Times for these flows are no longer needed but were included because they were already calculated

APPENDIX 5-f

SETTING PUMPS

SETTING THE PUMPS

1. Fill the trenches with water until the level is about an inch and a half from the standpipes.
2. First prime the pumps using the priming taps.
3. Open the hot water outlet tap and ensure that water runs through it.
4. Then turn ON the oil-recirculating pump and wait till oil flows through it.
5. Use the set pointer to set the required flow rate and adjust it so that fluctuations are reduced to the minimum. The Large pump generally only operates between 9 and 12 (on small gauge) for our range of flows.
6. The priming taps can now be shut off.
7. While chambers are filling, gradually increase pumping rate, while adding more water to the sump. Adding water to the sump distorts the flow meter.
8. After desired flow is achieved, allow flow to run for approximately 5-10 minutes, in order to ensure steady state.
9. Use the butterfly valve to ensure pipe fullness. At flow as low as 0.1-0.2 cfs butterfly valve should be at least ¾ closed. Check signal strength on flow meter to check that pipe is full. Opening and closing butterfly valve affects flow, so perform all adjustments prior to starting experiment.
10. After the experiment is finished, first turn the pump OFF and after a while turn the oil pump off.
11. Make sure to drain the water after each run and also turn the drain valve near the constant head tank ON.

APPENDIX- 5-g

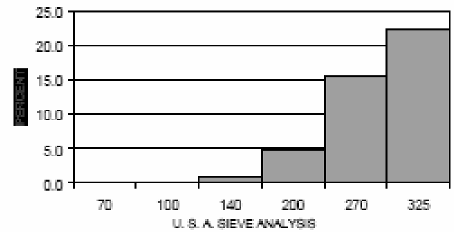
FLOW METER

1. Set up the flow meter using the slide track on the overhead supply pipes.
2. After making the necessary connections, turn the flow meter ON and go to menu 01 to take readings for flow and velocity.
3. The flow rate for the experiment is set using the display of flow rate on the screen.
4. Disregard flow meter readings while adding water to sump. Adding water introduces air bubbles to the system, and distorts the flow measurements.
5. After desired flow is achieved, allow system to run for approximately 5-10 minutes to ensure flow does not change.
6. Check “Signal Strength” menu – should read 100%.
7. To turn the data logger ON, go to menu 80 and select the type of operation required i.e., time based data logger or automatic or just manual.
8. This data can be downloaded to a computer through a USB port and viewed. The data logger stores the data for up to 44 days.
9. Download data to computer in lab, via DOS program. Be sure to name files appropriately (i.e., file name should be recognizable, including desired flow rate, reference to the experiment, and date conducted).
10. Save data to zip drive
11. Then turn the flow meter OFF.

APPENDIX 6

SIL-CO-SIL 106 and 250 Specification Sheets, US Silica

PRODUCT DATA



SIL-CO-SIL® 106

GROUND SILICA

PLANT: MILL CREEK, OKLAHOMA

USA STD SIEVE SIZE		TYPICAL VALUES		
		% RETAINED		% PASSING
MESH	MICRONS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	212	0.0	0.0	100.0
100	150	0.1	0.1	99.9
140	106	0.9	1.0	99.0
200	75	3.9	4.9	95.1
270	53	10.7	15.6	84.4
325	45	6.7	22.3	77.7

TYPICAL PHYSICAL PROPERTIES

HARDNESS (Mohs) **7**
MELTING POINT (Degrees F)......................... **3100**
MINERAL .... **QUARTZ**
pH... **7**

REFLECTANCE (%) **89.4**
YELLOWNESS INDEX.. **3.63**
SPECIFIC GRAVITY 2.65

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide)..................................... **99.7**
Fe_2O_3 (Iron Oxide).. **0.016**
Al_2O_3 (Aluminum Oxide)................................. **0.14**
TiO_2 (Titanium Dioxide)................................ **<0.01**
CaO (Calcium Oxide).................................... **<0.01**

MgO (Magnesium Oxide).. **<0.01**
Na_2O (Sodium Oxide)... **<0.01**
K_2O (Potassium Oxide).. **0.02**
LOI (Loss On Ignition).. **0.1**

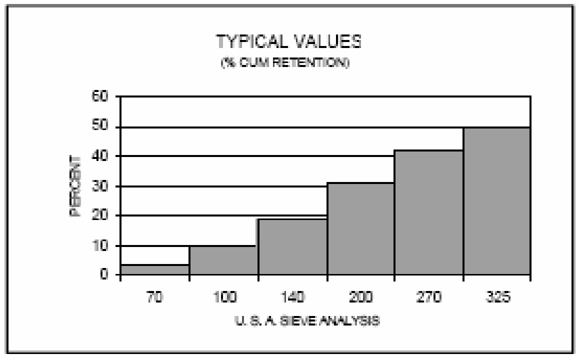
May 29, 1998

<u>DISCLAIMER</u>: The information set forth in this Product Data Sheet represents typical properties of the product described; the information and the typical values are not specifications. U.S. Silica Company makes no representation or warranty concerning the Products, expressed or implied, by this Product Data Sheet.

<u>WARNING</u>: The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer. **For detailed information on the potential health effect of crystalline silica - quartz, see the U.S. Silica Company Material Safety Data Sheet.**

U.S. Silica Company **P.O. Box 187, Berkeley Springs, WV 25411-0187** **(304) 258-2500**

PRODUCT DATA



SIL-CO-SIL® 250

GROUND SILICA

PLANT: OTTAWA, ILLINOIS

USA STD SIEVE SIZE		TYPICAL VALUES		
		% RETAINED		% PASSING
MESH	MICRONS	INDIVIDUAL	CUMULATIVE	CUMULATIVE
70	212	3.5	3.5	96.5
100	150	6.0	9.5	90.5
140	106	9.5	19.0	81.0
200	75	12.0	31.0	69.0
270	53	11.0	42.0	58.0
325	45	8.0	50.0	50.0

TYPICAL PHYSICAL PROPERTIES

HARDNESS (Mohs) **7**
MELTING POINT (Degrees F) **3100**
MINERAL .... **QUARTZ**
pH **7**

REFLECTANCE (%) **78**
YELLOWNESS INDEX **4.8**
SPECIFIC GRAVITY 2.65

TYPICAL CHEMICAL ANALYSIS, %

SiO_2 (Silicon Dioxide) **99.8**
Fe_2O_3 (Iron Oxide) **0.035**
Al_2O_3 (Aluminum Oxide) **0.05**
TiO_2 (Titanium Dioxide) **0.02**
CaO (Calcium Oxide) **0.01**

MgO (Magnesium Oxide) .... **<0.01**
Na_2O (Sodium Oxide) .... **<0.01**
K_2O (Potassium Oxide) **0.02**
LOI (Loss On Ignition) **0.1**

December 15, 1997

WARNING: The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer. **For detailed information on the potential health effect of crystalline silica - quartz, see the U.S. Silica Company Material Safety Data Sheet.**

U.S. Silica Company **P.O. Box 187, Berkeley Springs, WV 25411-0187** **(304) 258-2500**

APPENDIX 7

Micromeritics Size Distribution Analyzes

APPENDIX 7.1

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Dry Sample from 5, 50 lbs. bags.

Sample:	Sil-Co-Sil 106
Operator:	RS
Submitter:	Tennessee Tech University
Bar Code:	
File:	L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution:	silica powder / 2% NaCl
Measurement Principle:	Electrical Sensing Zone
	ASTM Practice E 1617 Compliant

Reported:	9/19/2006 2:19:19PM	Smoothing:	Off
Coinc. Correction:	Off	Background Sub.:	Off

Combined Report

Summary Report

Sample Statistics

Total Number	67549081
Total Surface Area	1.2644e+09 µm²
Total Volume	2.1331e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	25.35	Mode	36.57
Median	21.54		

Weighted Statistics (Number Distribution)

Mean	1.762	Mode	1.378
Median	1.354		

Geometric Statistics (Volume Distribution)

Mean	17.57	Mode	36.57
Median	21.54		

Geometric Statistics (Number Distribution)

Mean	1.445	Mode	1.378
Median	1.354		

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
109.97	1.4988×10^6	0.1	99.9	2	0.0	100.0
104.72	1.2942×10^6	0.1	99.9	2	0.0	100.0
99.72	2.2350×10^6	0.1	99.8	4	0.0	100.0
94.96	2.8948×10^6	0.1	99.6	6	0.0	100.0
90.42	3.7494×10^6	0.2	99.5	9	0.0	100.0
86.11	4.6764×10^6	0.2	99.2	13	0.0	100.0
81.99	5.9016×10^6	0.3	99.0	19	0.0	100.0
78.08	8.0461×10^6	0.4	98.6	30	0.0	100.0
74.35	1.0653×10^7	0.5	98.1	46	0.0	100.0
70.80	1.2998×10^7	0.6	97.5	65	0.0	100.0
67.42	1.6576×10^7	0.8	96.7	96	0.0	100.0
64.20	2.0128×10^7	0.9	95.8	135	0.0	100.0
61.13	2.3302×10^7	1.1	94.7	181	0.0	100.0
58.21	2.6902×10^7	1.3	93.4	242	0.0	100.0
55.43	3.0524×10^7	1.4	92.0	318	0.0	100.0
52.79	3.3568×10^7	1.6	90.4	405	0.0	100.0
50.27	3.6142×10^7	1.7	88.7	505	0.0	100.0
47.87	3.8252×10^7	1.8	86.9	619	0.0	100.0
45.58	4.0820×10^7	1.9	85.0	765	0.0	100.0
43.40	4.3356×10^7	2.0	83.0	941	0.0	100.0
41.33	4.6986×10^7	2.2	80.8	1181	0.0	100.0
39.36	4.9022×10^7	2.3	78.5	1427	0.0	100.0
37.48	5.0575×10^7	2.4	76.1	1705	0.0	100.0
35.69	5.1918×10^7	2.4	73.7	2027	0.0	100.0
33.98	5.1730×10^7	2.4	71.2	2339	0.0	100.0
32.36	5.1237×10^7	2.4	68.8	2683	0.0	100.0
30.82	5.1646×10^7	2.4	66.4	3132	0.0	100.0
29.34	5.1088×10^7	2.4	64.0	3588	0.0	100.0

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Smoothing: Off
Coinc. Correction: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
27.94	5.0568×10^7	2.4	61.6	4113	0.0	100.0
26.61	4.9534×10^7	2.3	59.3	4666	0.0	100.0
25.34	4.8510×10^7	2.3	57.0	5292	0.0	99.9
24.13	4.6961×10^7	2.2	54.8	5933	0.0	99.9
22.98	4.5409×10^7	2.1	52.7	6644	0.0	99.9
21.88	4.4031×10^7	2.1	50.6	7461	0.0	99.9
20.83	4.2749×10^7	2.0	48.6	8389	0.0	99.9
19.84	4.1462×10^7	1.9	46.7	9423	0.0	99.9
18.89	4.0102×10^7	1.9	44.8	10555	0.0	99.9
17.99	3.8466×10^7	1.8	43.0	11725	0.0	99.9
17.13	3.7302×10^7	1.7	41.3	13168	0.0	99.8
16.31	3.6257×10^7	1.7	39.6	14823	0.0	99.8
15.53	3.4564×10^7	1.6	37.9	16365	0.0	99.8
14.79	3.2550×10^7	1.5	36.4	17848	0.0	99.8
14.09	3.0816×10^7	1.4	35.0	19569	0.0	99.7
13.41	2.9190×10^7	1.4	33.6	21467	0.0	99.7
12.77	2.8038×10^7	1.3	32.3	23880	0.0	99.7
12.16	2.7346×10^7	1.3	31.0	26973	0.0	99.6
11.58	2.6654×10^7	1.2	29.8	30448	0.0	99.6
11.03	2.5638×10^7	1.2	28.6	33918	0.1	99.5
10.50	2.5676×10^7	1.2	27.4	39339	0.1	99.5
10.00	2.4925×10^7	1.2	26.2	44225	0.1	99.4
9.52	2.4257×10^7	1.1	25.1	49846	0.1	99.3
9.07	2.3948×10^7	1.1	23.9	56992	0.1	99.3
8.64	2.2852×10^7	1.1	22.9	62981	0.1	99.2
8.22	2.2398×10^7	1.1	21.8	71492	0.1	99.1
7.83	2.2640×10^7	1.1	20.7	83690	0.1	98.9
7.46	2.1619×10^7	1.0	19.7	92548	0.1	98.8

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
7.10	2.1045×10^{7}	1.0	18.7	104337	0.2	98.6
6.76	2.0412×10^{7}	1.0	17.8	117198	0.2	98.5
6.44	2.0028×10^{7}	0.9	16.8	133179	0.2	98.3
6.13	1.9594×10^{7}	0.9	15.9	150895	0.2	98.0
5.84	1.8814×10^{7}	0.9	15.0	167790	0.2	97.8
5.56	1.7969×10^{7}	0.8	14.2	185600	0.3	97.5
5.29	1.7408×10^{7}	0.8	13.4	208232	0.3	97.2
5.04	1.6260×10^{7}	0.8	12.6	225247	0.3	96.9
4.80	1.5528×10^{7}	0.7	11.9	249121	0.4	96.5
4.57	1.5157×10^{7}	0.7	11.2	281620	0.4	96.1
4.35	1.4757×10^{7}	0.7	10.5	317528	0.5	95.6
4.15	1.3984×10^{7}	0.7	9.8	348478	0.5	95.1
3.95	1.3297×10^{7}	0.6	9.2	383763	0.6	94.5
3.76	1.2619×10^{7}	0.6	8.6	421757	0.6	93.9
3.58	1.2227×10^{7}	0.6	8.1	473274	0.7	93.2
3.41	1.1782×10^{7}	0.6	7.5	528145	0.8	92.4
3.25	1.1111×10^{7}	0.5	7.0	576827	0.9	91.6
3.09	1.0718×10^{7}	0.5	6.5	644398	1.0	90.6
2.94	1.0432×10^{7}	0.5	6.0	726354	1.1	89.5
2.80	1.0019×10^{7}	0.5	5.5	807933	1.2	88.4
2.67	9.6578×10^{6}	0.5	5.1	901928	1.3	87.0
2.54	9.3270×10^{6}	0.4	4.6	1008754	1.5	85.5
2.42	8.9843×10^{6}	0.4	4.2	1125332	1.7	83.9
2.30	8.4425×10^{6}	0.4	3.8	1224667	1.8	82.0
2.19	8.0901×10^{6}	0.4	3.4	1359090	2.0	80.0
2.09	7.7077×10^{6}	0.4	3.1	1499584	2.2	77.8
1.99	7.2266×10^{6}	0.3	2.7	1628277	2.4	75.4
1.89	6.8223×10^{6}	0.3	2.4	1780245	2.6	72.8

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
1.80	6.2511×10^6	0.3	2.1	1889088	2.8	70.0
1.72	5.8376×10^6	0.3	1.8	2043052	3.0	66.9
1.64	5.3915×10^6	0.3	1.6	2185292	3.2	63.7
1.56	4.8298×10^6	0.2	1.4	2267112	3.4	60.4
1.48	4.4669×10^6	0.2	1.2	2428306	3.6	56.8
1.41	3.8922×10^6	0.2	1.0	2450401	3.6	53.1
1.35	3.3707×10^6	0.2	0.8	2457600	3.6	49.5
1.28	2.9018×10^6	0.1	0.7	2450277	3.6	45.9
1.22	2.4681×10^6	0.1	0.6	2413616	3.6	42.3
1.16	2.0825×10^6	0.1	0.5	2358455	3.5	38.8
1.11	1.7561×10^6	0.1	0.4	2303217	3.4	35.4
1.05	1.4677×10^6	0.1	0.3	2229321	3.3	32.1
1.00	1.2299×10^6	0.1	0.3	2163566	3.2	28.9
0.96	1.0500×10^6	0.0	0.2	2139102	3.2	25.7
0.91	882477.94	0.0	0.2	2082104	3.1	22.6
0.87	753261.94	0.0	0.1	2058234	3.0	19.6
0.82	635830.86	0.0	0.1	2012058	3.0	16.6
0.79	534818.96	0.0	0.1	1959999	2.9	13.7
0.75	459398.90	0.0	0.1	1949796	2.9	10.8
0.71	385111.96	0.0	0.0	1892938	2.8	8.0
0.68	324344.98	0.0	0.0	1846319	2.7	5.3
0.65	273695.07	0.0	0.0	1804333	2.7	2.6
0.61	231712.02	0.0	0.0	1769084	2.6	0.0

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

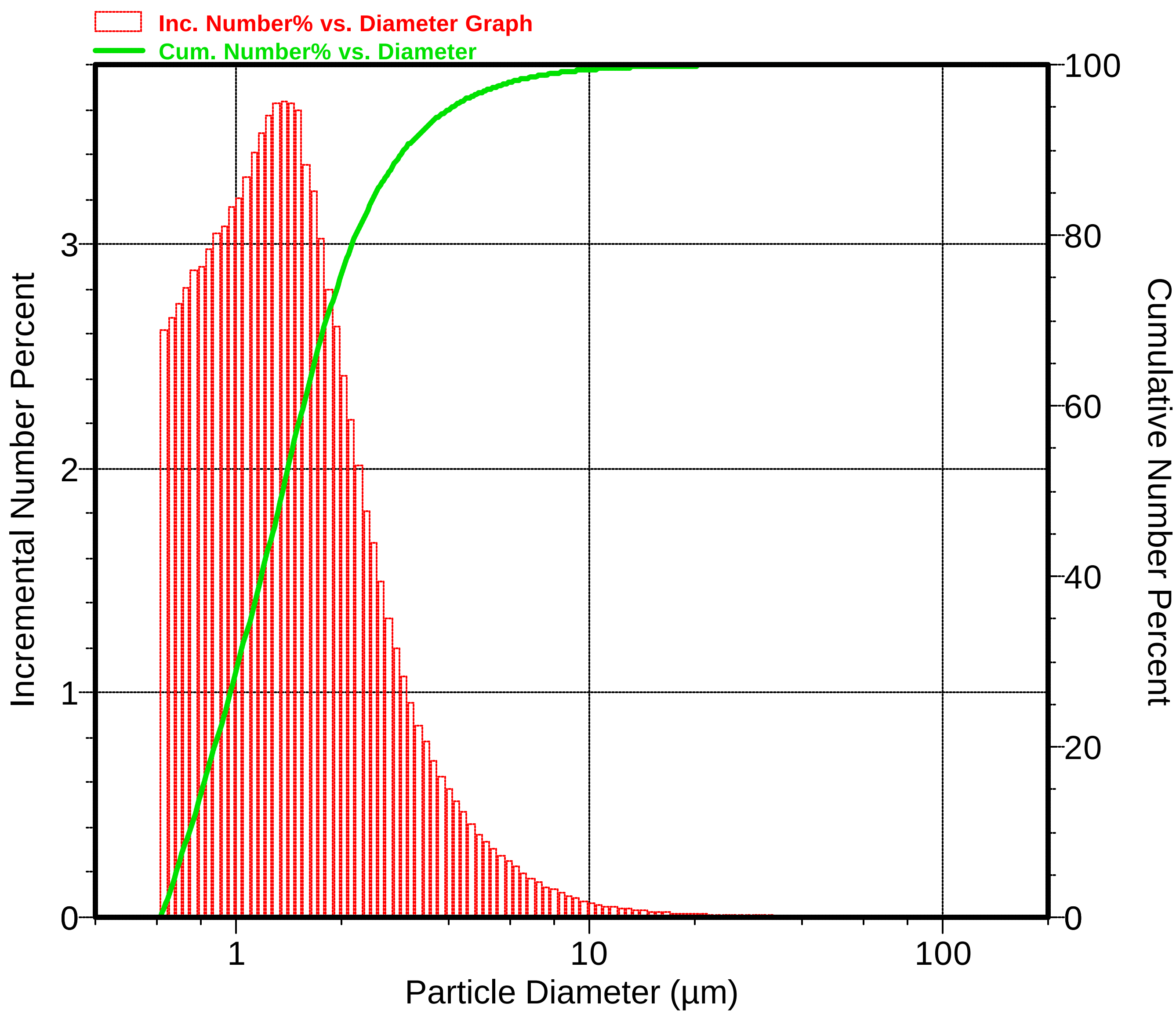
Report by Number Percent

Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
21.3	8.05	2.7	1.97	0.7	1.27	0.1	0.80
15.8	6.08	2.1	1.81	0.5	1.18	0.1	0.74
9.7	4.11	1.7	1.67	0.4	1.10	0.0	0.67
6.2	3.00	1.3	1.55	0.3	1.02	0.0	0.63
4.5	2.50	1.1	1.45	0.2	0.94		
3.4	2.19	0.8	1.35	0.1	0.87		

Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

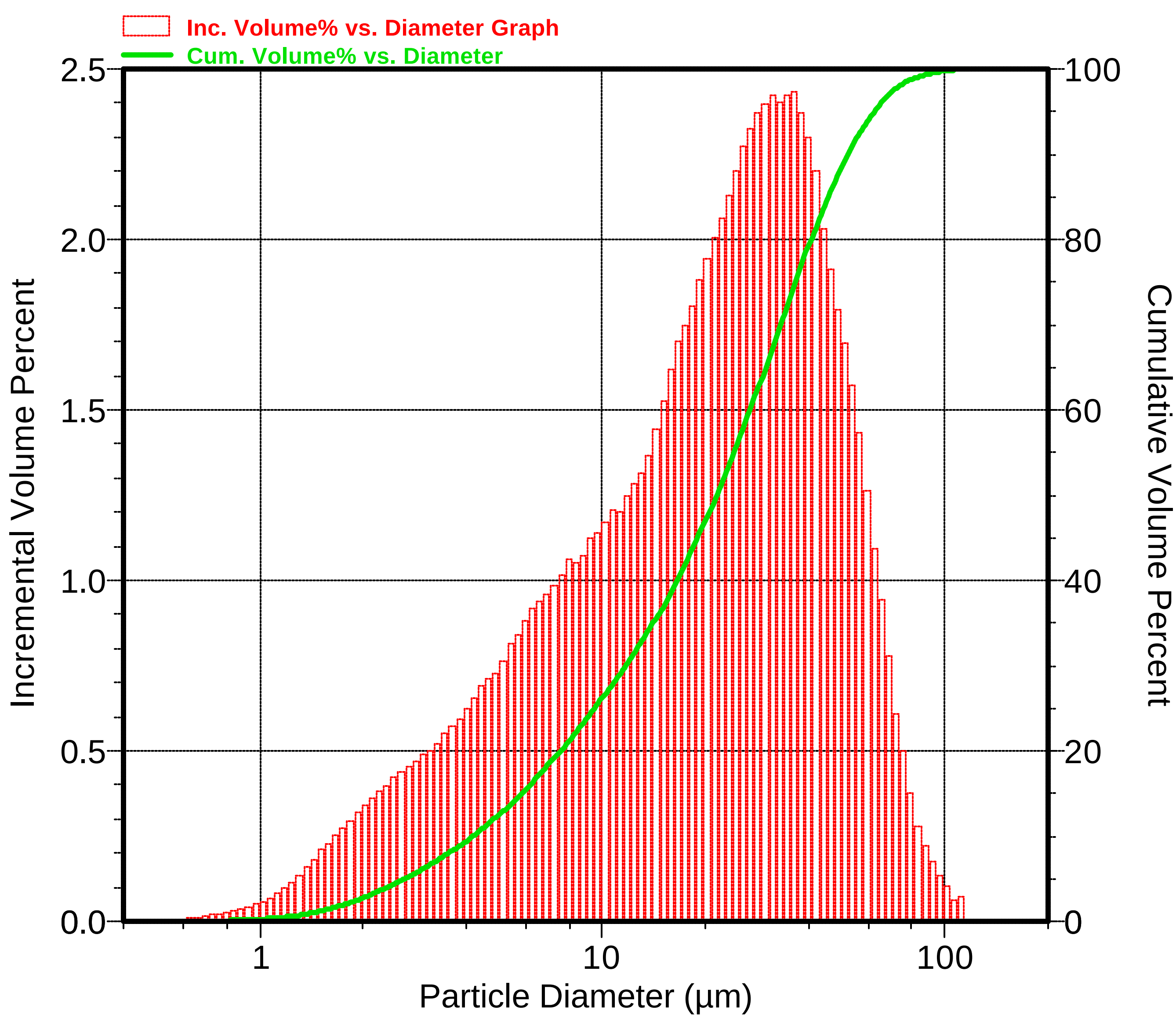
Incremental Number Percent vs. Particle Diameter Graph



Sample: Sil-Co-Sil 106
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3541.SMP
Material/Electrolyte Solution: silica powder / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/19/2006 2:19:19PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Incremental Volume Percent vs. Particle Diameter Graph



APPENDIX 7.2

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Influent

Sample from 28-August Test Run

Sample:	I-1A+I-3A+I-4A
Operator:	RS
Submitter:	Tennessee Tech University
Bar Code:	
File:	L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution:	silica slurry / 2% NaCl
Measurement Principle:	Electrical Sensing Zone
	ASTM Practice E 1617 Compliant

Reported:	9/28/2006 1:25:16PM	Smoothing:	Off
Coinc. Correction:	Off	Background Sub.:	Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Combined Report

Summary Report

Sample Statistics

Total Number	476062711
Total Surface Area	8.0686e+09 µm²
Total Volume	8.1841e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	13.98	Mode	14.43
Median	9.770		

Weighted Statistics (Number Distribution)

Mean	1.841	Mode	1.448
Median	1.476		

Geometric Statistics (Volume Distribution)

Mean	9.356	Mode	14.43
Median	9.770		

Geometric Statistics (Number Distribution)

Mean	1.563	Mode	1.448
Median	1.476		

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
121.28	5.0256×10^{6}	0.1	99.9	5	0.0	100.0
115.49	0.00	0.0	99.9	0	0.0	100.0
109.97	0.00	0.0	99.9	0	0.0	100.0
104.72	0.00	0.0	99.9	0	0.0	100.0
99.72	2.7937×10^{6}	0.0	99.9	5	0.0	100.0
94.96	2.4123×10^{6}	0.0	99.9	5	0.0	100.0
90.42	4.5826×10^{6}	0.1	99.8	11	0.0	100.0
86.11	3.9569×10^{6}	0.0	99.8	11	0.0	100.0
81.99	3.4167×10^{6}	0.0	99.7	11	0.0	100.0
78.08	5.6323×10^{6}	0.1	99.7	21	0.0	100.0
74.35	7.4108×10^{6}	0.1	99.6	32	0.0	100.0
70.80	8.5987×10^{6}	0.1	99.5	43	0.0	100.0
67.42	1.2950×10^{7}	0.2	99.3	75	0.0	100.0
64.20	1.7593×10^{7}	0.2	99.1	118	0.0	100.0
61.13	1.7251×10^{7}	0.2	98.9	134	0.0	100.0
58.21	2.7346×10^{7}	0.3	98.5	246	0.0	100.0
55.43	2.6781×10^{7}	0.3	98.2	279	0.0	100.0
52.79	2.8843×10^{7}	0.4	97.9	348	0.0	100.0
50.27	3.2993×10^{7}	0.4	97.5	461	0.0	100.0
47.87	4.1404×10^{7}	0.5	97.0	670	0.0	100.0
45.58	4.0020×10^{7}	0.5	96.5	750	0.0	100.0
43.40	4.6674×10^{7}	0.6	95.9	1013	0.0	100.0
41.33	4.7741×10^{7}	0.6	95.3	1200	0.0	100.0
39.36	5.4896×10^{7}	0.7	94.6	1598	0.0	100.0
37.48	6.0572×10^{7}	0.7	93.9	2042	0.0	100.0
35.69	6.9386×10^{7}	0.8	93.1	2709	0.0	100.0

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM Smoothing: Off
Coinc. Correction: Off Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
33.98	7.5726×10^{7}	0.9	92.1	3424	0.0	100.0
32.36	8.1410×10^{7}	1.0	91.1	4263	0.0	100.0
30.82	8.5202×10^{7}	1.0	90.1	5167	0.0	100.0
29.34	9.2764×10^{7}	1.1	89.0	6515	0.0	100.0
27.94	9.6561×10^{7}	1.2	87.8	7854	0.0	100.0
26.61	1.0248×10^{8}	1.3	86.5	9653	0.0	100.0
25.34	1.0646×10^{8}	1.3	85.2	11614	0.0	100.0
24.13	1.1778×10^{8}	1.4	83.8	14880	0.0	100.0
22.98	1.2496×10^{8}	1.5	82.3	18284	0.0	100.0
21.88	1.3254×10^{8}	1.6	80.6	22458	0.0	100.0
20.83	1.3822×10^{8}	1.7	79.0	27124	0.0	100.0
19.84	1.4390×10^{8}	1.8	77.2	32704	0.0	100.0
18.89	1.4958×10^{8}	1.8	75.4	39370	0.0	100.0
17.99	1.5337×10^{8}	1.9	73.5	46750	0.0	99.9
17.13	1.5337×10^{8}	1.9	71.6	54142	0.0	99.9
16.31	1.5527×10^{8}	1.9	69.7	63478	0.0	99.9
15.53	1.5716×10^{8}	1.9	67.8	74412	0.0	99.9
14.79	1.5717×10^{8}	1.9	65.9	86178	0.0	99.9
14.09	1.5717×10^{8}	1.9	64.0	99805	0.0	99.9
13.41	1.5528×10^{8}	1.9	62.1	114194	0.0	99.8
12.77	1.5554×10^{8}	1.9	60.2	132472	0.0	99.8
12.16	1.5233×10^{8}	1.9	58.3	150256	0.0	99.8
11.58	1.5282×10^{8}	1.9	56.4	174572	0.0	99.7
11.03	1.5500×10^{8}	1.9	54.5	205059	0.0	99.7
10.50	1.5184×10^{8}	1.9	52.7	232642	0.0	99.7
10.00	1.4727×10^{8}	1.8	50.9	261314	0.1	99.6

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
9.52	1.5207×10^{8}	1.9	49.0	312488	0.1	99.5
9.07	1.4671×10^{8}	1.8	47.2	349144	0.1	99.5
8.64	1.4881×10^{8}	1.8	45.4	410118	0.1	99.4
8.22	1.5476×10^{8}	1.9	43.5	493956	0.1	99.3
7.83	1.4541×10^{8}	1.8	41.8	537509	0.1	99.2
7.46	1.4853×10^{8}	1.8	39.9	635865	0.1	99.0
7.10	1.4121×10^{8}	1.7	38.2	700105	0.1	98.9
6.76	1.3761×10^{8}	1.7	36.5	790113	0.2	98.7
6.44	1.4098×10^{8}	1.7	34.8	937463	0.2	98.5
6.13	1.4021×10^{8}	1.7	33.1	1079735	0.2	98.3
5.84	1.3539×10^{8}	1.7	31.4	1207490	0.3	98.0
5.56	1.3279×10^{8}	1.6	29.8	1371537	0.3	97.7
5.29	1.2938×10^{8}	1.6	28.2	1547560	0.3	97.4
5.04	1.2615×10^{8}	1.5	26.7	1747536	0.4	97.1
4.80	1.2533×10^{8}	1.5	25.2	2010666	0.4	96.6
4.57	1.2283×10^{8}	1.5	23.7	2282141	0.5	96.2
4.35	1.1535×10^{8}	1.4	22.3	2482121	0.5	95.6
4.15	1.1144×10^{8}	1.4	20.9	2777097	0.6	95.0
3.95	1.0699×10^{8}	1.3	19.6	3087575	0.6	94.4
3.76	1.0401×10^{8}	1.3	18.3	3476467	0.7	93.7
3.58	1.0104×10^{8}	1.2	17.1	3911145	0.8	92.8
3.41	9.8073×10^{7}	1.2	15.9	4396377	0.9	91.9
3.25	9.5102×10^{7}	1.2	14.7	4937260	1.0	90.9
3.09	9.0646×10^{7}	1.1	13.6	5449934	1.1	89.7
2.94	8.6188×10^{7}	1.1	12.6	6001276	1.3	88.5
2.80	8.3218×10^{7}	1.0	11.5	6710575	1.4	87.1

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
2.67	7.9358×10^{7}	1.0	10.6	7411169	1.6	85.5
2.54	7.7660×10^{7}	0.9	9.6	8399256	1.8	83.7
2.42	7.3182×10^{7}	0.9	8.7	9166422	1.9	81.8
2.30	7.3771×10^{7}	0.9	7.8	10701161	2.2	79.6
2.19	6.6106×10^{7}	0.8	7.0	11105429	2.3	77.2
2.09	6.3975×10^{7}	0.8	6.2	12446777	2.6	74.6
1.99	5.9525×10^{7}	0.7	5.5	13412024	2.8	71.8
1.89	5.6117×10^{7}	0.7	4.8	14643417	3.1	68.7
1.80	5.1313×10^{7}	0.6	4.2	15506980	3.3	65.5
1.72	4.6973×10^{7}	0.6	3.6	16439710	3.5	62.0
1.64	4.2352×10^{7}	0.5	3.1	17166079	3.6	58.4
1.56	3.9036×10^{7}	0.5	2.6	18323716	3.8	54.6
1.48	3.6267×10^{7}	0.4	2.2	19715457	4.1	50.4
1.41	3.2321×10^{7}	0.4	1.8	20348633	4.3	46.2
1.35	2.7424×10^{7}	0.3	1.5	19995359	4.2	42.0
1.28	2.3180×10^{7}	0.3	1.2	19573088	4.1	37.8
1.22	1.9693×10^{7}	0.2	0.9	19258270	4.0	33.8
1.16	1.6271×10^{7}	0.2	0.7	18427579	3.9	29.9
1.11	1.2904×10^{7}	0.2	0.6	16924559	3.6	26.4
1.05	1.0534×10^{7}	0.1	0.4	16000370	3.4	23.0
1.00	8.1173×10^{6}	0.1	0.3	14279363	3.0	20.0
0.96	6.3301×10^{6}	0.1	0.3	12896203	2.7	17.3
0.91	4.9244×10^{6}	0.1	0.2	11618490	2.4	14.9
0.87	3.9918×10^{6}	0.0	0.2	10907360	2.3	12.6
0.82	3.2475×10^{6}	0.0	0.1	10276648	2.2	10.4
0.79	2.5492×10^{6}	0.0	0.1	9342445	2.0	8.4

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
0.75	2.0945×10^6	0.0	0.1	8889622	1.9	6.6
0.71	1.7085×10^6	0.0	0.0	8397681	1.8	4.8
0.68	1.3958×10^6	0.0	0.0	7945304	1.7	3.1
0.65	1.1573×10^6	0.0	0.0	7629405	1.6	1.5
0.61	964147.51	0.0	0.0	7361111	1.5	0.0

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Report by Number Percent

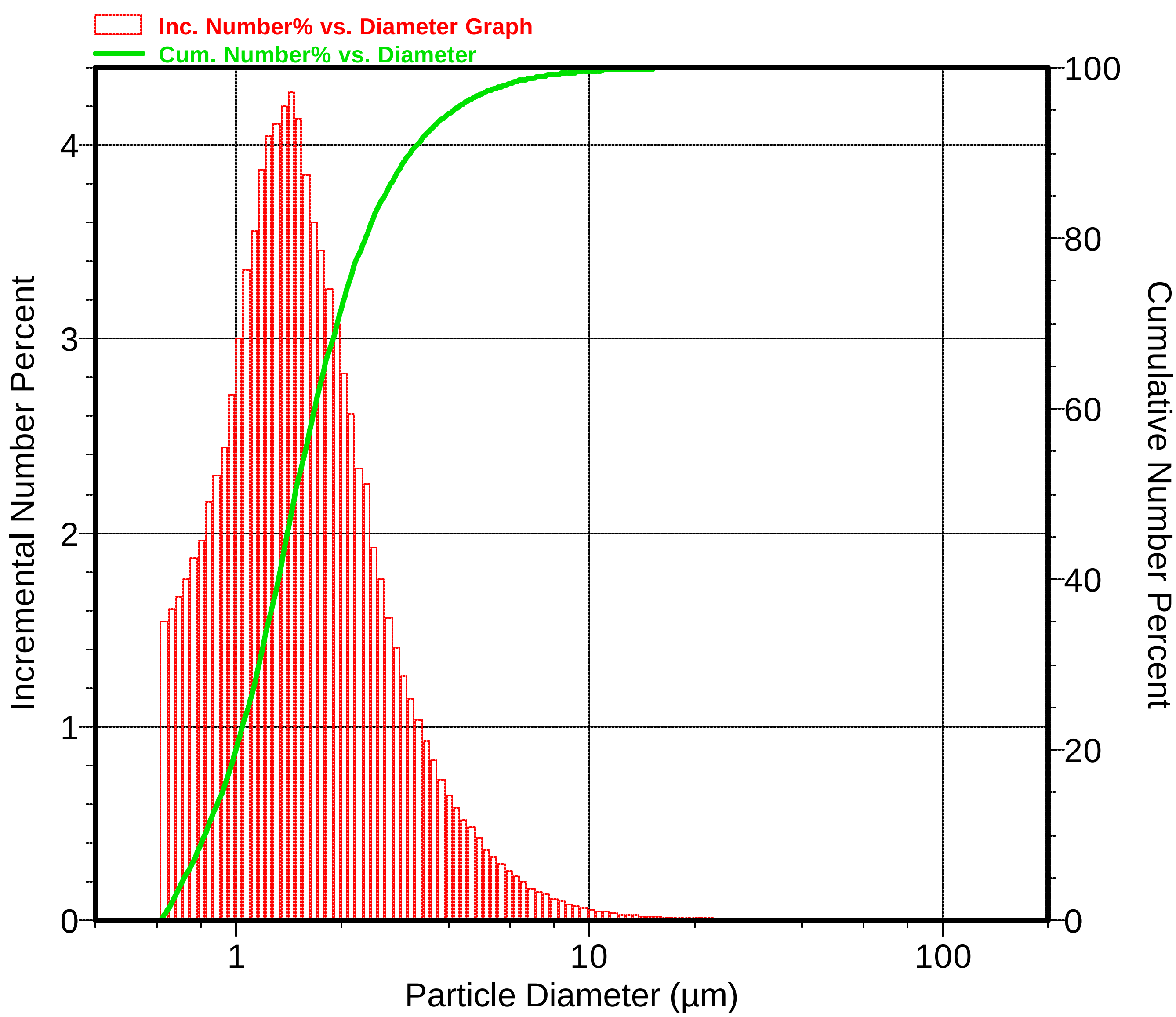
Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
39.6	7.40	6.3	2.10	1.7	1.39	0.2	0.91
31.2	5.80	5.1	1.93	1.3	1.31	0.1	0.82
20.8	4.13	4.1	1.79	1.0	1.24	0.0	0.72
13.8	3.12	3.3	1.67	0.7	1.16	0.0	0.63
10.3	2.63	2.7	1.57	0.5	1.08		
8.0	2.33	2.1	1.48	0.3	1.00		

Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Incremental Number Percent vs. Particle Diameter Graph

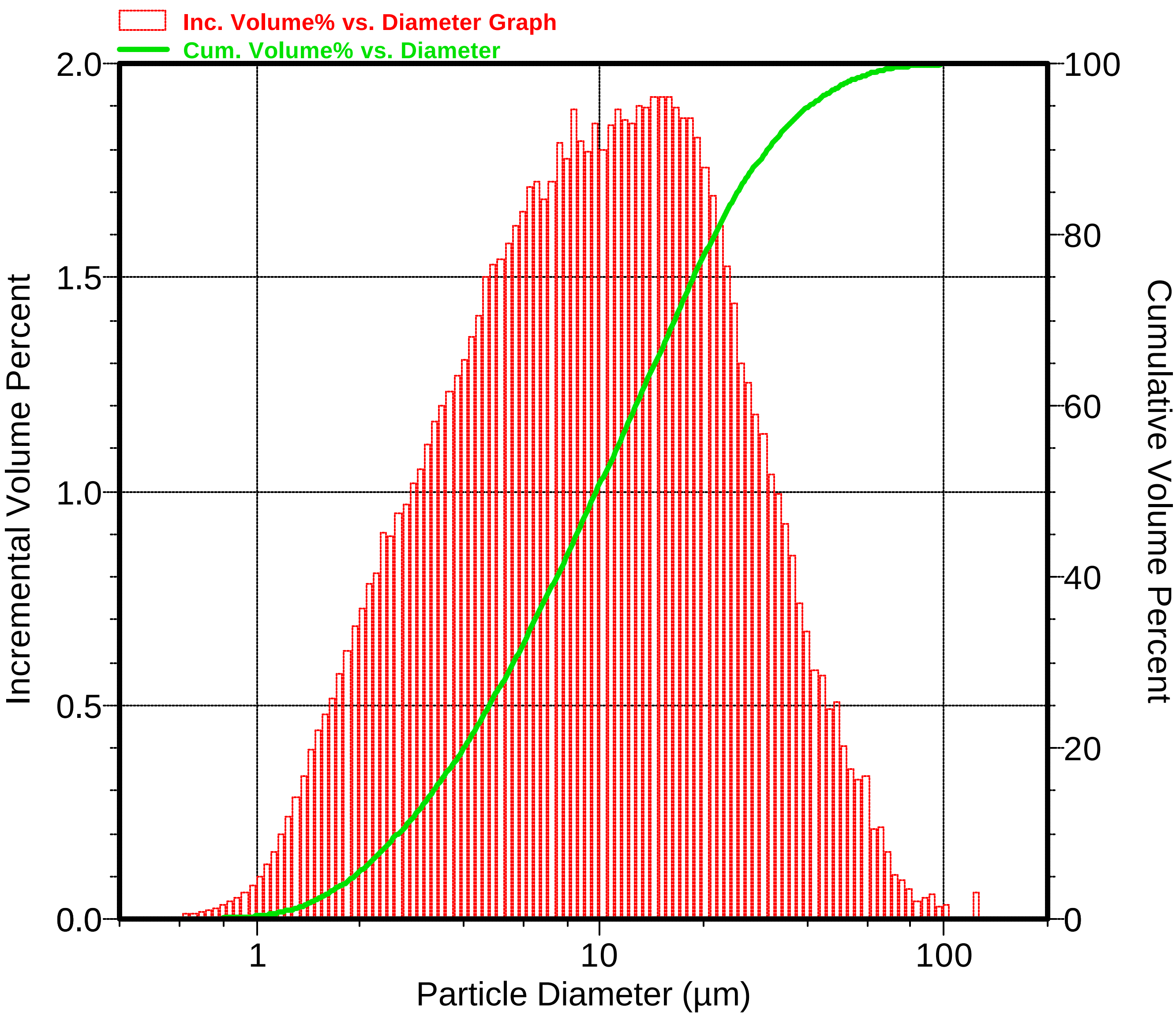


Sample: I-1A+I-3A+I-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3696.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:25:16PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining I-1A+I-3A+I-4A

Incremental Volume Percent vs. Particle Diameter Graph



APPENDIX 7.3

Micromeritics Size Distribution Analyzes – SIL-CO-SIL 106, Composite Effluent

Sample from 28-August Test Run

Micromeritics Analytical Services

Sample:	E-2A+E-3A+E-4A
Operator:	RS
Submitter:	Tennessee Tech University
Bar Code:	
File:	L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution:	silica slurry / 2% NaCl
Measurement Principle:	Electrical Sensing Zone
	ASTM Practice E 1617 Compliant

Reported:	9/28/2006 1:24:52PM	Smoothing:	Off
Coinc. Correction:	Off	Background Sub.:	Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Combined Report

Summary Report

Sample Statistics

Total Number	223341704
Total Surface Area	2.6223e+09 µm²
Total Volume	1.4599e+09 µm³

Weighted Statistics (Volume Distribution)

Mean	6.680	Mode	3.326
Median	3.954		

Weighted Statistics (Number Distribution)

Mean	1.677	Mode	1.448
Median	1.447		

Geometric Statistics (Volume Distribution)

Mean	4.382	Mode	3.326
Median	3.954		

Geometric Statistics (Number Distribution)

Mean	1.490	Mode	1.448
Median	1.447		

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
162.66	4.8501×10^6	0.3	99.7	2	0.0	100.0
154.89	0.00	0.0	99.7	0	0.0	100.0
147.50	0.00	0.0	99.7	0	0.0	100.0
140.45	0.00	0.0	99.7	0	0.0	100.0
133.75	0.00	0.0	99.7	0	0.0	100.0
127.36	0.00	0.0	99.7	0	0.0	100.0
121.28	0.00	0.0	99.7	0	0.0	100.0
115.49	0.00	0.0	99.7	0	0.0	100.0
109.97	0.00	0.0	99.7	0	0.0	100.0
104.72	1.2942×10^6	0.1	99.6	2	0.0	100.0
99.72	0.00	0.0	99.6	0	0.0	100.0
94.96	0.00	0.0	99.6	0	0.0	100.0
90.42	0.00	0.0	99.6	0	0.0	100.0
86.11	1.4389×10^6	0.1	99.5	4	0.0	100.0
81.99	0.00	0.0	99.5	0	0.0	100.0
78.08	0.00	0.0	99.5	0	0.0	100.0
74.35	0.00	0.0	99.5	0	0.0	100.0
70.80	0.00	0.0	99.5	0	0.0	100.0
67.42	690678.55	0.0	99.4	4	0.0	100.0
64.20	298191.88	0.0	99.4	2	0.0	100.0
61.13	0.00	0.0	99.4	0	0.0	100.0
58.21	222328.67	0.0	99.4	2	0.0	100.0
55.43	0.00	0.0	99.4	0	0.0	100.0
52.79	331531.76	0.0	99.4	4	0.0	100.0
50.27	500971.51	0.0	99.3	7	0.0	100.0
47.87	432576.44	0.0	99.3	7	0.0	100.0

Micromeritics Analytical Services

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
45.58	1.1739×10^6	0.1	99.2	22	0.0	100.0
43.40	691123.65	0.0	99.2	15	0.0	100.0
41.33	596768.08	0.0	99.1	15	0.0	100.0
39.36	755765.12	0.1	99.1	22	0.0	100.0
37.48	1.0975×10^6	0.1	99.0	37	0.0	100.0
35.69	1.6392×10^6	0.1	98.9	64	0.0	100.0
33.98	2.5213×10^6	0.2	98.7	114	0.0	100.0
32.36	1.9670×10^6	0.1	98.6	103	0.0	100.0
30.82	2.2756×10^6	0.2	98.4	138	0.0	100.0
29.34	2.5060×10^6	0.2	98.3	176	0.0	100.0
27.94	3.3195×10^6	0.2	98.0	270	0.0	100.0
26.61	3.1211×10^6	0.2	97.8	294	0.0	100.0
25.34	3.6758×10^6	0.3	97.6	401	0.0	100.0
24.13	4.3692×10^6	0.3	97.3	552	0.0	100.0
22.98	4.7090×10^6	0.3	97.0	689	0.0	100.0
21.88	5.0694×10^6	0.3	96.6	859	0.0	100.0
20.83	5.6614×10^6	0.4	96.2	1111	0.0	100.0
19.84	6.1513×10^6	0.4	95.8	1398	0.0	100.0
18.89	6.9301×10^6	0.5	95.3	1824	0.0	100.0
17.99	7.7620×10^6	0.5	94.8	2366	0.0	100.0
17.13	8.1867×10^6	0.6	94.2	2890	0.0	100.0
16.31	9.1677×10^6	0.6	93.6	3748	0.0	100.0
15.53	9.8233×10^6	0.7	92.9	4651	0.0	100.0
14.79	1.0806×10^7	0.7	92.2	5925	0.0	100.0
14.09	1.1459×10^7	0.8	91.4	7277	0.0	100.0
13.41	1.2635×10^7	0.9	90.5	9292	0.0	100.0

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
12.77	1.3425×10^7	0.9	89.6	11434	0.0	100.0
12.16	1.4080×10^7	1.0	88.7	13888	0.0	100.0
11.58	1.4596×10^7	1.0	87.7	16673	0.0	100.0
11.03	1.5172×10^7	1.0	86.6	20071	0.0	100.0
10.50	1.6150×10^7	1.1	85.5	24743	0.0	99.9
10.00	1.7296×10^7	1.2	84.3	30690	0.0	99.9
9.52	1.7355×10^7	1.2	83.1	35662	0.0	99.9
9.07	1.8296×10^7	1.3	81.9	43540	0.0	99.9
8.64	1.8338×10^7	1.3	80.6	50542	0.0	99.9
8.22	1.9215×10^7	1.3	79.3	61330	0.0	99.8
7.83	1.9958×10^7	1.4	77.9	73776	0.0	99.8
7.46	2.0455×10^7	1.4	76.5	87566	0.0	99.8
7.10	2.1385×10^7	1.5	75.1	106022	0.0	99.7
6.76	2.2644×10^7	1.6	73.5	130013	0.1	99.7
6.44	2.3722×10^7	1.6	71.9	157743	0.1	99.6
6.13	2.4301×10^7	1.7	70.2	187143	0.1	99.5
5.84	2.4918×10^7	1.7	68.5	222231	0.1	99.4
5.56	2.6200×10^7	1.8	66.7	270613	0.1	99.3
5.29	2.7838×10^7	1.9	64.8	332991	0.1	99.1
5.04	3.0459×10^7	2.1	62.7	421941	0.2	99.0
4.80	3.4296×10^7	2.3	60.4	550217	0.2	98.7
4.57	3.6580×10^7	2.5	57.9	679653	0.3	98.4
4.35	3.8504×10^7	2.6	55.2	828516	0.4	98.0
4.15	3.8648×10^7	2.6	52.6	963101	0.4	97.6
3.95	3.9304×10^7	2.7	49.9	1134295	0.5	97.1
3.76	3.8799×10^7	2.7	47.3	1296767	0.6	96.5

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
3.58	3.9305×10^{7}	2.7	44.6	1521376	0.7	95.8
3.41	3.9305×10^{7}	2.7	41.9	1761942	0.8	95.0
3.25	3.9305×10^{7}	2.7	39.2	2040548	0.9	94.1
3.09	3.8651×10^{7}	2.6	36.5	2323823	1.0	93.1
2.94	3.8324×10^{7}	2.6	33.9	2668469	1.2	91.9
2.80	3.7941×10^{7}	2.6	31.3	3059517	1.4	90.5
2.67	3.7428×10^{7}	2.6	28.7	3495359	1.6	89.0
2.54	3.5850×10^{7}	2.5	26.3	3877302	1.7	87.2
2.42	3.4245×10^{7}	2.3	23.9	4289392	1.9	85.3
2.30	3.3586×10^{7}	2.3	21.6	4871909	2.2	83.1
2.19	3.1634×10^{7}	2.2	19.5	5314347	2.4	80.7
2.09	3.1529×10^{7}	2.2	17.3	6134110	2.7	78.0
1.99	2.9456×10^{7}	2.0	15.3	6637000	3.0	75.0
1.89	2.7666×10^{7}	1.9	13.4	7219294	3.2	71.8
1.80	2.5490×10^{7}	1.7	11.7	7703101	3.4	68.3
1.72	2.3920×10^{7}	1.6	10.0	8371553	3.7	64.6
1.64	2.1390×10^{7}	1.5	8.5	8669726	3.9	60.7
1.56	1.9438×10^{7}	1.3	7.2	9124243	4.1	56.6
1.48	1.7896×10^{7}	1.2	6.0	9728546	4.4	52.3
1.41	1.5957×10^{7}	1.1	4.9	10045920	4.5	47.8
1.35	1.3433×10^{7}	0.9	4.0	9794182	4.4	43.4
1.28	1.1763×10^{7}	0.8	3.2	9932990	4.4	38.9
1.22	9.5847×10^{6}	0.7	2.5	9372922	4.2	34.7
1.16	7.7209×10^{6}	0.5	2.0	8744096	3.9	30.8
1.11	6.2303×10^{6}	0.4	1.6	8171574	3.7	27.2
1.05	5.0503×10^{6}	0.3	1.2	7671203	3.4	23.7

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM Smoothing: Off
Coinc. Correction: Off Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Size Class

Low Particle Diameter (µm)	Incremental Volume (µm³)	Incremental Volume Percent	Cumulative Volume Percent	Incremental Number	Incremental Number Percent	Cumulative Number Percent
1.00	3.8530×10^6	0.3	1.0	6777979	3.0	20.7
0.96	3.0936×10^6	0.2	0.7	6302572	2.8	17.9
0.91	2.4702×10^6	0.2	0.6	5828132	2.6	15.3
0.87	1.9848×10^6	0.1	0.4	5423260	2.4	12.8
0.82	1.5792×10^6	0.1	0.3	4997361	2.2	10.6
0.79	1.2642×10^6	0.1	0.2	4633130	2.1	8.5
0.75	1.0464×10^6	0.1	0.2	4441006	2.0	6.5
0.71	817666.46	0.1	0.1	4019070	1.8	4.7
0.68	668796.94	0.0	0.1	3807096	1.7	3.0
0.65	535028.66	0.0	0.0	3527173	1.6	1.5
0.61	425029.66	0.0	0.0	3245033	1.5	0.0

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
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Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Report by Number Percent

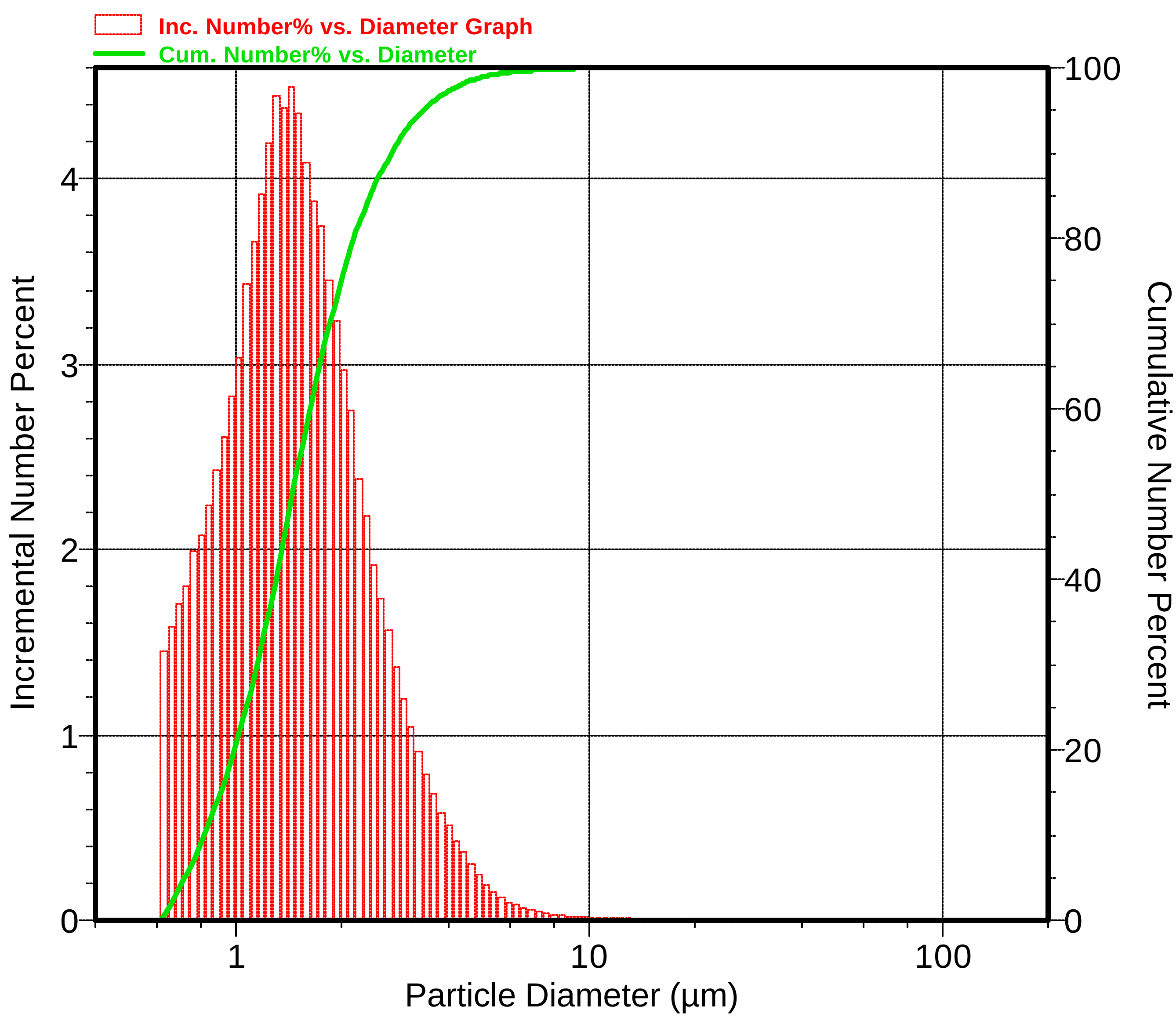
Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)	Cumulative Volume Percent	Low Particle Diameter (µm)
63.3	5.10	15.3	1.99	4.3	1.37	0.6	0.90
55.1	4.34	12.5	1.85	3.4	1.30	0.3	0.81
41.7	3.40	10.2	1.73	2.6	1.22	0.1	0.72
30.4	2.76	8.3	1.62	1.9	1.15	0.0	0.64
23.6	2.40	6.7	1.53	1.3	1.07		
18.9	2.16	5.4	1.45	0.9	0.99		

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Incremental Number Percent vs. Particle Diameter Graph



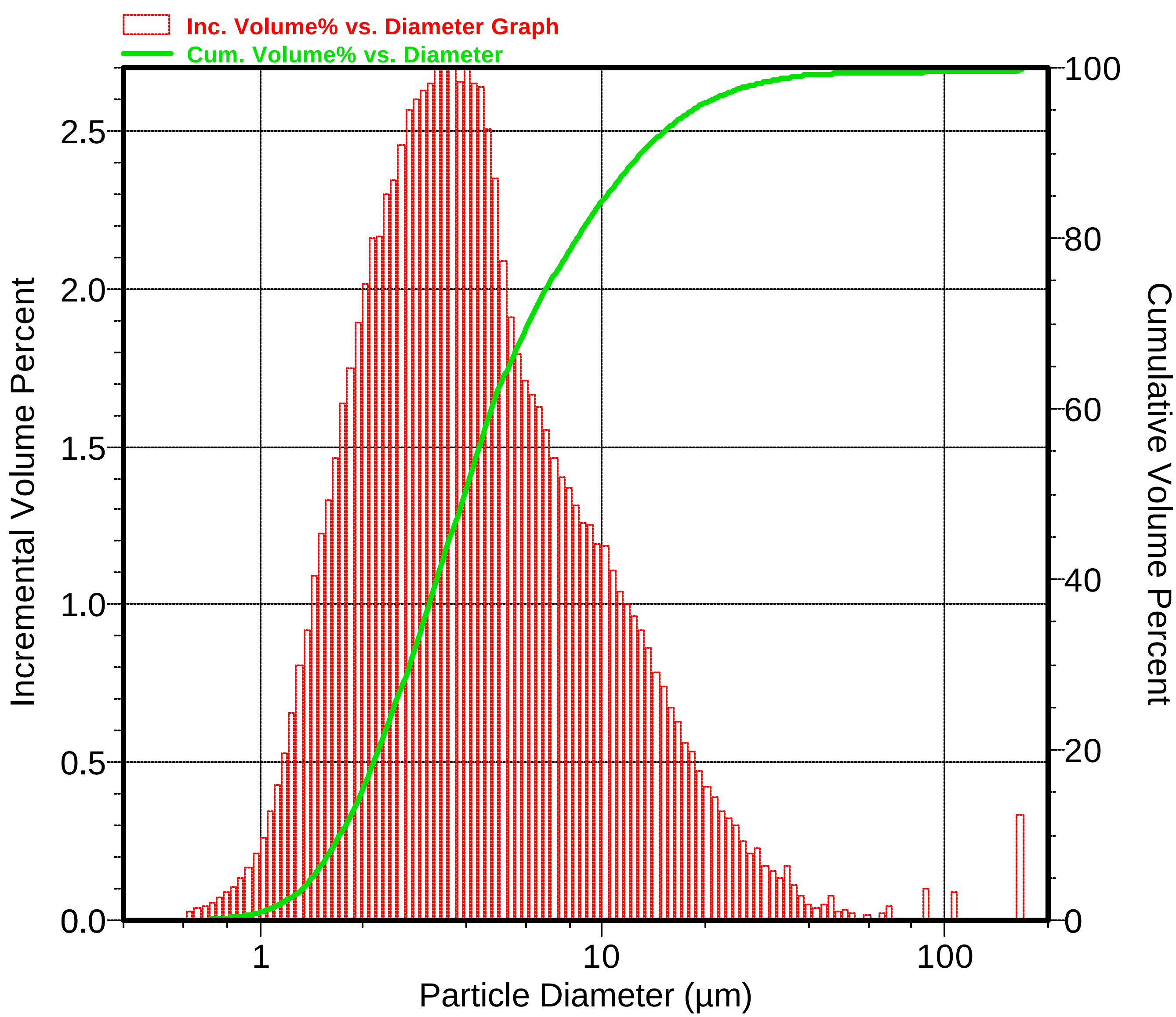
Micromeritics Analytical Services

Sample: E-2A+E-3A+E-4A
Operator: RS
Submitter: Tennessee Tech University
Bar Code:
File: L:\...\09SEP06\06-3697.SMP
Material/Electrolyte Solution: silica slurry / 2% NaCl
Measurement Principle: Electrical Sensing Zone
ASTM Practice E 1617 Compliant

Reported: 9/28/2006 1:24:52PM
Coinc. Correction: Off
Smoothing: Off
Background Sub.: Off

Comments: Results are from Combining E-2A+E-3A+E-4A

Incremental Volume Percent vs. Particle Diameter Graph



NJCAT TECHNOLOGY VERIFICATION

Isolator® Row PLUS

StormTech, LLC

July 2020

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1. Description of Technology

The Isolator® Row PLUS (**shown in Figures 1 and 2**) is the first row of StormTech chambers that is surrounded with filter fabric and connected to a closely located manhole for easy access. The Isolator Row PLUS provides for settling and filtration of sediment as stormwater rises in the chamber and ultimately passes through the filter fabric. The open-bottom chambers allow stormwater to flow out of the chambers, while sediment is captured in the Isolator Row PLUS.

A single layer of proprietary Advanced Drainage Systems (ADS) PLUS fabric is placed between the angular base stone and the Isolator Row PLUS chamber. The geotextile provides the means for stormwater filtration and provides a durable surface for maintenance operations. A non-woven fabric is placed over the chambers. See link to O&M Manual (pg. 23) for installation pictures.

The Isolator Row PLUS is designed to capture the "first flush" runoff and offers the versatility to be sized on a volume basis or a flow basis. An upstream manhole not only provides access to the Isolator Row PLUS but includes a high/low concept such that stormwater flow rates or volumes that exceed the capacity of the Isolator Row PLUS bypass through a manifold to the other chambers. This is achieved with either an elevated bypass manifold or a high-flow weir. This creates a differential between the Isolator Row PLUS row of chambers and the manifold to the rest of the system, thus allowing for settlement time in the Isolator Row PLUS. After Stormwater flows through the Isolator Row PLUS and into the rest of the StormTech chamber system it is either infiltrated into the soils below or passed at a controlled rate through an outlet manifold and outlet control structure. **Since this technology fits under the infiltration basin BMP in the New Jersey Stormwater BMP Manual, it is not eligible for NJDEP MTD certification.**

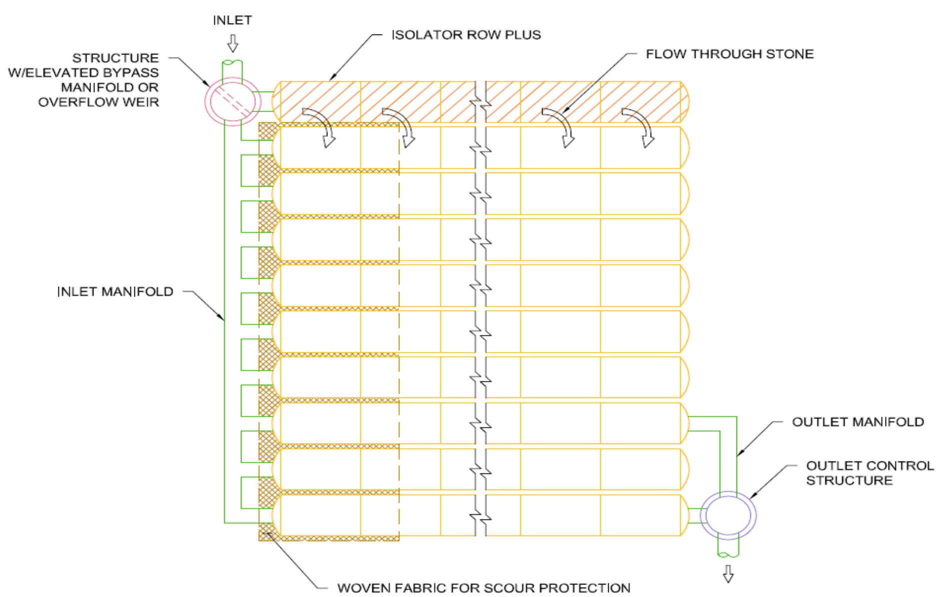

Figure 1 Schematic of the StormTech Isolator Row PLUS System

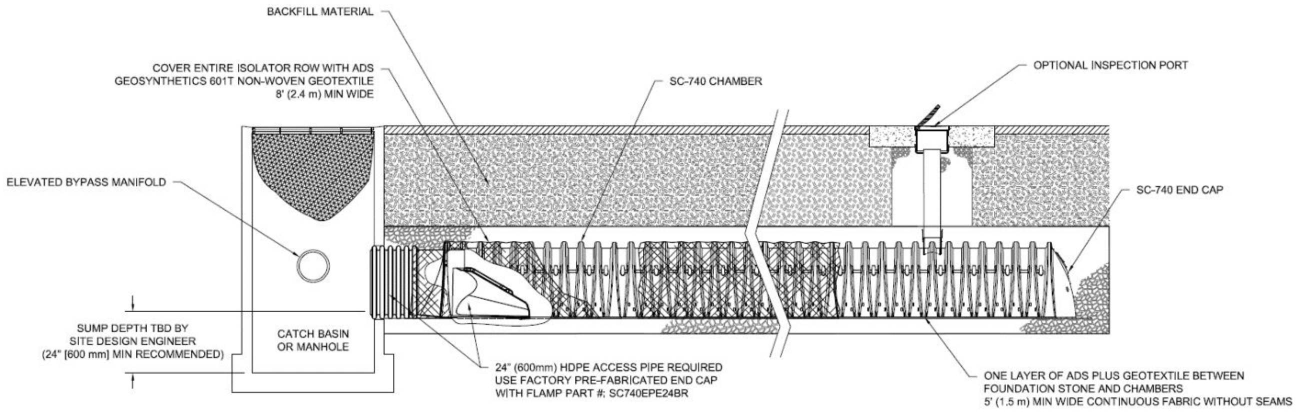

Figure 2 Isolator Row PLUS Detail

2. Laboratory Testing

Beginning in January 2020, two overlapping StormTech SC-740 Isolator Row PLUS commercial size chambers were installed at the BaySaver Laboratory in Mount Airy, Maryland, to evaluate the performance of Isolator Row PLUS on Total Suspended Solid (TSS) removal. Boggs Environmental Consultants (BEC) provided third-party review and oversight of all testing and data collection procedures, in accordance with the *New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device (January 2013)*. All sediment concentration samples were analyzed by Fredericktowne Labs (FTL) using ASTM D3977-97 (2019). All sediment PSD analysis was performed by Environmental Consulting Services (ECS), using the methodology of ASTM D422-63 (2007). Prior to the start of testing, a Quality Assurance Project Plan (QAPP), revision dated January 9, 2020, was submitted to, and approved by the New Jersey Corporation for Advanced Technology (NJCAT).

2.1 Test Setup

The testing system, shown in **Figure 3**, consisted of a source tank, feed pump, flow control valve, flow meter, background sample port, screw-auger sediment feeder (doser), and an Isolator Row PLUS test system. This verification report only addresses the performance of the Isolator Row PLUS and not the entire StormTech system, since this is the row designed to remove sediment until the system goes into bypass.

Testing Procedure

The water source was potable water from the Town of Mount Airy Water & Sewer Department, obtained from an onsite tap, which served as the raw water supply for the testing system. Municipal tap water was used to fill the source tank, and then pumped to the system. Flow rate was controlled to the target of 225 gpm by a flow control valve. An inline flow meter (FloCat MFE electromagnetic flow meter) was used to measure the flow, and a SeaMetrics DL76 data logger (pictured in **Figure 4**) recorded the flow at one-minute intervals. The test sediment was introduced to the inlet stream via a 12 -inch dosing port teed with a 12-inch influent line (pictured in **Figure 5**) located approximately 4 feet upstream of the system inlet. The dosing rate was controlled by a screw-auger Velodyne Barracuda 1000A volumetric feeder with a ½ HP variable speed motor. The dosing rate was set to deliver an amount of sediment that, when mixed with the water from the source tank, would produce influent water with a target test sediment concentration of 200 mg/L.

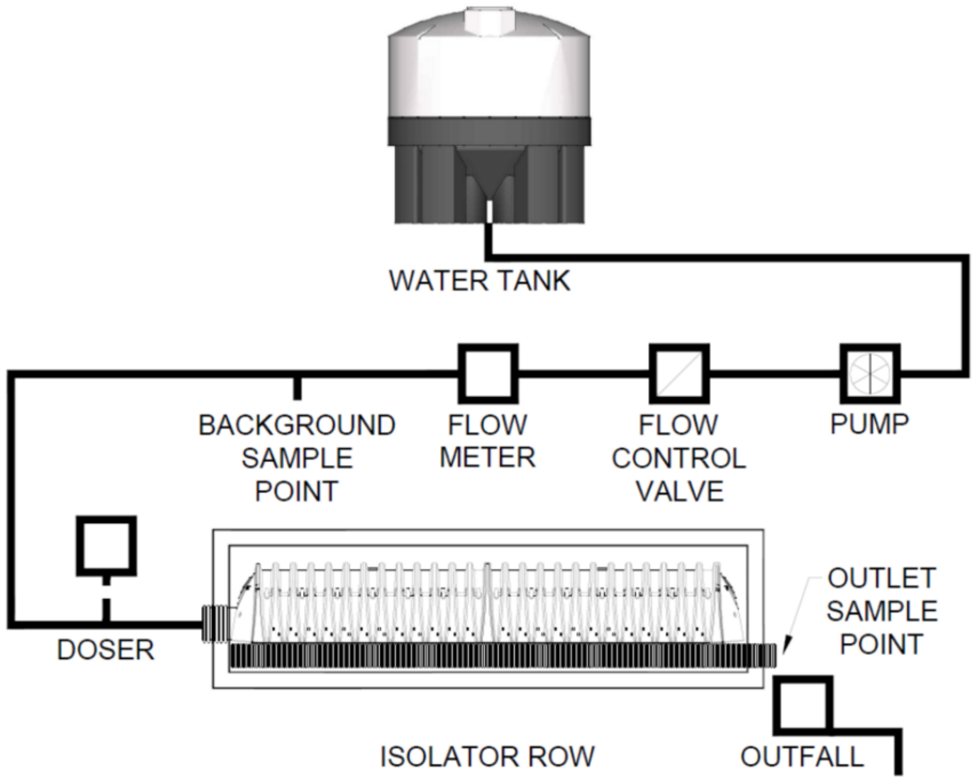

Figure 3 Schematic of the Isolator Row PLUS Test Configuration

The Isolator Row PLUS was installed inside a watertight 16'L x 6'W x 4'H test box (pictured in **Figures 6 and 7**). The Isolator Row PLUS is an arch-shaped stormwater detention/retention sediment collection and filtering device, sealed with end caps, with a 12"-inch inlet pipe welded into the upstream end cap. A ramp apparatus (patent pending) was attached to the inside of the chamber end cap to provide a smooth transition from pipe invert to fabric bottom. It is configured to improve chamber function performance over time by distributing sediment and debris that would otherwise collect at the inlet. It also serves to improve the fluid and solid flow back into the inlet pipe during maintenance and cleaning, and to guide cleaning and inspection equipment back into the inlet pipe when complete.

The chambers were installed on a 10-inch base of washed, angular, crushed stone, (#57, ¾ inch blue stone) containing an 8-inch perforated underdrain pipe running the length of the test box, penetrating the wall of the downstream end of the test box to the discharge collection point. An ADS non-woven geotextile fabric was placed over the top of the chamber row. The chambers were then backfilled with the washed crushed stone up to the top of the chamber elevation.

Additionally, an opening was cut into the top of one chamber to allow for visual monitoring and head measurement. No bypass or weir was installed upstream of the test box.

The test flow entered the chamber via the influent pipe and flowed across the filter fabric, filling the row. The water then flowed through the filter fabric, driven by hydrostatic head. The treated water exited the test box via the underdrain.

Figures 4 and 5 Photographs of Flow Meter and Sediment Delivery Port

Figure 6 Side View Photograph of Isolator Row PLUS Test Box

Figure 7 Top View Photograph of Isolator Row PLUS Test Box

Test Unit and Scaling Explanation

The Isolator Row PLUS used in this test was constructed from two (2) overlapping polypropylene open-bottom StormTech SC-740 chambers (one shortened by 5-in. to enable fitting into the test box), two (2) SC-740 end caps, a ramp apparatus and one layer of ADS PLUS geotextile fabric. The chamber floor filtration area (effective filtration treatment area, EFTA) was approximately 54.5 ft^2. (calculated using an average contact width inside the chamber of 45 in). The target test flow was 225 gpm. The calculated hydraulic loading rate, flow rate/EFTA is 4.13 gpm/ft^2 and the ratio of effective sedimentation treatment area to EFTA is 1.0. Given these data, one can effectively scale the test results for all commercial systems.

Sample Collection

The grab sampling method was used for all sample collection by sweeping a wide-mouth 1-L plastic bottle through the free-discharge effluent stream, to ensure the full cross section of the flow was sampled. The start time for each run was recorded.

The sampling schedule is provided in **Table 1**. The detention time for the Isolator Row PLUS unit operating at 20 inches hydrostatic head (maximum head tested) is 2.1 minutes. To comply with the NJDEP Filter Protocol, after initiating and stabilizing the flow rate at the MTFR and beginning sediment feed, effluent sampling did not begin until the filtration MTD has been in operation for a minimum of three detention times.

Background water samples were collected upstream of the doser (shown in **Figures 3 and 8**) in correspondence with the odd-numbered effluent samples (i.e., Samples E1, E3, E5 at t = 9, 20, 31 minutes).

Table 1 Sampling Schedule for the Isolator Row PLUS Tests

Time (min)	Sample(s)	Time (min)	Sample(s)
0	S1	22	S3
9	E1, BG1	31	E5, BG3
10	E2	32	E6
11	S2	33	Stop Flow
20	E3, BG2	N/A	DDA
21	E4	N/A	DDB

NOTE: S = sediment rate; E = effluent; BG = background; DD = drawdown

Figure 8 Photograph of Background Sampling Port

Two evenly-volume-spaced drawdown samples, DDA and DDB, were taken after the flow and sediment feed to the unit had been stopped.

Sediment injection rates were measured using a stopwatch and the mass collected measured on a calibrated scale once at the very beginning of the run and twice more during the run. A fourth sediment rate sample was taken after the run was finished as an internal check but was not included in the calculations for the report. The duration of each run was 33 minutes.

A Chain of Custody (COC) form was used for each test run to record sampling date and time for externally analyzed samples. Copies of these forms were maintained by BaySaver Laboratory and FTL. Sample bottles were labeled to identify the test run number and sample type (e.g., background, effluent), corresponding to the sample identification on the COC form. BEC was present during each test run and witnessed labeling, completion of COC forms, and packaging of samples for delivery to the external laboratory (FTL). Each person taking or relinquishing possession of the samples was required to sign a COC form before samples changed hands.

Other Instrumentation and Measurement

Water temperature was recorded every minute by a HOBO data logger placed in the source water tank of the test system. The water level in the Isolator Row PLUS was recorded every 5 minutes by visual observation of a yardstick mounted through the observation port on top of the first chamber. Run and sampling times were measured using a digital timer and a stopwatch, respectively.

2.2 Test Sediment

The test sediment had the particle size distribution (PSD) presented in **Figure 9**. The test sediment was custom-blended using various commercially available silica sands. The resulting blended sediment met the specification for the NJDEP Filter Protocol. The test sediment was batched, labeled, and stored in covered bins for the duration of this project. Under the supervision of BEC, twenty-one subsamples, taken from various locations within the test sediment containers, were composited. From the composite, three random samples were taken for PSD and moisture content analyses, which were performed by ECS, using the methodology of ASTM method D422-63 (2007).

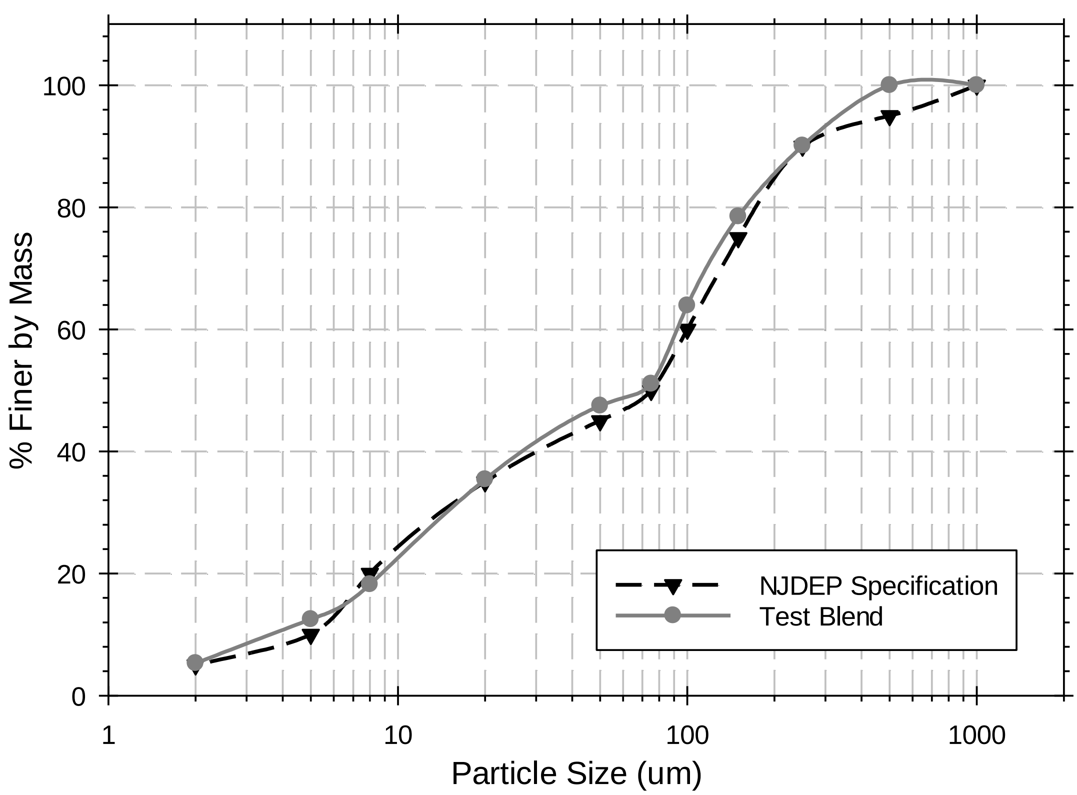

Figure 9 Average Particle Size Distribution of Test Sediment Verified by ECS

The PSD test analysis results are summarized in **Table 2**. ECS results showed that 17-19% of the particles were less than 8 µm and 89-90% of the particles were less than 250 µm. The d_{50} values (approximately 72 µm) also indicated that there was no significant difference between the NJDEP target gradation and the ECS-verified gradation of the test sediment. Thus, the blended test sediment was found to meet the NJDEP particle size specification and was acceptable for use. ECS also analyzed the sediment samples for moisture. The average moisture content was 0.1%.

Table 2 Particle Size Distribution of Test Sediment as Analyzed by ECS

Particle Size (µm)	Test Blend % Finer by Mass Analyzed by ECS				
	NJ Blend A	NJ Blend B	NJ Blend C	Average	NJDEP Specification (minimum % finer)
1000	100.0	100.0	100.0	100.0	98
500	100.0	100.0	100.0	100.0	93
250	90.3	89.8	90.2	90.1	88
150	79.3	78.1	78.1	78.5	73
100	66.0	63.2	62.7	63.9	58
75	52.0	50.9	50.3	51.1	50
50	47.5	47.7	47.4	47.5	43
20	35.9	36.0	34.3	35.4	33
8	18.6	18.7	17.4	18.2	18
5	13.0	13.0	11.6	12.5	8
2	5.5	5.4	5.1	5.3	3
d_{50}	69 µm	72 µm	74 µm	72 µm	75 µm

2.3 Sediment Removal Efficiency Testing

Sediment removal efficiency testing adhered to the guidelines set forth in Section 5 of the NJDEP Laboratory Protocol for Filtration MTDs. The target flow through the system was 225 gpm, with a target sediment concentration of 200 mg/L. All samples were collected in clean, 1-L wide-mouth bottles. Three background samples were taken at 9, 20 and 31 minutes after the test began to ensure the supply water met the sediment concentration requirement. According to the NJDEP Filter Protocol, these background concentrations cannot exceed a TSS concentration of 20 mg/L.

The test sediment screw-auger feeder introduced the test sediment into the influent stream to achieve the target influent TSS concentration of 200 mg/L. According to the NJDEP Filter Protocol, this influent concentration must stay within 10% of target, allowing for a 180 mg/L to 220 mg/L influent concentration. The feeder was calibrated prior to each run. In order to confirm sediment feed rates during the test, in accordance with the NJDEP Filter Protocol, three samples of the test sediment were collected from the injection point (**Figure 3**, "Doser") into a clean one-liter container for verification of sediment feed rate, over an interval timed to the nearest second, with a minimum volume of 0.1 liter or a collection interval not exceeding one minute (whichever came first). The time was measured with a stopwatch. The samples were weighed to the nearest milligram in the BaySaver Laboratory under the observation of BEC. The sediment feed rate coefficient of variance (COV) for the test sediment samples did not exceed 0.10. The mass from the sediment feed rate measurement samples was subtracted from the total mass introduced to the system when removal efficiency was calculated.

Effluent sampling was performed by the grab sampling method during each run, according to the schedule in **Table 1**. When the test sediment feed was interrupted for test sediment measurements, the next effluent samples were collected after at least three detention times had elapsed. During the drawdown period, two evenly volume-spaced samples were collected after flow and sediment feed had stopped. All sediment concentration samples were analyzed by Fredericktowne Labs (FTL) using ASTM D3977-97 (2019) "Standard Test Methods for Determining Sediment Concentrations in Water Samples."

2.4 Sediment Mass Loading Capacity

The sediment mass loading capacity testing occurred as a continuation of removal efficiency testing, with the target for influent concentration remaining at 200 mg/L, and all aspects of testing procedures kept the same to ensure consistency throughout. The sediment mass loading capacity of the Isolator Row PLUS is defined per the protocol as the point at which the cumulative mass removal drops below 80.0%. For this testing program, the sediment mass loading testing was stopped prior to that point (after Run 16), because it was incorrectly assumed this criterion was reached. Thus, the mass loading is defined as mass loaded into the unit through the end of Run 16.

3. Supporting Documentation

The Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from NJCAT states that copies of the laboratory test reports, all data from performance evaluation test runs, original data, pertinent calculations, and documentation of any maintenance activities that occur during the testing process are to be included in this section. All of this information has been provided to NJCAT and is available upon request. It is not practical to include it in this report.

4. Testing Results

A total of 16 removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow and influent sediment concentration were 225 gpm and 200 mg/L, respectively. The results from all 16 runs were used to calculate the overall cumulative removal efficiency of the Isolator Row PLUS.

4.1 Flow Rate

Flow was monitored by an inline flow meter (FloCat MFE electromagnetic flow meter) and recorded by a SeaMetrics DL76 data logger every minute during each run. For each run, the flow was maintained within 10% of the target (202.5 – 247.5 gpm). The average flow for all 16 runs was 226.1 gpm. The flow data with coefficient of variance (COV) values for all 16 runs are summarized in **Table 3**.

4.2 Water Temperature

Temperatures were recorded every minute by a HOBO water level logger (U20L-04). On average for all runs, the water temperature during testing was 45.7 degrees Fahrenheit, with a maximum of 52.2 degrees Fahrenheit, meeting the NJDEP Filter Protocol requirement to be below 80 degrees Fahrenheit. Data are summarized in **Table 3**.

Table 3 Flow Rate and Temperature Summary for All Runs

Run	Max Flow (gpm)	Min Flow (gpm)	Average Flow (gpm)	Flow COV	Flow Compliance (COV< 0.1)	Maximum Temperature (Fahrenheit)	NJDEP Temperature Compliance (< 80 F)
1	232.8	223.9	226.3	0.0078	Y	48.2	Y
2	228.9	218.6	220.8	0.0104	Y	51.5	Y
3	229.4	220.0	227.2	0.0094	Y	44.7	Y
4	230.2	218.7	223.2	0.0138	Y	40.5	Y
5	228.7	216.9	222.2	0.0103	Y	44.7	Y
6	227.6	217.0	224.2	0.0115	Y	46.7	Y
7	229.7	221.9	226.4	0.0092	Y	44.6	Y
8	230.3	222.2	226.8	0.0089	Y	43.5	Y
9	233.2	218.4	225.6	0.0136	Y	45.5	Y
10	232.2	219.7	228.4	0.0126	Y	44.7	Y
11	226.9	219.2	224.1	0.0088	Y	52.4	Y
12	232.2	222.1	226.9	0.0107	Y	48.5	Y
13	234.7	221.2	226.1	0.0109	Y	48.5	Y
14	231.9	223.4	228.7	0.0103	Y	45.6	Y
15	236.8	224.1	231.4	0.0131	Y	52.2	Y
16	232.5	221.3	229.0	0.0137	Y	47.8	Y
Average			226.1			45.7	
Max						52.2	

4.3 Head

The head level in the Isolator Row PLUS was recorded to the nearest 1/8 inch every five minutes, through visual observation of a yard stick mounted through the observation port of the first chamber. With each run, after the first several measurements, the head during the run remained the same or increased slightly over that of the previous run. The maximum head reached during all 16 runs was 18.75 inches. Maximum head for each run is summarized in **Table 4**.

Table 4 Maximum Head (inches) for All Runs

Run	Maximum Head (inches)	Run	Maximum Head (inches)
1	9.00	9	17.50
2	12.00	10	18.00
3	14.00	11	17.25
4	15.25	12	18.00
5	15.75	13	18.25
6	16.25	14	18.50
7	17.50	15	18.75
8	17.25	16	18.75

4.4 Sediment Concentration and Removal Efficiency

Background TSS

Municipal tap water was used as the water source during testing. The background TSS concentration for all runs was well below the 20 mg/L NJDEP Protocol limit. Background TSS concentrations for each run are provided in **Table 5**. The average background TSS concentration for each run was subtracted from the effluent and drawdown concentrations to provide adjusted figures, per the protocol.

Sediment Dosing Rate and Influent TSS

Influent TSS concentration was calculated by dividing the total mass of sediment added during a given run by the total volume of water flowing through the MTD during the addition of test sediment during that run. The volume of water flowing through the device during the run was calculated by multiplying the average measured flow by the time of sediment addition only. The average influent TSS was 204.2 mg/L, with individual run averages ranging from 195.9 to 216.7 mg/L. All values are within the target range of 200 ± 20 mg/L. **Tables 6 and 7** provide the measured sediment rates for each run, and the resulting calculated influent TSS concentration. In these tables, NJDEP Protocol compliance is defined as a TSS concentration in the range 180 – 220 mg/L and sediment feed rate COV < 0.1.

Table 5 Background TSS Concentrations

Run	BG TSS 9 min (mg/L)	BG TSS 20 min (mg/L)	BG TSS 31 min (mg/L)	Average (mg/L)	MDL (mg/L)
1	0.5	4	2	2.2	1.0
2	1	1	0.5	0.8	1.0
3	1	0.5	0.5	0.7	1.0
4	0.5	0.5	0.5	0.5	1.0
5	0.5	0.5	0.5	0.5	1.0
6	0.5	0.5	0.5	0.5	1.0
7	0.5	0.5	0.5	0.5	1.0
8	0.5	0.5	0.5	0.5	1.0
9	0.5	0.5	0.5	0.5	1.0
10	0.5	0.5	0.5	0.5	1.0
11	0.5	0.5	0.5	0.5	1.0
12	0.5	0.5	0.5	0.5	1.0
13	0.5	0.5	0.5	0.5	1.0
14	0.5	0.5	0.5	0.5	1.0
15	0.5	0.5	0.5	0.5	1.0
16	0.5	0.5	0.5	0.5	1.0

Note: In cases where the measured background TSS concentration was below the Minimum Detection Level (MDL) of 1.0 mg/L, half the MDL was reported for the background concentration.

Table 6 Sediment Rate Measurements for Runs 1-10

Run	Run Time (min)	Sediment Weight (g)	Duration (s)	Sediment Feed Rate (g/min)	Influent Water Flow Rate (gpm)	Influent TSS Conc. (mg/L)	NJDEP Compliance
1	0	117.767	39.78	177.6	226.3	202.9	Y
	11	110.674	40.16	165.4			
	22	118.819	40.00	178.2			
	COV			0.0418			
2	0	114.921	39.91	172.8	220.8	198.5	Y
	11	106.158	39.96	159.4			
	22	110.429	40.10	165.2			
	COV			0.0404			
3	0	117.364	39.85	176.7	227.2	206.8	Y
	11	116.700	39.90	175.5			
	22	120.156	39.72	181.5			
	COV			0.0179			
4	0	121.043	39.79	182.5	223.2	216.7	Y
	11	125.058	39.88	188.2			
	22	118.657	39.85	178.7			
	COV			0.0261			
5	0	111.624	40.03	167.3	222.2	215.0	Y
	11	117.883	40.00	176.8			
	22	132.393	39.88	199.2			
	COV			0.0904			
6	0	114.723	39.94	172.3	224.2	206.6	Y
	11	119.043	40.03	178.4			
	22	117.644	40.28	175.2			
	COV			0.0174			
7	0	115.351	40.00	173.0	226.4	198.1	Y
	11	110.196	40.25	164.3			
	22	114.603	40.00	171.9			
	COV			0.0281			
8	0	115.664	39.72	174.7	226.8	201.5	Y
	11	117.915	39.93	177.2			
	22	110.840	39.82	167.0			
	COV			0.0307			
9	0	116.845	39.87	175.8	225.6	205.2	Y
	11	114.135	39.81	172.0			
	22	117.894	39.75	178.0			
	COV			0.0172			
10	0	111.306	39.57	168.8	228.4	203.0	Y
	11	119.680	39.81	180.4			
	22	118.275	39.90	177.9			
	COV			0.0347			

Table 7 Sediment Rate Measurements for Runs 11-16

Run #	Run Time (min)	Sediment Weight (g)	Duration (s)	Sediment Feed Rate (g/min)	Influent Water Flow Rate (gpm)	Influent TSS Conc. (mg/L)	NJDEP Compliance
11	0	114.505	39.90	172.2	224.1	207.8	Y
	11	119.160	39.94	179.0			
	22	118.629	40.03	177.8			
	COV			0.0207			
12	0	115.516	39.78	174.2	226.9	208.8	Y
	11	118.805	39.87	178.8			
	22	124.236	40.22	185.3			
	COV			0.0311			
13	0	114.776	39.78	173.1	226.1	198.0	Y
	11	106.924	39.85	161.0			
	22	115.083	39.69	174.0			
	COV			0.0429			
14	0	112.871	39.72	170.5	228.7	199.9	Y
	11	116.869	39.84	176.0			
	22	114.529	39.81	172.6			
	COV			0.0161			
15	0	112.091	39.72	169.3	231.4	195.9	Y
	11	112.200	39.81	169.1			
	22	117.588	39.94	176.6			
	COV			0.0250			
16	0	118.503	39.59	179.6	229.0	202.3	Y
	11	116.834	39.78	176.2			
	22	112.971	39.84	170.1			
	COV			0.0273			

Effluent TSS

During each run, grab samples were taken of the effluent according to the schedule in **Table 1**, and all TSS analyses were conducted by Fredericktowne Labs. For each run, the average effluent concentration was adjusted by subtracting the average background TSS concentration. The average adjusted effluent TSS concentration during testing was 39 mg/L, with individual run averages ranging from 32.0 to 45.5 mg/L. Effluent and adjusted effluent TSS concentrations for each run are given in **Table 8**.

Table 8 Effluent Sample TSS Concentrations

Run	EFF TSS 9 min	EFF TSS 10 min	EFF TSS 20 min	EFF TSS 21 min	EFF TSS 31 min	EFF TSS 32 min	Mean	MDL	Adjusted Effluent TSS
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	48	48	47	47	48	48	47.7	1.0	45.5
2	32	32	33	32	35	33	32.8	1.0	32.0
3	33	37	37	40	38	38	37.2	1.0	36.5
4	28	31	34	38	32	38	33.5	1.0	33.0
5	40	41	39	33	42	42	39.5	1.0	39.0
6	38	41	39	37	41	44	40.0	1.0	39.5
7	37	40	37	36	37	38	37.5	1.0	37.0
8	38	41	38	40	32	38	37.8	1.0	37.3
9	35	41	36	36	42	41	38.5	1.0	38.0
10	39	44	34	38	37	41	38.8	1.0	38.3
11	35	41	38	38	38	43	38.8	1.0	38.3
12	36	43	36	41	46	47	41.5	1.0	41.0
13	41	46	37	37	42	45	41.3	1.0	40.8
14	44	49	39	42	42	45	43.5	1.0	43.0
15	40	43	41	39	40	45	41.3	1.0	40.8
16	43	45	41	44	45	46	44.0	1.0	43.5

Note: Adjusted effluent TSS concentration is the average effluent TSS concentration minus the average background TSS concentration (Table 5).

Drawdown TSS

According to the NJDEP Filter Protocol, the amount of sediment that leaves the filter during the drawdown period must be accounted for and documented. During each run, two evenly volume-spaced grab samples were taken of the drawdown, and all TSS analyses were conducted by Fredericktowne Labs. For each run, the average drawdown concentration was adjusted by subtracting the average background TSS concentration (**Table 9)**.

Table 9 Drawdown Sample TSS Concentrations

Run	DDA	DDB	Average	MDL	Adjusted Drawdown TSS
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	62	11	36.5	1.0	34.3
2	39	16	27.5	1.0	26.7
3	42	14	28.0	1.0	27.3
4	41	18	29.5	1.0	29.0
5	42	16	29.0	1.0	28.5
6	45	17	31.0	1.0	30.5
7	44	16	30.0	1.0	29.5
8	48	17	32.5	1.0	32.0
9	42	18	30.0	1.0	29.5
10	45	17	31.0	1.0	30.5
11	43	17	30.0	1.0	29.5
12	44	16	30.0	1.0	29.5
13	46	18	32.0	1.0	31.5
14	50	18	34.0	1.0	33.5
15	47	17	32.0	1.0	31.5
16	48	15	31.5	1.0	31.0

Note: Adjusted drawdown TSS concentration is the average drawdown TSS concentration minus the average background TSS concentration (Table 5).

In order to estimate the volume of water during drawdown, under observation by BEC, the unit was filled prior to all testing with clean water and the drawdown volume as a function of time was calculated from the height of the flow stream in the effluent pipe as a function of time. Total drawdown volume was estimated at 268.6 gal at an operating head of 2.5 inches. This volume was used to determine the volume of the void space of the gravel bed, which was then used, along with the dimensions of the Isolator Row PLUS chambers, to calculate the drawdown volume for incremental head levels above 2.5 inches. Adjusted average drawdown TSS concentrations and drawdown losses are given in **Table 10**.

Table 10 Drawdown Losses

Run	Head Level at End of Run (in)	Drawdown Volume (gal)	Average Adjusted Drawdown TSS Conc. (mg/L)	Total Sediment Lost During Drawdown (g)
1	9.00	285.2	34.3	37.1
2	12.00	354.2	26.7	35.7
3	14.00	403.3	27.3	41.7
4	15.25	432.8	29.0	47.5
5	15.75	443.9	28.5	47.9
6	16.25	454.2	30.5	52.4
7	17.50	476.0	29.5	53.2
8	17.00	468.2	32.0	56.7
9	17.25	472.3	29.5	52.7
10	17.75	476.0	30.5	55.0
11	17.25	472.3	29.5	52.7
12	17.5	476.0	29.5	53.2
13	18.00	482.4	31.5	57.5
14	18.25	484.9	33.5	61.5
15	18.50	486.8	31.5	58.1
16	18.25	484.9	31.0	56.9

Removal Efficiency Calculation

Removal efficiency was calculated using the following equation from the NJDEP Filter Protocol:

$$\text{Removal Efficiency (\%)} = \frac{\begin{pmatrix}\text{Average Influent}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Test Water}\end{pmatrix} - \begin{pmatrix}\text{Adjusted Effluent}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Effluent Water}\end{pmatrix} - \begin{pmatrix}\text{Average}\\ \text{Drawdown Flow}\\ \text{TSS Concentration x}\\ \text{Total Volume}\\ \text{of Drawdown Water}\end{pmatrix}}{\text{Average Influent TSS Concentration x Total Volume of Test Water}} \text{ x } 100$$

For each run, sediment concentrations of background, influent, effluent, and drawdown, as well as the calculated removal efficiency, are summarized in **Table 11**. As shown in this summary table, the Isolator Row PLUS demonstrated a cumulative sediment removal efficiency of 81.2% over the course of 16 test runs.

Table 11 Removal Efficiency Results

Run	Average Influent TSS (mg/L)	Influent Water Volume (gal)	Adjusted Average Effluent TSS (mg/L)	Effluent Water Volume (gal)	Adjusted Average Drain Down TSS (mg/L)	Drain Down Water Volume (gal)	Single Run Removal Efficiency (%)	Mass of Captured Sediment (g)	Cumulative Removal Efficiency (%)
1	203	7166	46	6881	34	285	77.8	4282	77.8
2	199	6993	32	6639	27	354	84.0	4415	80.8
3	207	7197	37	6793	27	403	82.6	4654	81.4
4	217	7068	33	6635	29	433	84.9	4923	82.3
5	215	7037	39	6593	29	444	82.2	4705	82.3
6	207	7097	40	6643	31	454	81.2	4504	82.1
7	198	7169	37	6693	30	476	81.6	4386	82.0
8	201	7184	37	6716	32	468	81.6	4473	82.0
9	205	7147	38	6675	30	472	81.8	4539	82.0
10	203	7235	38	6759	31	476	81.4	4523	81.9
11	208	7096	38	6624	30	472	81.8	4567	81.9
12	209	7185	41	6709	30	476	80.7	4584	81.8
13	198	7162	41	6680	32	482	79.7	4277	81.6
14	200	7242	43	6757	34	485	78.8	4318	81.4
15	196	7329	41	6842	32	487	79.5	4320	81.3
16	202	7254	44	6769	31	485	78.9	4384	81.2
Ave.	204.2	7160	39	6713	31	447	81.2	4491	N/A
Cumulative Mass Removed (g)							71854		
Cumulative Mass Removed (lb)							158.4		
Total Mass Loaded (lb)							195.2		
Cumulative Removal Efficiency (%)							81.2		

4.5 Sediment Mass Loading

Sediment mass loading for each run was approximately 12.2 lbs on average. These data are summarized in **Table 12**.

Sediment mass loading was calculated from the summation of the total sediment mass added during dosing in each run.

Table 12 Sediment Mass Loading Summary

Run	Sediment Loading (lbs)	Cumulative Sediment Loading (lbs)	Run	Sediment Loading (lbs)	Cumulative Sediment Loading (lbs)
1	12.1	12.1	9	12.2	110.0
2	11.6	23.7	10	12.3	122.2
3	12.4	36.1	11	12.3	134.5
4	12.8	48.9	12	12.5	147.0
5	12.6	61.5	13	11.8	158.9
6	12.2	73.8	14	12.1	170.9
7	11.9	85.6	15	12.0	182.9
8	12.1	97.7	16	12.2	195.2

Overall, a total of 195.2 lbs of sediment was loaded into the Isolator Row PLUS over the course of the 16 runs. Total captured mass over the 16 runs was 158.4 lbs (**Table 11**).

The relationship between removal efficiency and sediment mass loading is shown in **Figure 10**. The relationship between driving head and sediment mass loading is shown in **Figure 11**.

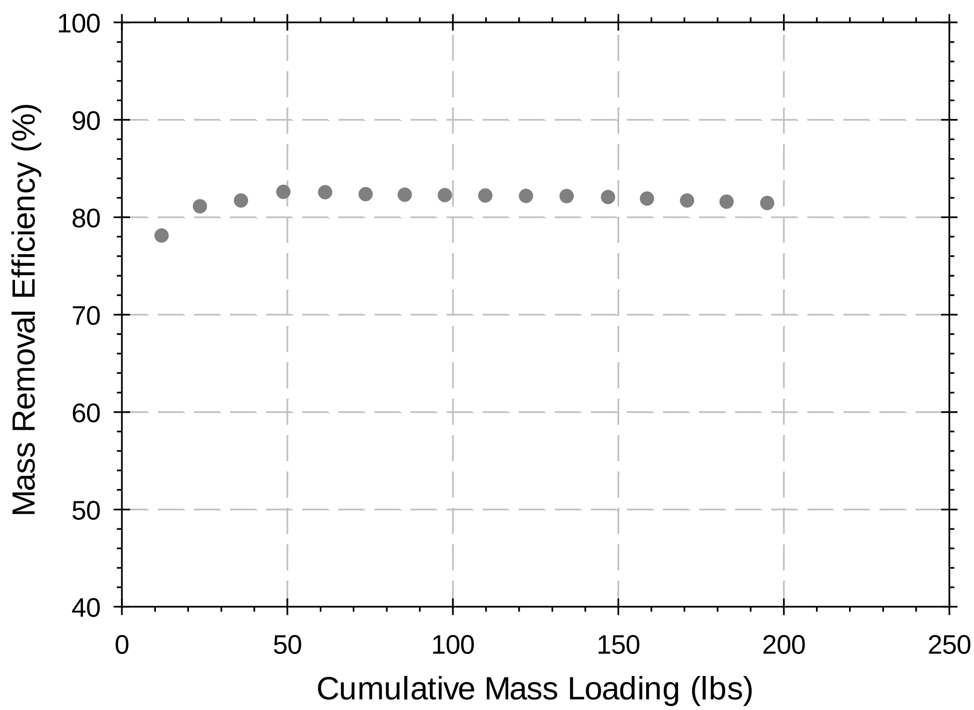

Figure 10 Removal Efficiency vs. Sediment Mass Loading

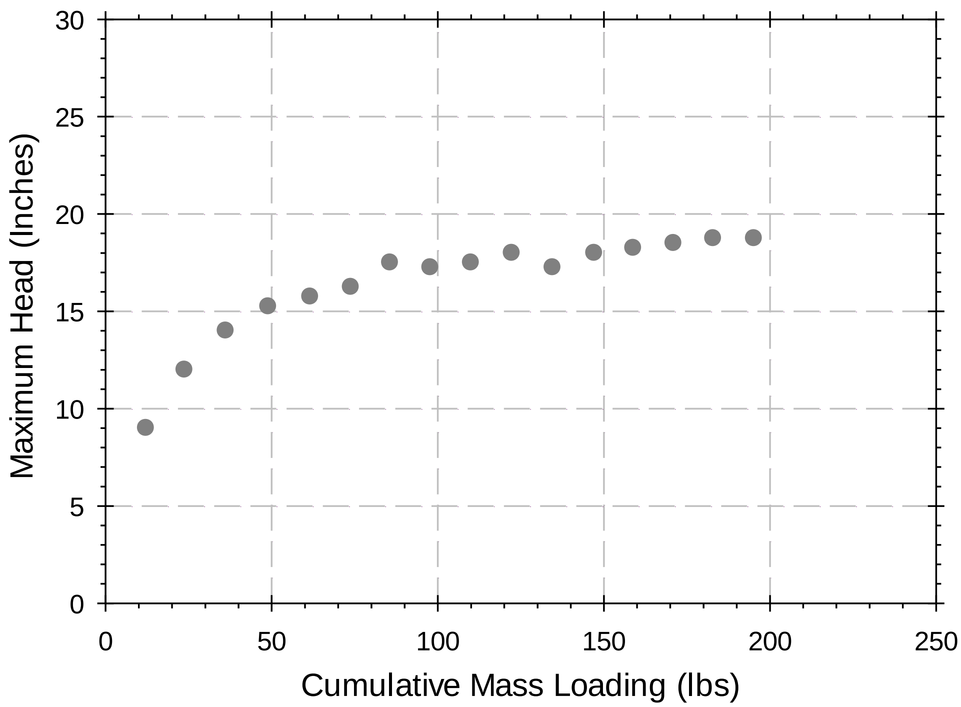

Figure 11 Driving Head vs. Sediment Mass Loading

5. Performance Verification

The Isolator Row PLUS used in this test, constructed from two (2) overlapping StormTech SC-740 chambers and one layer of ADS PLUS fabric, demonstrated a cumulative mass TSS removal efficiency of 81.2% and a sediment mass loading capacity of 3.58 lb./ft^2 (mass capture capacity of 2.91 lb./ft^2) of geotextile fabric filtration area when operated with a driving head < 20 inches at a hydraulic loading rate of 4.13 gpm/ft^2 of geotextile fabric filtration area. The MTFR's and maximum allowable drainage area for other StormTech Isolator Row PLUS models are shown in **Table 13**.

Table 13 Isolator Row PLUS System Model Sizes and New Jersey Treatment Capacities

Model	Surface Loading Rate (gpm/ft^2) Single Chamber	Effective Filtration Treatment Area (ft^2) Single Chamber	MTFR (cfs)[1] Single Chamber	Mass Loading Capacity (lbs) Single Chamber	Mass Capture Capacity (lbs) Single Chamber	Drainage Area (acres) Single Chamber
StormTech SC-160	4.13	11.45	0.105	41.0	33.4	0.06
StormTech SC-310	4.13	17.7	0.163	63.4	51.6	0.09
StormTech SC-740	4.13	27.8	0.256	99.6	81.0	0.14
StormTech DC-780	4.13	27.8	0.256	99.6	81.0	0.14
StormTech MC-3500	4.13	42.9	0.395	153.7	125.0	0.21
StormTech MC-4500	4.13	30.1	0.277	107.8	87.7	0.15

1. Based on 4.13 gpm/ft^2 of effective filtration treatment area.
2. Drainage Area is based on the equation in the NJDEP Filter Protocol wherein drainage area is calculated by dividing the pounds of mass captured by 600 lb/acre.

6. Design Limitations

Maximum Flow Rate

The StormTech Isolator Row PLUS unit has an MTFR of 0.501 cfs (225 gpm) and an effective filtration treatment area (EFTA) of 54.5 ft^2 (loading rate 4.13 gpm/ft^2).

Slope

The StormTech Isolator Row PLUS is recommended for installation with little to no slope to ensure proper, consistent operation. Steep slopes should be reviewed by ADS/StormTech Engineering support.

Allowable Head Loss

There is an operational head loss associated with the StormTech Isolator Row PLUS. The head loss will increase over time due to the sediment loading to the system. Site-specific treatment flow rates, peak flow rates, pipe diameter, and pipe slopes should be evaluated to ensure there is appropriate head for the system to function properly.

Sediment Load Capacity

Based on laboratory testing results, the StormTech Isolator Row PLUS unit has a mass loading capacity of 195.2 lbs. while operating at a sediment removal efficiency of 81.2%; the total sediment load captured by the tested Isolator Row PLUS is 158.4 lbs.

Pre-treatment Requirements

The StormTech Isolator Row PLUS unit does not require additional pre-treatment.

Configurations

The StormTech Isolator Row PLUS is available in multiple configurations. The length and size can be adjusted to meet project specific design volumes or flow rates.

Structure Load Limitations

The StormTech Isolator Row PLUS, as part of the overall chamber system, is designed to meet the full scope of design requirements of the American Society of Testing Materials (ASTM) International specification F2787 "Standard Practice for Structural Design of Thermoplastic Corrugated Wall Stormwater Collection Chambers" and produced to the requirements of the ASTM F2418 "Standard Specification for Polypropylene (PP) Corrugated Stormwater Collection Chambers". The StormTech chambers provide the full AASHTO safety factors for live loads and permanent earth loads. The ASTM F 2787 standard provides specific guidance on how to design thermoplastic chambers in accordance with AASHTO Section 12.12. of the AASHTO LRFD Bridge Design Specifications. ASTM F 2787 requires that the safety factors included in the AASHTO guidance are achieved as a prerequisite to meeting ASTM F 2418. The three standards provide both the assurance of product quality and safe structural design.

7. Maintenance Plan

The frequency of Inspection and Maintenance varies by location. A routine inspection schedule needs to be established for each individual location, based upon site-specific variables. The type of land use (i.e. industrial, commercial, public, residential), anticipated pollutant load, percent imperviousness, climate, rainfall data, etc., all play a critical role in determining the actual frequency of inspection and maintenance practices.

The Isolator Row PLUS may also be part of a treatment train. By treating stormwater prior to entry into the chamber system, the service life can be extended and pollutants such as hydrocarbons can be captured.

At a minimum, StormTech recommends annual inspections. Initially, the Isolator Row PLUS chamber should be inspected every 6 months for the first year of operation. For subsequent years, the inspection schedule should be adjusted based upon previous observation of sediment deposition.

The Isolator Row PLUS incorporates a combination of standard manhole(s) and strategically located inspection ports (as needed). The inspection ports allow for easy access to the Isolator Row PLUS from the surface, eliminating the need to perform a confined space entry for inspection purposes.

If, upon visual inspection, it is found that sediment has accumulated, a stadia rod should be inserted to determine the depth of sediment. When the average depth of sediment exceeds 3 inches throughout the length of the Isolator Row PLUS, clean-out should be performed.

The Isolator Row PLUS was designed to reduce the cost of periodic maintenance. By "isolating" sediment to just one row of the StormTech system, costs are dramatically reduced by eliminating the need to clean out each row of the entire storage bed. If inspection indicates the potential need for maintenance, access is provided via a manhole(s) located on the end(s) of the row for cleanout.

Maintenance is accomplished with the JetVac process. The JetVac process utilizes a high-pressure water nozzle to propel itself down the Isolator Row PLUS while scouring and suspending sediment. As the nozzle is retrieved, the captured pollutants are flushed back into the manhole for vacuuming. Most sewer and pipe maintenance companies have vacuum/JetVac combination vehicles. Selection of an appropriate JetVac nozzle will improve maintenance efficiency.

Fixed nozzles designed for culverts or large diameter pipe cleaning are preferable. Rear-facing jets with an effective spread of at least 45" are best. Most JetVac reels have 400 feet of hose, allowing maintenance of an Isolator Row PLUS up to 50 chambers long. The JetVac process should only be performed on StormTech Isolator Rows PLUS that have AASHTO class 1 woven geotextile (as specified by StormTech) over their angular base stone.

Complete details of the design, operation, and maintenance of the Isolator Row PLUS can be found in the StormTech O&M Manual, available online at:
https://www.stormtech.com/download_files/pdf/11081-stormtech-isolator-row-plus-manual-07-20.pdf

8. Statements

The attached pages include signed statements from the manufacturer (Advanced Drainage Systems, Inc.), the third-party environmental consulting firm (Boggs Environmental Consultants, Inc.), and NJCAT. These statements are included as a requirement for the verification process.

June 26th, 2020

Dr. Richard S. Magee, Sc.D., P.E., BCEE
NJCAT
Center for Environmental Systems
Steven Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030-0000

Dr. Magee,

Advanced Drainage Systems is pleased to provide this letter as our statement certifying that the protocol, “New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a filtration Manufactured Treatment Device” (NJDEP Filter Protocol, January 25, 2013), was strictly followed while testing our StormTech Isolator® Row PLUS. The testing was performed at BaySaver Laboratories, located in Mount Airy, MD. All data pertaining to the StormTech Isolator Row PLUS NJDEP Protocol test is included in the Verification Report.

Respectfully,

Greg Spires, PE
General Manager - StormTech
Advanced Drainage Systems
614.325.0032
greg.spires@ads-pipe.com

June 25, 2020

StormTech
Advanced Drainage Systems, Inc.
520 Cromwell Avenue
Rocky Hill, CT 06067
gregory.spires@ads-pipe.com

ATTENTION Greg Spires, PE
General Manager, StormTech
Advanced Drainage Systems, Inc.

REFERENCE: Third Party Review of Testing Procedures of the Isolator® Row PLUS at the
BaySaver Laboratory
1207 Park Ridge Drive
Mount Airy, MD 21771

Boggs Environmental Consultants, Inc. (BEC) provided Third Party Review services for the testing of the Isolator® Row PLUS to evaluate if the required testing meets certification standards established by the New Jersey Department of Environmental Protection (NJDEP).

LABORATORY TESTING PROCEDURES & METHODOLOGIES

The following two procedures and testing requirements were followed during the testing process of the Isolator® Row PLUS:

- *New Jersey Department of Environmental Protection, Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device, dated January 25, 2013.*
- *QAPP for Isolator® Row PLUS, New Jersey Department of Environmental Protection Testing,* prepared by StormTech (a subsidiary of Advanced Drainage Systems, Inc.), Revision dated January 9, 2020.

ONSITE THIRD-PARTY OBSERVATION OF TESTING PROCEDURES

BEC was present at the BaySaver Laboratory, at 1207 Park Ridge Drive, in Mount Airy, MD 21771, to observe the following testing of the Isolator® Row PLUS:

- The mixing and establishment of a sediment blend that included manufactured sands that when delivered to the feed water would result in influent Total Suspended Solids (TSS) concentrations within the established range of approximately 200 mg/L and a particle size distribution specified and approved by NJDEP;
- BEC assisted in the establishment of a Procedure Checklist to be used on each run to verify and document the following: Verify that pumps and measurement devices are turned on and functioning; Verification that the correct measurements of dry sediments are added to the doser and feed stream; Document that, background effluent, and duplicate samples are collected at established intervals during the run; and, Recording of periodic flow rates and head measurements during each run;
- Observation of Runs 1 through 16 from January 14, 2020 to February 12, 2020 and verified that that sediment, background, effluent samples were collected during each 33-minute run, and that drawdown samples were collected after the end of each run.
- After sampling was completed for each run, BEC was present for the downloading of flow data as well as sediment feed rates to verify that calculated sediment feed rates met NJDEP protocols for testing. BEC also verified that that sample containers were properly labeled and chain of custodies were filled and were boxed and sealed for delivery to Fredericktowne Labs for analysis of Total Suspended Solids (TSS).

THIRD-PARTY VERIFICATION & OPINIONS

Based on observations during the runs and the reported TSS analytical results, BEC verified the following:

- That the testing of the Isolator® Row PLUS at the BaySaver Laboratory was conducted in accordance with the *New Jersey Department of Environmental Protection, Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device, dated January 25, 2013* and procedures established in Advanced Drainage Systems, Inc.'s *QAPP for Isolator® Row PLUS, New Jersey Department of Environmental Protection Testing,* prepared by StormTech (a subsidiary of Advanced Drainage Systems), Revision dated January 9, 2020.
- The report titled *NJCAT Technology Verification, of Isolator® Row PLUS,* prepared by StormTech, dated June 2020, used applicable NJCAT protocol and accurately reflects the testing observed by BEC.

BEC has no financial conflict of interest, as defined in the *Procedure for Obtaining Verification of a Stormwater Manufactured Treatment Device from New Jersey Corporation of Advanced Technology* (NJEP 2013).

Should you have any questions, contact our office at your earliest convenience.

Sincerely,
BOGGS ENVIRONMENTAL CONSULTANTS, INC.

William R. Warfel

William R. Warfel
Principal Environmental Scientist

Center for Environmental Systems
Stevens Institute of Technology
One Castle Point
Hoboken, NJ 07030-0000

May 1, 2020

George F. Ives III, P.E.
StormTech, LLC
520 Cromwell Ave
Rocky Hill, CT 06067

Dear Mr. Ives,

Based on my review, evaluation and assessment of the testing conducted on the StormTech , LLC Isolator Row PLUS at the BaySaver Laboratory (Storm Tech, LLC and BaySaver Technologies, LLC are subsidiaries of Advanced Drainage Systems, Inc.), under the independent third-party oversight of Boggs Environmental Consultants (BEC), Inc., the test protocol requirements contained in the "New Jersey Department of Environmental Protection Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device" (NJDEP Filter Protocol, January 2013) were met or exceeded. Specifically:

Test Sediment Feed

The test blend was custom-blended using various commercially available silica sands under the oversight of BEC. The particle size distribution was independently analyzed by Environmental Consulting Services (ECS), using the methodology of ASTM method D422-63. The blended silica met the specification within tolerance as described in Section 5B of the NJDEP filter protocol and was acceptable for use.

Removal Efficiency Testing

Sixteen (16) removal efficiency testing runs were completed in accordance with the NJDEP filter protocol. The target flow rate was 225 gpm and the influent sediment concentration was 200 mg/L. The average flow rate for all 16 runs was 226.1, with a coefficient of variation (COV) below the flow compliance (COV) < 0.1 for all the runs. Likewise, for all runs the sediment feed rate COV was below the < 0.03 protocol limit. The Isolator Row PLUS demonstrated a cumulative sediment removal efficiency of 81.2% over the course of the 16 test runs.

Sediment Mass Loading Capacity

Mass loading capacity testing was conducted concurrently with removal efficiency testing. The Isolator Row PLUS has a mass loading capture capacity of 158.4 lbs (2.91 lbs/ft^2 of filtration area).

No maintenance was performed on the test system during the entire testing program.

Scour Testing

No scour testing was performed. Hence the Isolator Row PLUS is verified for off-line installation only.

Sincerely,

Richard S. Magee, Sc.D., P.E., BCEE

Specifications

Introduction

- Manufacturer – StormTech, LLC, 520 Cromwell Ave, Rocky Hill, CT 06067
- Website: http://www.StormTech.com. Phone: 888-892-2694
- MTD – StormTech Isolator Row PLUS verified models are shown in **Table 13**
- TSS Removal Rate – 81.2%
- Off-line installation

Detailed Specification

• NJDEP sizing tables and physical dimensions of StormTech Isolator Row PLUS verified models are shown in **Table 13**. These sizing tables are valid for NJ following NJDEP Water Quality Design Storm Event of 1.25" in 2 hours (NJAC 7:8-5.5(a)).

• Maximum inflow drainage area

- ◦ The maximum inflow drainage area is governed by the maximum treatment flow rate of each model as presented in **Table 13**.

• Driving head will vary for a given Isolator Row PLUS model based on the site-specific configuration. The maximum head without bypass is 36”, but the minimum head varies depending on the flow rate through the unit. Design support is given by StormTech for each project, and site-specific drawings (cut sheets) will be provided that show pipe inverts, finish surface elevation, and peak treatment and maximum flow rates through the unit.

• The drawdown flow exits via the underdrain. A clean filter draws down in approximately 20 minutes.

PERFORMANCE EVALUATION REPORT OF THE STORMTECH ISOLATOR ROW® TREATMENT UNIT

Submitted to

STORMTECH LLC

September 2010

Prepared by

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FINAL REPORT ON FIELD VERIFICATION TESTING OF THE STORMTECH ISOLATOR ROW® TREATMENT UNIT
BY THE UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

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FINAL REPORT ON FIELD VERIFICATION TESTING OF THE STORMTECH ISOLATOR ROW® TREATMENT UNIT May, 2010

1.0 EXECUTIVE SUMMARY

The StormTech Isolator Row® was monitored from December 2006 through September 2009 in Durham, NH at the University of New Hampshire Stormwater Center test facility. The system was installed in September 2006. The Isolator Row® system was designed and sized by Stormtech LLC for a 1 cubic foot per second water quality flow and a corresponding water quality volume equivalent to runoff from 1" of runoff from an impervious area or 3300 cubic feet. This system was comprised of 5 chambers wrapped in a combination of filter fabric and geotextile. The hydraulic configuration included a high flow bypass weir structure located at the entrance to the chambers. Bypass flows were not monitored for water quality, only for occurrence. The Isolator Row® was monitored for performance for six major water quality contaminants, hydrologic performance, sediment capture, and sediment accumulation as it relates to hydraulic efficiency of the filter bed. The water quality results are based on treated flows only.

After 3 years of operation, sediment (TSS and SSC) performance and effluent EMCs reveal strong performance and low effluent concentrations that do not vary significantly across fluxuations in loading concentration, seasons, or time. A median performance was observed for TSS >80% removal for both years, and SSC >90% for the end of year 2. Five of the seven events with poor performance were attributed to events exceeding the water quality design flow (WQF=1 cfs). Metals performance as measured by TZn increased from 53% for year 1 to 81% removal by the end of year 2. TPH and TP removal efficiencies and effluent EMCs demonstrate strong performance that was enhanced over the course of the study. As would be expected for non-vegetated filtration systems, dissolved inorganic nitrogen (DIN = NO3, N02, NH4) removal efficiencies and effluent EMCs reveal poor performance and high effluent concentrations relative to influent values.

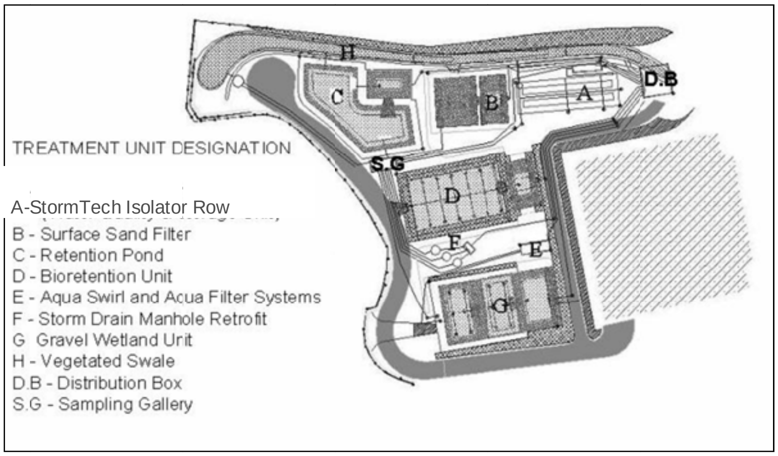
Sediment depths over the 3 year installation and monitoring period (September 2006 September 2009) had accumulated to 1.2 in, nearly half of the manufacturers recommended depth for maintenance (3 inches). By this measure, it would take another 3 years of operation before maintenance would be required, or a total of 6 years of operation.

2.0 INTRODUCTION

Under an agreement from STORMTECH LLC, field verification testing of a StormTech Isolator Row® stormwater treatment unit was conducted at the University of New Hampshire Stormwater Center, Durham NH. Testing consisted of determining the water quality performance for a range of parameters including sediments, metals, nutrients, and petroleum hydrocarbons.

Performance tests were conducted under normalized conditions across a range of seasons, rainfall conditions, and pollutant concentrations; all important variables reflective of natural

Figure 1: Site Plan: Plan view of the University of New Hampshire field research facility



field performance conditions. This report reflects analyses performed from September 2007 through July 2009. This included monitoring of 23 rainfall runoff events in total.

The Isolator Row® treatment unit is one of 10 devices that are currently configured and tested in parallel, with a single influent source providing uniform loading to all devices. All treatment strategies were uniformly sized to target either a water quality volume (WQV), or a water quality flow (WQF). Under the parallel and uniformly sized configuration, a normalized performance evaluation is possible because different treatment strategies of the same scale receive runoff from events of the same duration, intensity, peak flow, volume, antecedent dry period, and pollutant loading.

Primary funding for the Center program has been provided by the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) and the National Oceanic and Atmospheric Administration (NOAA).The UNH Stormwater Center is housed within the Environmental Research Group (ERG) of the Department of Civil Engineering at the University of New Hampshire (UNH) in Durham, New Hampshire.

3.0 TEST FACILITY DESCRIPTION

The UNH Stormwater Center studies stormwater-related water quality and quantity issues. The Stormwater Center's field facility is designed to evaluate and verify the performance of stormwater management devices and technologies in a parallel, event normalized setting. Ten different management systems are currently undergoing side-by-side comparison testing under strictly monitored natural conditions (Figure 1).

The site was designed to function as a field testing site for numerous, uniformly sized, isolated, parallel treatment systems. Rainfall-runoff is evenly divided at the head of the facility in a distribution box, designed with the floor slightly higher than the outlet invert elevations to allow for particulate scour into the pipe network. Effluent from all systems is piped into a central sampling gallery, where system sampling and flow monitoring occurs. The parallel configuration normalizes the treatment processes for event and watershed-loading variations.

The testing facility is located on the perimeter of a 9 acre commuter parking lot at the University of New Hampshire in Durham. The parking lot is standard dense mix asphalt that was installed in 1996, and is used to near capacity throughout the academic year. The sub-catchment area is large enough to generate substantial runoff, which is gravity fed to the parallel treatment processes. The lot is curbed and entirely impervious. Activity is a combination of passenger vehicles and routine bus traffic. The runoff time of concentration for the lot is 22 minutes, with slopes ranging from 1.5-2.5%. The area is subject to frequent plowing, salting, and sanding during the winter months. Literature reviews indicate that contaminant concentrations are above or equal to national norms for commercial parking lot runoff. The climatology of the area is characterized as a coastal, cool temperate forest. Average annual precipitation is 48 inches uniformly distributed throughout the year, with average monthly precipitation of 4.02 in +/- 0.5. The mean annual temperature is 48°F, with the average low in January at 15.8°F, and the average high in July at 82°F.

2.1 System Configuration and Sizing

A 5 chambered Isolator Row® system was tested in an offline configuration. A 6 foot diameter manhole with a 4 foot sump was installed upstream of the Isolator Row®. The manhole was connected to the Isolator Row® with a short length of 24 inch diameter HDPE pipe. Within the manhole a high-flow bypass was constructed using a broad-crested weir. A 12” bypass pipe routes bypass flows around the Isolator Row® to discharge downstream. The bypass and treated effluent are monitored separately. The crest of the overflow weir was set 0.2 feet below the top of the Isolator Row chamber, this allows stormwater in excess of the Isolator Row’s storage capacity to bypass in an offline configuration without routing through the system and avoids any potential for pressurized flow through the underlying geotextile. Each chamber of the Isolator Row is 51” in width, 30” in height, and 85.4” in length. 5 chambers are connected. The system has a design peak flow rate of 1 cfs (cubic feet per second). The system is lined with HDPE liner and effluent is collected by a 6” perforated underdrain that is continuously monitored. As mentioned, non-design flow (flow rates > 1 cfs) bypass the treatment system and are monitored for occurrence only. Figures 2 and 3 show system installation and construction drawings. The system was installed in late September 2006. System monitoring began in early 2007 to allow for system flushing and to prevent influences that may be construction associated.

Figure 2: Installation of Isolator Row September 2006; (a, top left) HDPE liner installation to monitor full treated effluent; (b, top right) Crushed stone subbase 12" thick installation; (c, bottom left) Installation of Isolator Row chambers on top of double layer of woven geotextile fabric (bottom) non-woven geotextile fabric (sides) and stone subbase; (d, bottom right) Installation of hydraulic inlet structure, chamber entrance (left), influent source (top right), and high flow bypass weir bottom right.

2.2 Reference TSS Information

Comparisons of the TSS concentrations for varied land uses are presented in Figure 4. Urban highway pollutant concentrations tend to be twice the mean concentration measured for parking lots and residential uses. The data collected from the UNH facility is within the national norm for commercial parking lots and is within the range of typical concentrations observed for a range of land uses. Occasional storms are monitored that have exceptionally high solids concentrations.

Figure 3: System Drawings for Isolator Row (top, plan view; bottom, cross-section)

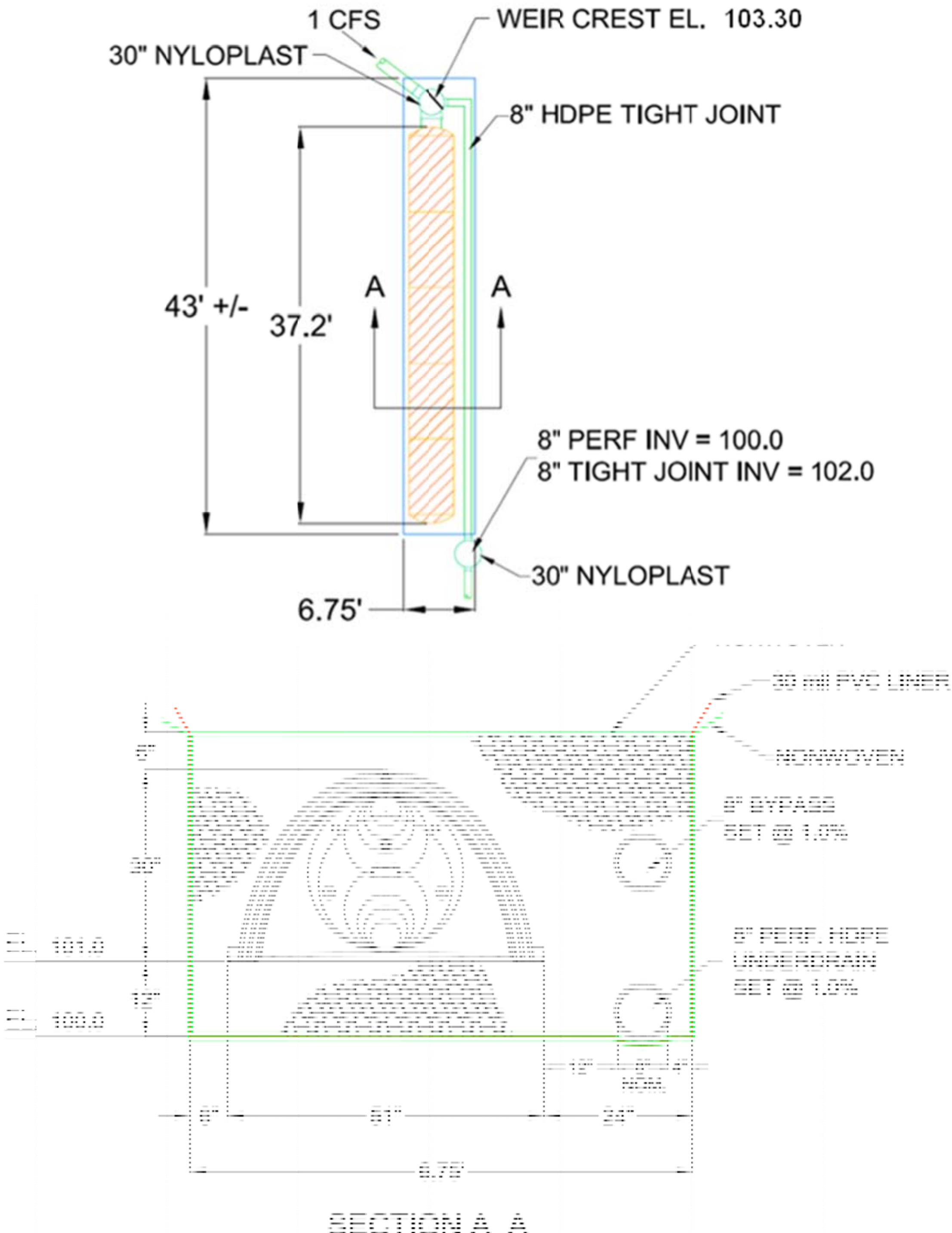
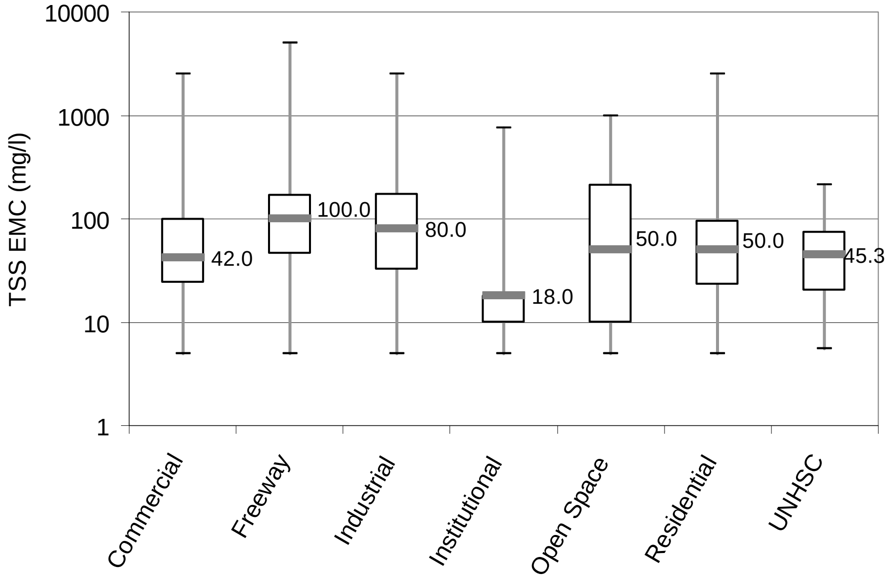


Figure 4: Total Suspended Solids (TSS) for varied land uses and at the UNH Stormwater Center (UNHSC); (Source: National Stormwater Quality Database, 2005[1] , UNHSC, 2007[2])



3.0 INSTRUMENTATION AND MEASURING TECHNIQUES

3.1 Flow

Influent flows were monitored using Teledyne Isco 6712 Automated samplers accompanied by Teledyne Isco 750 Area Velocity probes. The influent depths were also secondarily monitored using Teledyne Isco 730 Bubbler Flow Modules and flows generated from a stage vs discharge rating curve for redundancy. Effluent flow depths were measured using Teledyne Isco 6712 Automated samplers accompanied by Teledyne Isco 730 Bubbler Flow Modules in combination with Thelmar compound weirs with laboratory developed rating curves to yield flows.

3.2 Other Measurements

Temperature, pH, Specific Conductivity, and Dissolved Oxygen, are collected by YSI 600XL multi-parameter sondes. These parameters are monitored real-time for the influent and effluent flows but are not included under this contract.

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[1] Pitt, R. E., Maestre, A., and Center for Watershed Protection. (2005) "The National Stormwater Quality Database (NSQD, version 1.1)." USEPA Office of Water, Washington, D.C.

[2] UNHSC, Roseen, R., T. Ballestero, and Houle, J. (2007). "UNH Stormwater Center 2007 Annual Report." University of New Hampshire, Cooperative Institute for Coastal and Estuarine Environmental Technology, Durham, NH.

3.3 Water Quality Analysis

Samples were processed and analyzed by an EPA and National Environmental Laboratory Accreditation Conference (NELAC) certified laboratory using the standard methodologies outlined in Table 1.

Table 1: Laboratory analytical methods and detection limits for each analyte.

Analyte	Analytical Method	Sample Detection Limit (mg/L)	Method Detection Limit (mg/L)[a]
Nitrate/Nitrite in water	EPA 300.0A	0.1	0.008
Total Suspended Solids	SM 2540 D	Variable, 1-10	0.4
Suspended Sediment Concentration	ASTM D-3977	Variable, 1-2	1
Total Phosphorus	EPA 365.3	0.01	0.008
Zinc in water	EPA 200.7	0.05	0.001-0.05
Total Petroleum Hydrocarbons –Diesel Range	SW 3510C 8015B	Variable ≤ 3.5	0.1-3.0

[a]Method detection limit is different than sample detection limit which will be often be higher as they are based on sample volume available for analyses.

4.0 TEST PROCEDURES

4.1 Rainfall Collection and Measurement

A rainfall collection system consisting of 6”diameter 2 foot high anodized aluminum housing, HDPE funnel, debris screen, and tipping bucket mechanism is installed at a controlled site within the research complex and used rainfall measurement to 0.01”depth resolution. Specified components are the ISCO Model 674 Tipping Bucket Rain Sensor with Rain Gauge. The precipitation event data is stored in the ISCO 6712 and the accumulated rainfall is retrieved and stored through a FlowLink 4.21 database via a desktop computer located on-site.

4.2 Field Sampling Procedures

Composite samples were taken for influent and effluent waters by automated samplers. Automatic samplers are programmed to sample 100 ml aliquots at flow weighted intervals into 24 x 1L containers. The sampling program is designed to ensure adequate coverage of the storm event and adjusted to accommodate seasonal fluctuations in rainfall patterns. Rejection criteria included minimum rainfall depth of 0.1 inches, 10 aliquots per event, and minimum 70% sampling coverage of the storm event. Influent time of concentration is approximately 22 minutes. Effluent time of concentrations vary for each device depending on conveyance lengths and treatment strategies. All samples are stored in thermostatically controlled conditions at 39°F until processed.

One Liter disposable LDPE sample bags are used to assure clean, non-contaminated sample containers. Full storm composites are generated using a United States Geological Survey (USGS) Dekaport Cone Sample Splitter. Composite samples are then sealed and labeled with a unique, water proof, adhesive bar code that corresponds with a field identification number containing information relating to the stormwater treatment unit and date of sampling. Records are kept that correlate sample bar code with sample time, date, flow, and other real time water quality parameters. Detailed written and electronic records are kept identifying the date, time, and unique bar code and field identification numbers. This begins the chain-of-custody record that accompanies each sample to track handling and transportation throughout the sampling process.

All analyses and procedures comply with the Technology Acceptance and Reciprocity Partnership (TARP), and the Technology Acceptance Protocol – Ecology (TAPE) guidelines to the maximum extent possible. We operate under a detailed Quality Assurance Project Plan (QAPP) which is available on request.

5.0 DATA EVALUATION

Exploratory data analyses are presented to examine influent and effluent conditions. These data are presented along with simple statistical analyses to examine performance trends. Data analyses included a range of approaches:

- evaluation of storm characteristics
- time series scatter plots for evaluation of event mean concentrations
- time series scatter plots for evaluation of removal efficiencies
- quartile distributions with notched box and whisker plots
- influent and effluent cumulative distribution functions
- simple statistics summary
- particle size distribution (PSD) analysis
- residual solid accumulation measurements

Storm characteristics such as total depth of rainfall, peak intensity, total storm volume, antecedent dry period, among others are presented for each storm event. Results for all storms sampled are presented in Table 2.

Event mean concentrations (EMC's) are presented in time series scatter plots along with removal efficiencies across a range of seasons. EMC's are a parameter used to represent the flow-proportional average concentration of a given parameter during a storm event. It is defined as the total constituent mass divided by the total runoff volume. When combined with flow measurement data, the EMC can be used to estimate the pollutant loading from a given storm or an annual basis. Most of the EMC data collected during this study were based upon direct measurement from flow-weighted composite samples. Due to the variability of precipitation events and resultant runoff conditions sample trigger conditions and flow-weighted sample pacing were variable and adjusted on a storm by storm basis according to the most up-to-date precipitation forecasts.

Interquartile distributions are presented as notched box and whisker plots for the range of contaminants for influent and effluent. Analysis of quartile distributions helps characterize trends in terms of range, and maximum and minimum, and median.

The cumulative probability distributions of observed concentrations are presented for both influent and effluent conditions. The cumulative distributions illustrate the probability of observed EMCs for both influent runoff conditions and the Stormtech Isolator Row treatment.

EMCs are compared for each pollutant parameter using simple statistics over multiple years of observations. The data provides a basis to evaluate the primary study question; i.e., to discern whether stormwater treatment unit BMP's have served to produce observable improvement in quality and reduction in volume of stormwater runoff. Calculation of medians is used because it is a measure that is more robust in the presence of outlier values than is the mean (average).

Particle size distribution (PSD) information for 4 influent events was determined by composite samples obtained with an auto-sampler and analyzed by laser diffraction. Auto-sampler PSD is reflective of the particle size range pulled by a sampler using a 3/8th ID sampling line and a peristaltic pump.

The quantity of the solids captured by the system were assessed on an annual basis and consisted of residual solids depth measurements throughout the lateral and longitudinal profile of the system. Particle size distributions were performed for captured solids.

6.0 RESULTS

Results presented below for the Isolator Row® represent data collected from the period of monitoring from December 2006 through September 2009 conducted at the UNHSC field facility. The data set reflects rainfall across all four seasons and covers a wide range of rainfall characteristics. Table 2 displays rainfall event characteristics for the 23 monitored storm events. Storms ranged in size from low intensity to high intensity, small volume to large volume. The design flow rate for the Isolator Row is 1 cfs, or 448.8 gpm.

6.1 Event Mean Concentrations (EMC) and Removal Efficiencies (RE) and Statistics

Influent and effluent EMC and system performance values are presented for each storm for the 5 contaminants across all monitored storm events in both tabular format in tables 4-5 and graphical format in Figures 5-10. The tables display discrete storm event data including influent and effluent EMCs and event based removal efficiencies. The graphical time series plots show performance for individual storm events as well as seasonal and annual trends with a 6-month cold season, or winter period displayed in blue. When EMC results are below detection limit (BDL) a value of zero is used and plotted as a unique time series and represented as a green triangle on the plots. No clear methodology for representing BDL values in stormwater treatment system effluent currently exists especially with respect to systems that detain a large volume of runoff and exhibit a longer effluent hydrograph than influent waters. Where detection limits are low enough (< 1 mg/L for TSS) the conventional statistical approach of using 0.5 X DL[3] would be adequate however, where detection limits are higher (≥ 10 mg/L for TSS) 0.5 x DL may add artificial mass and obscure overall system performance. Influent and

[3] Helsel, D. R., and Hirsch, R. M. (2002). Statistical Methods in Water Resources, U.S. Geological Survey.

Table 2: Rainfall-Runoff event characteristics for 23 storm events.

Rainfall Event	Peak Intensity (in/hr)	Storm Duration (min)	Total Depth (in)	Peak Flow (gpm)	Volume (gal)	Anticedent Dry Period (days)	Season
3/11/2007	0.12	430	0.28	85	23,323	7.0	Winter
4/12/2007	0.12	590	0.37	115	30,421	6.0	Spring
4/27/2007	0.24	450	0.54	146	31,005	7.5	Spring
5/11/2007	0.60	115	0.26	488	13,150	8.5	Spring
7/4/2007	0.48	235	0.45	260	23,976	13.0	Summer
9/9/2007	1.32	345	0.48	923	19,228	21.0	Summer
12/24/2007	1.08	305	0.33	499	21,608	2.5	Winter
12/29/2007	0.36	655	0.42	114	29,399	1.5	Winter
1/11/2008	0.72	690	0.68	233	47,832	1.5	Winter
1/18/2008	0.48	250	0.59	146	14,423	3.5	Winter
2/1/2008	0.12	620	1.23	187	39,921	1.5	Winter
3/7/2008	0.24	365	0.34	139	27,390	1.0	Winter
5/31/2008	0.72	80	0.11	344	6,807	3.5	Spring
6/4/2008	0.24	665	0.40	158	43,908	3.5	Spring
6/20/2008	1.08	165	0.20	718	16,016	2.0	Summer
7/23/2008	0.96	745	0.86	619	63,145	1.5	Summer
10/21/2008	0.36	290	0.24	183	18,154	4.5	Fall
11/13/2008	0.60	3,875	1.17	180	147,896	3.5	Fall
12/10/2008	0.36	435	0.60	221	39,504	0.5	Winter
4/3/2009	1.32	580	0.79	153	44,928	0.5	Spring
4/21/2009	0.36	685	0.64	1,342	509,189	2.5	Spring
5/5/2009	0.36	1,345	0.72	521	54,180	3.5	Spring
6/18/2009	1.08	1,295	1.46	590	42,092	3.5	Spring

effluent EMC quartile distributions are presented in Figure 11 as box and whisker plots that displays the minimum, 25th percentile, median, 75th percentile and maximum values for the range of storms monitored and the range of contaminants measured. The range of effluent concentrations are useful in discerning overall performance trends and in comparing UNHSC results to other datasets that may exist for the treatment technology. Figure 12 displays the same range of data for EMC displayed as exceedance probabilities. The cumulative distributions of the entire dataset is ranked with influent and effluent values plotted against the percent of recurrence or exceedance. The cumulative distributions are useful as it demonstrates the probability that a given concentration has been observed, and presumably will occur.

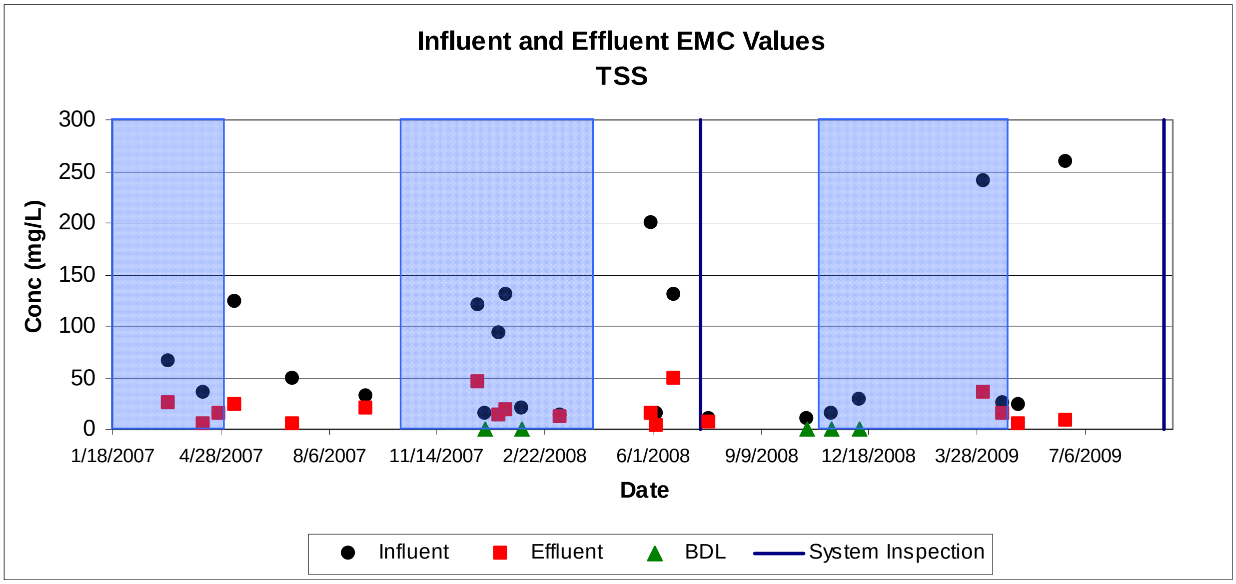
Table 3 Influent and effluent Event Mean Concentrations Removal Efficiencies for TSS, SSC and TPH-D for 23 storm events of the Isolator Row®

	Total Suspended Solids (TSS)			Suspended Sediment Concentration (SSC)			Total Petroleum Hydrocarbons - Diesel (TPH-D)		
Date	influent EMC (mg/L)	effluent EMC (mg/L)	Removal Efficiency (%)	influent EMC (mg/L)	effluent EMC (mg/L)	Removal Efficiency (%)	influent EMC (ug/L)	effluent EMC (ug/L)	Removal Efficiency (%)
3/11/2007	66	25	62%				1648	472	71%
4/12/2007	36	5	86%				631	422	33%
4/27/2007	16	15	3%				456	45	90%
5/11/2007	123	23	81%				970	402	59%
7/4/2007	48	5	90%				927	436	53%
9/9/2007	32	20	38%				261		99%
12/24/2007	120	46	62%				890	340	62%
12/29/2007	16	0 (BDL)	99%						
1/11/2008	94	14	85%				750	0 (BDL)	99%
1/18/2008	130	18	86%				3200	300	91%
2/1/2008	21	0 (BDL)	99%						
3/7/2008	14	12	14%				850	0 (BDL)	99%
5/31/2008	200	16	92%						
6/4/2008	15	3	80%				370	0 (BDL)	99%
6/20/2008	130	50	62%						
7/23/2008	10	7	30%						
10/21/2008	11	0 (BDL)	99%	19	2	89%			
11/13/2008	15	0 (BDL)	99%	30	12	60%			
12/10/2008	29	0 (BDL)	99%	75	8	89%	480	0 (BDL)	99%
4/3/2009	240	36	85%						
4/21/2009	25	16	36%	220	22	90%			
5/5/2009	23	5	78%				310	0 (BDL)	99%
6/18/2009	260	9	97%	360	4	99%			
Median	32	16	85%	75	8	89%	750	402	91%
Average	73	18	72%	141	10	85%	903	345	81%

Table 4 Influent and effluent Event Mean Concentrations Removal Efficiencies for DIN, TZn and TP for 23 storm events of the Isolator Row®

	Dissolved Inorganic Nitrogen (DIN)			Total Zinc (TZn)			Total Phosporus (TP)		
Date	influent EMC (mg/L)	effluent EMC (mg/L)	Removal Efficiency (%)	influent EMC (mg/L)	effluent EMC (mg/L)	Removal Efficiency (%)	influent EMC (mg/L)	effluent EMC (mg/L)	Removal Efficiency (%)
3/11/2007	0.43	0.46	-8%	0.077	0.036	53%	0.18	0.10	44%
4/12/2007	0.05	0.26	-421%	0.046	0.022	53%	0.07	0.05	29%
4/27/2007	0.11	0.24	-117%	0.021	0.005	76%	0.06	0.04	33%
5/11/2007	0.26	0.46	-77%	0.087	0.036	58%	0.20	0.07	65%
7/4/2007				0.046	0.017	63%	0.17	0.08	53%
9/9/2007	0.19	0.60	-216%	0.049	0.030	37%	0.10	0.09	10%
12/24/2007				0.150	0.090	40%	0.17	0.07	59%
12/29/2007	0.50	0.70	-40%	0.030	0.020	33%	0.04	0.02	50%
1/11/2008	0.20	0.50	-150%	0.060	0.010	83%	0.12	0.04	67%
1/18/2008				0.090	0.040	56%	0.12	0.04	67%
2/1/2008	0.10	0.40	-300%	0.040	0.020	50%	0.06	0.03	50%
3/7/2008				0.020	0.020	0%	0.02	0.03	-50%
5/31/2008	0.60	1.10	-83%	0.130	0.030	77%	0.33	0.08	76%
6/4/2008	0.20	0.40	-100%	0.030	0 (BDL)	99%	0.05	0.05	0%
6/20/2008	0.50	1.20	-140%	0.080	0.030	63%	0.12	0.06	50%
7/23/2008	0.30	0.50	-67%	0.020	0.010	50%	0.01	0.02	-100%
10/21/2008	0.50	0.60	-20%	0.040	0.020	50%	0.03	0.03	0%
11/13/2008	0.20	0.40	-100%	0.030	0 (BDL)	99%	0.04	0.03	25%
12/10/2008				0.020	0 (BDL)	99%	0.05	0.01	80%
4/3/2009				0.070	0.010	86%	0.16	0.01	94%
4/21/2009	0.30	0.30	0%				0.03	0.03	0%
5/5/2009	0.40	0.60	-50%				0.04	0.03	25%
6/18/2009	0.30	0.20	33%	0.020	0 (BDL)	99%	0.02	0.02	0%
	0.30	0.46	-83%	0.046	0.020	58%	0.06	0.04	44%
	0.30	0.52	-109%	0.055	0.026	63%	0.10	0.04	32%

Figure 5: Total Suspended Solids Event Mean Concentrations at influent and effluent locations and Removal Efficiencies for 23 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



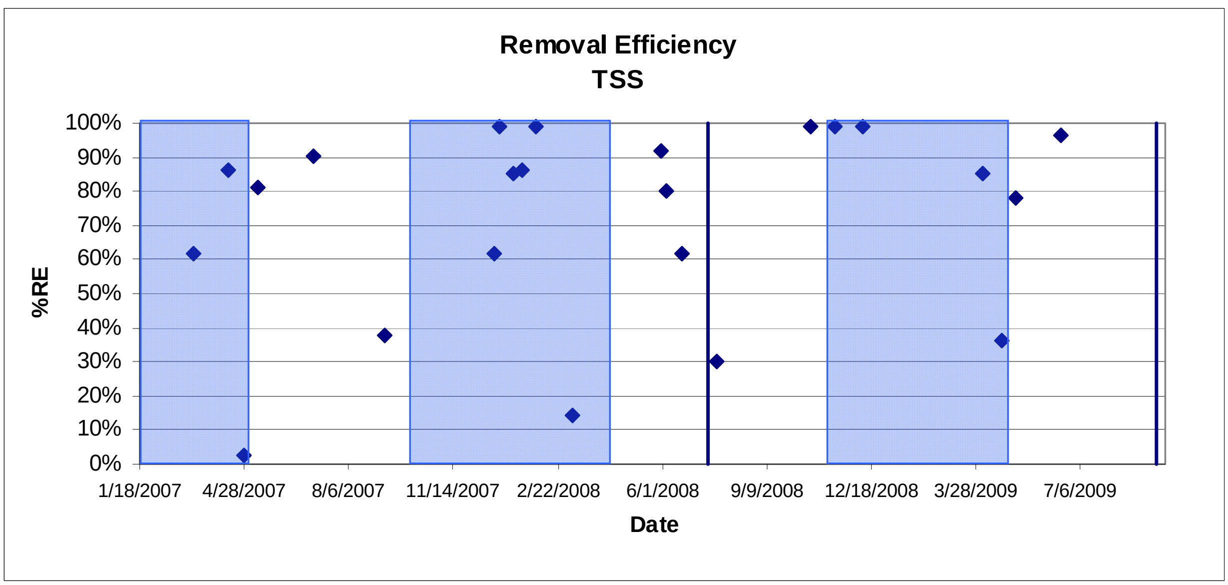
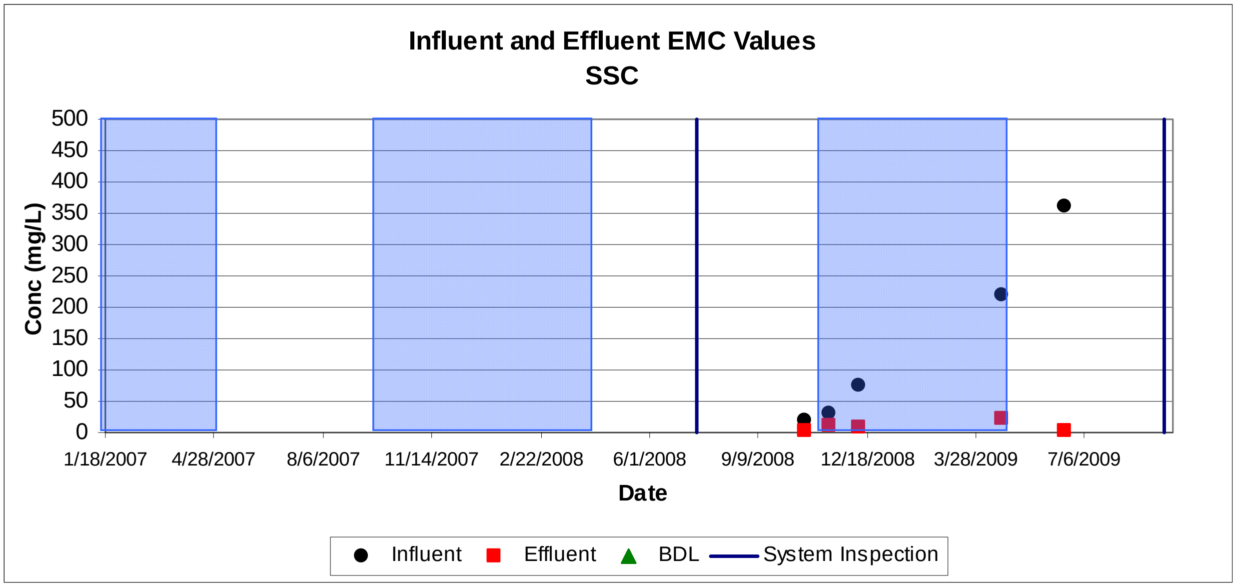


Figure 6: Suspended Sediment Concentration Event Mean Concentrations at influent and effluent points and Removal Efficiencies for 6 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



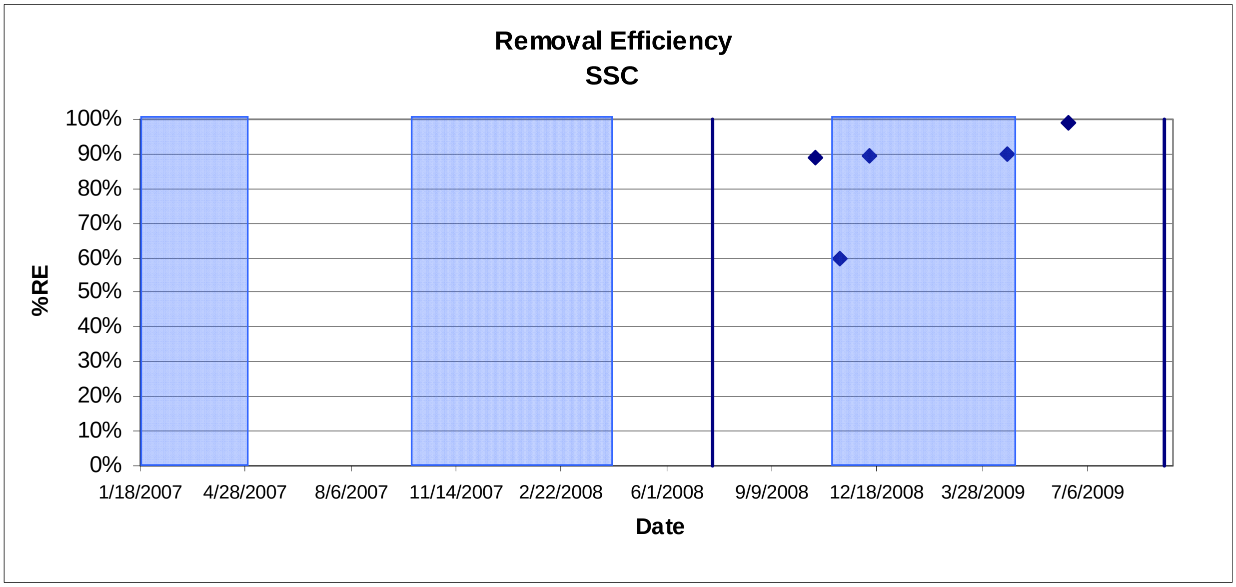
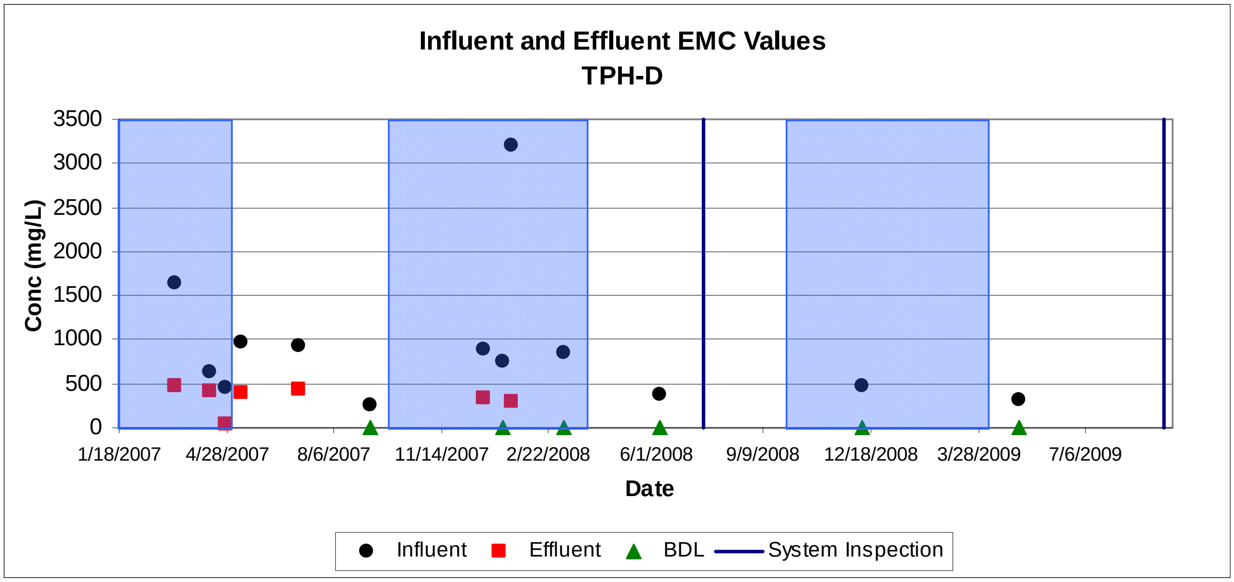


Figure 7: Total Petroleum Hydrocarbons-Diesel Range Event Mean Concentrations at influent and effluent points and Removal Efficiencies for 13 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



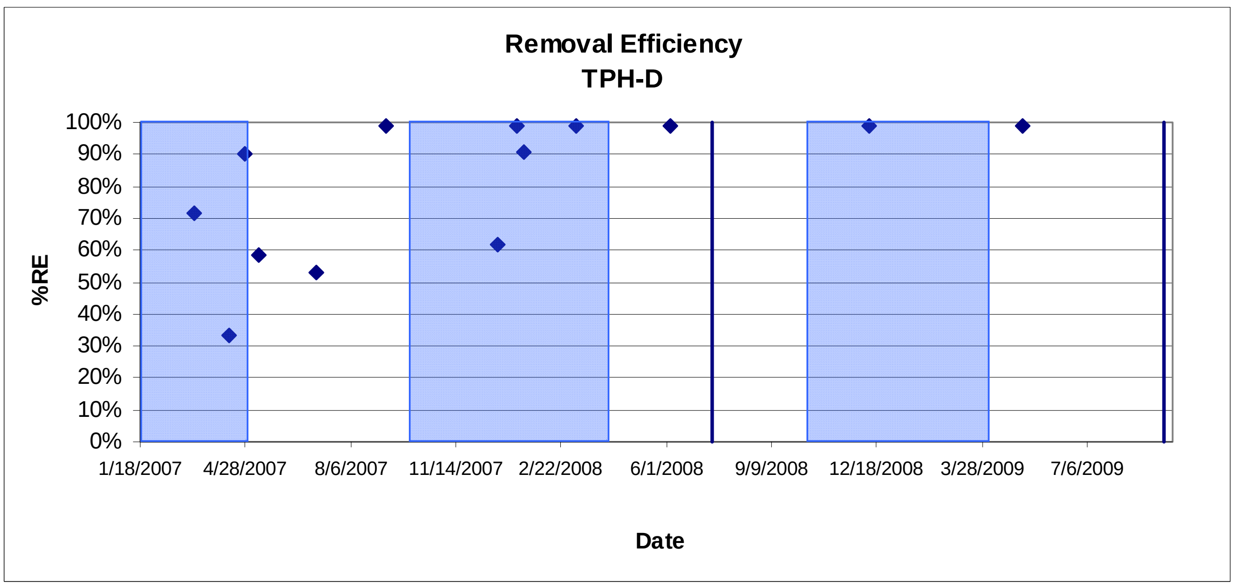
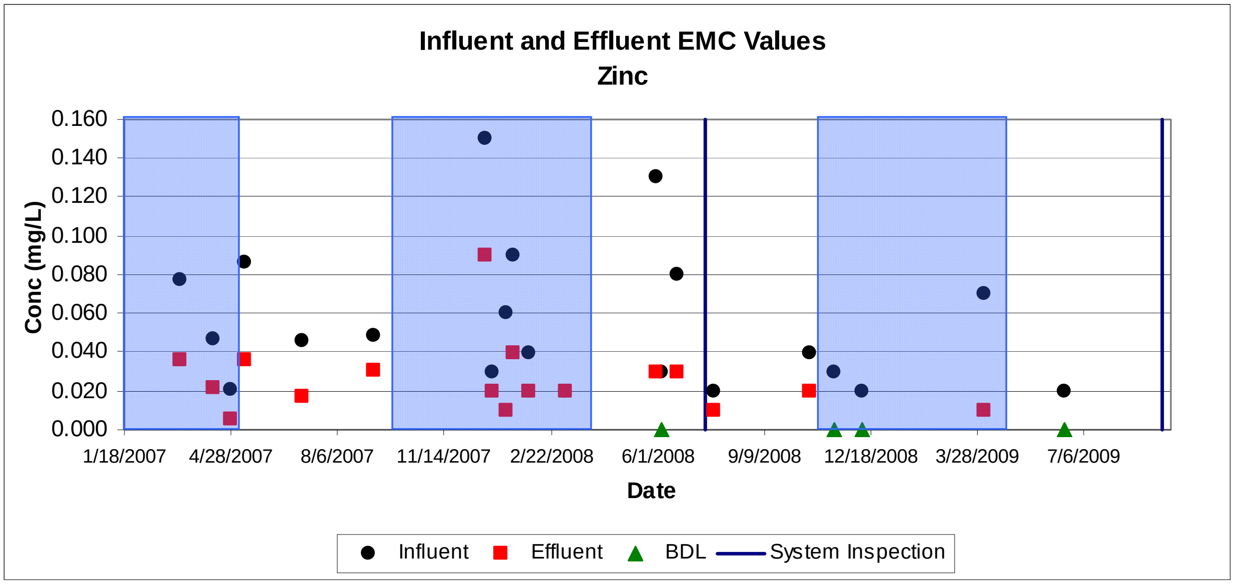


Figure 8: Total Zinc Event Mean Concentrations at influent and effluent locations and Removal Efficiencies for 21 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



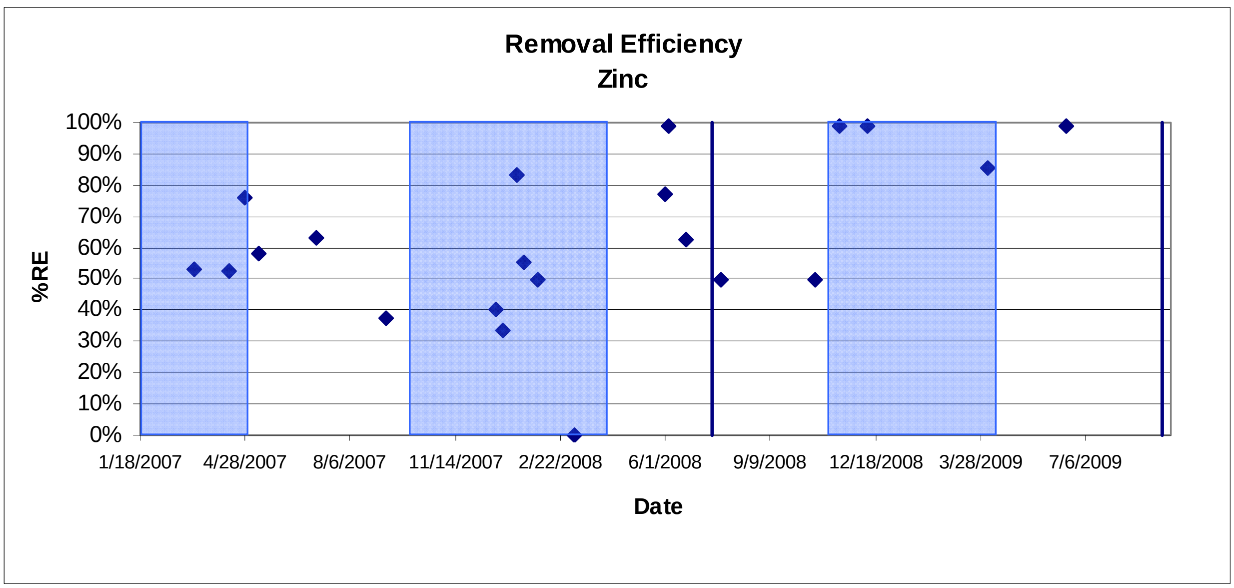
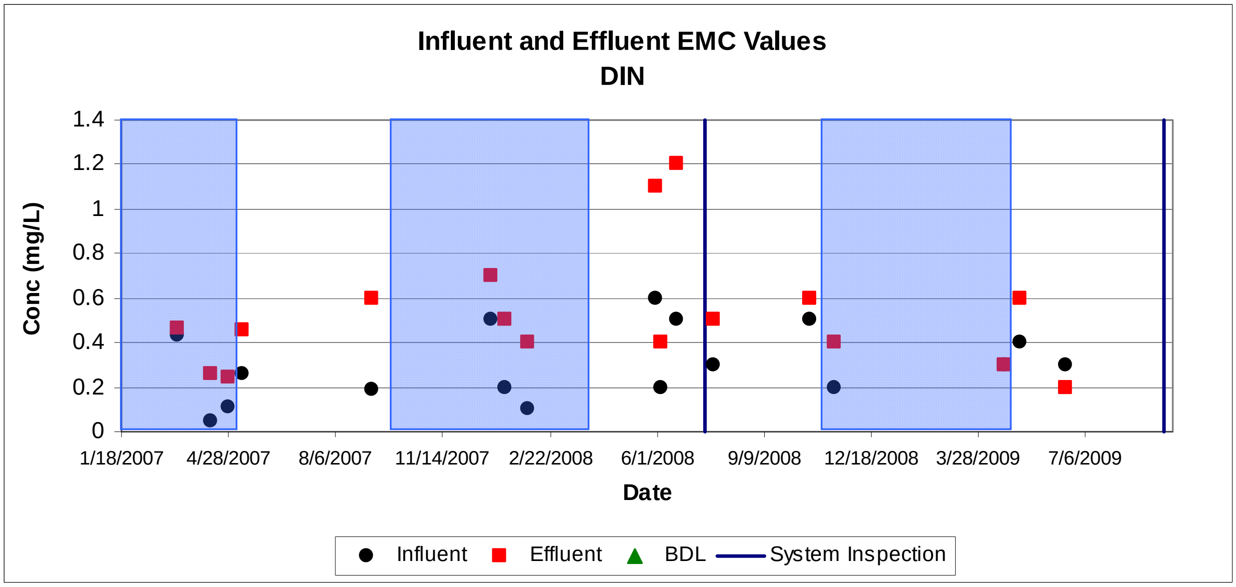


Figure 9: Nitrate Event Mean Concentrations at influent and effluent points and Removal Efficiencies for 18 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



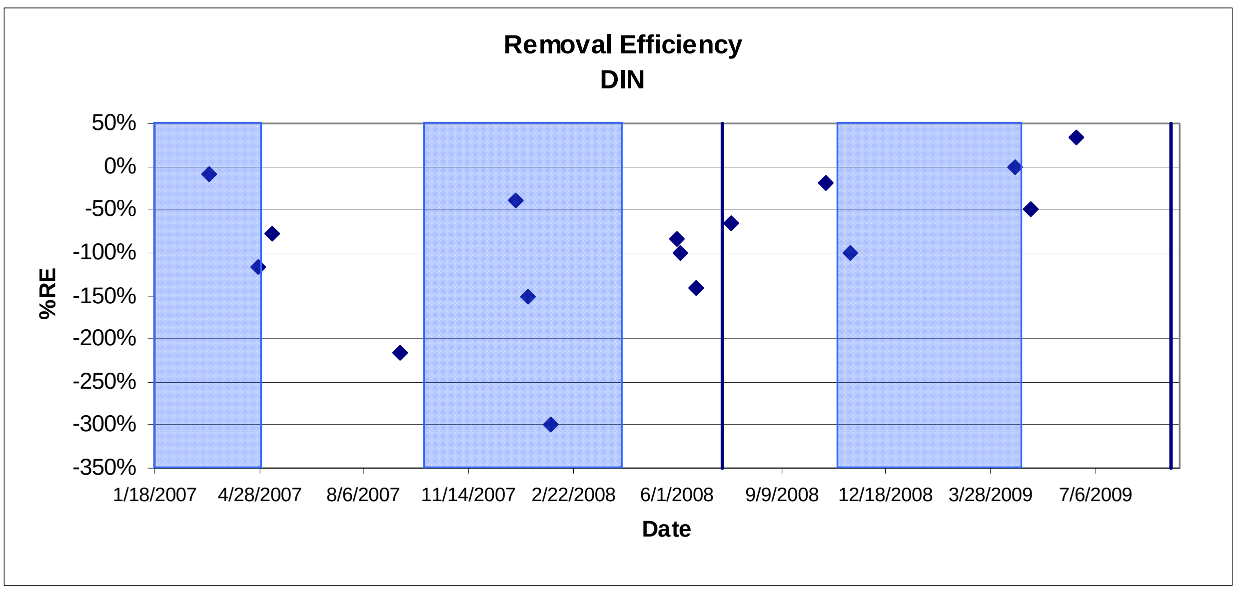
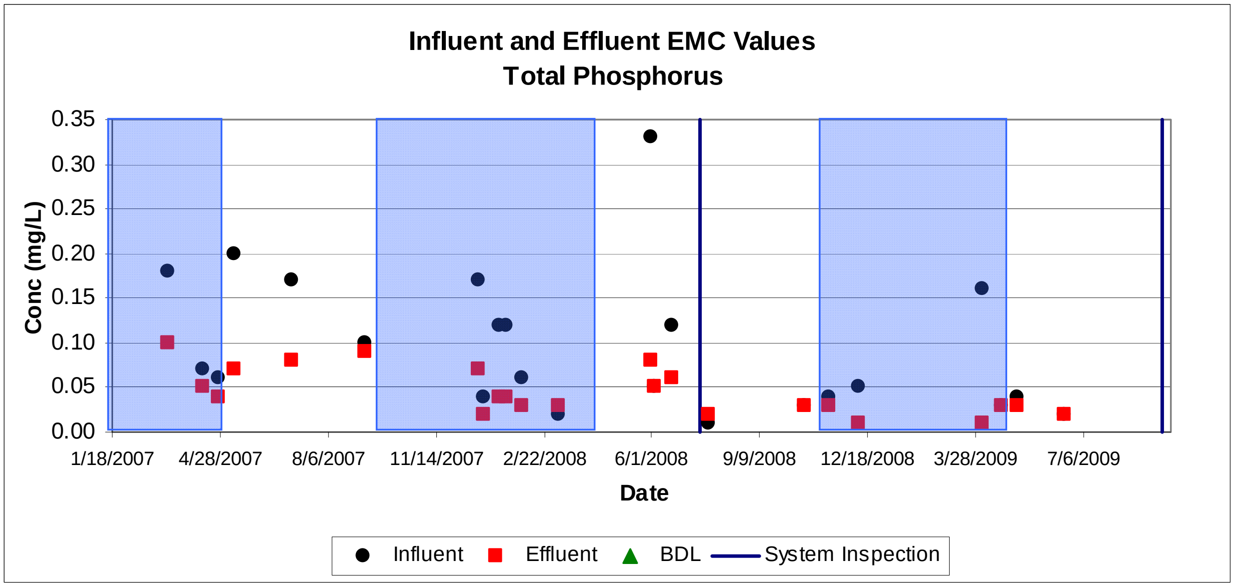


Figure 10: Total Phosphorus Event Mean Concentrations at influent and effluent points and Removal Efficiencies for 23 storm events of the Isolator Row®. A 6-month winter period (Nov-April) is displayed in blue.



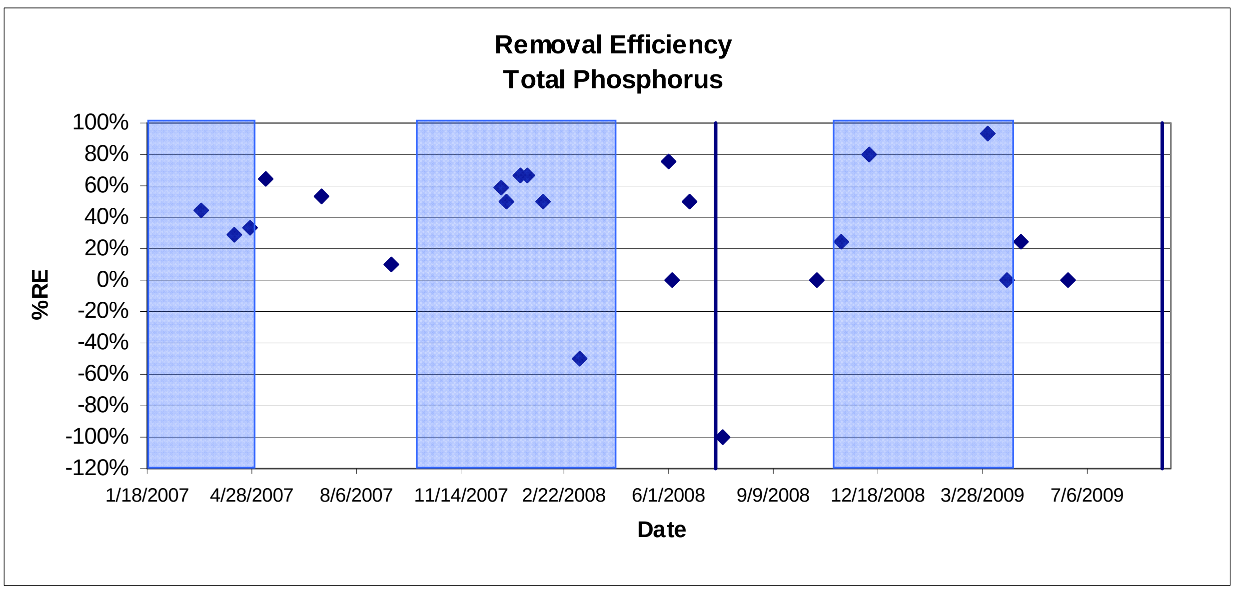


Figure 11: Effluent EMC box and whisker plot comparisons for the range of contaminants for the Isolator Row® . Box reflects the 25th and 75th percentile, the line reflects the median and the whiskers reflect minimum and maximum values of the entire dataset.

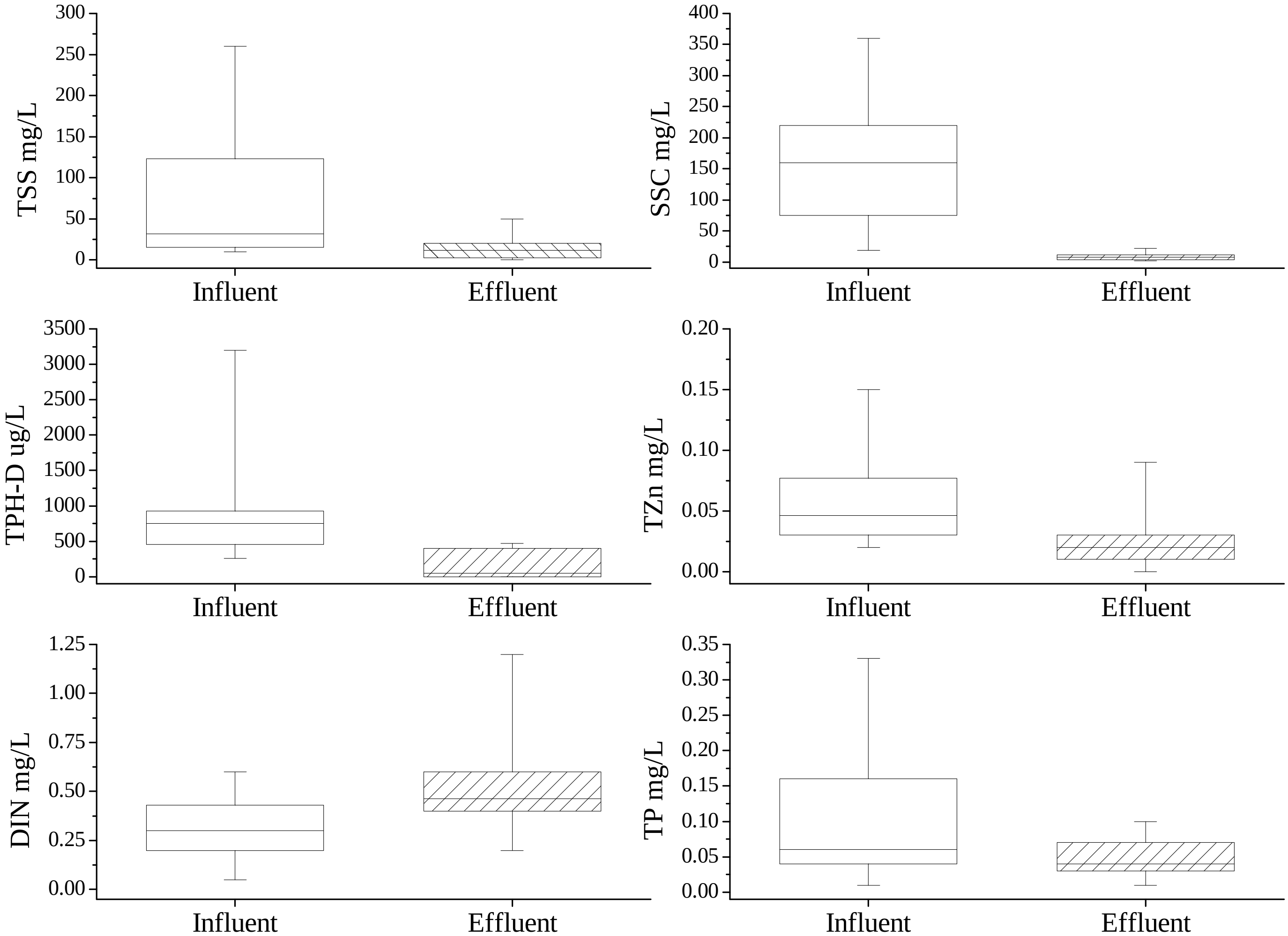


Figure 12: Exceedance probabilities for influent and effluent EMCs for TSS, SSC, TPH-D, TZn, DIN, TP

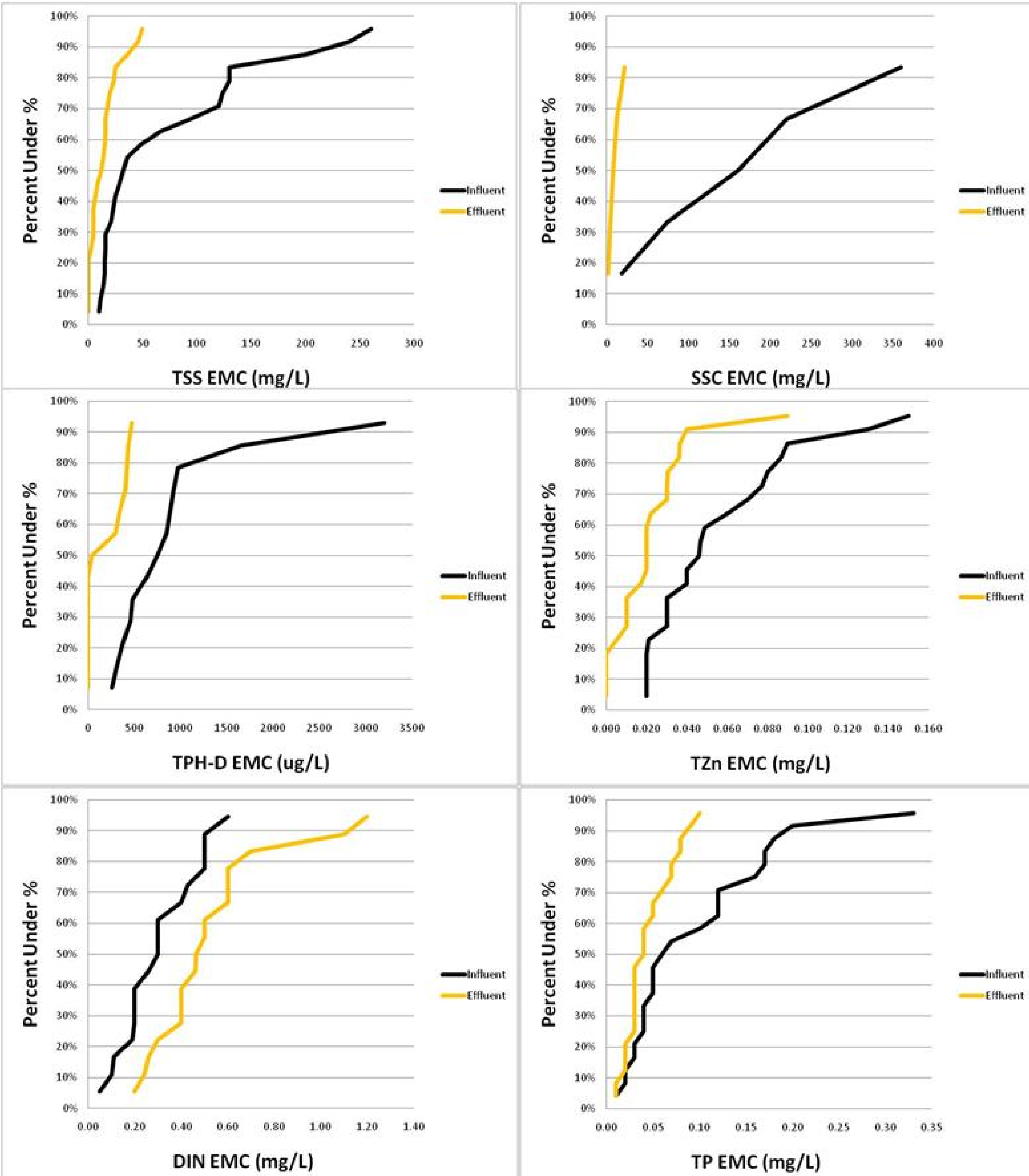


Table 5: Simple statistics for influent and effluent event mean concentrations.

System / Pollutant	Statistic	Influent year 1	StormTech Effluent year 1	Influent year 2	StormTech Effluent year 2	Influent overall	StormTech Effluent overall
TSS (mg/l)	mean	64	16	81	13	73	14
	ER		76%		84%		81%
	AVG RE		66%		73%		69%
	Median RE		83%		83%		83%
	n		11		12		23
	SD	45	14	98	15	76	14
	Cv	0.709	0.867	1.213	1.207	1.049	1.012
TPH-D (ug/l)	mean	1081	269	503	BDL	903.3	186
	ER		75%		99%		79%
	AVG RE		73%		99%		81%
	Median RE		71%		99%		91%
	n		9		4		13
	SD	885	197	242	N/A	783	206
	Cv	0.818	0.734	0.482	N/A	0.867	1.109
DIN (mg/l)	mean	0.23	0.45	0.37	0.59	0.30	0.52
	ER		-97%		-61%		-74%
	AVG RE		-129%		-52%		-97%
	Median RE		-97%		-58%		-80%
	n		8		9		17
	SD	0.16	0.16	0.14	0.34	0.16	0.27
	Cv	0.696	0.345	0.386	0.585	0.535	0.521
TZn (mg/l)	mean	0.063	0.030	0.046	0.012	0.055	0.021
	ER		53%		74%		61%
	AVG RE		50%		72%		60%
	Median RE		53%		81%		57%
	n		11		10		21
	SD	0.036	0.023	0.037	0.012	0.037	0.020
	Cv	0.575	0.770	0.795	1.024	0.665	0.954
TP (mg/l)	mean	0.12	0.06	0.08	0.03	0.09	0.04
	ER		51%		56%		53%
	AVG RE		42%		17%		29%
	Median RE		50%		13%		33%
	n		11		12		23
	SD	0.06	0.03	0.09	0.02	0.08	0.03
	Cv	0.491	0.456	1.221	0.618	0.826	0.579
SSC (mg/l)	mean	No Data		166.70	9.60	166.70	9.60
	ER				94%		94%
	AVG RE				93%		93%
	Median RE				91%		91%
	n				5		5
	SD			132.87	7.92	132.87	7.92
	Cv			0.797	0.825	0.797	0.825

Note: ER = average efficiency ratio; AVG RE = average removal efficiency; median RE= median removal efficiency; n = number of storms; SD = standard deviation; Cv = coefficient of variation

The statistical analyses presented reveal a range of performance trends. Efficiency Ratio (ER) analysis was performed on the final dataset (Table 3). For many stormwater treatment system datasets, ER is a stable estimation of overall treatment performance as it minimizes the impact of low concentration values, or relatively clean storms with low influent EMC concentrations. Where Removal Efficiencies (RE) reflect treatment unit performance on a storm by storm basis, ERs weight all storms equally and reflect overall influent and effluent averages across the entire data set. For this reason they are often discouraged as a performance measure. REs are presented as both an average and median of aggregate storm values. In general, aggregate median RE values are more reliable in highly variable, non-normally distributed datasets such as those experienced in stormwater treatment unit performance studies. A review of REs on a per event basis, ERs for the entire period of monitoring, and EMCs per event and probabilistically over the entire period of monitoring will reveal the measured performance variations attributable to season, flow, concentration, and other factors.

Sediment (TSS and SSC) performance and effluent EMCs reveal strong performance and low effluent concentrations that do not vary significantly across fluxuations in loading concentration, seasons, or time. There is little variation in performance for sediments with respect to influent concentration as can be observed in Figure 10. Mean effluent concentrations were x_{TSS}= 14.0 mg/l +/- 14.0 and x_{SSC}=9.6 +/- 7.9. Median TSS performance was >80% removal for both years, and SSC was >90% for a limited duration of monitoring for the end of year 2. Five of the seven events with poor performance can be attributable to storm events exceeding the water quality design flow (WQF=1 cfs)[4]. There were 3 other events that exceed the WQF that averaged above 80% removal. Total zinc appears to be improving over time presumably with development of the filter cake within the chambers.

TZn performance increased from 53% for year 1 to 81% removal by the end of year 2. TPH removal efficiencies and effluent EMCs demonstrate strong performance that was enhanced over the course of the study. TP removal was moderate at 33% over the course of the study. Performance was higher and effluent EMC's lower as the study progressed. While TPH removals did not indicate seasonal variability, TP results seemed to be influenced by seasonal changes and maintenance intervals although clear trends were unable to be established in this study. The enhancement of treatment over time of these analytes is of interest and seems to be associated with the development of an organic filter cake over the fabric. As the filter cake develops treatment of TPH and Phosphorus is improved.

DIN removal efficiencies and effluent EMCs reveal poor performance and high effluent concentrations relative to influent values indicating that this system offers no identifiable treatment for dissolved inorganic nitrogen.

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[4] Five of the seven events exceeding the water quality design flow had poor performance: 9/9/2007, 12/24/2007, 6/20/2008, 7/23/2008, 4/21/2009

6.2 Particle Size Distributions (PSD) & Sediment Accumulation

Particle size information for 4 influent events was determined by composite samples obtained with an auto-sampler and analyzed by laser diffraction. Particle size ranges in the influent range from 0.01 mm to 0.12 mm, with the median particle size around 0.038 mm (Figure 12). Influent and effluent PSD characterization are created using the same sampling methods. The d15, d50, and d85 runoff particle sizes are 0.015mm, 0.044mm, and 0.130mm respectively. These values represent the mean runoff values for 2006 – 2008.

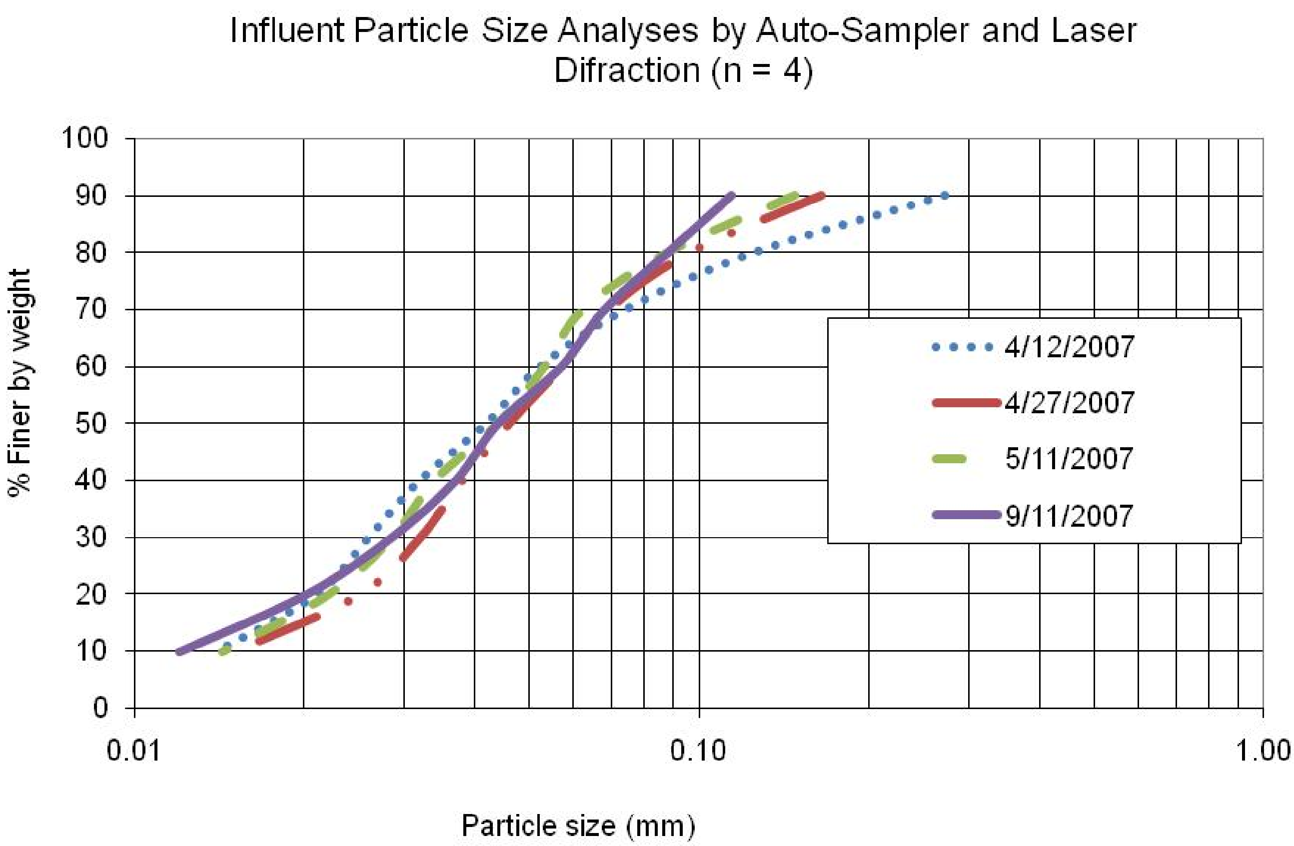

Figure 13: Influent particle size distributions by auto-sampler and laser diffraction for 4 storms

Sediments captured by the Isolator Row® were sampled and analyzed by dry sieve and hydrometer PSD analysis. Grab samples taken at 1 and 2 year monitoring intervals, along the longitudinal centerline at 2 foot and 30 foot locations from the inlet were weighed, dried, and put into a sieve set and shaker. The sieves used were 2mm, 850µm, 425 µm, 250 µm, 150 µm, and 75 µm. Figure 13 presents PSD and hydrometer test results of these sediment samples.

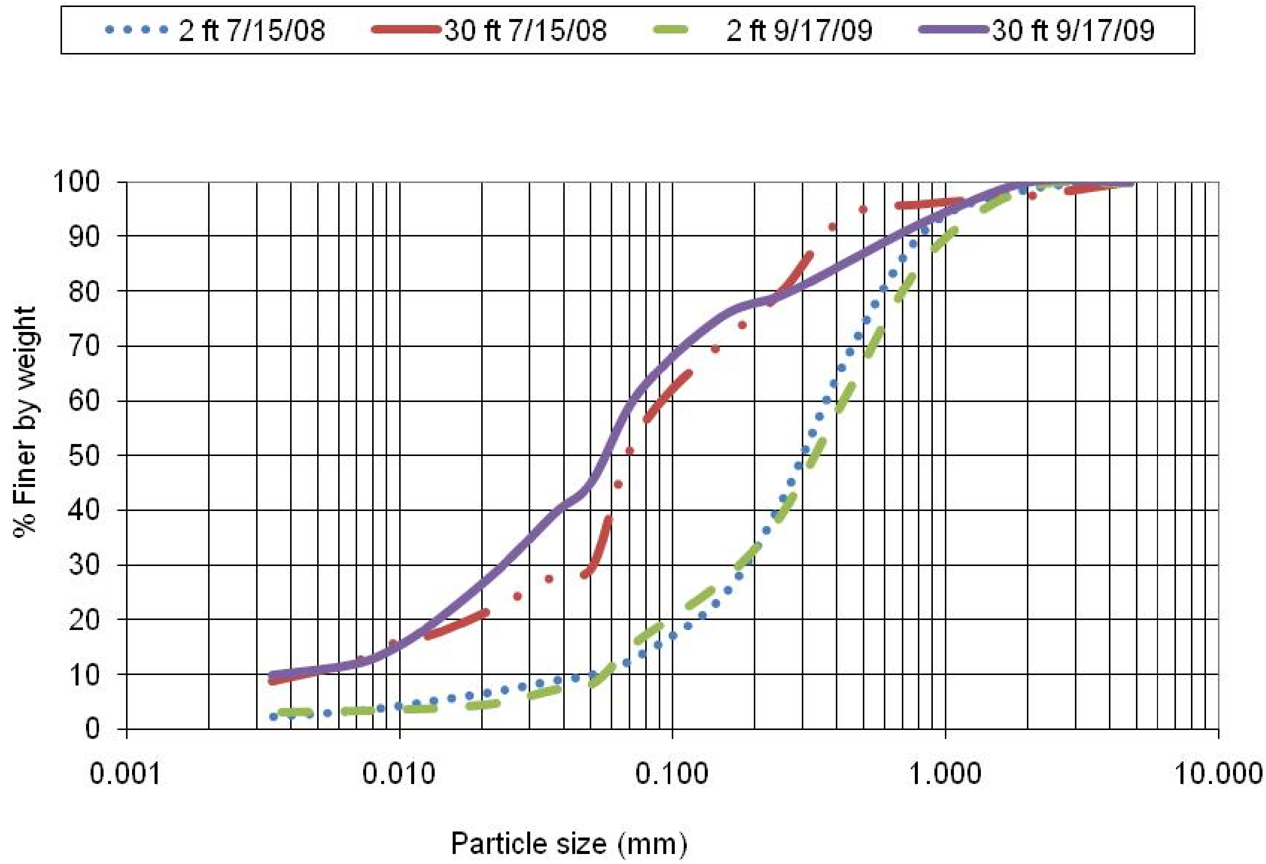

Figure 14: PSD of sediment grab samples taken at 2 feet and 30 feet from the inlet to the Isolator Row.

Depth of sediment accumulation was measured at the same time the sediment grab samples were taken. Comparison of the PSD results taken at the influent by the auto-sampler and by grab sample at 2 feet from the inlet to the chamber show that the sediments filtered out by the system are approximately a magnitude larger at the d50. The data also illustrates a longitudinal differentiation in particle settling in the chamber with larger diameter particles settling toward the front of the system and smaller diameter particles settling toward the back. Figure 15 shows depth of sediment across the longitudinal profile of the system from 2 feet to 30 feet from the inlet. The chart shows a consistent sediment depth over the 2 year monitoring period except at the 30 foot mark. An increase in depth at the 10 foot mark represents consistent sediment deposition due to flow dissipation. At the 30 foot mark there is an increase in sediment depth from 0.25 in to 1.17 in. This is likely due to sediment being pushed towards the back of the system as it experiences more intense events.

The total sediment accumulation of 1.2 inches from September 2006 September 2009, is nearly half of the manufacturers recommended depth for maintenance (3 inches). By this measure, it

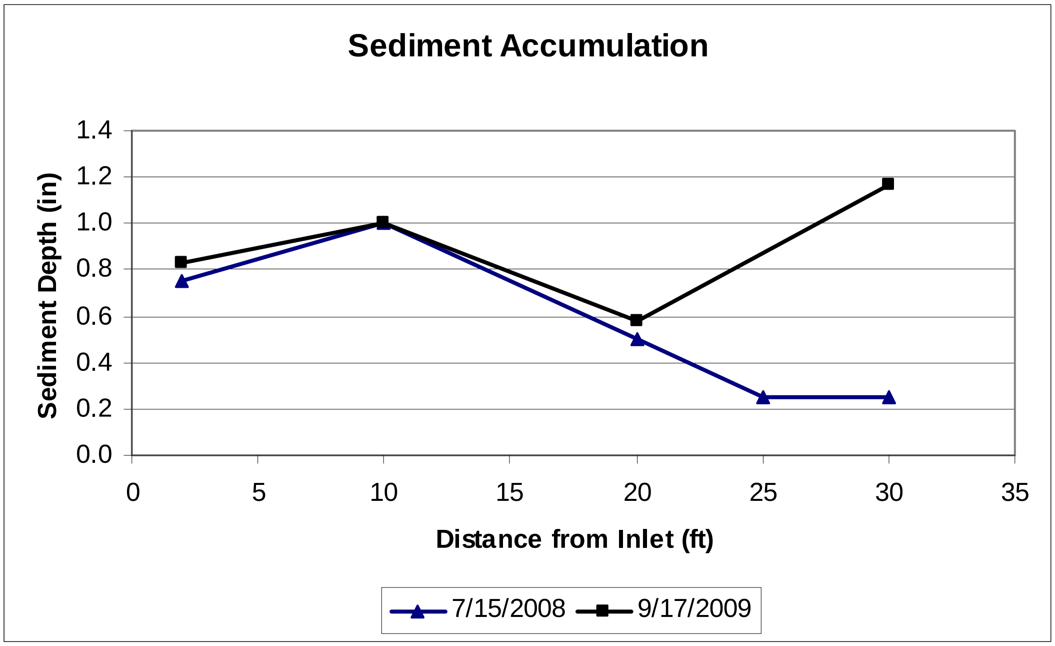

Figure 15: Record of sediment depth inside the StromTech Isolator Row at 1 and 2 year monitoring intervals.

would take another 3 years of operation before maintenance would be required, or a total of 6 years of operation.

6.4 Analysis of Water Level Drain Down

The rate of water level drain down in the Isolator Row® system is a function of depth of water (driving head) and the hydraulic conductivity of the confining layer. Initially the confining layer is the geotextile, and then becomes controlled by the development of a filter cake on top of the geotextile. The maximum specific discharge (or hydraulic conductivity) reported here (q_{max}) is calculated as discharge per square foot of filter area value (gpm/ft^2) for 12 of the monitored storms and is plotted in Figure 16. The bypass weir elevation as measured from the bottom of the chamber (27.7 in), the top of Isolator Row® chamber (30.0 in), and a sandy soil (8 in/hr or 0.08 gpm/ft^2) are plotted for reference. The plot indicates reduction in filter capacity over time. Figure 17 plots q_{max} along with the recorded maximum water depth within the Isolator Row® chamber for each of the 12 storms. Drain down for 12 storms are attached as Appendix A. These drain down plot the effluent flows along the left y-axis and water level and stage-discharge along the right y-axis versus time. Note, the stage-discharge values have been scaled up by a factor of 10 in order to display clearly.

Rate and trend of clogging was examined by monitoring of drain down for events at or near the maximum treatment flow rate. The maximum treatment flow rate for the system was calculated for seven events when in-system depths were at or near the maximum depth as regulated by the bypass (27.7 inches). Figure 16 illustrates the seven events of maximum treatment flow rate versus q_{max}, and a linear regression trendline. Examination of the linear regression shows a relatively weak correlation (r^2=0.337) due largely to the limited number of

Table 6: Tabular values for in-system hydraulic conductivity calculations

Storm Date	Effluent Peak Flow (gpm)	q max	max depth (in)	q max / max depth	Season	Antecedent Dry Period (days)
7/4/2007	80.8	0.53	20.88	0.31	Summer	13.0
12/24/2007	110.4	0.73	27.48	0.35	Winter	2.5
12/29/2007	26.0	0.17	18.00	0.12	Winter	1.5
5/31/2008	7.0	0.05	21.36	0.04	Spring	3.5
11/13/2008	23.5	0.16	18.96	0.12	Fall	3.5
12/10/2008	64.4	0.43	24.72	0.25	Winter	0.5
4/3/2009	73.8	0.49	29.52	0.22	Spring	0.5
5/5/2009	56.8	0.38	28.80	0.20	Spring	3.5
5/27/2009	32.5	0.21	27.96	0.12	Spring	9.0
6/9/2009	13.9	0.09	13.08	0.19	Spring	7.5
6/11/2009	82.2	0.54	29.76	0.28	Spring	1.5
6/18/2009	91.9	0.61	30.84	0.33	Spring	3.5

events where maximum depth at or near bypass was observed (seven of twelve). The regression was only applied to these seven events were driving head would all be nearly equivalent. Hydraulic conductivity is dependent on driving head and therefore needs to be constant.

For comparative purposes, the linear regression was solved for a condition where the filter efficiency would be equal to a sandy soil reference condition. Given the current trendline, the filter will have reduced to the reference condition (sandy soil) by September 2010, 4 years after installation (September 2006). This point does not necessarily indicate the need for maintenance, but does indicate an 89% reduction in filter efficiency by September 2010. This maintenance requirement point could be determined by monitoring of water quality and occurrence of bypass. This is not the same as a reduction in initial maximum treatment flow rate. That point is not known for the starting condition, but was determined from 12/2007-6/2009.

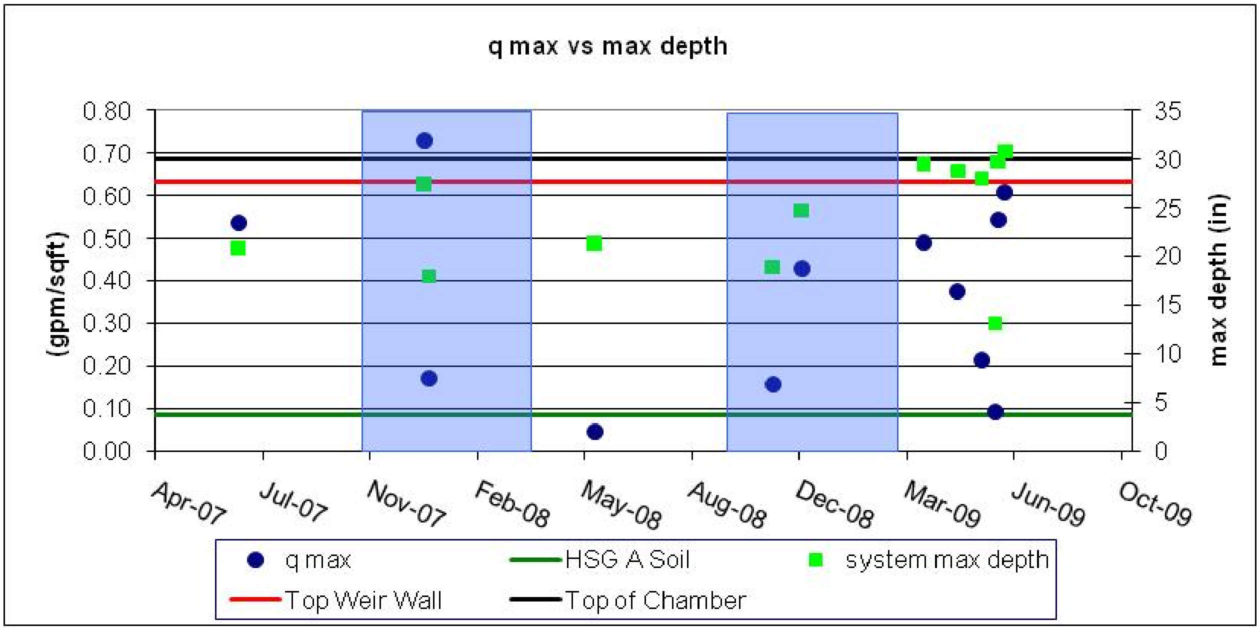

Figure 16: Plot of the stage-discharge and maximum water level measured for 12 monitored storm events. Also plotted are the hydraulic conductivity of an HSG A soil and relative elevations of the bypass weir wall and the top of the Isolator Row chamber all as horizontal lines.

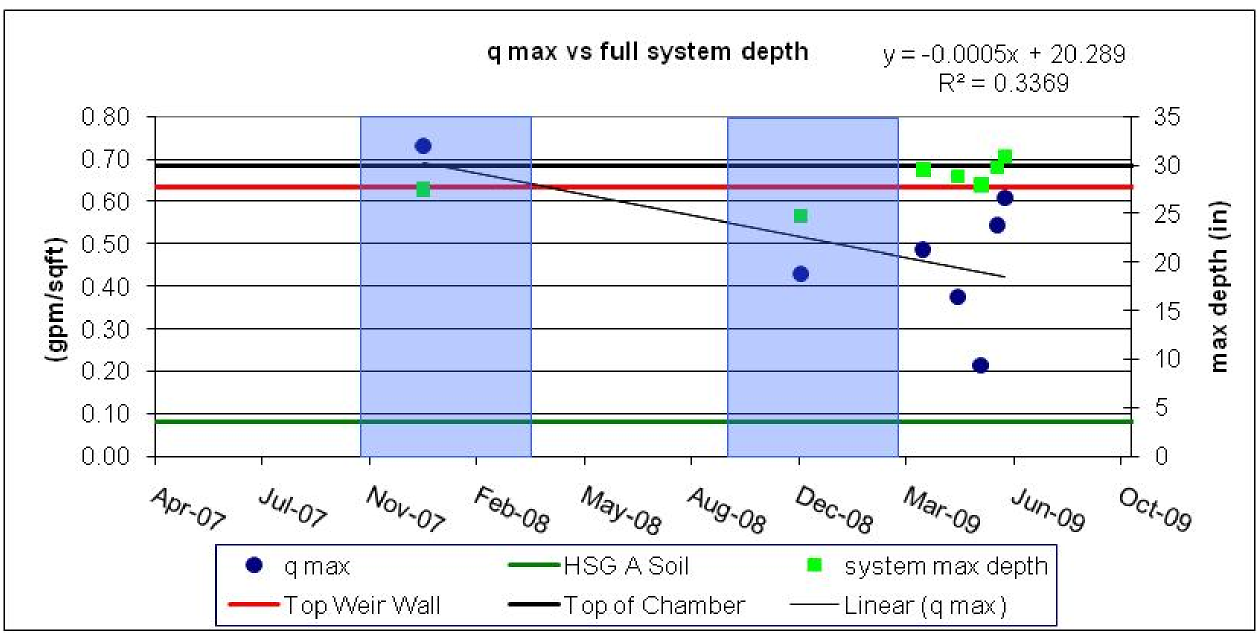

Figure 17: Plot of the stage-discharge and maximum water level measured for 7 monitored storm events with equal system depths (elevation of weir wall crest +/- 3 in.). A trendline showing gradual decline in q max is plotted with its regression equation.

6.5 INDIVIDUAL STORM REPORTS

Individual storm reports (ISR) are presented for two storms, May 5, 2009 and June 18, 2009. The ISR's illustrate performance, with respect to storm characteristics, and provide detailed information on storm coverage and sampling . Both storms exceeded the design flow rate of 448 gpm. The May5, 2009 storm was a relatively clean storm with influent TSS =23 mg/l, good removal performance was observed at 78%, and an effluent concentration of 5 mg/l. This is quite good considering both the high flow and low concentration. The June 18 storm had a high influent concentration TSS=260 mg/l, a 97% removal performance, and 9 mg/l effluent concentration was observed. Both events were less than 10 mg/l, commonly considered to be the lowest reasonable treatment threshold, sometimes referred to as irreducible concentration[5].

7.0 SUMMARY AND CONCLUSIONS

A five chamber configuration of the StormTech Isolator Row® showed strong water quality treatment performance for the three year installation. Sediment (TSS and SSC) performance and effluent EMCs reveal strong performance and low effluent concentrations that do not vary significantly across fluxuations in loading concentration, seasons, or time. The influent sediment concentrations for the period of monitoring were TSS median =32.0 mg/l, an average of 73.0 mg/l ±76.0, and for SSC a median =160.0 mg/l, and an average of 166.7 mg/l ±132.9 was observed. A median effluent concentration of TSS=12.0 mg/l, an average of 14.0 mg/l ±14.0, and a median removal efficiency of 83% was observed. A median effluent concentration of SSC=8.0 mg/l, an average of 9.6 mg/l ±7.9, and a median removal efficiency of 91% was observed. Five of the seven events with poor performance were attributed to events exceeding the water quality design flow (WQF=1 cfs). Metals performance as measured by TZn increased from 53% for year 1 to 81% removal by the end of year 2.   TPH performance was very strong at 91% removal and TP removal was modest at 33%. As would be expected for non-vegetated filtration systems, dissolved inorganic nitrogen (DIN = NO3, N02, NH4) removal efficiencies and effluent EMCs reveal poor performance and high effluent concentrations relative to influent values. After 3 years of installation, sediment depths had accumulated to 1.2 in, only half of the manufacturers recommended depth for maintenance (3 inches). Presumably treatment performance will continue to improve with increase filter cake development, as will incident of bypass.

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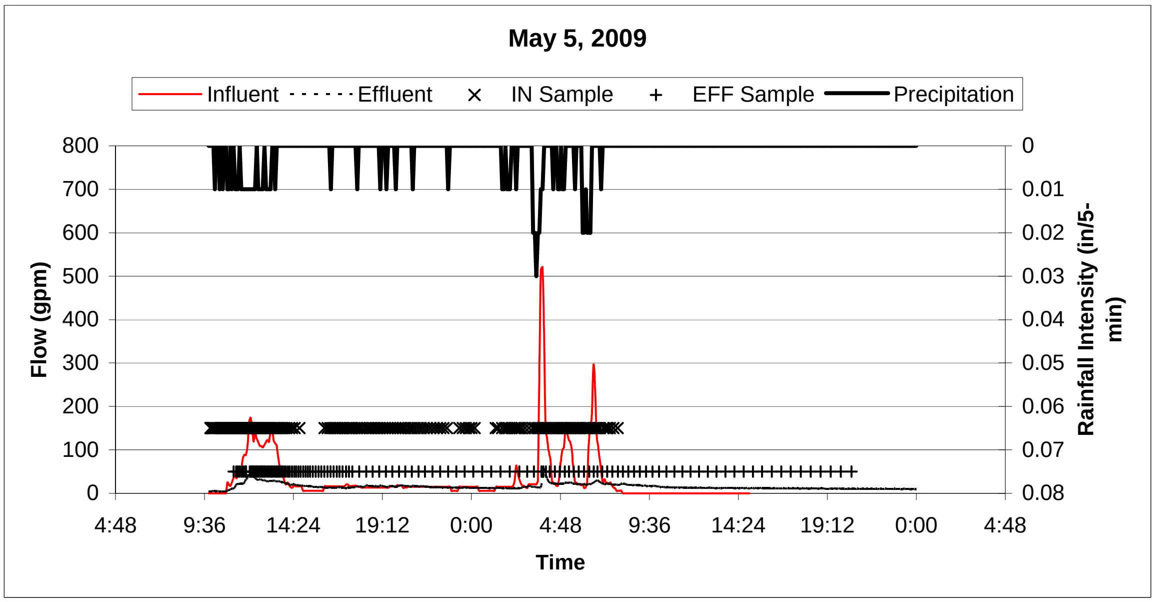
[5] Schueler, T. (2000). "National Pollutant Removal Database: for Stormwater Treatment Practices." Center for Watershed Protection.

General Information	
Site:	University of New Hampshire Stormwater Center, Durham, NH
System Description:	5 x 40 Stormtech Infiltation Chamber
Event Date:	5/5/2010
Date of Last Maintenance:	Never been maintained. Installed September 2006
Antecedent Conditions:	3.5 days

Hydrology	Influent	Effluent	Bypass
Total Precipitation (in):	0.72		
Peak Flow, (gpm):	521	57	246
Total Runoff Volume (gal):	54,180	36,139	15,281
SF Vol. Coverage (nearest 10%):	99.9%	100.0%	

Event Hydrograph



Analytical

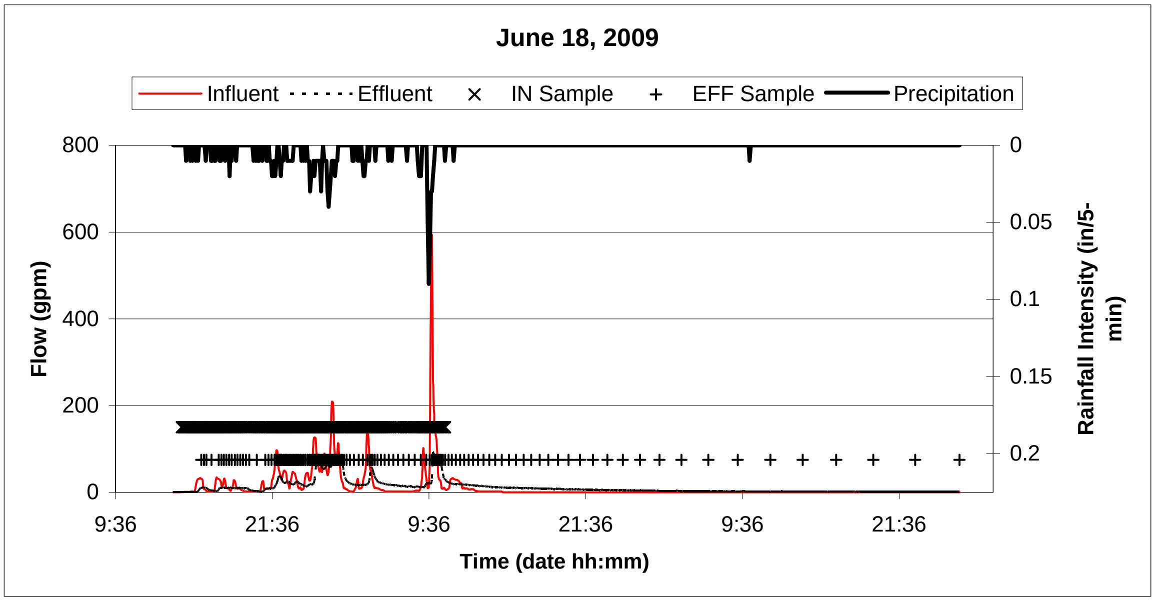
Number of Aliquots
Influent: 200
Effluent: 129

Parameter	Influent	RDL	Effluent	RDL	RE%
TSS (mg/L)	23	2	5	1	78%
TPH-D (ug/L)	310	290	< 330	330	99%
DIN (mg/L)	0.40	0.1	0.60	0.1	-50%
TZn (mg/L)	< 0.05	0.05	< 0.05	0.05	BDL
TP (mg/L)	0.04	0.01	0.03	0.01	25%

General Information	
Site:	University of New Hampshire Stormwater Center, Durham, NH
System Description:	5 x 40 Stormtech Infiltation Chamber
Event Date:	6/18/2009
Date of Last Maintenance:	Never been maintained. Installed September 2006
Antecedent Conditions:	3.5 days

Hydrology	Influent	Effluent	Bypass
Total Precipitation (in):	1.46		
Peak Flow, (gpm):	590	92	100
Total Runoff Volume (gal):	42,092	38,295	1,398
SF Vol. Coverage (nearest 10%):	94.2%	100.0%	100.0%

Event Hydrograph

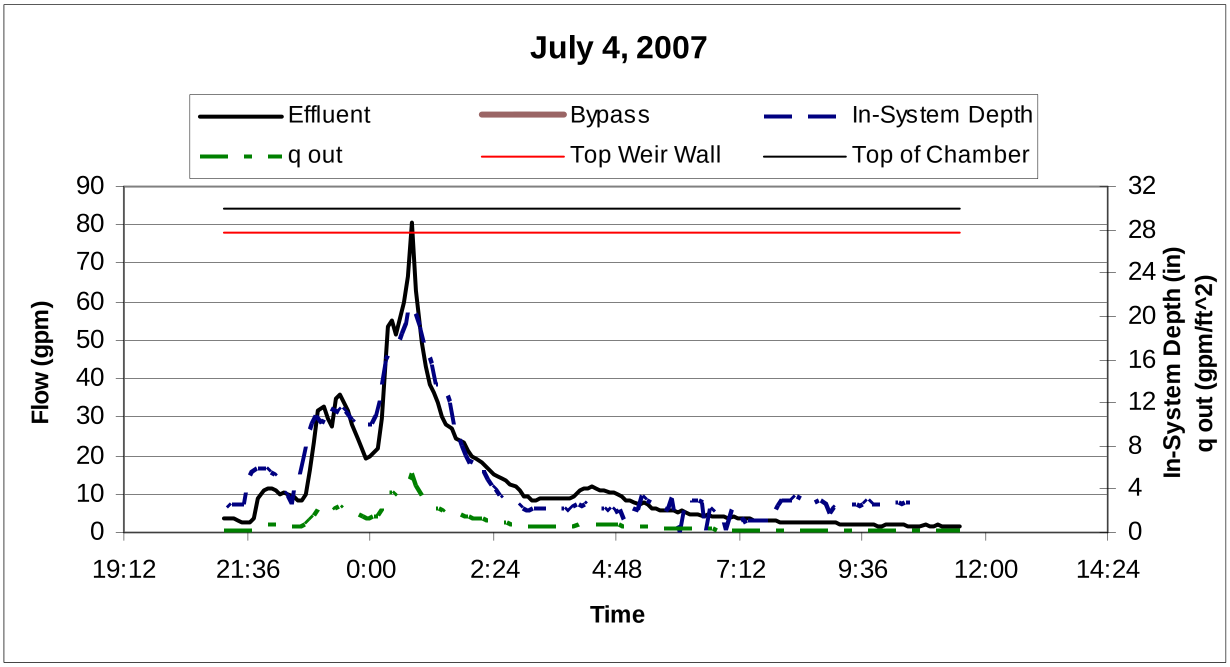


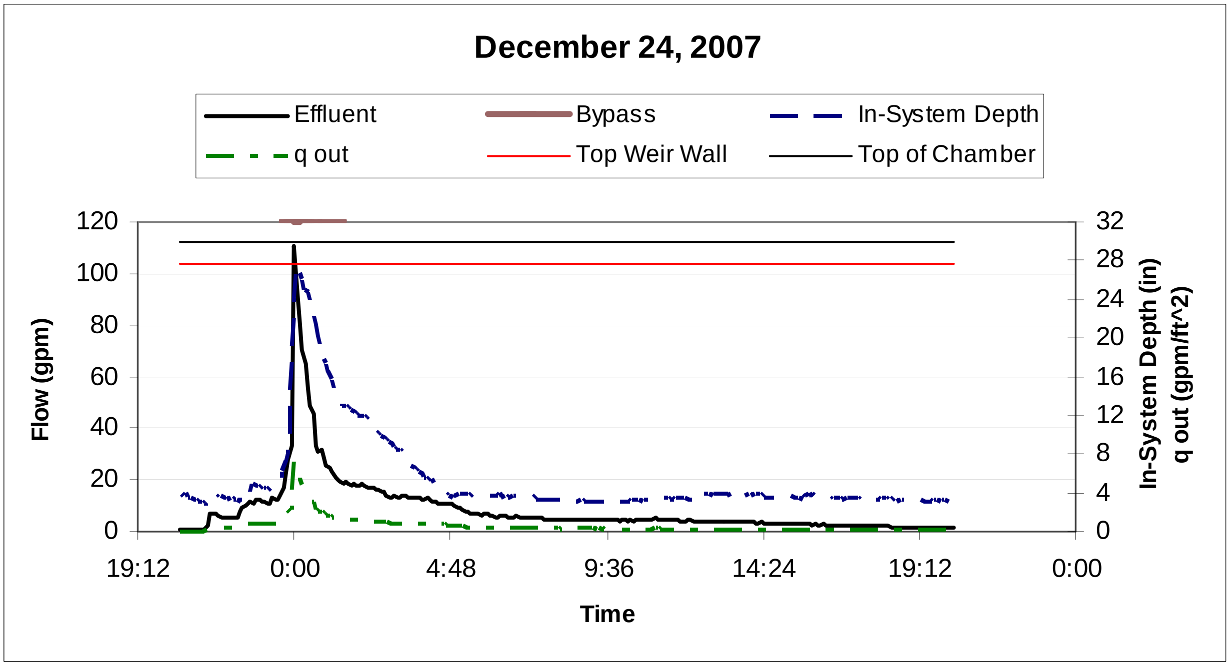
Analytical

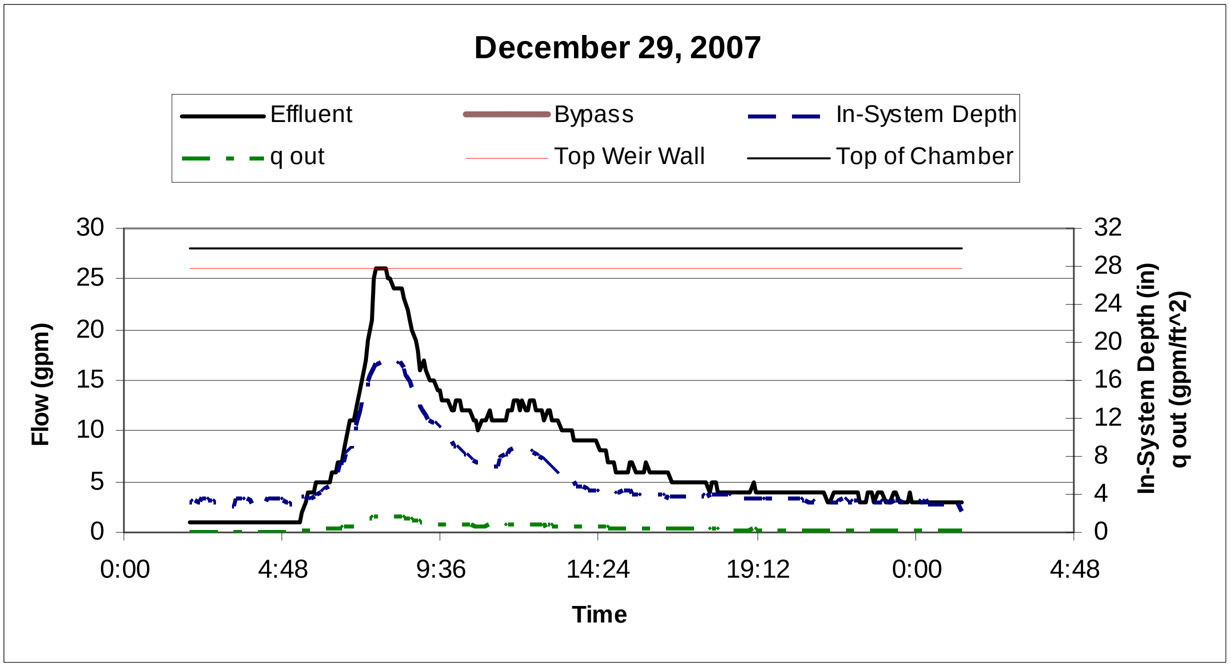
Number of Aliquots
Influent: 240
Effluent: 150

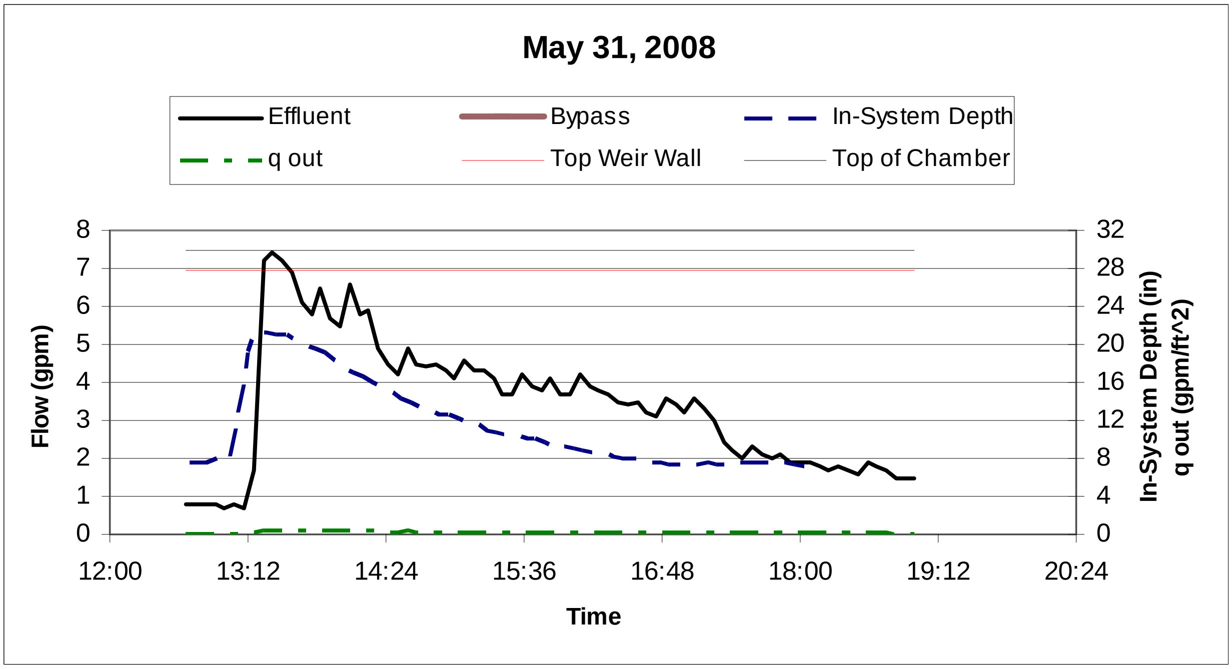
Parameter	Influent	RDL	Effluent	RDL	RE%
TSS (mg/L)	260	1	9	1	97%
TPH-D (ug/L)	< 400	400	< 300	300	BDL
DIN (mg/L)	0.30	0.1	0.20	0.1	33%
TZn (mg/L)	0.020	0.01	BDL	0.01	99%
TP (mg/L)	0.02	0.01	0.02	0.01	0%

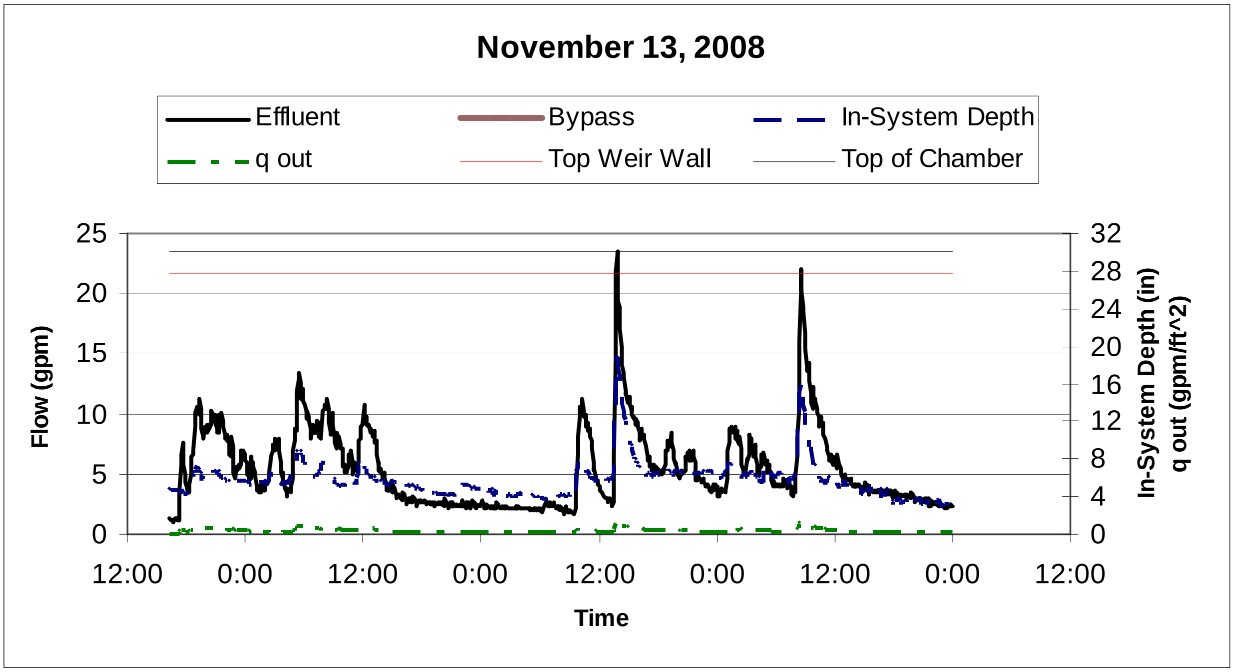
APPENDIX A: DRAIN DOWN AND FILTER CAPACITY PLOTS FOR 12 MONITORED STORM EVENTS.

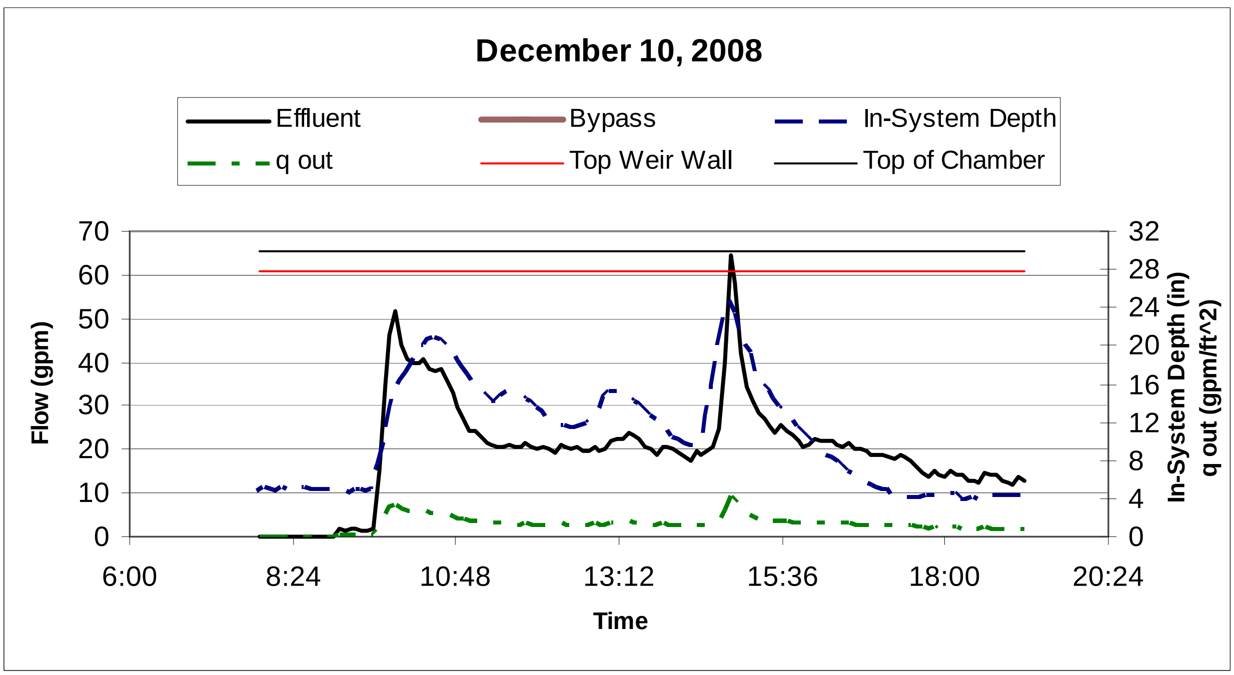


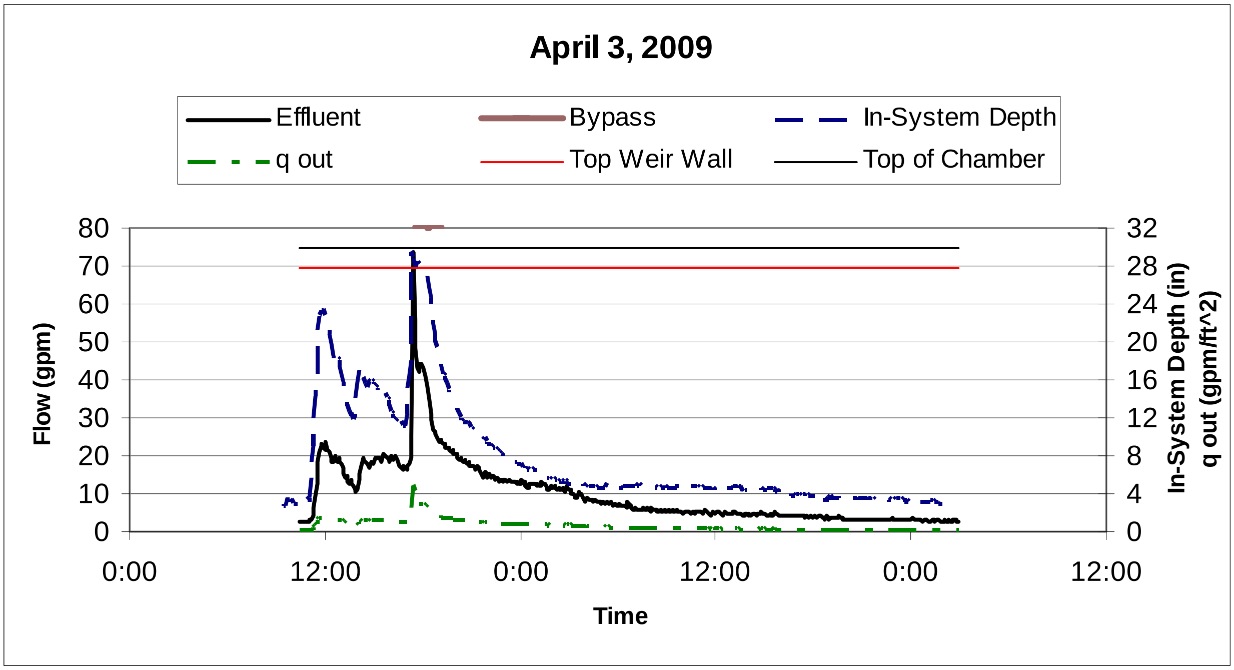



December 29, 2007
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
30
25
20
15
10
5
0
32
28
24
20
16
12
8
4
0
0:00
4:48
9:36
14:24
19:12
0:00
4:48
Time

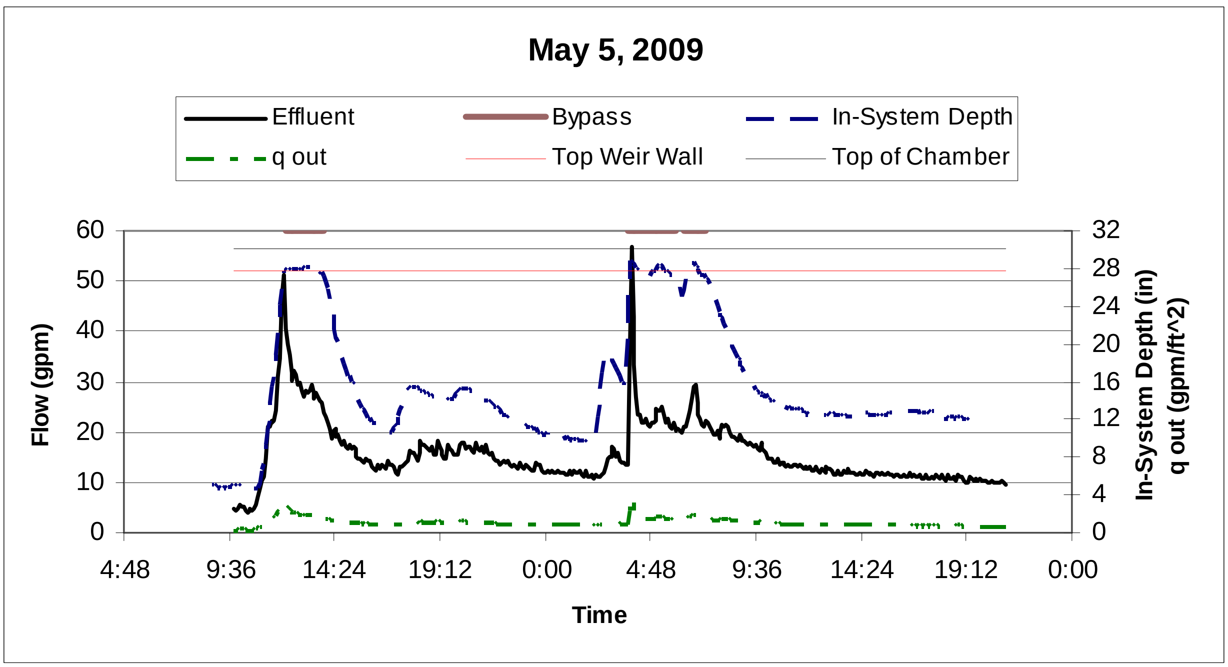

May 31, 2008
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
8
7
6
5
4
3
2
1
0
32
28
24
20
16
12
8
4
0
12:00
13:12
14:24
15:36
16:48
18:00
19:12
20:24
Time


November 13, 2008
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
25
20
15
10
5
0
32
28
24
20
16
12
8
4
0
In-System Depth (in)
q out (gpm/ft^2)
12:00
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time

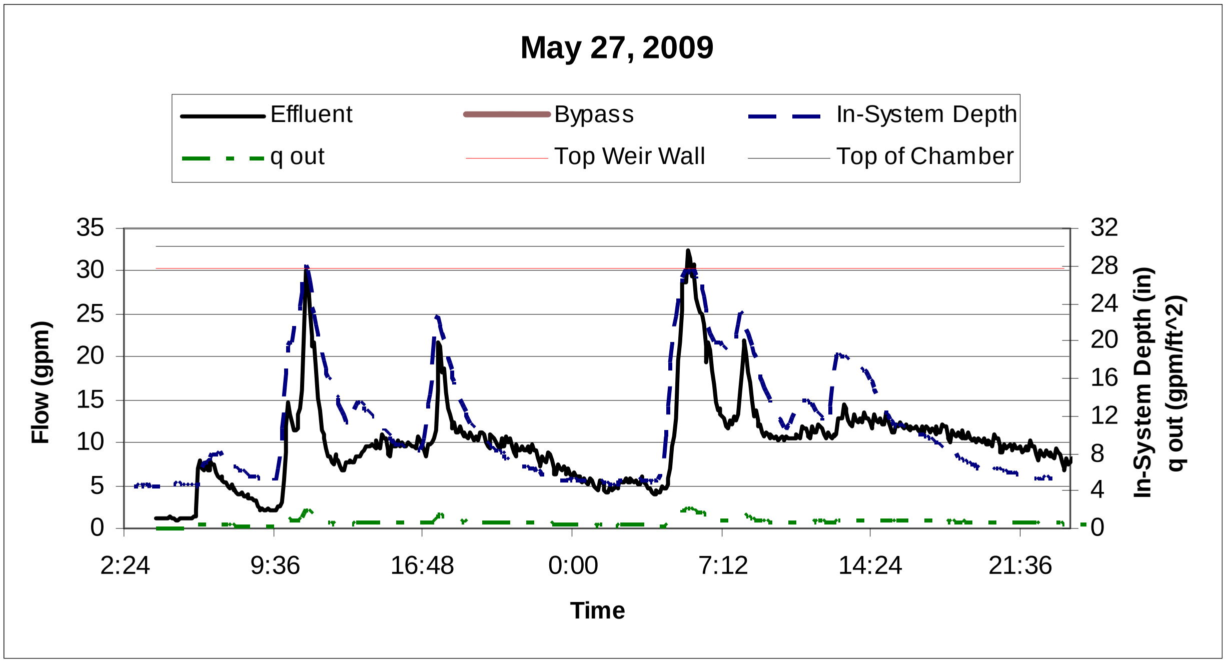

December 10, 2008
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
70
60
50
40
30
20
10
0
32
28
24
20
16
12
8
4
0
In-System Depth (in)
q out (gpm/ft^2)
6:00
8:24
10:48
13:12
15:36
18:00
20:24
Time

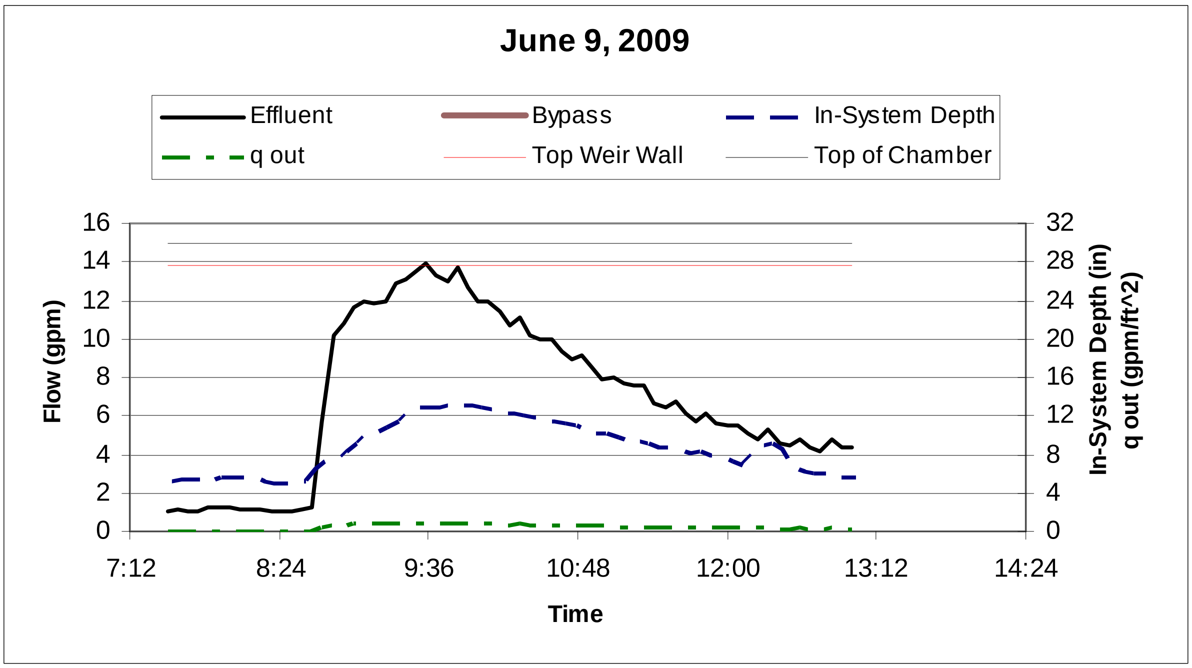


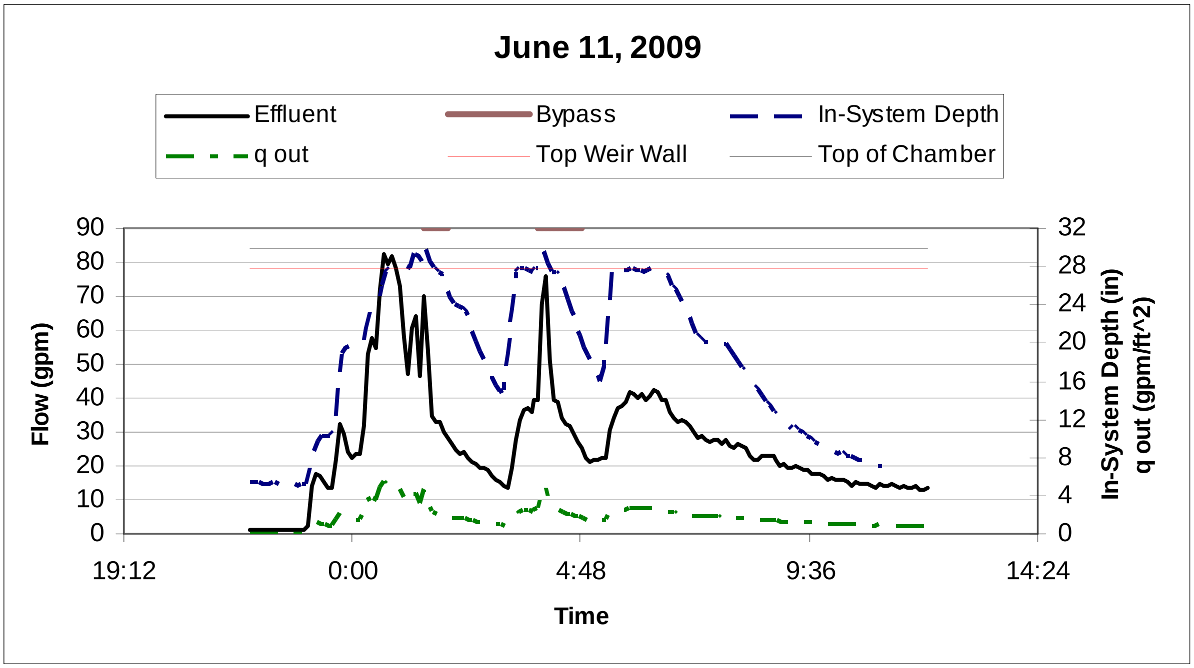
April 3, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
Time

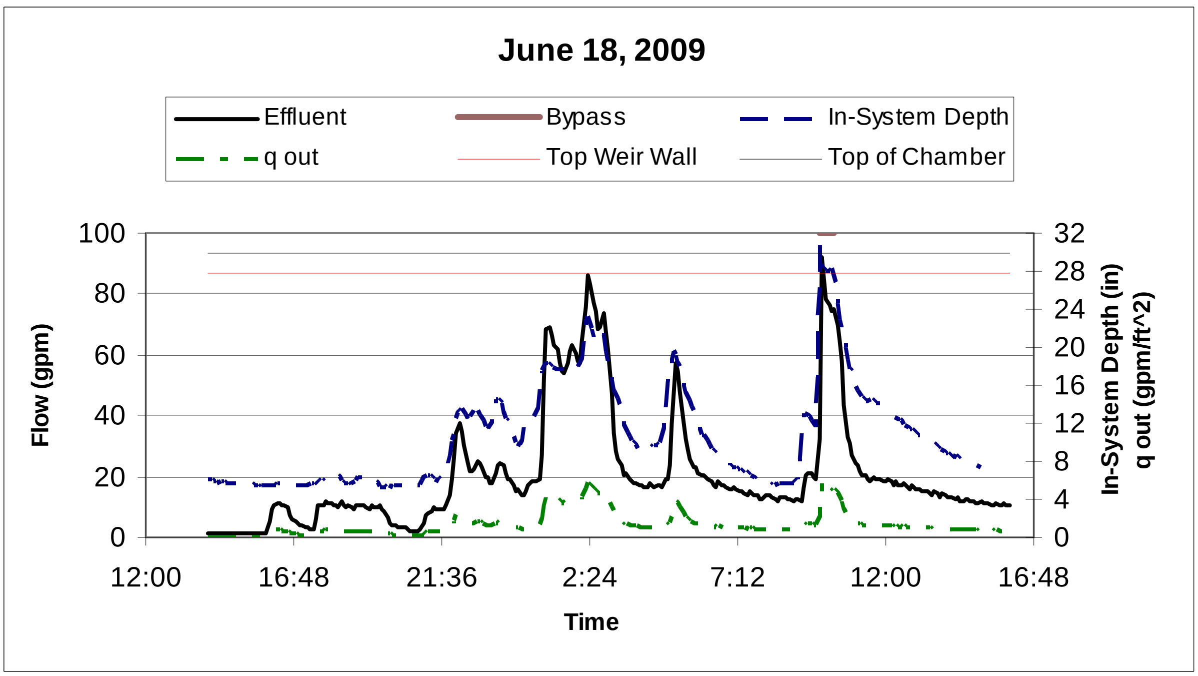


May 5, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
Time


May 27, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
35
30
25
20
15
10
5
0
Flow (gpm)
32
28
24
20
16
12
8
4
0
In-System Depth (in)
q out (gpm/ft^2)
2:24
9:36
16:48
0:00
7:12
14:24
21:36
Time


June 9, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
16
14
12
10
8
6
4
2
0
Flow (gpm)
32
28
24
20
16
12
8
4
0
In-System Depth (in)
q out (gpm/ft^2)
7:12
8:24
9:36
10:48
12:00
13:12
14:24
Time


June 11, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
Time
19:12
0:00
4:48
9:36
14:24


June 18, 2009
Effluent
Bypass
In-System Depth
q out
Top Weir Wall
Top of Chamber
Flow (gpm)
In-System Depth (in)
q out (gpm/ft^2)
Time
12:00
16:48
21:36
2:24
7:12
12:00
16:48

APPENDIX B: MANUFACTURERS PRODUCT SPECIFICATIONS, DRAWINGS, GENERAL NOTES, OPERATIONS AND MAINTENANCE MANUAL

STORMTECH PRODUCT SPECIFICATIONS

1.0 GENERAL

1.1 STORMTECH CHAMBERS ARE DESIGNED TO CONTROL STORMWATER RUNOFF. AS A SUBSURFACE RETENTION SYSTEM, STORMTECH CHAMBERS RETAIN AND ALLOW EFFECTIVE INFILTRATION OF WATER INTO THE SOIL. AS A SUBSURFACE DETENTION SYSTEM, STORMTECH CHAMBERS DETAIN AND ALLOW FOR THE METERED FLOW OF WATER TO AN OUTFALL.

2.0 CHAMBER PARAMETERS

2.1 THE CHAMBER SHALL BE INJECTION MOLDED OF POLYPROPYLENE RESIN TO BE INHERENTLY RESISTANT TO ENVIRONMENTAL STRESS CRACKING (ESCR), AND TO MAINTAIN ADEQUATE STIFFNESS THROUGH HIGHER TEMPERATURES EXPERIENCED DURING INSTALLATION AND SERVICE.

2.2 THE NOMINAL CHAMBER DIMENSIONS OF THE STORMTECH SC-740 SHALL BE 30.0 INCHES TALL, 51.0 INCHES WIDE AND 90.7 INCHES LONG. THE NOMINAL CHAMBER DIMENSIONS OF THE STORMTECH SC-310 SHALL BE 16.0 INCHES TALL, 34.0 INCHES WIDE AND 90.7 INCHES LONG. THE INSTALLED LENGTH OF A JOINED CHAMBER SHALL BE 85.4 INCHES.

2.3 THE CHAMBER SHALL HAVE A CONTINUOUSLY CURVED SECTION PROFILE.

2.4 THE CHAMBER SHALL BE OPEN-BOTTOMED.

2.5 THE CHAMBER SHALL INCORPORATE AN OVERLAPPING CORRUGATION JOINT SYSTEM TO ALLOW CHAMBER ROWS OF ALMOST ANY LENGTH TO BE CREATED. THE OVERLAPPING CORRUGATION JOINT SYSTEM SHALL BE EFFECTIVE WHILE ALLOWING A CHAMBER TO BE TRIMMED TO SHORTEN ITS OVERALL LENGTH.

2.6 THE NOMINAL STORAGE VOLUME OF A JOINED STORMTECH SC-740 CHAMBER SHALL BE 74.9 CUBIC FEET PER CHAMBER WHEN INSTALLED PER STORMTECH'S TYPICAL DETAILS (INCLUDES THE VOLUME OF CRUSHED ANGULAR STONE WITH AN ASSUMED 40% POROSITY). THIS EQUATES TO 2.2 CUBIC FEET OF STORAGE/SQUARE FOOT OF BED. THE NOMINAL STORAGE VOLUME OF AN INSTALLED STORMTECH SC-310 CHAMBER SHALL BE 31.0 CUBIC FEET PER CHAMBER WHEN INSTALLED PER STORMTECH'S TYPICAL DETAILS (INCLUDES THE VOLUME OF CRUSHED ANGULAR STONE WITH AN ASSUMED 40% POROSITY). THIS EQUATES TO 1.3 CUBIC FEET OF STORAGE/SQUARE FOOT OF BED.

2.7 THE CHAMBER SHALL HAVE FORTY-EIGHT ORIFICES PENETRATING THE SIDEWALLS TO ALLOW FOR LATERAL CONVEYANCE OF WATER.

2.8 THE CHAMBER SHALL HAVE TWO ORIFICES NEAR ITS TOP TO ALLOW FOR EQUALIZATION OF AIR PRESSURE BETWEEN ITS INTERIOR AND EXTERIOR.

2.9 THE CHAMBER SHALL HAVE BOTH OF ITS ENDS OPEN TO ALLOW FOR UNIMPEDED HYDRAULIC FLOWS AND VISUAL INSPECTIONS DOWN A ROW'S ENTIRE LENGTH.

2.10 THE CHAMBER SHALL HAVE 14 CORRUGATIONS.

2.11 THE CHAMBER SHALL HAVE A CIRCULAR, INDENTED, FLAT SURFACE ON THE TOP OF THE CHAMBER FOR AN OPTIONAL 4-INCH INSPECTION PORT.

2.12 THE CHAMBER SHALL BE ANALYZED AND DESIGNED USING AASHTO METHODS FOR THERMOPLASTIC CULVERTS CONTAINED IN THE LRFD BRIDGE DESIGN SPECIFICATIONS, 2ND EDITION, INCLUDING INTERIM SPECIFICATIONS THROUGH 2001. DESIGN LIVE LOAD SHALL BE THE AASHTO HS20 TRUCK. DESIGN SHALL CONSIDER EARTH AND LIVE LOADS AS APPROPRIATE FOR THE MINIMUM TO MAXIMUM SPECIFIED DEPTH OF FILL.

2.13 THE CHAMBER SHALL BE MANUFACTURED IN AN ISO 9001:2000 CERTIFIED FACILITY.

3.0 END CAP PARAMETERS

3.1 THE END CAP SHALL BE INJECTION MOLDED OF POLYETHYLENE RESIN TO HELP FACILITATE FACTORY MANUFACTURED PIPE FITTINGS.

3.2 THE END CAP SHALL BE DESIGNED TO FIT INTO ANY CORRUGATION OF A CHAMBER, WHICH ALLOWS: CAPPING A CHAMBER THAT HAS ITS LENGTH TRIMMED; SEGMENTING ROWS INTO STORAGE BASINS OF VARIOUS LENGTHS.

3.3 THE END CAP SHALL HAVE SAW GUIDES TO ALLOW EASY CUTTING FOR VARIOUS DIAMETERS OF PIPE THAT MAY BE USED TO INLET THE SYSTEM.

3.4 THE END CAP SHALL HAVE EXCESS STRUCTURAL ADEQUACIES TO ALLOW CUTTING AN ORIFICE OF ANY SIZE AT ANY INVERT ELEVATION.

3.5 THE PRIMARY FACE OF AN END CAP SHALL BE CURVED OUTWARD TO RESIST HORIZONTAL LOADS GENERATED NEAR THE EDGES OF BEDS.

3.6 THE END CAP SHALL BE MANUFACTURED IN AN ISO 9001:2000 CERTIFIED FACILITY.

* NOTE: CHAMBER SYSTEM DESIGN MUST BE IN ACCORDANCE WITH STORMTECH DESIGN MANUAL

STORMTECH LLC CONCEPTUAL PLAN DISCLAIMER

THIS STORMTECH CHAMBER SYSTEM LAYOUT WAS PRODUCED TO DEMONSTRATE A BED LAYOUT THAT WILL HANDLE THE DESIGN VOLUME LISTED ABOVE. THE SIZING, FIT AND APPLICABILITY OF THE STORMTECH CHAMBER SYSTEM FOR THIS SPECIFIC PROJECT HAS NOT BEEN DETERMINED. IT IS THE ULTIMATE RESPONSIBILITY OF THE DESIGN ENGINEER TO ASSURE THAT THE STORMWATER SYSTEM DESIGN IS IN FULL COMPLIANCE WITH ALL APPLICABLE LAWS AND REGULATIONS. STORMTECH PRODUCTS MUST BE DESIGNED AND INSTALLED IN ACCORDANCE WITH STORMTECH'S MINIMUM REQUIREMENTS. STORMTECH LLC DOES NOT APPROVE PLANS, SIZING, OR SYSTEM DESIGNS. THE DESIGN ENGINEER IS RESPONSIBLE FOR ALL DESIGN DECISIONS.

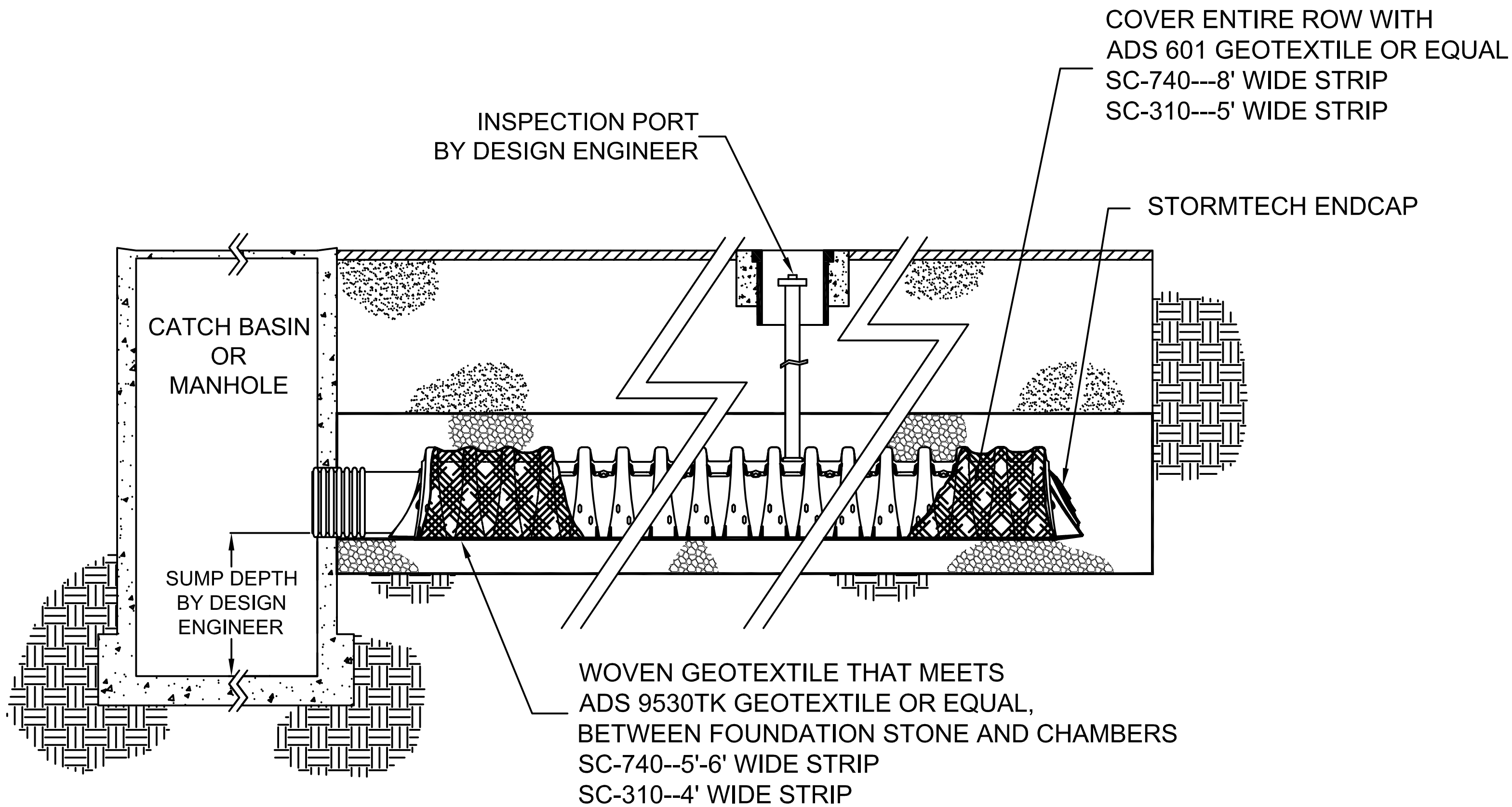
S:\AppEng-shared\ADS-Hancor Standard Details\Stormtech\ADS\StormTech Product Specifications.dwg, Model, 10/23/2007 9:58:36 AM, csimmers, Adobe PDF

StormTech Detention•Retention•Recharge
Subsurface Stormwater Management℠

20 Beaver Road, Suite 104
Wethersfield, CT 06109
Phone: 888-892-2694
Fax: 866-328-8401
www.stormtech.com

STORMTECH PRODUCT SPECIFICATIONS

SCALE: NTS	CHECKED
DATE:	ACAD No.
DRAWN BY:	SHEET OF



* NOTE: CHAMBER SYSTEM DESIGN MUST BE IN ACCORDANCE WITH STORMTECH DESIGN MANUAL

STORMTECH LLC CONCEPTUAL PLAN DISCLAIMER

THIS STORMTECH CHAMBER SYSTEM LAYOUT WAS PRODUCED TO DEMONSTRATE A BED LAYOUT THAT WILL HANDLE THE DESIGN VOLUME LISTED ABOVE. THE SIZING, FIT AND APPLICABILITY OF THE STORMTECH CHAMBER SYSTEM FOR THIS SPECIFIC PROJECT HAS NOT BEEN DETERMINED. IT IS THE ULTIMATE RESPONSIBILITY OF THE DESIGN ENGINEER TO ASSURE THAT THE STORMWATER SYSTEM DESIGN IS IN FULL COMPLIANCE WITH ALL APPLICABLE LAWS AND REGULATIONS. STORMTECH PRODUCTS MUST BE DESIGNED AND INSTALLED IN ACCORDANCE WITH STORMTECH'S MINIMUM REQUIREMENTS. STORMTECH LLC DOES NOT APPROVE PLANS, SIZING, OR SYSTEM DESIGNS. THE DESIGNING ENGINEER IS RESPONSIBLE FOR ALL DESIGN DECISIONS.

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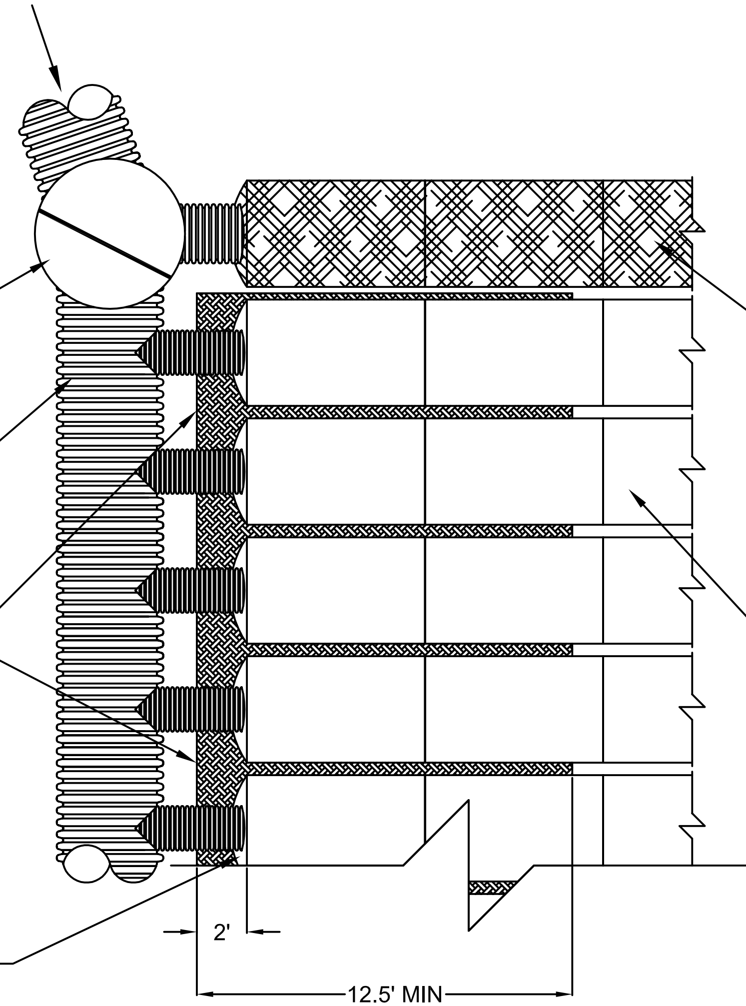
Detention•Retention•Recharge
Subsurface Stormwater Management™
20 Beaver Road, Suite 104
Wethersfield, CT 06109
Phone: 888-892-2694
Fax: 866-328-8401
www.stormtech.com

STORMTECH ISOLATOR ROW PROFILE

SCALE: NTS	CHECKED
DATE:	ACAD No.
DRAWN BY:	SHEET OF



* NOTE: CHAMBER SYSTEM DESIGN MUST BE IN ACCORDANCE WITH STORMTECH DESIGN MANUAL

STORMTECH LLC CONCEPTUAL PLAN DISCLAIMER

THIS STORMTECH CHAMBER SYSTEM LAYOUT WAS PRODUCED TO DEMONSTRATE A BED LAYOUT THAT WILL HANDLE THE DESIGN VOLUME LISTED ABOVE. THE SIZING, FIT AND APPLICABILITY OF THE STORMTECH CHAMBER SYSTEM FOR THIS SPECIFIC PROJECT HAS NOT BEEN DETERMINED. IT IS THE ULTIMATE RESPONSIBILITY OF THE DESIGN ENGINEER TO ASSURE THAT THE STORMWATER SYSTEM DESIGN IS IN FULL COMPLIANCE WITH ALL APPLICABLE LAWS AND REGULATIONS. STORMTECH PRODUCTS MUST BE DESIGNED AND INSTALLED IN ACCORDANCE WITH STORMTECH'S MINIMUM REQUIREMENTS. STORMTECH LLC DOES NOT APPROVE PLANS, SIZING, OR SYSTEM DESIGNS. THE DESIGNING ENGINEER IS RESPONSIBLE FOR ALL DESIGN DECISIONS.

FOR STORMTECH INFORMATION
CALL 1-888-892-2694

StormTech Detention•Retention•Recharge
Subsurface Stormwater Management™
20 Beaver Road, Suite 104
Wethersfield, CT 06109
Phone: 888-892-2694
Fax: 866-328-8401
www.stormtech.com

ISOLATOR ROW MANIFOLD DETAIL

SCALE:	NTS	CHECKED	
DATE:	9/25/2007	ACAD NO.	
DRAWN BY:		SHEET	OF

STORMTECH GENERAL NOTES

1. STORMTECH LLC ("STORMTECH") REQUIRES INSTALLING CONTRACTORS TO USE AND UNDERSTAND STORMTECH'S LATEST INSTALLATION INSTRUCTIONS PRIOR TO BEGINNING SYSTEM INSTALLATION.

2. OUR TECHNICAL SERVICES DEPARTMENT OFFERS INSTALLATION CONSULTATIONS TO INSTALLING CONTRACTORS. CONTACT OUR TECHNICAL SERVICES REPRESENTATIVE AT LEAST 30 DAYS PRIOR TO SYSTEM INSTALLATION TO ARRANGE A PRE-INSTALLATION CONSULTATION. OUR REPRESENTATIVES CAN THEN ANSWER QUESTIONS OR ADDRESS COMMENTS ON THE STORMTECH CHAMBER SYSTEM AND INFORM THE INSTALLING CONTRACTOR OF THE MINIMUM INSTALLATION REQUIREMENTS BEFORE BEGINNING THE SYSTEM'S CONSTRUCTION. CALL **1-888-892-2694** TO SPEAK TO A TECHNICAL SERVICE REPRESENTATIVE OR VISIT **WWW.STORMTECH.COM** TO RECEIVE A COPY OF OUR INSTALLATION INSTRUCTIONS.

3. STORMTECH'S REQUIREMENTS FOR SYSTEMS WITH PAVEMENT DESIGN (ASPHALT, CONCRETE PAVERS, ETC.): MINIMUM COVER IS 18 INCHES NOT INCLUDING PAVEMENT; MAXIMUM COVER IS 96 INCHES INCLUDING PAVEMENT. FOR INSTALLATIONS THAT DO NOT INCLUDE PAVEMENT, WHERE RUTTING FROM VEHICLES MAY OCCUR, MINIMUM REQUIRED COVER IS 24 INCHES, MAXIMUM COVER IS 96 INCHES.

4. THE CONTRACTOR MUST REPORT ANY DISCREPANCIES WITH CHAMBER FOUNDATION MATERIALS BEARING CAPACITIES TO THE DESIGN ENGINEER.

5. AASHTO M288 CLASS 2 NON-WOVEN GEOTEXTILE (FILTER FABRIC) MUST BE USED AS INDICATED IN THE PROJECT PLANS.

6. STONE PLACEMENT BETWEEN CHAMBERS ROWS AND AROUND PERIMETER MUST FOLLOW INSTRUCTIONS AS INDICATED IN THE MOST CURRENT VERSION OF STORMTECH'S INSTALLATION INSTRUCTIONS.

7. BACKFILLING OVER THE CHAMBERS MUST FOLLOW REQUIREMENTS AS INDICATED IN THE MOST CURRENT VERSION OF STORMTECH'S INSTALLATION INSTRUCTIONS.

8. THE CONTRACTOR MUST REFER TO STORMTECH'S INSTALLATION INSTRUCTIONS FOR A TABLE OF ACCEPTABLE VEHICLE LOADS AT VARIOUS DEPTHS OF COVER. THIS INFORMATION IS ALSO AVAILABLE AT STORMTECH'S WEBSITE: **WWW.STORMTECH.COM**. THE CONTRACTOR IS RESPONSIBLE FOR PREVENTING VEHICLES THAT EXCEED STORMTECH'S REQUIREMENTS FROM TRAVELING ACROSS OR PARKING OVER THE STORMWATER SYSTEM. TEMPORARY FENCING, WARNING TAPE AND APPROPRIATELY LOCATED SIGNS ARE COMMONLY USED TO PREVENT UNAUTHORIZED VEHICLES FROM ENTERING SENSITIVE CONSTRUCTION AREAS.

9. THE CONTRACTOR MUST APPLY EROSION AND SEDIMENT CONTROL MEASURES TO PROTECT THE STORMWATER SYSTEM DURING ALL PHASES OF SITE CONSTRUCTION PER LOCAL CODES AND DESIGN ENGINEER'S SPECIFICATIONS.

10. STORMTECH PRODUCT WARRANTY IS LIMITED. SEE CURRENT PRODUCT WARRANTY FOR DETAILS. TO ACQUIRE A COPY CALL STORMTECH AT **1-888-892-2694** OR VISIT **WWW.STORMTECH.COM**.

* NOTE: CHAMBER SYSTEM DESIGN MUST BE IN ACCORDANCE WITH STORMTECH DESIGN MANUAL

STORMTECH LLC CONCEPTUAL PLAN DISCLAIMER

THIS STORMTECH CHAMBER SYSTEM LAYOUT WAS PRODUCED TO DEMONSTRATE A BED LAYOUT THAT WILL HANDLE THE DESIGN VOLUME LISTED ABOVE. THE SIZING, FIT AND APPLICABILITY OF THE STORMTECH CHAMBER SYSTEM FOR THIS SPECIFIC PROJECT HAS NOT BEEN DETERMINED. IT IS THE ULTIMATE RESPONSIBILITY OF THE DESIGN ENGINEER TO ASSURE THAT THE STORMWATER SYSTEM DESIGN IS IN FULL COMPLIANCE WITH ALL APPLICABLE LAWS AND REGULATIONS. STORMTECH PRODUCTS MUST BE DESIGNED AND INSTALLED IN ACCORDANCE WITH STORMTECH'S MINIMUM REQUIREMENTS. STORMTECH LLC DOES NOT APPROVE PLANS, SIZING, OR SYSTEM DESIGNS. THE DESIGNING ENGINEER IS RESPONSIBLE FOR ALL DESIGN DECISIONS.

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STORMTECH GENERAL NOTES

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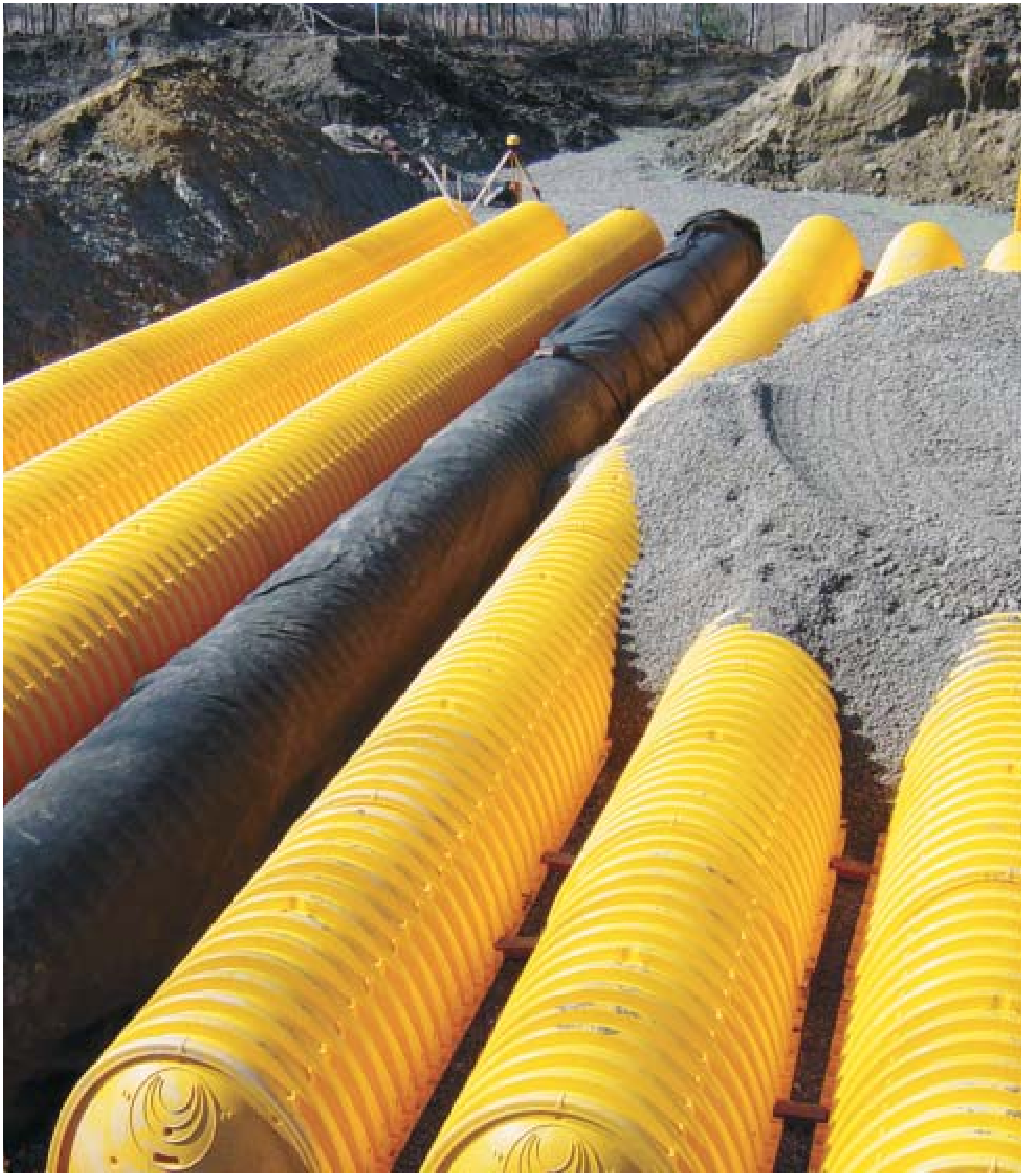


Isolator™ Row O&M Manual

StormTech® Chamber System for Stormwater Management

1.0 The Isolator™ Row

1.1 INTRODUCTION

An important component of any Stormwater Pollution Prevention Plan is inspection and maintenance. The StormTech Isolator Row is a patent pending technique to inexpensively enhance Total Suspended Solids (TSS) removal and provide easy access for inspection and maintenance.

Looking down the Isolator Row from the manhole opening, woven geotextile is shown between the chamber and stone base.

1.2 THE ISOLATOR™ ROW

The Isolator Row is a row of StormTech chambers, either SC-740 or SC-310 models, that is surrounded with filter fabric and connected to a closely located manhole for easy access. The fabric-wrapped chambers provide for settling and filtration of sediment as storm water rises in the Isolator Row and ultimately passes through the filter fabric. The open bottom chambers and perforated sidewalls allow storm water to flow both vertically and horizontally out of the chambers. Sediments are captured in the Isolator Row protecting the storage areas of the adjacent stone and chambers from sediment accumulation.

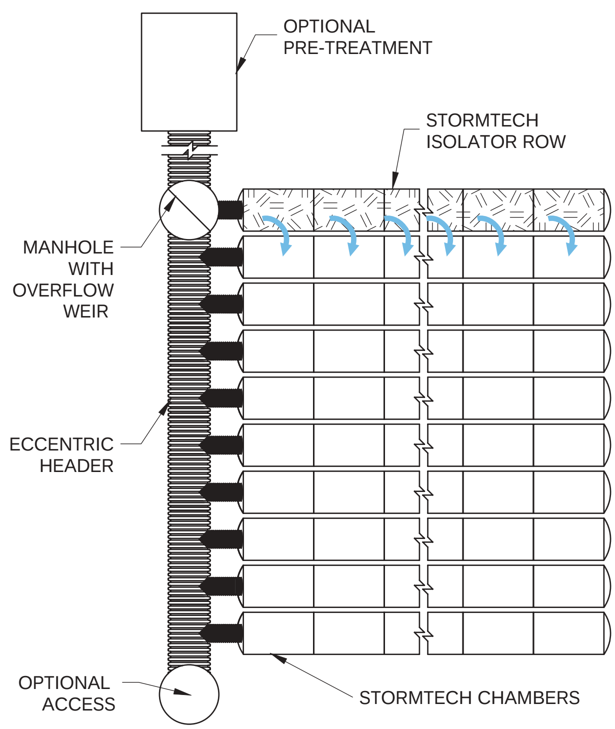
Two different fabrics are used for the Isolator Row. A woven geotextile fabric is placed between the stone and the Isolator Row chambers. The tough geotextile provides a media for storm water filtration and provides a durable surface for maintenance operations. It is also designed to prevent scour of the underlying stone and remain intact during high pressure jetting. A non-woven fabric is placed over the chambers to provide a filter media for flows passing through the perforations in the sidewall of the chamber.

The Isolator Row is typically designed to capture the "first flush" and offers the versatility to be sized on a volume basis or flow rate basis. An upstream manhole not only provides access to the Isolator Row but typically includes a high flow weir such that storm water flowrates or volumes that exceed the capacity of the Isolator Row overtop the over flow weir and discharge through a manifold to the other chambers.

The Isolator Row may also be part of a treatment train. By treating storm water prior to entry into the chamber system, the service life can be extended and pollutants such as hydrocarbons can be captured. Pre-treatment best management practices can be as simple as deep sump catch basins, oil-water separators or can be innovative storm water treatment devices. The design of the treatment train and selection of pretreatment devices by the design engineer is often driven by regulatory requirements. Whether pretreatment is used or not, the Isolator Row is recommended by StormTech as an effective means to minimize maintenance requirements and maintenance costs.

Note: See the StormTech Design Manual for detailed information on designing inlets for a StormTech system, including the Isolator Row.

StormTech Isolator Row with Overflow Spillway
(not to scale)



2.1 INSPECTION

The frequency of Inspection and Maintenance varies by location. A routine inspection schedule needs to be established for each individual location based upon site specific variables. The type of land use (i.e. industrial, commercial residential), anticipated pollutant load, percent imperviousness, climate, etc. all play a critical role in determining the actual frequency of inspection and maintenance practices.

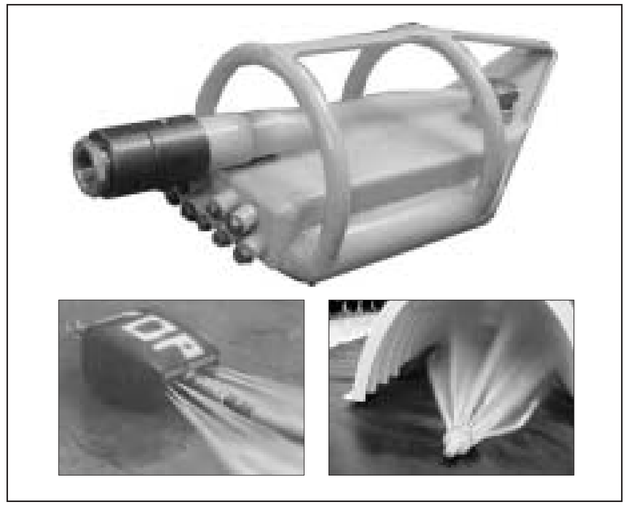
At a minimum, StormTech recommends annual inspections. Initially, the Isolator Row should be inspected every 6 months for the first year of operation. For subsequent years, the inspection should be adjusted based upon previous observation of sediment deposition.

The Isolator Row incorporates a combination of standard manhole(s) and strategically located inspection ports (as needed). The inspection ports allow for easy access to the system from the surface, eliminating the need to perform a confined space entry for inspection purposes.

If upon visual inspection it is found that sediment has accumulated, a stadia rod should be inserted to determine the depth of sediment. When the average depth of sediment exceeds 3 inches throughout the length of the Isolator Row, clean-out should be performed.

2.2 MAINTENANCE

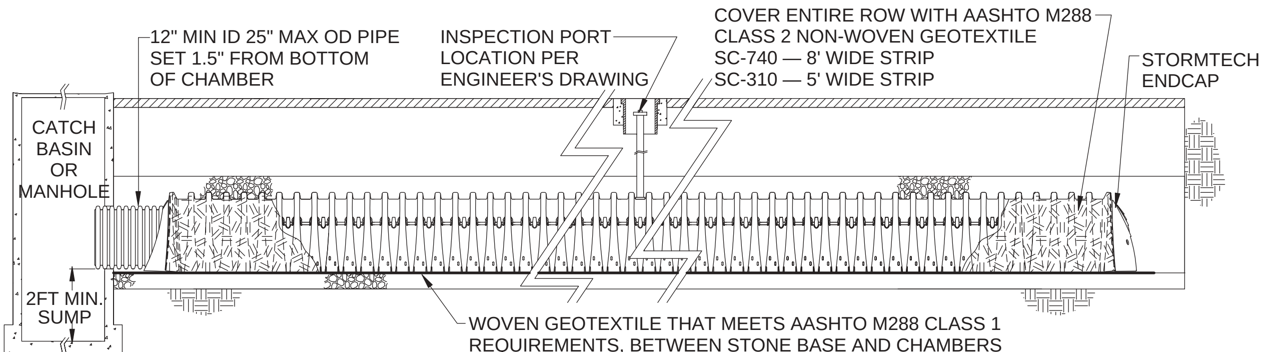
The Isolator Row was designed to reduce the cost of periodic maintenance. By “isolating” sediments to just one row, costs are dramatically reduced by eliminating the need to clean out each row of the entire storage bed. If inspection indicates the potential need for maintenance, access is provided via a manhole(s) located on the end(s) of the row for cleanout. If entry into the manhole is required, please follow local and OSHA rules for a confined space entries.



Examples of culvert cleaning nozzles appropriate for Isolator Row maintenance. (These are not StormTech products.)

Maintenance is accomplished with the JetVac process. The JetVac process utilizes a high pressure water nozzle to propel itself down the Isolator Row while scouring and suspending sediments. As the nozzle is retrieved, the captured pollutants are flushed back into the manhole for vacuuming. Most sewer and pipe maintenance companies have vacuum/JetVac combination vehicles. Selection of an appropriate JetVac nozzle will improve maintenance efficiency. Fixed nozzles designed for culverts or large diameter pipe cleaning are preferable. Rear facing jets with an effective spread of at least 45” are best. Most JetVac reels have 400 feet of hose allowing maintenance of an Isolator Row up to 50 chambers long. **The JetVac process shall only be performed on StormTech Isolator Rows that have AASHTO class 1 woven geotextile (as specified by StormTech) over their angular base stone.**

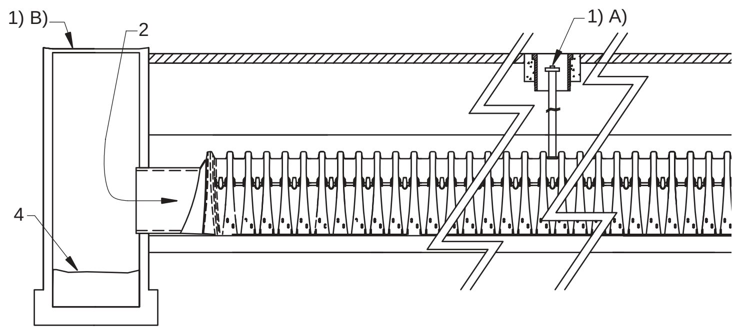
StormTech Isolator Row (not to scale)



3.0 Isolator Row Step By Step Maintenance Procedures

Step 1) Inspect Isolator Row for sediment
- A) Inspection ports (if present)
  - i. Remove lid from floor box frame
  - ii. Remove cap from inspection riser
  - iii. Using a flashlight and stadia rod, measure depth of sediment and record results on maintenance log.
  - iv. If sediment is at, or above, 3 inch depth proceed to Step 2. If not proceed to step 3.
- B) All Isolator Rows
  - i. Remove cover from manhole at upstream end of Isolator Row
  - ii. Using a flashlight, inspect down Isolator Row through outlet pipe
    1. Mirrors on poles or cameras may be used to avoid a confined space entry
    2. Follow OSHA regulations for confined space entry if entering manhole
  - iii. If sediment is at or above the lower row of sidewall holes (approximately 3 inches) proceed to Step 2. If not proceed to Step 3.

StormTech Isolator Row (not to scale)



Step 2) Clean out Isolator Row using the JetVac process
- A) A fixed culvert cleaning nozzle with rear facing nozzle spread of 45 inches or more is preferable
- B) Apply multiple passes of JetVac until backflush water is clean
- C) Vacuum manhole sump as required

Step 3) Replace all caps, lids and covers, record observations and actions

Step 4) Inspect & clean catch basins and manholes upstream of the StormTech system

Sample Maintenance Log

Date	Stadia Rod Readings		Sediment Depth (1) - (2)	Observations/Actions	Inspector
	Fixed point to chamber bottom (1)	Fixed point to top of sediment (2)			
3/15/01	6.3 ft.	none		New installation. Fixed point is CI frame at grade	djm
9/24/01		6.2	0.1 ft.	Some grit felt	sm
6/20/03		5.8	0.5 ft.	Mucky feel, debris visible in manhole and in Isolator row, maintenance due	rv
7/7/03	6.3 ft.		0	System jetted and vacuumed	djm

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CITY of CHARLOTTE
Pilot SCM Monitoring Program

Cherry Gardens Senior Apartments
Storm Tech Chambers Stormwater Treatment Structure

Final Monitoring Report

July 2013

Prepared By:

Steve Jadlocki
Kyle Hall, EI
Jeff Price

Charlotte-Mecklenburg Storm Water Services

INTRODUCTION

The City of Charlotte through its Stormwater Services Division maintains an aggressive Pilot Stormwater Control Measure (SCM) Program. The purpose of the pilot program is to monitor various types of structural SCMs within varied land use types to determine their best use and effectiveness in Charlotte's overall stormwater quality management program. Specifically, the program strives to determine the cost benefit, pollutant removal and load reduction efficiency, quantity control, and operation & maintenance costs/requirements of the various structural SCMs within the pilot program. The City utilizes information gained under the Pilot SCM Program to support water quality management efforts and the development and refinement of local SCM standards for land development projects.

During 2008, the City of Charlotte began reviewing plans for the Cherry Gardens Senior Apartments in Charlotte. The developer for the project had requested to utilize Storm Tech Chambers, a proprietary SCM technology in lieu of conventional stormwater treatment for the site. Although this proprietary technology was not approved for use within the City, under the Pilot SCM program the City was able to grant approval for installation of the SCM technology within the project stormwater system design.

Storm Tech chambers feature a unique sub-surface design of open bottom polypropylene chambers set on a stone bed within an excavation trench. The internal volume of the chambers, as well as the void space of the stone bedding and chamber surrounding stone material provide stormwater storage volume designed to meet water quality and detention requirements. In addition, the system features an "isolator row" to provide water quality treatment of stormwater as it enters the system. The isolator row features a typical Storm Tech chamber wrapped with filter fabric. Stormwater first enters the isolator row which traps sediments and pollutants via the filter fabric and then allows stormwater to pass through the fabric in a treated state to the adjacent chambers and stone material via hydrostatic flow. The overall system typically features a 6-inch HDPE perforated under drain line placed along one side of the excavation bottom to provide flow discharge control from the system. Because the excavation for the system is typically unlined, some infiltration of stormwater can be expected if sub-surface soils are conducive to infiltration.

This monitoring report will focus on the installation, monitoring, and water quality treatment effectiveness of the Storm Tech Chambers installed to treat the parking lot portion of the site. Additional information about the SCM is available at the Storm Tech website: www.stormtech.com

PROJECT DESIGN

The project design called for the installation of a Storm Tech Chamber system to treat 0.41 acres of the site. The watershed area draining to the SCM consisted of approximately 85% impervious surface comprised of a parking lot and adjoining sidewalk within a residential land use. The SCM system was designed to treat the 1-inch water quality volume and meet the stormwater detention requirements for Charlotte. The system was also designed with a bypass pipe to allow higher flows to bypass the isolator row and flow directly into adjoining chambers in the system.

The overall system design called for 5 rows of Storm Tech chambers, one of which was the isolator row. **Figures 1 and 2** show the plan view layout and SCM details for the project respectively.

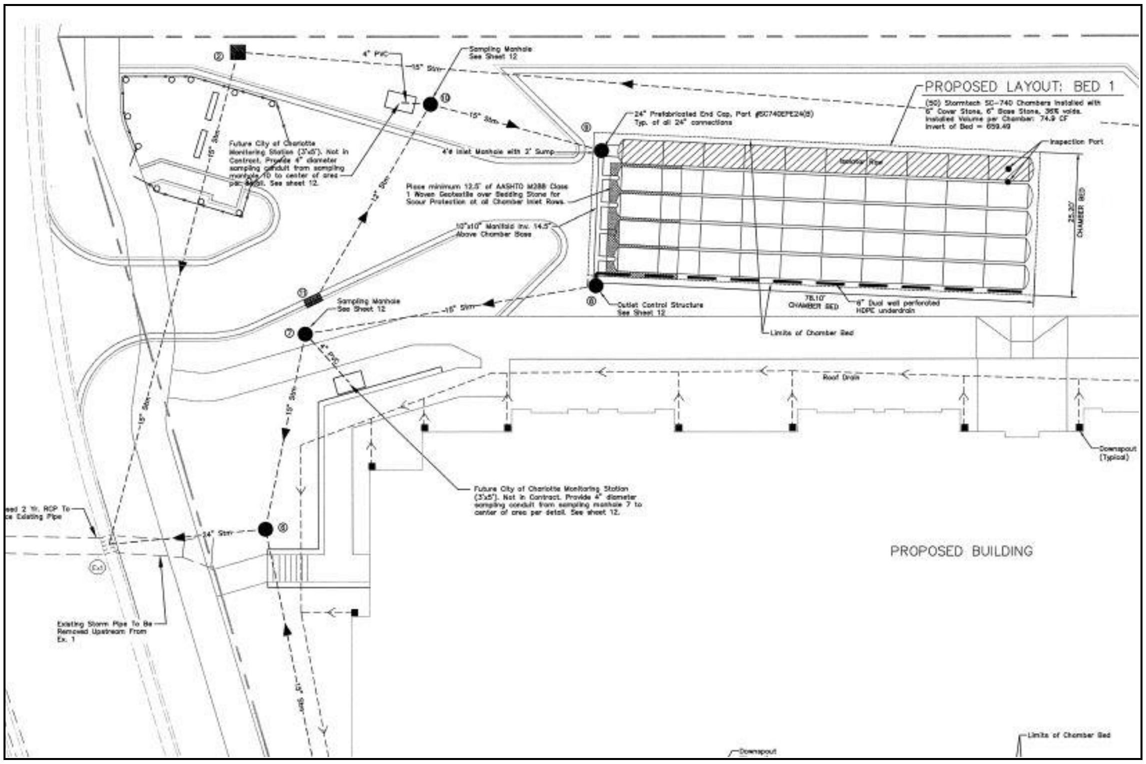
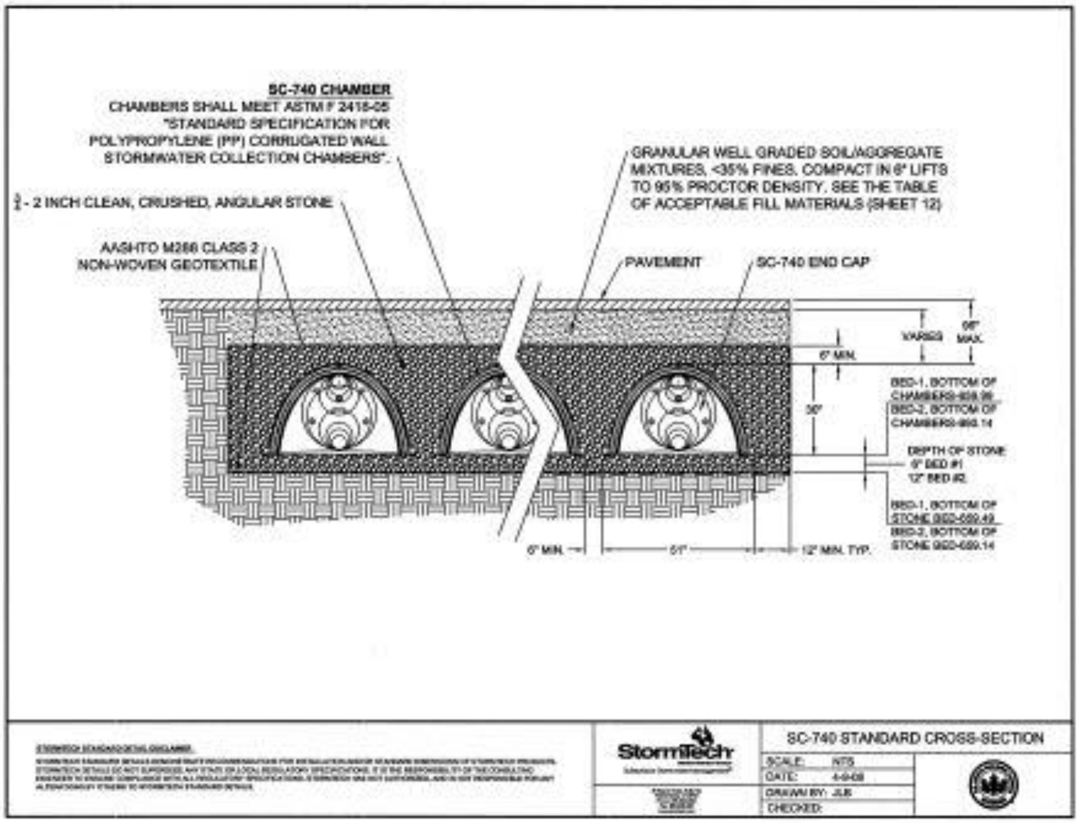


Figure 1: Cherry Gardens Storm Tech Plan View Layout



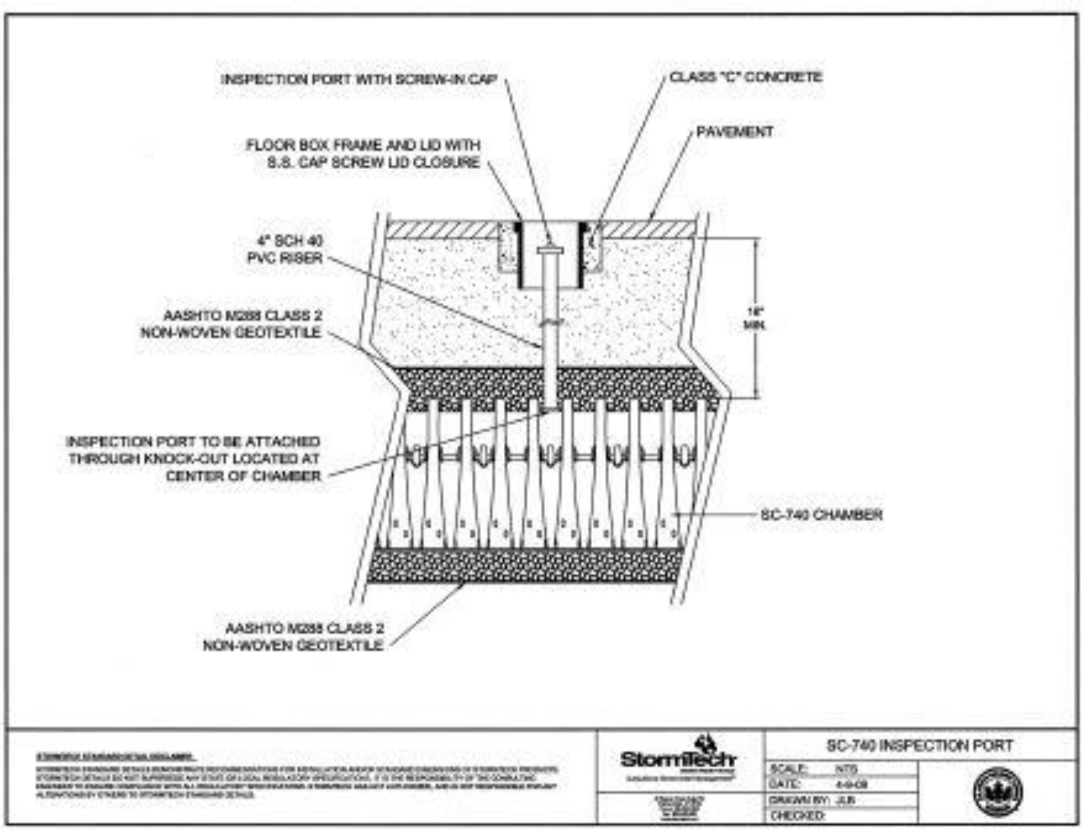


Figure 2: Storm Tech Details

Figure 3 shows the installation of the Storm Tech unit at Cherry Gardens. Note the five Storm Tech chamber rows with the Isolator Row at the left.

Figure 3: Storm Tech Unit Installation – *Photo courtesy of Dan Trask, Storm Tech*

SCM PERFORMANCE MONITORING

Performance monitoring for the Storm Tech Chambers SCM on site consisted of conducting full storm hydrograph flow-weighted composite sampling of the stormwater influent to and effluent from the SCM. Teledyne ISCO Avalanche Model 6712 refrigerated auto-sampling equipment with ISCO Model 720 bubbler flow module was used to conduct the monitoring. In-line weirs were placed at the influent and effluent sampling locations as a primary device for flow measurement in conjunction with the ISCO Model 720 bubbler flow module.

Composite samples were collected over the period from December 2010 to May 2012 and yielded 14 paired storm event samples suitable for statistical analysis. Laboratory sample analysis was conducted for the parameters shown in **Figure 6** with each sample result yielding an Event Mean Concentration (EMC) for each parameter at each monitoring location. Monitoring and subsequent statistical data analysis was based on guidance provided by the EPA and ASCE in the 2002 and 2009 publications, *Urban Stormwater Performance Monitoring*. **Figures 4 and 5** show typical monitoring equipment utilized. **Appendices B, C, and D** discuss the Pilot SCM program monitoring protocols and operating procedures. **Appendix F** discusses the Charlotte-Mecklenburg monitoring program QAPP.

Figure 4: In-Line Monitoring Weir

Figure 5: Automated Monitoring Equipment

DATA ANALYSIS

As stated above, project monitoring yielded data from 14 paired storm event samples suitable for statistical analysis. This produced Event Mean Concentrations (EMCs) for each parameter analyzed for both the SCM influent and effluent monitoring points. The data were analyzed using non-parametric statistical methods that account for data below detection limits (Helsel, 2005). Specifically robust regression on order statistics were used to calculate summary statistics, including the median event mean concentrations used to calculate the percent concentration reduction for each parameter. The modified sign test was used to test for significant differences between influent and effluent paired samples. For parameters where data analysis did not produce a statistically significant result, a value of zero percent (0%) reduction was assigned to the parameter as non-significant results are considered to be not statistically different from zero.

Figure 6 shows the parameters sampled and corresponding information including median event mean concentrations and statistically significant percent reductions. **Appendix E** discusses the Pilot SCM program data analysis protocol.

Parameter	Units	# of paired samples	Influent (median values)	Effluent (median values)	% Reduction	P-Value	Significant at 0.05
Ammonia Nitrogen	**mg/L**	**14**	**0.32**	**0.09**	**71.5%**	**0.0182**	**Y**
Nitrite + Nitrate	mg/L	14	0.28	0.35	0%	0.9713	N
TKN	**mg/L**	**13**	**1.10**	**0.45**	**59.5%**	**0.0001**	**Y**
Total Nitrogen	**mg/L**	**13**	**1.24**	**0.78**	**37.1%**	**0.0001**	**Y**
Total Phosphorus	**mg/L**	**14**	**0.19**	**0.06**	**68.1%**	**0.0001**	**Y**
SSC	**mg/L**	**13**	**98.0**	**5.90**	**94%**	**0.0017**	**Y**
TSS	**mg/L**	**14**	**54.0**	**5.60**	**89.6%**	**0.0001**	**Y**
Turbidity	**NTU**	**13**	**18.0**	**6.85**	**61.9%**	**0.0001**	**Y**
Chromium	ug/L	14	2.11	*	*	*	*
Copper	ug/L	14	10.20	9.50	0%	0.6047	N
Lead	ug/L	14	1.55	*	*	*	*
Zinc	**ug/L**	**14**	**54.50**	**13.0**	**76.1%**	**0.0001**	**Y**

* Data set contained too many non-detect values to accurately calculate summary statistics or provide statistical analysis

Figure 6: Cherry Gardens Apartments – Storm Tech Chambers - Data Analysis Results

CONCLUSIONS

The results of the data analysis for the Storm Tech Chambers SCM showed statistically significant event mean concentration reductions of the median values of various parameters, including <u>Ammonia Nitrogen</u> by 71.5%; <u>TKN</u> by 59.5%; <u>Total Nitrogen</u> by 37.1%; <u>Total Phosphorus</u> by 68.1%; <u>Suspended Sediment Concentration (SSC)</u> by 94%; <u>TSS</u> by 89.6%; <u>Turbidity</u> by 61.9%; and <u>Zinc</u> by 76.1%. While all parameter data collected and analyzed under the Pilot SCM Program is vital for water quality management efforts, one of the most important parameters for evaluating SCM performance is Total Suspended Solids (TSS) and the percent removal efficiency thereof. This is because the City's NPDES MS4 Stormwater permit requires that SCMs (BMPs) be capable of achieving a target removal efficiency of 85% for TSS and data evaluated under the Pilot SCM Program can assist in determining whether or not a particular SCM is approved for use within the City's Local BMP manual.

For this particular study site, the Storm Tech Chambers showed excellent removal of TSS at a statistically significant event mean concentration reduction of 89.6%. It should be noted that the watershed draining to the SCM was very small at 0.41 acres and produced a median inflow volume of 821 cf for monitored events. In addition, landscaped areas around the site parking lot likely would have produced increased input of sediments to the parking lot during heavy rain events due to their graded slopes toward the parking lot, and thus raising median influent TSS values. Mulch materials were noted on the parking lot surface during several site visits during the study period, which would support this assumption.

While this study yielded a positive result in the evaluation of TSS removal, more performance monitoring study of the Storm Tech Chambers SCM will be needed within the City's Pilot SCM program to adequately determine the performance capabilities of this SCM within other varying watershed sizes and land use types.

Appendix A shows data graphs for the Cherry Gardens Storm Tech Chambers SCM based on the SCM data analysis discussed in this report.

REFERENCES

Helsel, 2005. *Nondetects And Data Analysis: Statistics for Censored Environmental Data*. Wiley Publishers 250p.

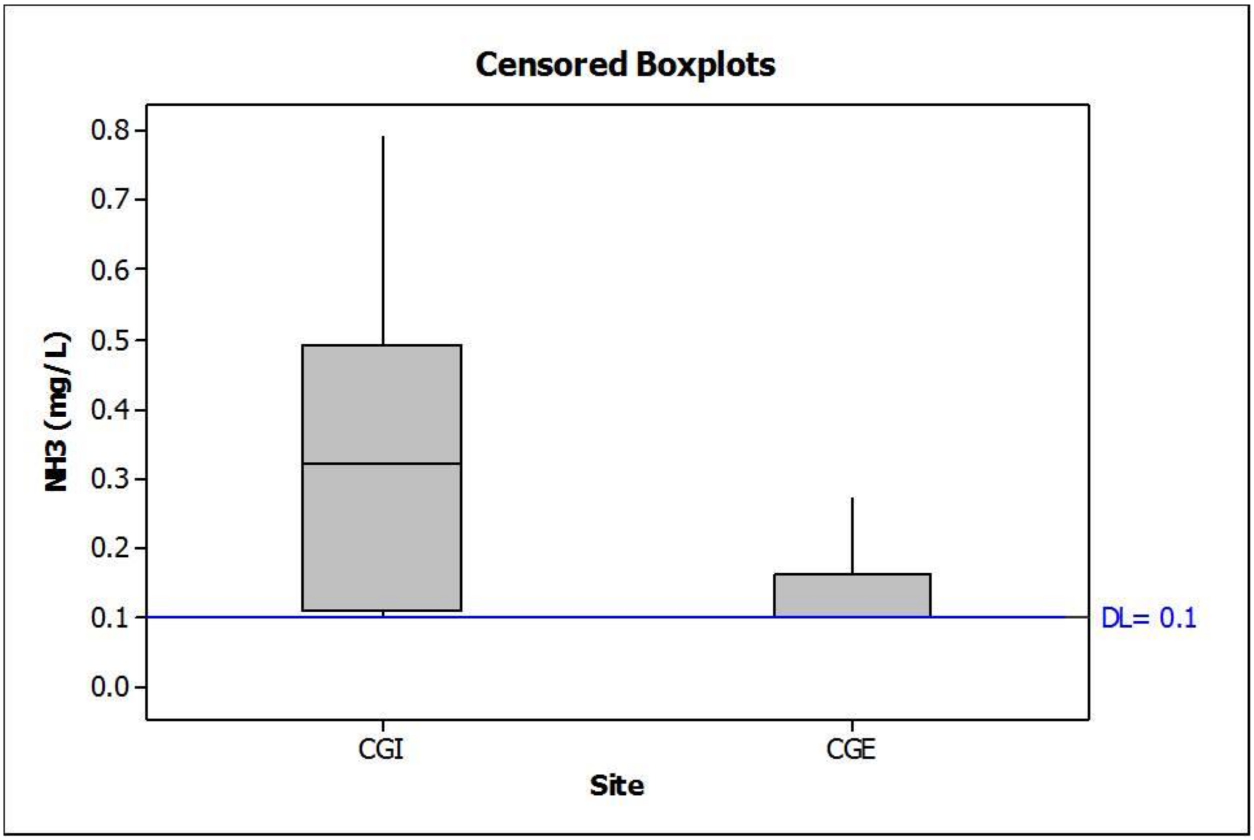
EPA and ASCE, 2002. *Urban Stormwater Performance Monitoring*

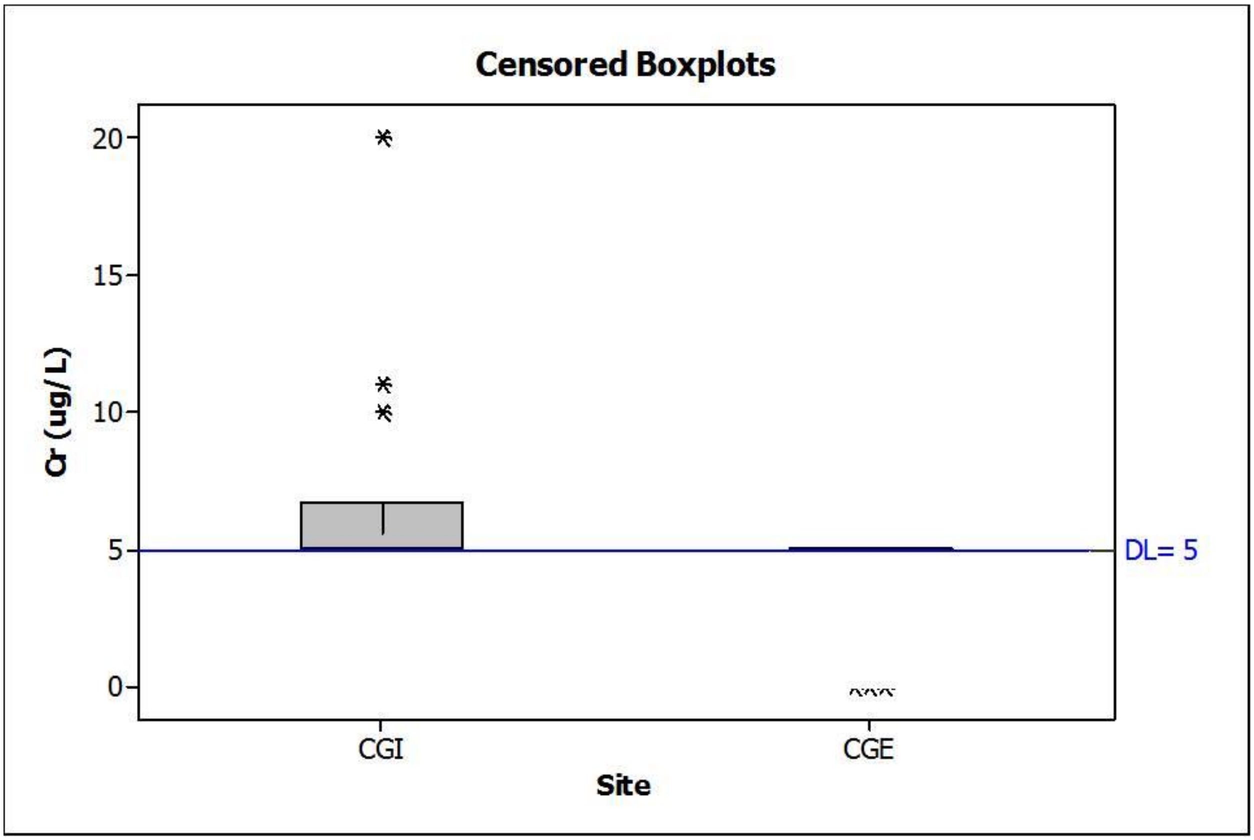
EPA and ASCE, 2009. *Urban Stormwater Performance Monitoring*

Storm Tech website: www.stormtech.com

APPENDIX A

Data Analysis Figures

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20
15
10
5
0
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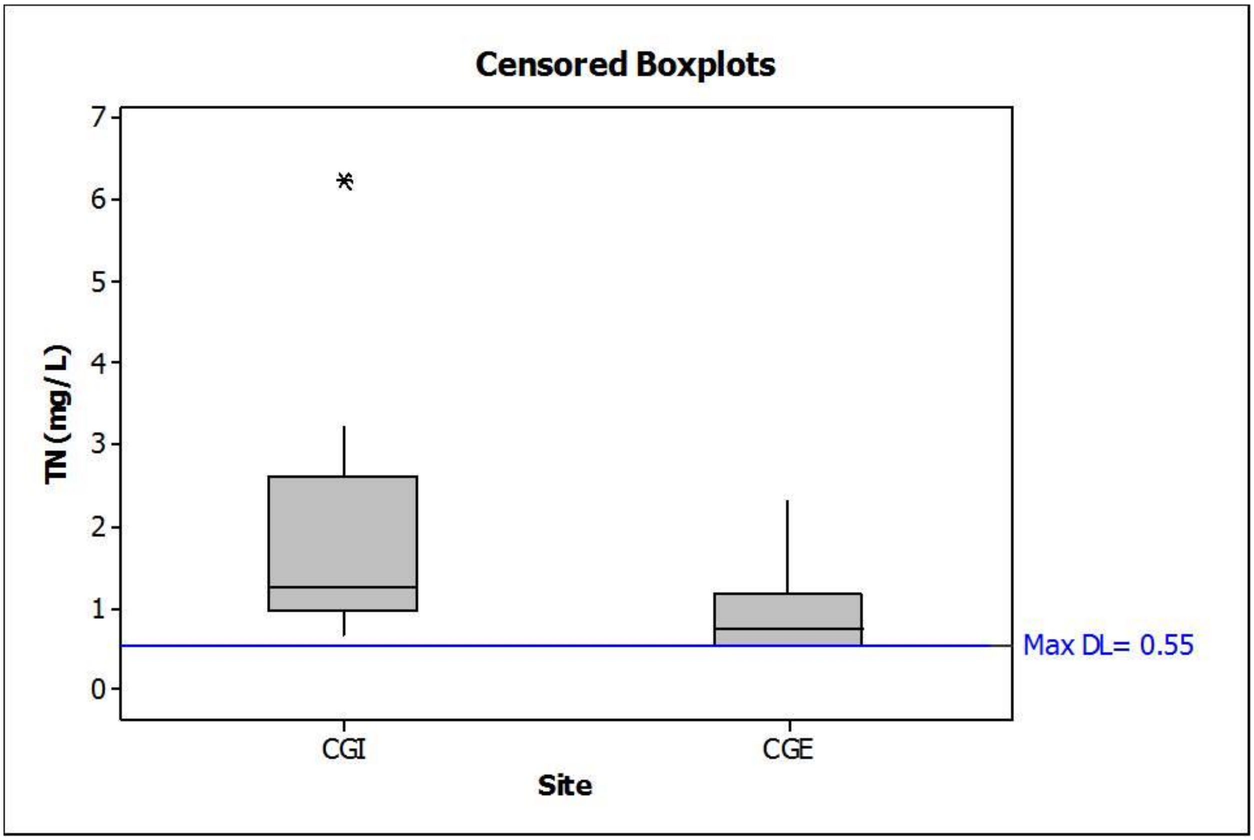
CGI
CGE
Site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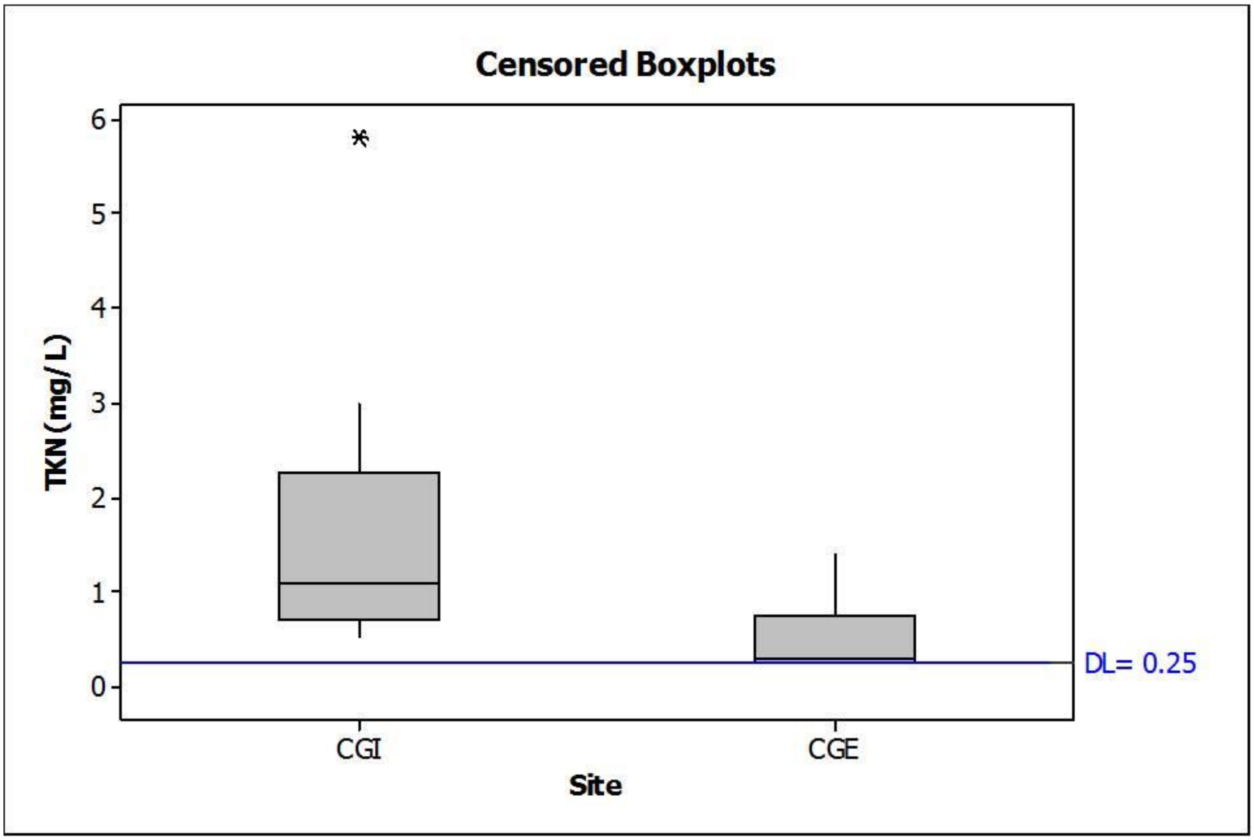
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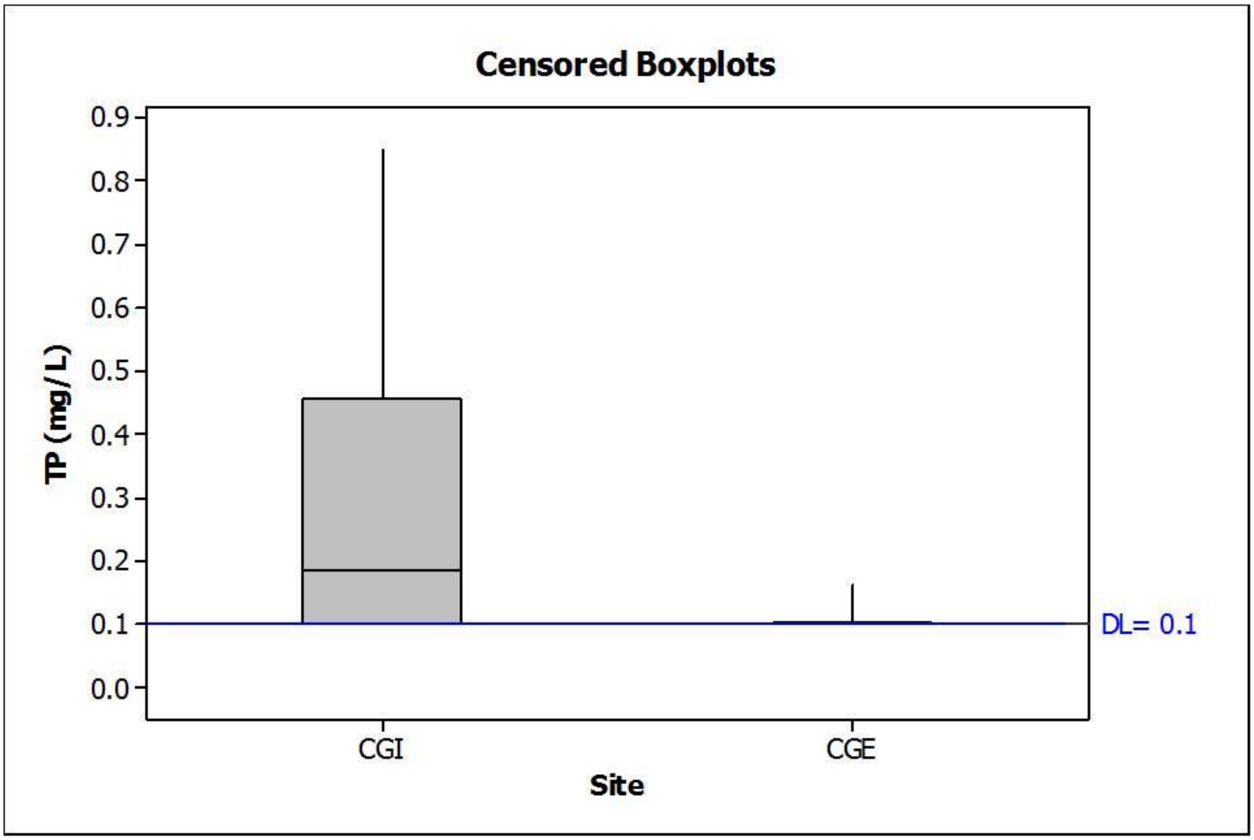
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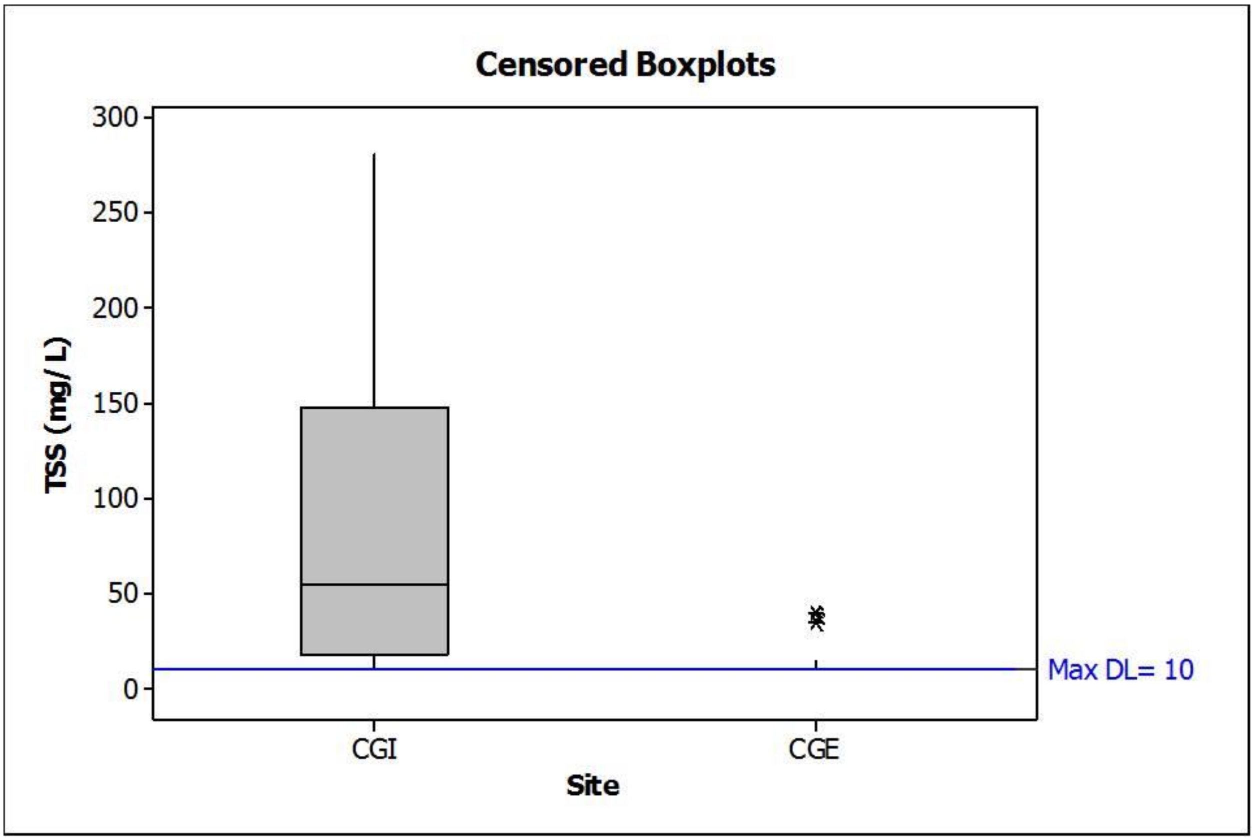
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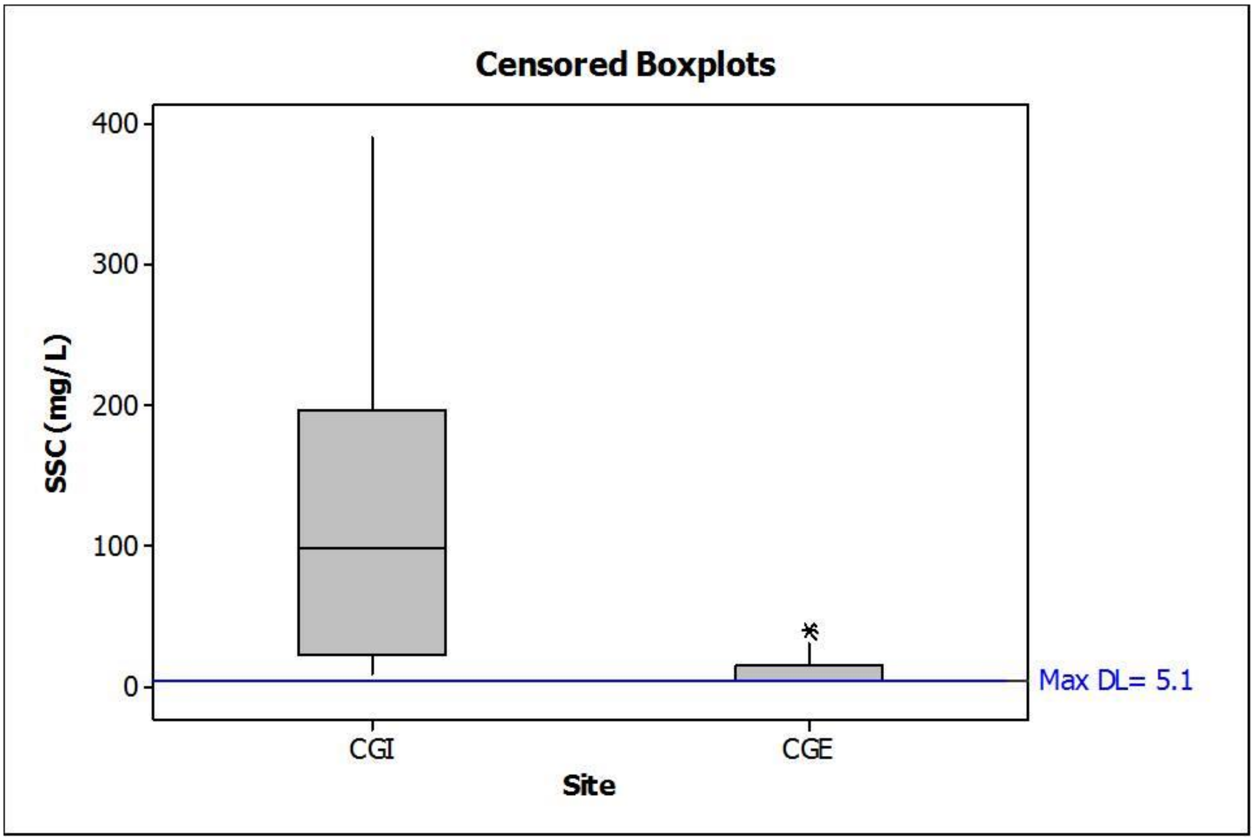
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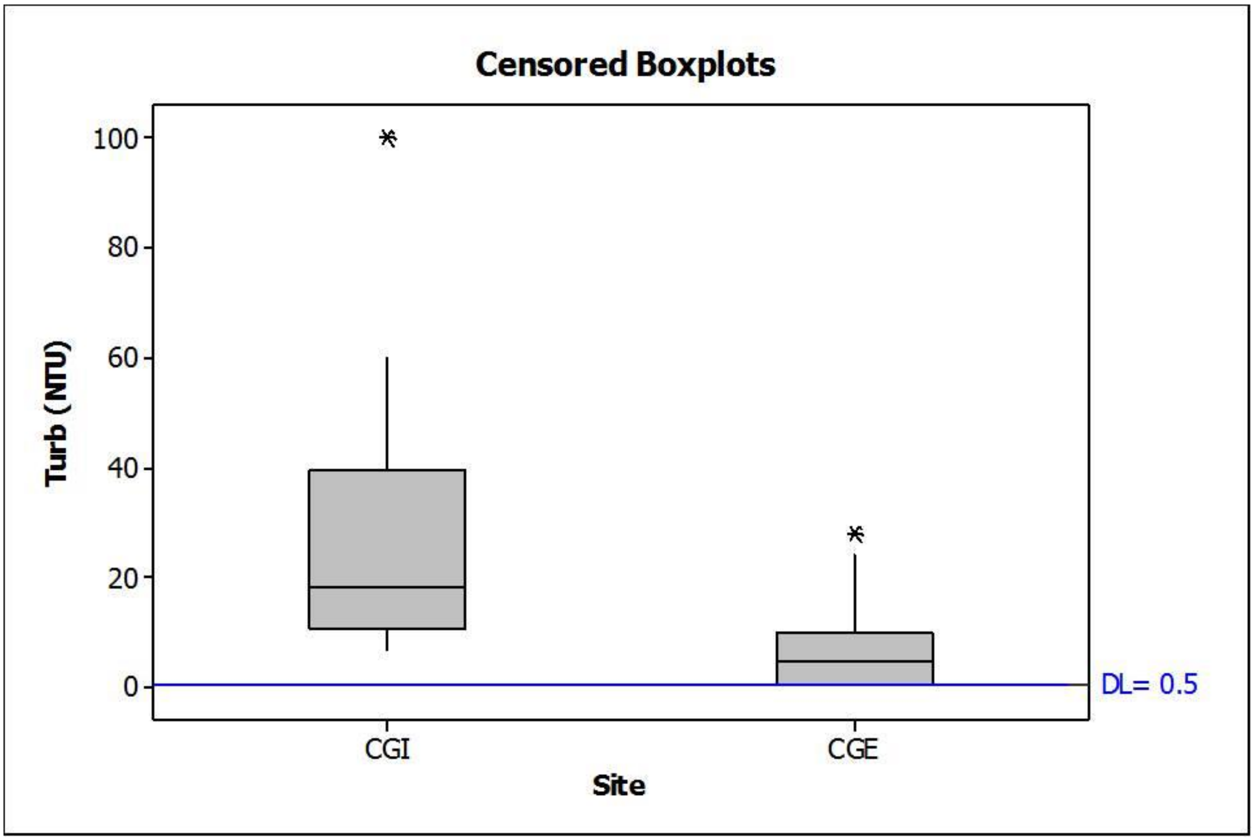
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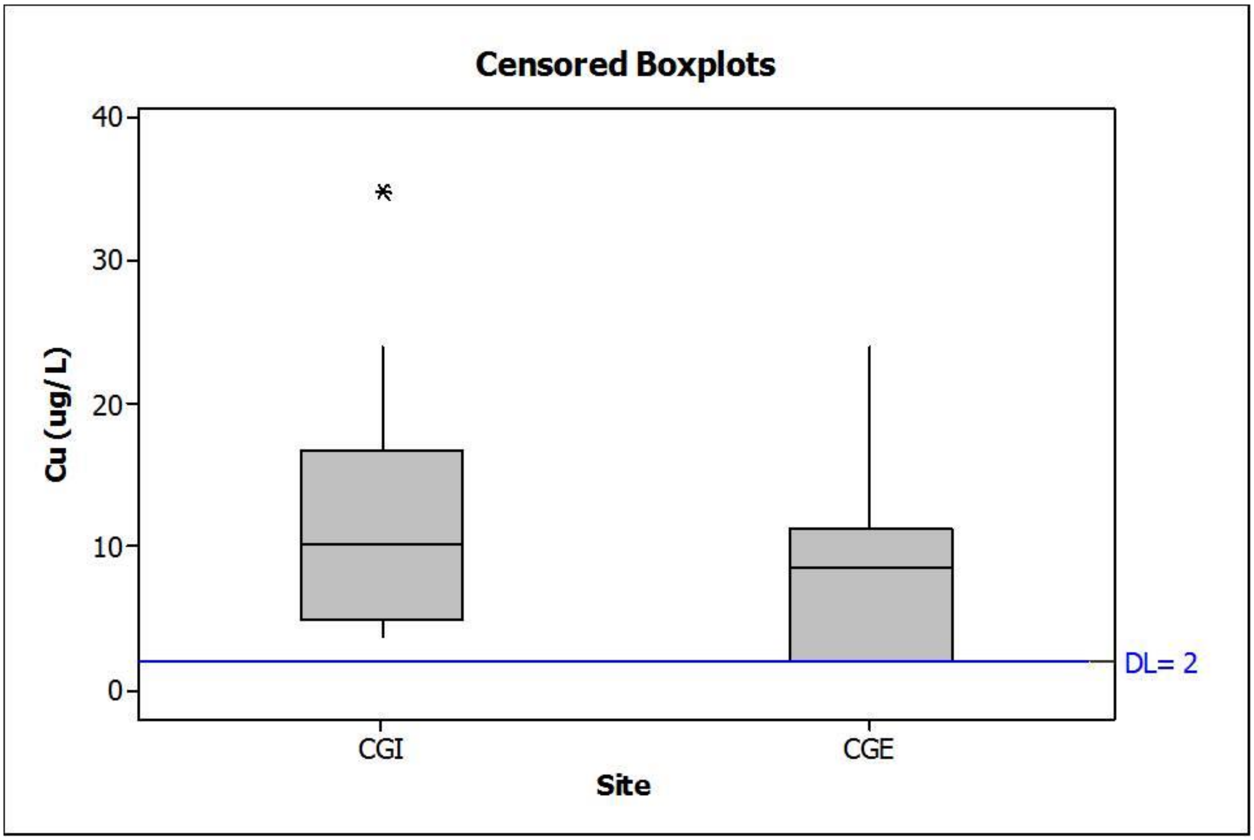
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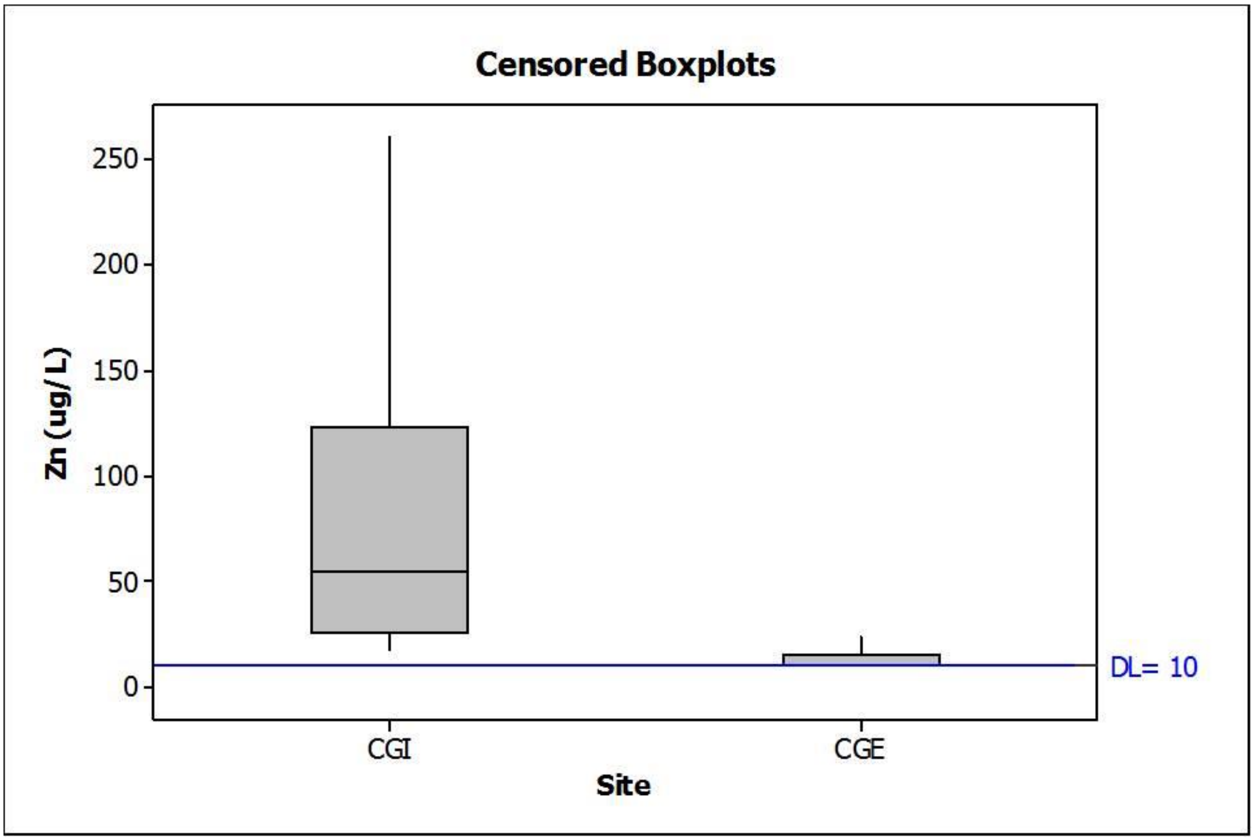
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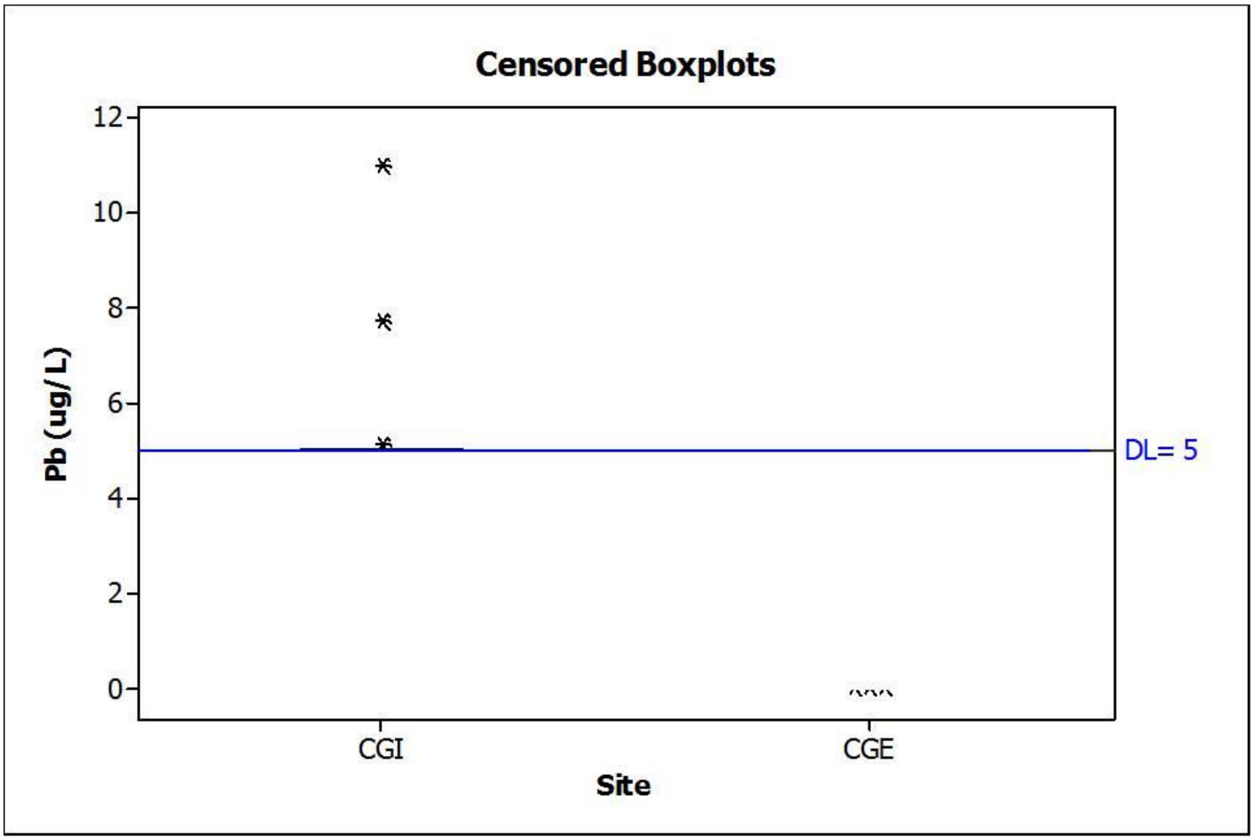
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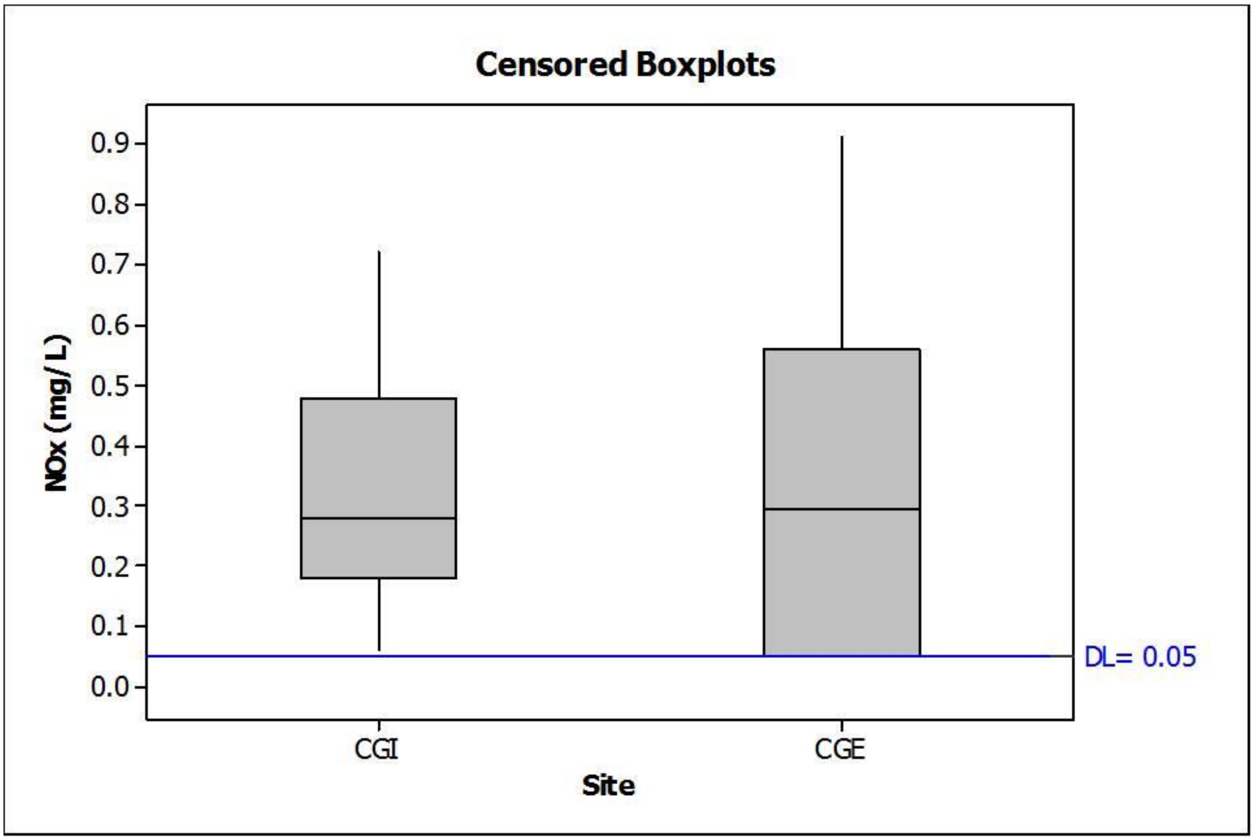
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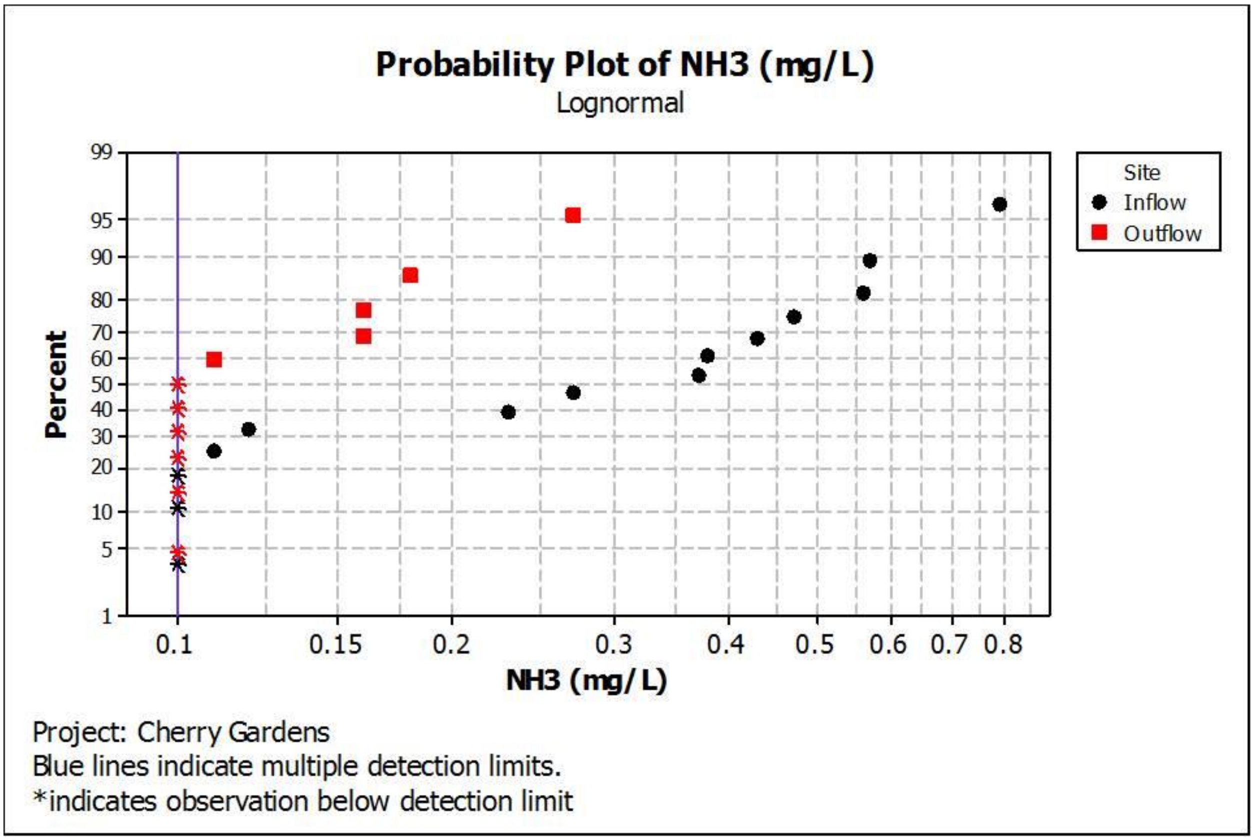
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0.15
0.2
0.3
0.4
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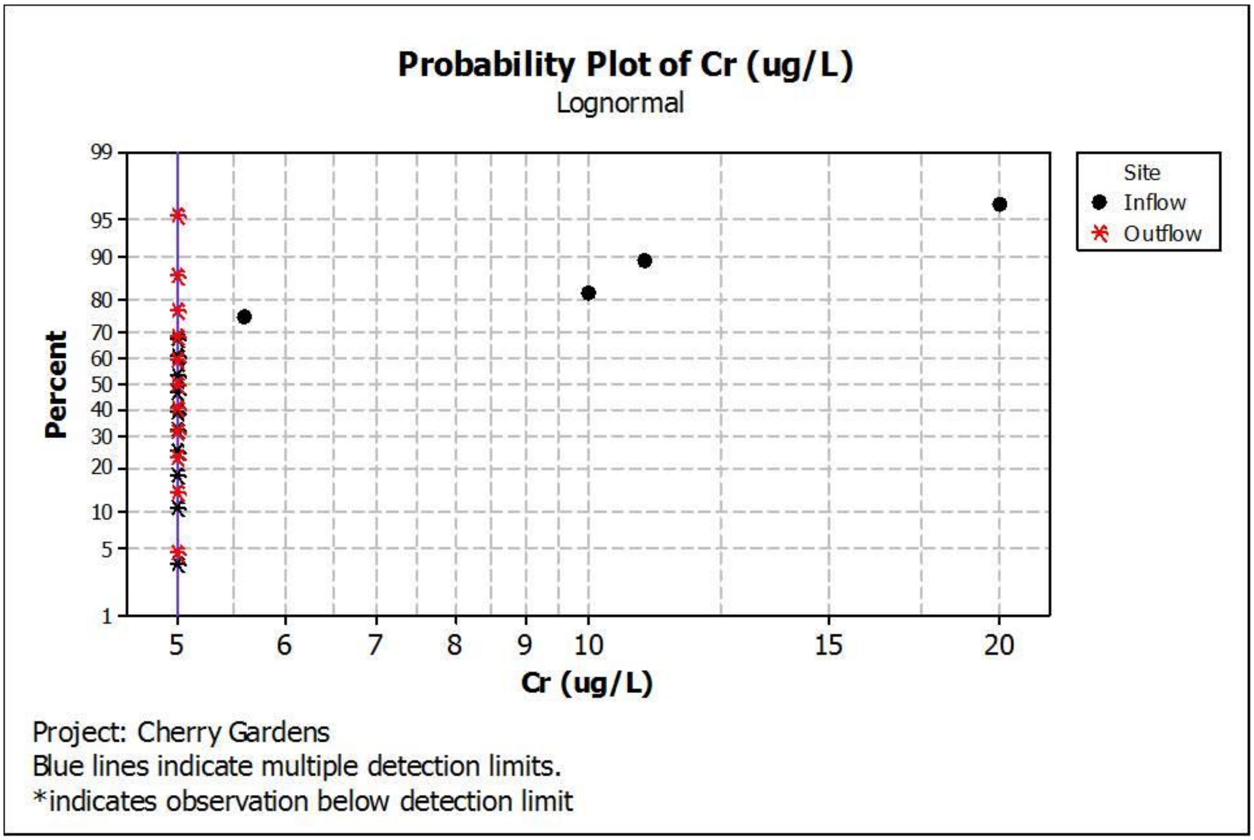
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Lognormal
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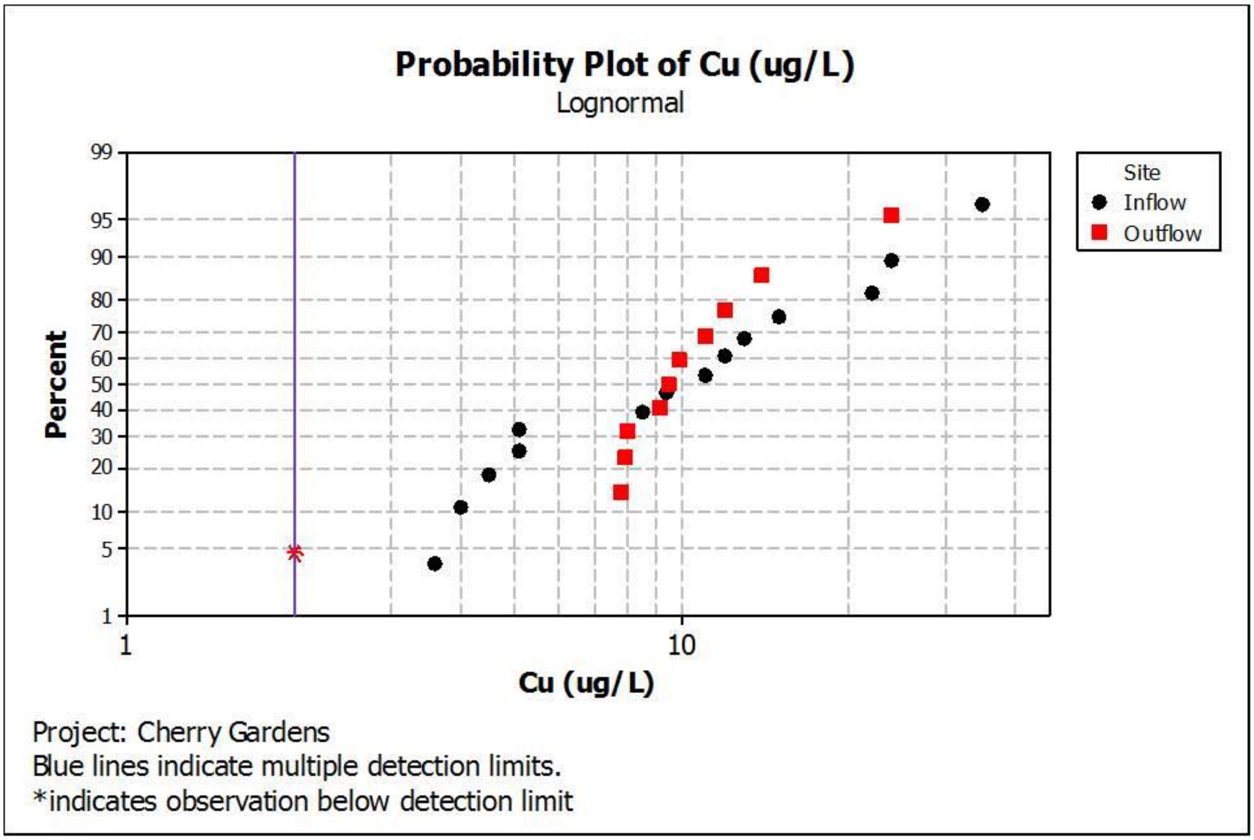
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Lognormal
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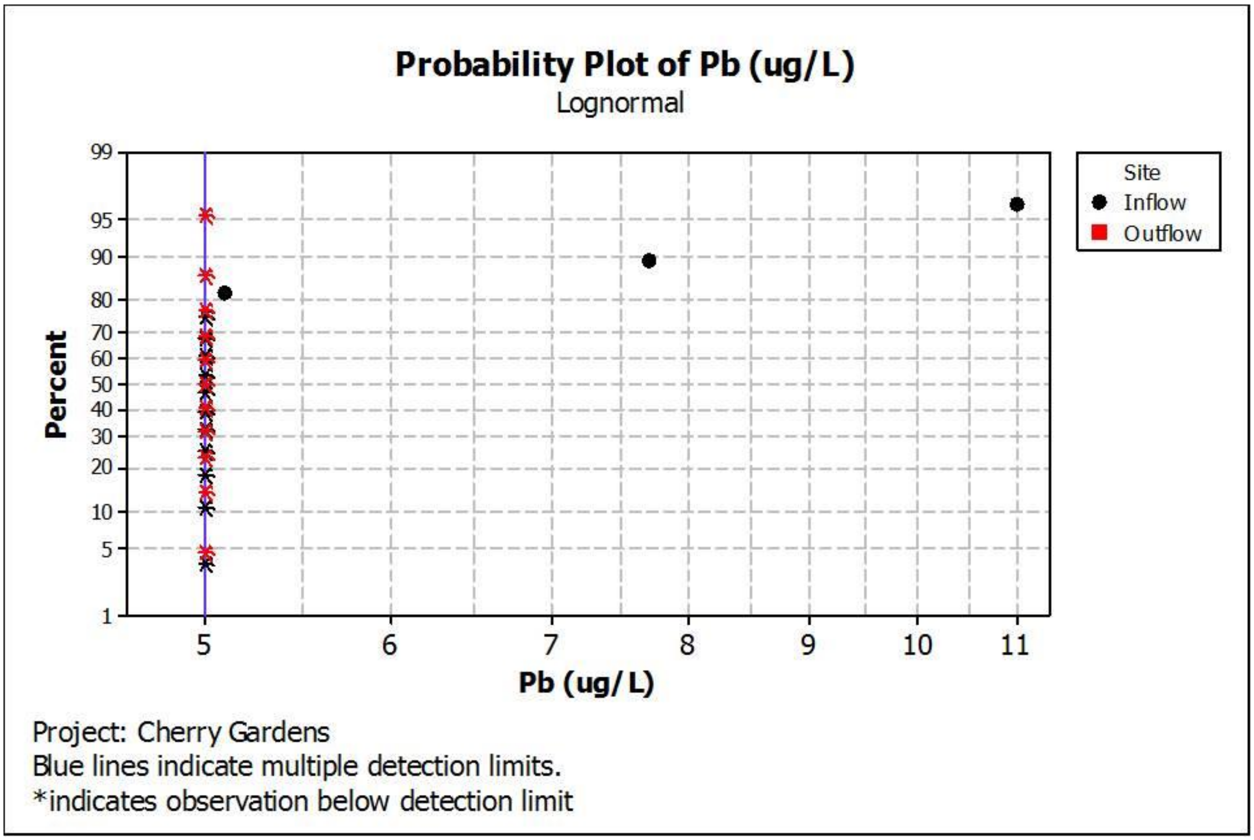
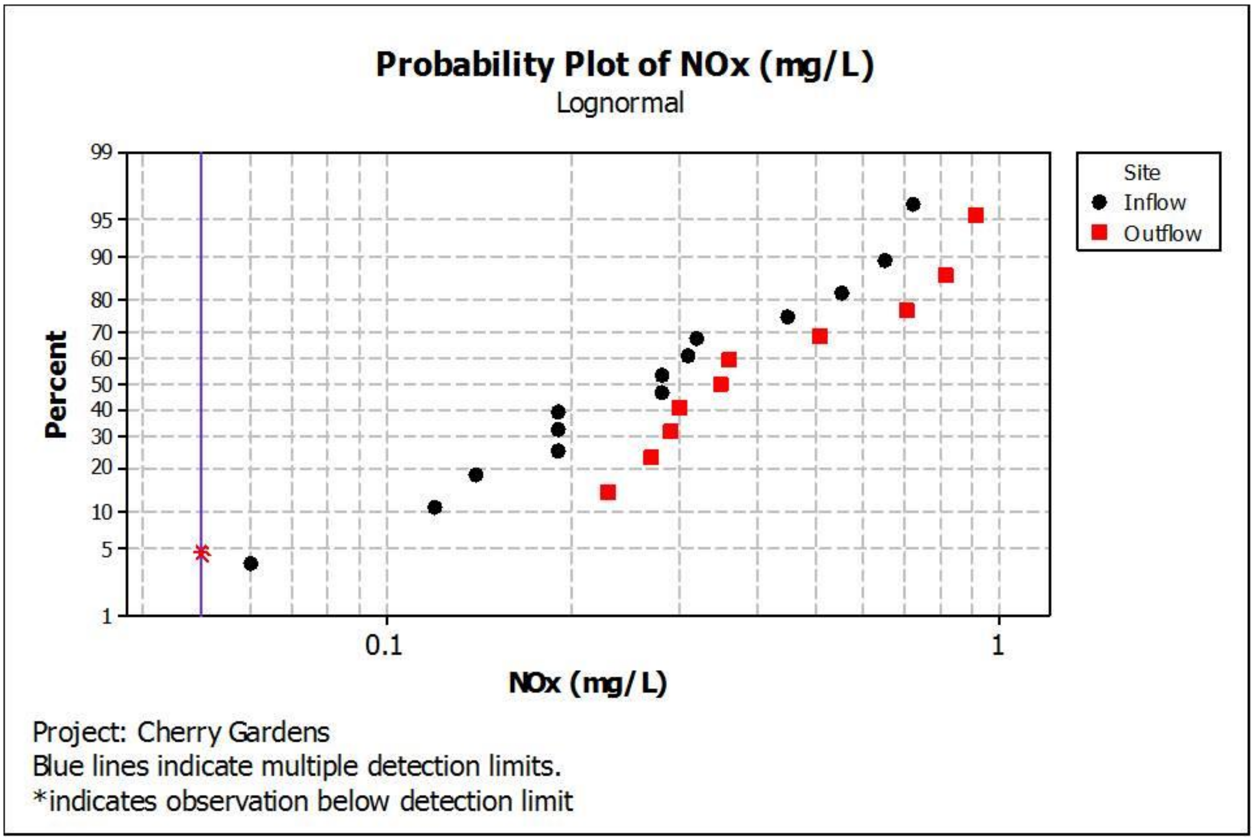
1
10
Cu (ug/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit


Probability Plot of Pb (ug/L)
Lognormal
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
5
6
7
8
9
10
11
Pb (ug/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Lognormal
Percent
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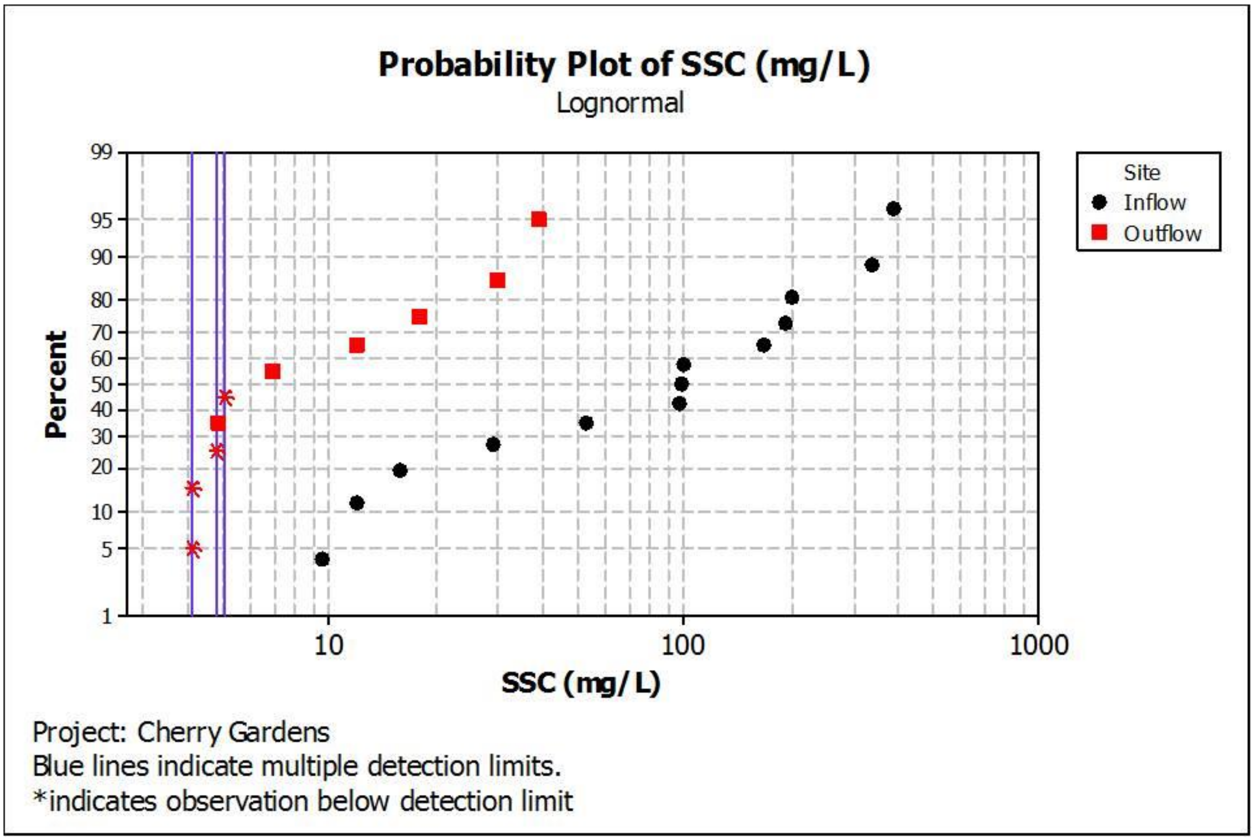
95
90
80
70
60
50
40
30
20
10
5
1
0.1
1
NOx (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit


Probability Plot of SSC (mg/L)
Lognormal
Percent
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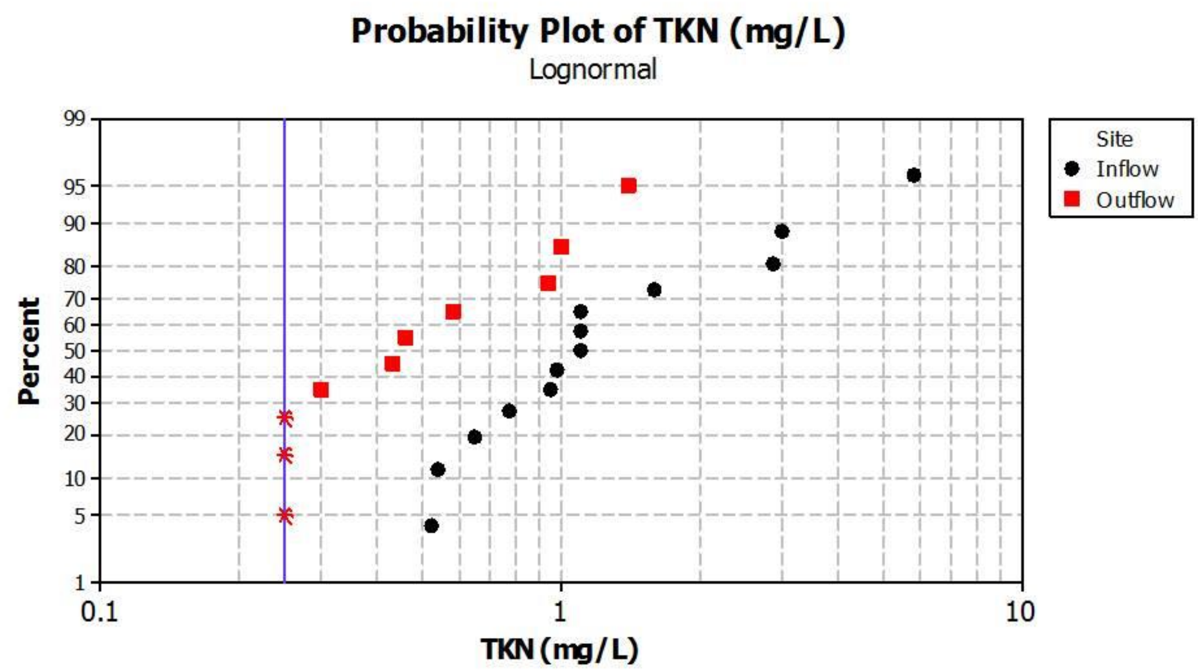
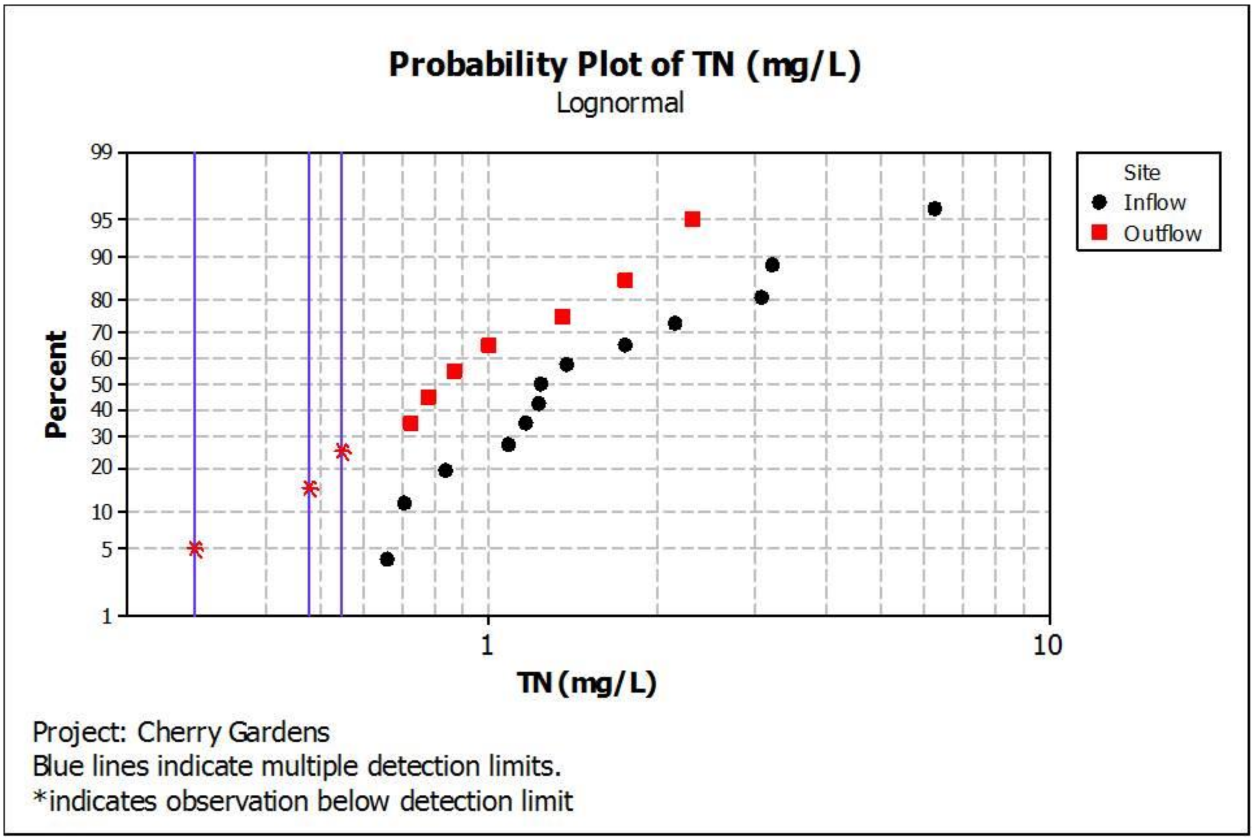
95
90
80
70
60
50
40
30
20
10
5
1
10
100
1000
SSC (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit



Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Percent
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95
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30
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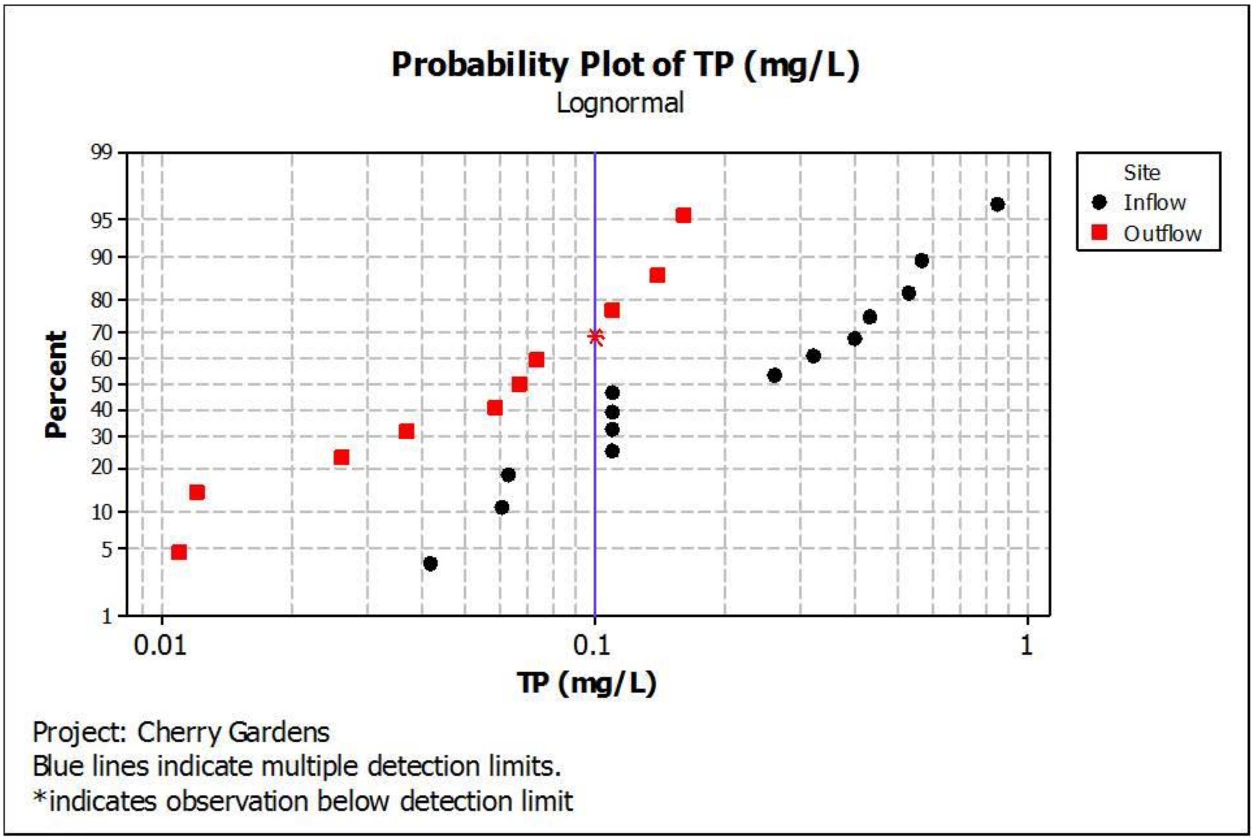
1
10
TN (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit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Lognormal
Percent
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95
90
80
70
60
50
40
30
20
10
5
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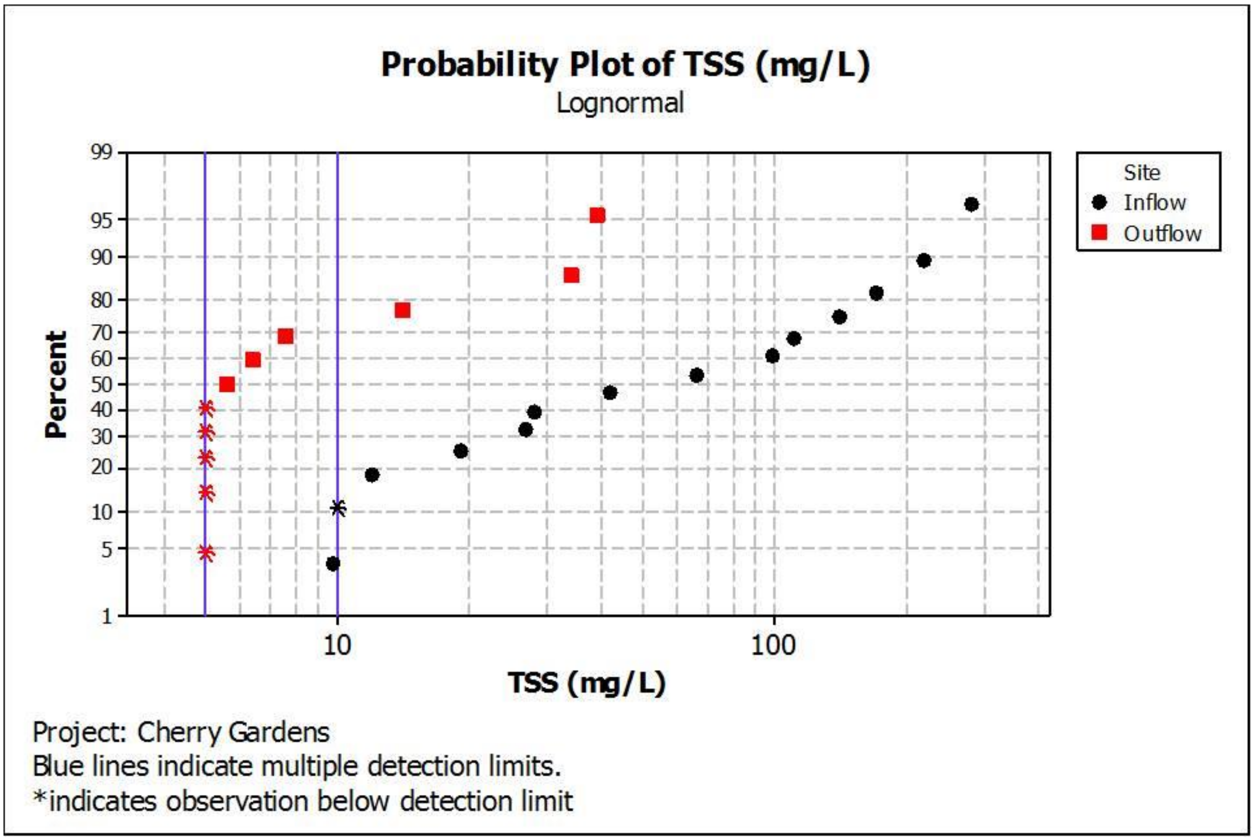
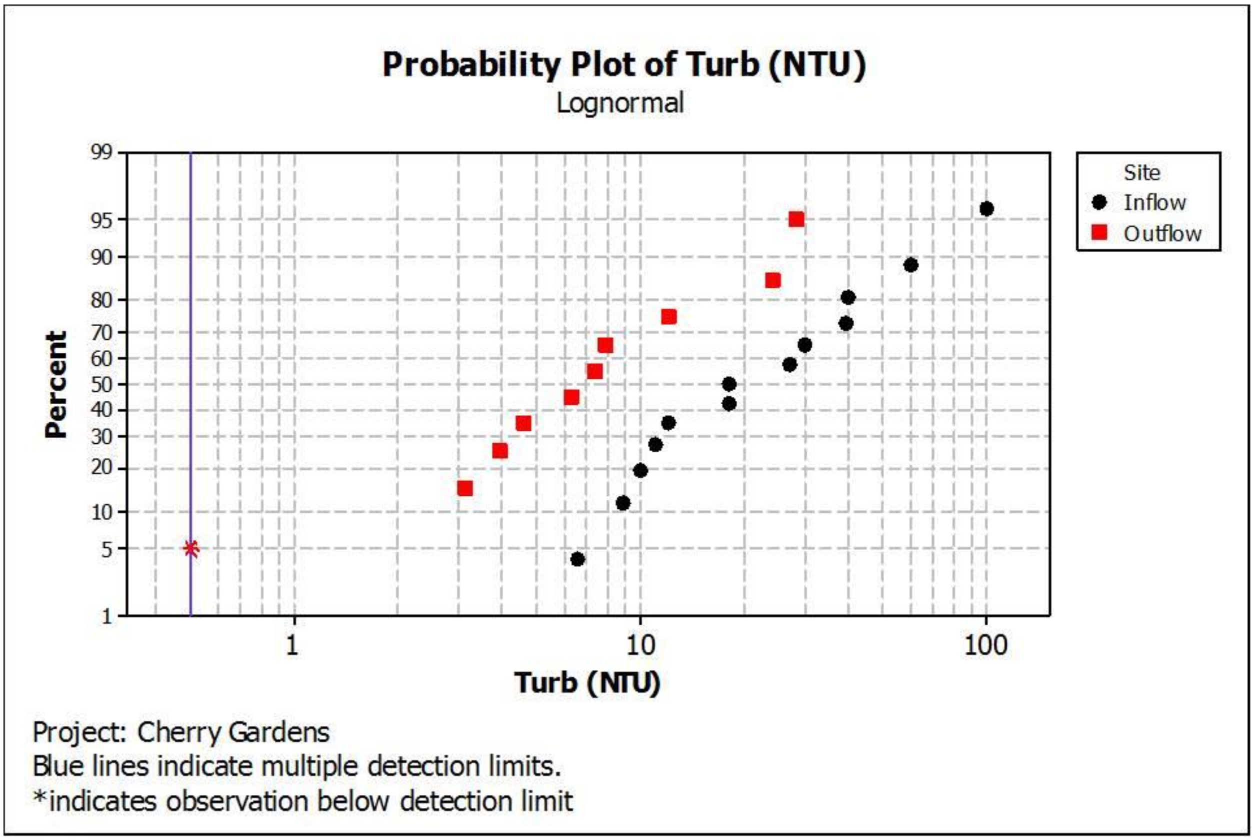
0.01
0.1
1
TP (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit


Probability Plot of TSS (mg/L)
Lognormal
Percent
TSS (mg/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit


Probability Plot of Turb (NTU)
Lognormal
Percent
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95
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80
70
60
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40
30
20
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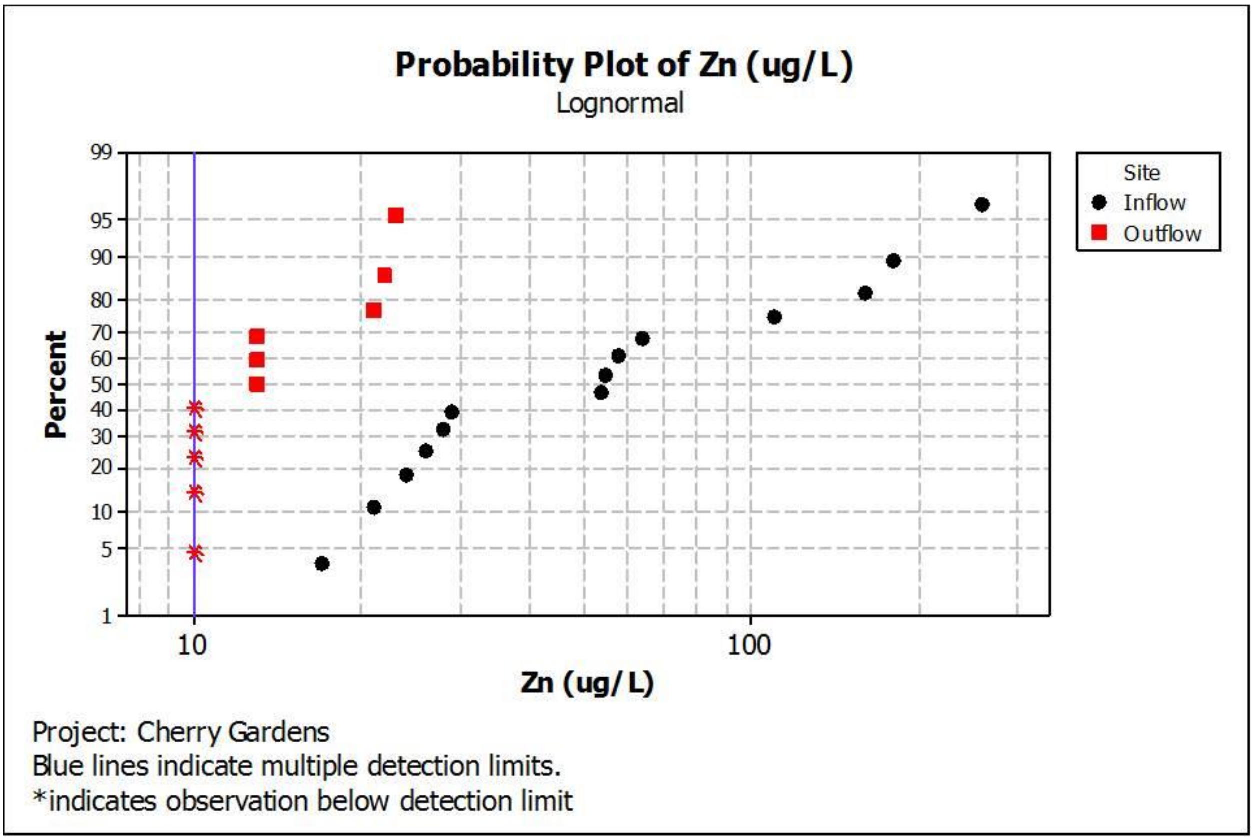
5
1
1
10
100
Turb (NTU)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit



Probability Plot of Zn (ug/L)
Lognormal
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
10
100
Zn (ug/L)
Site
Inflow
Outflow
Project: Cherry Gardens
Blue lines indicate multiple detection limits.
*indicates observation below detection limit

APPENDIX B

Pilot SCM General Monitoring Protocol

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Prepared for:
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Table of Contents

Acknowledgments

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Ronald Eubanks Mecklenburg County-LUESA Water Quality
Richard Farmer Mecklenburg County-LUESA Water Quality

Updated March 2013 by *Steve Jadlocki* – City of Charlotte-Stormwater Services

1. Introduction

The purpose of this document is to provide the City of Charlotte with information necessary in order to quickly and easily develop and implement a monitoring system to assess the performance of Pilot Stormwater Control Measures (SCMs). The guidelines recommended here will allow the reader to collect data meeting the United States Environmental Protection Agency (US-EPA) national Stormwater BMP data base requirements. These requirements are discussed in more detail in "Urban Stormwater BMP Performance Monitoring" (EPA 2009). The reader is encouraged to refer to this guidance for more information.

Specifically these methodologies will be incorporated into the City's Pilot SCM monitoring program. This program currently has the following goals:

- Determine overall removal efficiencies of Stormwater SCMs common to the Charlotte area, as well as new and/or innovative SCM types.
- Compare removal efficiencies among different SCMs.
- Determine seasonal effects on removal efficiencies of SCMs.
- Determine periodic maintenance needs of SCMs.
- Determine cost/benefit of SCMs
- Determine annual maintenance costs
- Provide SCM data, if warranted, to the National EPA database and other national, state, local or regional agencies for use in research and developing SCM design standards.

2. Characteristics to Monitor

a. What storms to monitor

Unfortunately, it is very difficult to design a monitoring system to collect stormwater runoff samples and data from all precipitation events. Larger storms often exceed the design capacity of SCMs and stormwater drainage systems making measurements difficult. Smaller storms produce relatively small amounts of runoff often resulting in sample volumes insufficient for complete chemical analysis. In addition, the high cost of chemical analysis strains budgets and laboratory personnel. It is important then to identify the storm size and frequency to warrant data collection.

The inability to accurately predict the precipitation depth of individual storms requires that each sampler be programmed to accommodate a range of storm sizes. Precipitation events larger than 2 inches occur only a few times annually in the piedmont region of North Carolina. As a result it is not advisable to design a sampling system to accommodate such events. Likewise, events of less than 0.1 inches of rainfall will typically produce very little or no runoff. It is not advised that storms smaller than 0.1 inches be targeted for sampling. See Section 6 for more information on setting up samplers for the targeted storm size.

In order to statistically defend the results of a monitoring program a sufficient number of storms must be collected during the monitoring period. Ultimately, determining the number of samples to collect in order to satisfy statistical analysis will depend on the monitoring goals of the project. More information on selecting sample numbers to match monitoring goals can be found in *Development of Performance Measures* (EPA 1999). Collecting samples from at least 10 storms covering all four seasons in a year period will enable defending the goals and hypotheses discussed in Section 1. Samples should be collected at a minimum frequency of one per month in order to determine the effect of seasonal variations on pollutant removal performance. See Table 2.1 for recommendations on storm size, frequency and number of samples.

Table 2.1 Recommendations for storm size and frequency for monitoring

	Minimum recommended	Maximum recommended
Storm Size	0.1 inches	2 inches
Storm sampling frequency	1/ month	2/ month
Number of samples	10/ yr	20/yr
Inter-Event Dry Period	6 hours	N/A
Antecedent Dry Period	24 hours	N/A

The most basic information that can be collected from stormwater runoff is its physical characteristics. Such information as flow rate, volume, and temperature are important pieces of information when analyzing SCM performance. No other single parameter is more important to SCM performance analysis than continuously recorded flow rate. For SCMs with a storage/detention component inherent to their function it is preferred that flow be measured at both the inflow and outflow locations. For SCMs without any detention component inherent to their design it is possible to measure flow at only one sampling station to save on equipment costs. Structures and instrumentation necessary to monitor flow are discussed in later sections.

Any performance monitoring program should also include continuously monitored rainfall. For smaller sites such as most stormwater SCMs it is acceptable to use a single rain gage at one of the monitoring stations or even a nearby gauging station such as a USGS precipitation gage. For larger SCMs it may be necessary to use a multiple gauging locations sited within the watershed to accurately determine the net precipitation amount treated by the SCM.

In many portions of the US thermal pollution as a result of stormwater runoff is a very important issue. Relative to other parameters, temperature is very economical to measure and record. Where possible it is advised that temperature be measured and recorded at both the inflow and outflow points of the SCM.

Listed below are the physical parameters which should be measured and recorded at each sampling location:

Physical parameters to monitor include:

1. Flow rate
    - inflow station
    - outflow station (optional for non-detention SCM)
2. Rainfall
3. Temperature (continuous recording)
    - Inflow
    - Outflow
4. pH (optional)

Selection of chemical analysis to be completed on stormwater runoff can be a very challenging task. Specific analysis may be chosen to satisfy the following questions.

- For what pollutants have TMDL's been established within the watershed of interest?
- What pollutants will the SCM potentially have an impact on?
- What pollutants are regulated by state or regional regulations?

Listed below are the chemical analyses that are recommended for inclusion into this study.

Composite Samples:

Total Suspended Solids
Suspended Sediment Concentration
Total Kjeldahl Nitrogen
Nitrate-Nitrite Nitrogen
Ammonia-Nitrogen
Total Phosphorus
Copper
Chromium
Lead
Zinc
Aluminum*

*Aluminum collected and analyzed for proprietary filter cartridge SCMs only

Grab Samples:

Fecal Coliform Bacteria
E-Coli Bacteria
Enterococcus Bacteria

Additional pollutants may be included in the chemical analysis as a "suite" of pollutants (for instance a metals suite might include Cadmium, Magnesium as well as Iron) or additional pollutants may be analyzed in order to compare samples to other types of water quality data such as stream flow. Chemical analysis of water quality samples should be analyzed using methods described in Methods for Determination of Metals and Inorganic Chemicals in Environmental Samples (USEPA 1996).

3. Choosing Equipment

Many instrumentation suppliers have responded to the need for equipment for monitoring stormwater runoff. The most common style of stormwater sampler consists of a peristaltic pump operated by a main sampler controller depositing samples in one or a combination of bottles within the sampler housing. The sampler controller may have in-situ physical or chemical monitoring capability built into it. If not, accessory equipment should allow for monitoring of the parameters discussed in the previous section. Samples collected by the sampler are usually deposited within the sampler housing body into either a single or multiple bottles of either glass or polypropylene. The selection of bottle type will primarily be dependent on the types of analysis to be conducted. The user should consult the standards and methods book for when polypropylene bottles will be acceptable.

For the City of Charlotte's Pilot SCM monitoring program, ISCO Avalanche samplers will be used, which consist of a refrigerated single bottle system. Fig 3.1 shows a sampler in use at one of the monitoring sites. In addition to the sampler's flow monitoring modules use a bubbler flow meter system to measure and record flow at each station. The model 730 bubblers should be used where a flume, weir or orifice is used as a primary device. This should be considered the preferred system of flow measurement as it results in typically more accurate readings and repairs to damaged bubbler tubes are very easy and economical. Model 750 area velocity meters can be used in areas where a defined flow channel exists such as a culvert or chute of known dimensions. Area velocity meters have the advantage of operating under submerged flow conditions (such as with a tail water) and are useful when a limited head loss is available. However they should not be considered as accurate as the bubbler type model 730 flow meters matched with an appropriate primary device. The user should consult the ISCO operating manuals for more information on selecting equipment to match individual sites.

Fig 3.1 ISCO Avalanche Model 6712 sampler

4. Selecting SCMs to monitor

When choosing SCMs to monitor, it is important to keep in mind the reasons for monitoring in the first place. For a regional or municipal stormwater program such as the City of Charlotte, monitoring of SCMs might be necessary to determine types of practices to recommend to developers. It is not advisable to research SCMs that will not be easily accepted into local use. Table 3.1 lists the most common SCMs currently in use in the Piedmont area of North Carolina as well as others which might see additional use in the future.

Table 3.1 Structural Stormwater Control Measure usage and potential for monitoring

Type	Current Use	Future Use	Recommended sites
Wet pond	High	medium	5
Wet detention pond	High	medium	5
Wet detention pond with littoral Shelf	medium	high	5
Dry detention pond	medium	medium	5
Stormwater Wetland	medium	medium	10
Bioretention	low	high	10
Pervious pavements	very low	medium	5
Greenroofs	very low	medium	2
Sand filter	low	medium	3
Proprietary devices	low	unknown	20

i. Correctly designed stormwater SCMs

When choosing SCMs for monitoring one should be careful to identify not only SCM types that fit within the guidelines mentioned above, but also individual SCMs that have been designed and constructed according to the desired local, regional, or national design standard. The most common design guidelines used are those specified in the North Carolina Stormwater BMP Design Manual (NCDENR, 2012) as well as the Charlotte-Mecklenburg BMP Design manual. Some SCMs installed in North Carolina may be constructed according to the State of Maryland Stormwater Manual (MDE,2000) One of the primary purposes of developing a monitoring program is to enable the comparison of specific SCMs to one another. Comparing two SCMs designed under different criteria will produce results that are hard to support or defend. In North Carolina, most detention SCMs are designed for the “first flush” event. In the Lower Piedmont this “first flush” event would currently constitute the runoff associated with 1 inch of rainfall.

ii. Identifying Sites for suitability

Many individual stormwater SCMs currently in use are either impossible or extremely difficult to monitor. The most common characteristic inhibiting monitoring is the existence of multiple inflow points requiring multiple sampling stations thereby driving up the cost and labor requirement. Additionally, it is important that a location at each sampling point be identified which will allow accurate monitoring of flow. However for many SCMs, such as bioretention, sheet flow at the inlet is a recommended design characteristic. It is still possible to monitor flow in such a case however a well-defined watershed must exist. Setting up a sampling system under such conditions is discussed further in Chapter 6. Fig 3.2 lists a number of criteria for determining if a site is a good candidate for monitoring.

Fig 3.2 Checklist for Individual site suitability for monitoring

- □ Does the site have a single inflow and outflow?
- □ Is it possible to collect a well-mixed sample at each sampling station?
- □ Is the flow path at the inflow and outflow well defined?
- □ If inflow is sheet flow, is watershed well defined and mostly impervious?
- □ Will inlet or outlet have a free flowing outfall during storm event?
- □ No backwater conditions are present that would affect proper flow measurement

If the answer to each of these questions is yes then the site may be a good candidate for stormwater monitoring. It is the author’s experience that less than 5% of all stormwater SCMs are good candidates for performance monitoring. As the reader gains experience in setting up monitoring systems, it will become easier to determine which sites are suitable.

5 Installing Structures and Equipment for Monitoring

Where possible, individual sites will be chosen in order to minimize retrofitting required to allow monitoring as discussed in section 4. However nearly all sites will require some efforts in order to accurately measure performance.

Weirs, flumes or orifices may need to be installed to allow the measurement of flow. Such devices should be designed to accommodate the full range of storm flows expected from monitoring events. For the Pilot Stormwater Monitoring Program, structures should be sized to allow measurement of flows up to the peak discharge from the 2-yr 24-hr storm. Additionally the structures should be built such that they do not cause damage to the SCMs when larger storm events occur Fig 5.1 shows a V-notch weir being used to measure runoff from a parking lot.

Fig 5.1 120 degree V-notch weir measuring flow from a parking lot.

The designer should keep in mind that sampler intakes will need to be placed in a well-mixed area that does not impair the measurement of flow. Also, measurement sensors will need to be placed where they will not become clogged with debris. Design features should allow the attachment of sensors and sampler intakes to the structure.
Table 5.1 lists the preferred placement of sensors and intakes for Weir and Orifice type structures. For information on setting up flumes correctly see ISCO (1978).

Table 5.1 Preferred structure and sensor placement

	Weir	Orifice	Culvert
Geometry	V- Notch	Circular	Circular
Material	Cold Rolled Steel or 1/8" Aluminum	Stainless Steel,	Existing storm drainage system
Placement of	0.0-1.0" below invert	0.0-1.0" below invert	Invert of culvert

Sensor			
Location of Sensor	At a distance of 4X maximum head expected if possible upstream of invert	N/A	N/A
Placement of intake	At invert	At invert	Invert of culvert or in center of plunge pool downstream
Location of Intake	Upstream of outlet a minimum of 4 X maximum expected head	2X Diameter of orifice upstream	Downstream of Sensor

Samplers themselves should be installed as near to the sampling points as possible to reduce the amount and length of intake tubing and sensor cable required. For area-velocity cables, maximum cable length is 30 feet requiring that samplers be installed within that distance to the structure/measurement point. Likewise bubbler tubes should be limited to 30' to reduce the effect of friction within the bubbler tube on water level readings. It is advisable that the sampler itself be installed at an elevation higher than the intake point to allow the intake tube to fully discharge after each sub-sample is collected. Ideally the sampler should be installed 5-25 feet above the intake point. If the sampler is installed at an elevation higher than 25 feet above the intake, the sampler pump will have difficulty drawing a sample.

Automatic tipping bucket rain gages such as ISCO model 674 should be installed in a location away from interference from overhanging trees or power lines. Care should be taken to ensure that the tipping mechanism is installed as close to horizontally level as possible. In most cases the rain gage can be installed adjacent to the sampler housing. It is recommended that a backup method of measuring rainfall be utilized such as a second tipping bucket system or a manual rain gage.

6. Programming Monitoring Equipment

In order to calculate Event Mean Concentration (EMC) values, each sampler station shall collect a flow-weighted composite sample. A flow-weighted sample is a sample of known volume that is collected each time a predetermined volume of flow passes by the sampling point. Flow values shall be measured and collected in the electronic memory of each sampler. It is advised that for most SCMs flow values should be logged at a frequency of every 5 minutes or less. The frequency of sample collection will depend on a number of factors including the sample size desired and SCM watershed characteristics. When beginning monitoring efforts at a site a user has two options for determining sampler program setting. A predictive model such as the NRCS CN method (USDA 1986) can be used to estimate the runoff volume associated with the desired storms. For small highly impervious watersheds of well-known dimensions it is more accurate to directly relate runoff to rainfall assuming some reduction due to initial abstraction. Another option is to install the samplers and monitor several storms to determine a rainfall-runoff response curve. Regardless of approach the user may be required to further adjust the sampler settings as monitoring efforts continue to satisfactorily collect the correct sample volume.

For sites identified for the Pilot SCM monitoring program, individual monitoring protocols should be developed detailing the sampler settings for each sampler station. These protocols are included in Section 11 of this document. In addition, information on how to set up and program samplers are included in the operational manuals for the samplers, and flow modules (ISCO 2001).

8. Data Analysis

As discussed in the introduction, one of the overall objectives of this project is to provide data that can be included into the USEPA National Stormwater BMP database, if applicable. In order to produce defensible data, statistical analysis of the collected data will need to be completed. There are several different statistical methods which may be used depending on the type of SCM, hypothesis of the test, and type of data available for analysis.

The Effluent Probability Method will most likely become a standard statistical method for use with the National Stormwater Database. Where possible this analysis will be completed for the data collected in this study. However there are other methods which may prove useful. For instance the Summation of Loads method may be used to estimate efficiencies and the Mean Concentration method may be used for some comparisons of SCM effectiveness.

Data analysis for all water quality analysis and flow monitoring data was completed initially by NCSU project personnel for the first 12 SCMs in the study. Upon completion of the study, technical reports were provided to the City of Charlotte detailing the results of the monitoring efforts. As of 2009, City and County staff has conducted all data analysis internally.

9. Maintenance of Sites and Equipment

Proper maintenance of stormwater SCMs is important to ensure proper operation and removal efficiency. When conducting monitoring at a site, proper maintenance becomes even more critical. Maintenance issues such as clogging around structures can impair sensor and intake operation. Monitoring equipment also has its own maintenance requirements.

Failure to conduct proper maintenance on a SCM may cause a reduction in pollutant removal efficiency over time or even structural damage to the SCM. Such changes make statistical analysis of data problematic. As part of this study, general maintenance guidelines will be developed for the SCM sites included in the study. When available, these guidelines should be consulted for specific instructions on site maintenance. Any maintenance conducted during the study period should be recorded in the in the sampling log book for each site. In general, the inlet and outlet structures should be cleared of any debris prior to each sampling event.

In order to keep monitoring equipment operating properly, regular maintenance should be performed. The following figures describe the maintenance to be performed for each type of equipment. More specific maintenance recommendations are discussed in the operational manuals for each type of sampler or sensor (ISCO, 2001), the user is encouraged to refer to these documents for more information.

The following maintenance items should be performed on ISCO Samplers prior to each sampling event.

1. Check that power supply is sufficient to power sampler thru sampling event
2. Remove debris collected around intake strainer
3. Inspect intake tubing for cuts or crimps, replace if necessary
4. Verify that desiccant indicator window in sampler controller is blue
5. Remove debris that has collected in rain gage if applicable

The following maintenance should be performed on ISCO Model 730 Bubble Module prior to each sampling event.

1. Inspect bubbler tube for damage or crimps, replace if necessary
2. Calibrate water level of bubbler sensor to ensure that it is within acceptable limits
3. Verify that bubbler pump is working and producing "bubbles"

The following maintenance should be performed on ISCO Model 750 Area Velocity Meter prior to each sampling event.

1. Inspect cable for nicks or cuts.
2. Verify that module is situated properly in bottom of culvert or flume.
3. Calibrate water level over module if possible.

10. References

ISCO. 2003 6712 Portable Sampler Instruction Manual. ISCO Inc. Lincoln NE

ISCO. 2003 730 Bubbler Module Instruction Manual. ISCO Inc. Lincoln NE

ISCO. 2003 750 Area-Velocity Module Instruction Manual. ISCO Inc. Lincoln NE

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11. Appendices

Appendix 1
General Monitoring Protocol

Introduction

The protocols discussed here are for use by City of Charlotte and Mecklenburg County Water Quality personnel in setting up and operating the stormwater SCM monitoring program. The monitoring program is detailed in the parent document "Stormwater Control Measure (SCM) Monitoring Plan for the City of Charlotte"

Equipment Set-up

For the program, 1-2 events per month will be monitored at each site. As a result, equipment may be left on site between sampling events or transported to laboratory or storage areas between events for security purposes. Monitoring personnel should regularly check weather forecasts to determine when to plan for a monitoring event. When a precipitation event is expected, sampling equipment should be installed at the monitoring stations according to the individual site monitoring protocols provided. It is imperative that the sampling equipment be installed and started prior to the beginning of the storm event. Failure to measure and capture the initial stages of the storm hydrograph may cause the "first flush" to be missed.
The use of ISCO refrigerated single bottle samplers will be used in the study. Two different types of flow measurement modules will be used depending on the type of primary structure available for monitoring

Programming

Each sampler station will be programmed to collect up to 96 individual aliquots during a storm event. Each aliquot will be 200 mL. in volume. Where flow measurement is possible, each sampling aliquot will be triggered by a known volume of water passing the primary device. The volume of flow to trigger sample collection will vary by site depending on watershed size and characteristic.

Sample and data collection

Due to sample hold time requirements of some chemical analysis, it is important that monitoring personnel collect samples and transport them to the laboratory in a timely manner. For the analysis recommended in the study plan, samples should be delivered to the lab no more than 48 hours after sample collection by the automatic sampler if no refrigeration or cooling of samples is done. Additionally, samples should not be collected/retrieved from the sampler until the runoff hydrograph has ceased or flow has resumed to base flow levels. It may take a couple of sampling events for the monitoring personnel to get a good "feel" for how each SCM responds to storm events. Until that time the progress of the sampling may need to be checked frequently. Inflow sampling may be completed just after cessation of the precipitation event while outflow samples may take 24-48 hours after rain has stopped to complete. As a result it may be convenient to collect the inflow samples then collect the outflow samples several hours or a couple of days later.

As described above, samples are collected in single bottle containers. Once the composited sample has been well mixed in the container, samples for analysis should be placed in the appropriate container as supplied by the analysis laboratory.

Chain of custody forms should be filled in accordance with CMU Laboratory requirements.

Collection of rainfall and flow data is not as time dependent as sample collection. However it is advised that data be transferred to the appropriate PC or storage media as soon as possible.

Data Transfer

Sample analysis results as well as flow and rainfall data will be QA/QC'd per standard operating procedure and entered into the water quality database (WQD).

APPENDIX C

STANDARD ADMINISTRATIVE PROCEDURE

Structural Best Management Practice (BMP) Monitoring
CR-MP (3), SWIM2 McDowell

Mecklenburg County Land Use and Environmental Services Agency Water Quality Program

Jon Beller	Sr. Environmental Specialist	Project Officer
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Steve Jadlocki	WQ Administrator	
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Charlotte-Mecklenburg Storm Water Services
Charlotte, NC

Standard Administrative Procedure
Modification / Review Log

Version	Eff. Date	Author	Summary of Changes	Approved
1.0		Jeff Price	Original Draft.	Jeff Price
1.1	8/13/07	Jeff Price	Formatting changes – minor.	Jeff Price
1.2	1/1/08	Jeff Price	Minor formatting changes, updates.	Jeff Price
1.3	4/1/09	Jeff Price	Minor formatting changes, updates.	Jeff Price
1.4	8/10/09	Jeff Price	Added Bacteriological sample collection utilizing automated samplers.	Jeff Price
1.5	9/2/09	Jon Beller	Updated site list, removed PSD sampling requirements.	Jeff Price
1.6	7/1/10	Jon Beller	Updated site list	
1.7	7/1/11	Jon Beller	Updated site list, updates.	

1.0 Purpose

1.1 To collect stormwater runoff data in support of the City of Charlotte's Pilot BMP Study Program and Mecklenburg County Special project sites, including the North Mecklenburg Recycling Center and CMC Huntersville sites.

2.0 Applicability

2.1 This Standard Administrative Procedure (SAP) is applicable to all storm water runoff events collected from BMPs under the Charlotte-Mecklenburg - Water Quality Work Plan; Program Elements CR-MP (3), and SWIM Phase II McDowell.

3.0 Program Summary

3.1 Collect flow-weighted storm water composite samples from the influent(s) and effluent of each of the BMP sites identified in Attachment 10.1

3.2 The data end-user will utilize the sample results to calculate pollutant removal efficiencies for each BMP sampled.

4.0 Health and Safety Warnings

4.1 Always exercise caution and consider personal safety first. Surface water sampling poses a number of inherent risks, including steep and hazardous terrain negotiation, threatening weather conditions, deep and/or swift moving water, stinging insects and incidental contact with wild animals.

4.2 Always were gloves and exercise universal precautions. Decontaminate hands frequently using a no-rinse hand sanitizer. Urban surface waters pose potential for pathogenic contamination.

4.3 Always exercise caution in handling the equipment. Automated samplers utilize 12-volt DC power sources and peristaltic pumps. Electrical and mechanical hazards are inherent in their maintenance and use.

4.4 Never lift or carry more than you can comfortably handle give site conditions. 12-volt batteries and 20-liter carboys full of sample water are very heavy.

5.0 Interferences

5.1 For pre-preserved sample collection bottles; overfilled, spilled or otherwise damaged containers should be discarded and a new sample should be collected. This reduces the risk of sample contamination and improper chemical preservation.

5.2 ISCO sample collection containers should be thoroughly mixed prior to pouring up individual sample collection bottles. This will ensure that representative samples are submitted for analysis.

5.3 Any observed equipment problems or any identified inconsistencies with Standard Operating Procedures during a sample event should be reported to the QA/QC Officer immediately. Issues identified in conflict with programmatic Data Quality Objectives may result in re-samples, additional samples, a scratched run or a scratched sample event.

6.0 Sample Collection Procedure

Preparation

6.1 Identify staff resources responsible for sample collection. Coordinate the sample event details with staff resources and the CMU lab as necessary.

6.2 For each site sampled, print the following:

6.2.1 Chain of Custody forms (Attachment 10.2)
6.2.2 BMP Event Data Sheet (Attachment 10.3)
6.2.3 Sample collection bottle labels (Attachment 10.4)

Note: Bottle labels require the use of special adhesive backed, waterproof label paper and a label printer. Otherwise, labels may be printed by hand utilizing

6.3 Assemble sets of the following sample collection bottles for each site; one set per sampler.

Note: *Bacteriological samples are not required at all sites, see Attachment 10.1.

6.3.1 1 x 1000ml (unpreserved) – TSS, Turbidity
6.3.2 1 x 500ml (HNO3) – Metals (Cr, Cu, Pb, Zn)
6.3.3 1 x 500ml (H2SO4) – Nutrients (N-NH3, NOX, TKN, TP)
6.3.4 3 x 100ml (sterile, NA2S2O3) – Bacteriological (Fecal Coliform, E Coli, Enterococcus)*
6.3.5 1 x 250ml (unpreserved) – SSC

6.4 Affix the self-adhesive labels to the appropriate sample collection bottles. Leave the Sample Collection Time blank. The sample collection time will be recorded from the automated monitoring equipment.

Sample Collection

6.5 At **each** sample site location; collect automated flow-weighted composite samples utilizing the Automated Surface Water Sample Collection procedure (Ref. 9.2).

6.6 Where required; collect bacteriological samples directly from the automated flow-weighted composite.

6.7 Create entry in Water Quality Database (WQD) stating what site was set-up and the date of set-up and sample collection.

6.8 When sample is collected, Monitoring Team Lead will enter event data into WQD for each site.

6.9 For failed events, staff will enter reason(s) event failed into WQD and forward to Monitoring Team Lead for review.

7.0 Performance / Acceptance Criteria

7.1 For each site, a complete sample event includes a flow weighted composite and in-stream instantaneous measurements for the following parameters, where appropriate.

F Coliform	TKN	*Chromium	Dissolved O2	*% Hydrograph
E Coli	*TP	*Copper	Sp. Conductivity	*Rainfall
Enterococcus	*TSS	*Lead	pH	
N-NH3	*SSC	*Zinc	*ISCO Flow	
NOx	*Turbidity	*Temp	*Event Duration	

* Denotes critical parameters.

7.2 Samples must be analyzed by a NC State certified laboratory for each parameter identified in 7.1 in order to be considered complete.

7.3 If utilized, YSI multi-parameter sondes must be calibrated before use and checked-in after use. All calibration data must be recorded in the calibration log.

7.4 Samples should be collected only after a minimum of 72 hours dry weather. Samples should be submitted for analysis only if all key ISCO samplers functioned for the entire event, as defined by the percentage of storm event hydrograph collected. Samples must meet or exceed 70% of the hydrograph in order to be considered complete. For additional guidance regarding ISCO Bacteriological sample collection, see Attachment 10.5.

7.5 All data must be submitted to the QA/QC Officer.

8.0 Data and Records Management

8.1 All field data must be entered by staff into WQD. Data is reviewed by Monitoring Team Lead and submitted to the QA/QC Officer for final approval.

8.2 All lab data must be submitted to the QA/QC Officer in electronic format.

8.3 All completed COCs must be submitted to the QA/QC Officer.

8.4 Electronic transfer of analytical data from the Laboratory database to the WQDR will be administered by the QA/QC Officer.

8.5 Transfer of all collected field data (flow and instantaneous in-stream measurements) to the WQDR will be administered by the QA/QC Officer.

9.0 References

9.1 YSI SOP – YSI Multiprobe Calibration and Field Data Collection (Short-term Deployment).

9.2 ISCO SOP - Automated Surface Water Sample Collection.

10.0 Attachments

10.1 – Example Chain of Custody

CHARLOTTE-MECKLENBURG UTILITIES - LABORATORY SERVICES DIVISION

Hal Marshall Laboratory, 700 North Tryon St., Charlotte, NC 28202, 704/336-5460

CLIENT:	MECKLENBURG COUNTY, LUESA - WATER QUALITY PROGRAM
FACILITY:	NA
PROJECT:	Pilot BMP Monitoring
LAB CODE:	CRMP3

Report To:	Jeff Price
	700N Tryon St. Ste. 205
	Charlotte, NC 28202

CHAIN OF CUSTODY RECORD			
PAGE	1	OF	1
COC#:			
Sampled By (Print Name)			

Location Code		Sample Collection: Staff ID	Date	Time	Chlorinated	Sample Temp: Coll Temp	Rcpt Temp	Sample Type: Depth Comp	Auto Comp	Hand Comp	Grab	Sample Containers: Plastic	Glass	# Containers	Chemical / Preservative: None	HNO3	H2SO4	NaOH	HCl	Na2S2O3	pH Correct	Analyses Requested: Fecal Coliform	E Coli	Nutrients	TSS	Turbidity	SSC	Metals	PSD
W-	Influent				N						X	100 ml		2						X		X	X						
W-	Influent				N				X			500 ml		1			X							X					
W-	Influent				N				X			1000 ml		1	X										X	X			
W-	Influent				N				X			250 ml		1	X												X		
W-	Influent				N				X			500 ml		1		X												X	
W-	Influent				N				X			250 ml		1	X														X
W-	Effluent				N						X	100 ml		2						X		X	X						
W-	Effluent				N				X			500 ml		1			X							X					
W-	Effluent				N				X			1000 ml		1	X										X	X			
W-	Effluent				N				X			250 ml		1	X												X		
W-	Effluent				N				X			500 ml		1		X												X	
W-	Effluent				N				X			250 ml		1	X														X

NOTES: Complete yellow shaded sections; each "X" needs to be circled.	Relinquished By: (Signature)	Received By: (Signature)	Date	Time
Metals = Cr, Cu, Pb, Zn				
Nutrients = NH3, NOx, TKN, TP	Relinquished By: (Signature)	Received By: (Signature)	Date	Time
Form Revision 2; effective 7/01/07				

10.2 – Example BMP Event Data Sheet

BMP Pilot Monitoring CR-MP(3)

Site Name:	

Composite Sample Information	**Sampling Date:**
Total Rainfall	
Total Rainfall Duration	
Days Since Previous Rain Event	
ISCO Event Duration	
Aliquots Sampled	
Sampler Pacing	
Sampled Storm Volume	
Total Discharge	
Percent of Hydrograph	

Grab Sample Information	**Sampling Date:**
pH	
Conductivity	
Dissolved Oxygen	
% Dissolved Oxygen	
Temperature	

Comments:

10.3 – BMP Example Sample Collection Bottle Label

Mecklenburg County LUESA/WQP BMP Monitoring	
Sample ID: (W–Site Name)	
Date: **/**/**	Time:_____________
Sample Type: Composite	Staff ID:___________
Preservative: (Preservative)	Bottle: (Vol) ml (type)
Tests: (Parameter)	

10.4 – ISCO Bacteriological Sample Collection Guidance

The following guidelines must be met in order to collect valid Bacteriological samples:

1. At the time of collection, the composite sample must be comprised of ≥15 sample aliquots.

2. Bacteriological samples must be pulled from the composite sampler ≤24 hours from the time that the first sample aliquot is collected.

3. ISCO refrigeration unit must be functional and the sample must be cooled to ≤4°C at the time of bacteriological extraction.

4. Bacteriological samples must be extracted in the field and immediately placed in a cooler on ice, for direct transport to the CMU lab.

APPENDIX D

STANDARD OPERATING PROCEDURE

AUTOMATED SURFACE WATER SAMPLE COLLECTION

Mecklenburg County
Land Use and Environmental Services Agency
Water Quality Program

Jon Beller	Sr. Environmental Specialist	Project Officer
Jeff Price	Environmental Analyst	QA/QC Officer
Rusty Rozzelle	Water Quality Program Manager	

City of Charlotte
Engineering and Property Management
Storm Water Services

Steve Jadlocki	WQ Administrator	
Daryl Hammock	Water Quality Program Manager	

Charlotte-Mecklenburg Storm Water Services
Charlotte, NC

Standard Operating Procedure
Modification / Review Log

Version	Eff. Date	Author	Summary of Changes	Approved
1.0	2/26/07	Jeff Price	Original Draft	Jeff Price
1.1	1/1/08	Jeff Price	Formatting changes – minor	Jeff Price
1.2	7/1/08	Jon Beller	Field Validation, minor formatting changes	Jeff Price
1.3	1/1/09	Jeff Price	Formatting changes – minor	Jeff Price
1.4	9/2/09	Jon Beller	New updates to account for ISCO Automated Fecal collection	Jeff Price
1.5	9/8/11	Jon Beller	New updates to account for addition of Water Quality Database	Jeff Price

1.0 Scope and Applicability

1.1 This SOP is applicable to the collection of flow-weighted composite surface water samples utilizing portable auto-samplers. Flow weighted auto-composite samples are suitable for both chemical and physical parameter analysis.

1.2 Automated samplers are not sterilized and therefore bacteriological samples collected in this manner are known to be in conflict with standard methods and commonly accepted protocols. However, bacteriological samples will be collected from full storm composites for research purposes. This data will be identified as special purpose data and utilized as such.

6.0 Summary of Method

3.1 Flow-weighted composite samples of surface water are collected from either free flowing streams or impounded water sources utilizing automated samplers.

3.2 Surface water sub-samples, or aliquots, are pumped from the source utilizing a peristaltic pump and a computer-controlled sampling "head". The sample aliquots are drawn from the source in proportion to measured water flow (discharge in cf) so that the final composite sample represents the entire range of flow conditions, or hydrograph, observed at a site during a precipitation event.

3.3 The final composite sample is distributed among various certified clean, pre-preserved bottles suitable for relevant laboratory analysis. All samples are submitted to a NC State certified laboratory for the analysis and quantification of surface water pollutants.

6.0 Health and Safety Warnings

3.1 Caution should always be exercised and personal safety considerations must be considered paramount for field monitoring. Surface water sampling poses a number of inherent risks, including steep and hazardous terrain negotiation, deep and/or swift moving water, stinging insects and occasional contact with wild animals.

3.2 Always wear gloves when sampling and decontaminate hands frequently using a no-rinse hand sanitizer. Universal precautions should be exercised when exposed to urban surface waters with unknown potential for contamination.

3.3 Always exercise caution in handling the equipment. Automated samplers utilize 12-volt DC power sources and peristaltic pumps. Electrical and mechanical hazards are inherent in their maintenance and use.

3.4 Never lift or carry more than you can comfortably handle give site conditions.
12-volt batteries and 20-liter carboys full of sample water are very heavy.

4.0 Interferences

4.1 Improper sample pacing. Automated samplers are limited by the number of aliquots (of a given volume) that can be drawn before the sample carboy is filled. Improperly paced sampling equipment has potential to miss portions of a precipitation event.

4.2 Improperly cleaned (or contaminated) sampling equipment. Sample collection carboys must be cleaned and QC equipment blanks are used to verify equipment decontamination.

4.3 Cross-contamination of samples during transport. Always place filled samples collection bottles (samples) upright in the cooler so that the neck and cap are above the level of the ice. Drain ice melt-water from coolers periodically to ensure that sample bottles are not submerged.

4.4 Battery failure following sample collection. Failed refrigeration due to battery failure results in improperly preserved samples.

4.5 Vandalism of equipment. Sampling equipment is often placed near inhabited areas that have the potential to be damaged by vandalism.

5.0 Equipment and Supplies

5.1 The following equipment is generally needed for automated, flow-weighted composite surface water sample collection:

- ISCO 6712 Avalanche refrigerated auto-sampler
- ISCO 750 Area Velocity Flow Module or ISCO 730 Bubbler Flow Module
- Continuous Temperature Probe
- ISCO 674 Rain Gage
- ISCO 581 Rapid Transfer Device
- Cleaned 18.9-liter sample collection carboy
- 12-volt deep cycle battery
- Sampler collection tubing
- Stainless steel bubbler tubing
- Metal job box
- Chain
- Lock
- Anchor

- CMU Lab Chain of Custody Form (Attachment 13.1)
- CMU Sample Collection Bottle Selection Guidance Chart (Attachment 13.2)
- Certified clean, pre-preserved sample collection bottles appropriate for intended parameter analysis (provided by CMU)
- Sample bottle self-adhesive labels
- 4-liters of lab distilled/de-ionized reagent grade water
- CMU lab sterilized buffered bacteriological blank solution
- Sharpie, pen
- Map Book
- Gloves
- Hip waders, rubber boots
- Hand sanitizer

6.0 Automated Sampling Site Set Up

6.5 Identify a suitable site to locate the auto-sampler depending on objectives of the sampling program.

6.6 Set up metal job box near the stream or site to be sampled but far enough away to be out of the flow range during storm events.

6.7 Screw the trailer anchors into the ground near the job box and lock the job box to the anchor with the safety chain.

6.8 Place the ISCO 6712 Avalanche automated sampler in the job box along with a 12-volt battery.

6.9 Attach the strainer tube and metal bubbler or Area Velocity sensor at the desired height in the stream, pipe or pond.

6.10 Connect a measured length of vinyl tubing from the sampler through the bottom of the job box to the strainer.

6.11 Depending on the configuration, either connect a piece of vinyl tubing from the sampler to the metal bubbler tube or connect the cable to the Area Velocity module.

6.12 Connect the power cables to the 12 V battery.

6.13 Complete the initial programming of the 6712 Sampler using the procedure in Section 7.0. Refer to the ISCO Operating manual or consult the Monitoring Team Supervisor for further details.

6.14 Create new BMP entry for each site set-up in the Water Quality Database (WQD).

7.0 ISCO 6712 Avalanche Auto-Sampler General Set-up and Programming

Note: Programming steps represent general examples and choices only. Actual programming is unique to an individual site and must be modified in order to collect representative samples. Modification of the programming steps is based on knowledge of the site, expected conditions, professional judgment and experience.

7.1 Place a cleaned, 18.9-liter sample collection carboy in the auto-sampler's refrigerated sample collection compartment. Insure that lid is removed and sample tube is placed into the carboy.

7.2 Place a charged 12-volt battery in the auto-sampler Job-Box and connect the unit's power lead to the battery terminals.

7.3 Insert appropriate Flow Module into auto-sampler unit.

7.4 Turn on the auto-sampler "Power".

7.5 Select "Program".

7.6 Enter the Program Name (site id).

7.7 Enter the Site Description (site id repeated).

7.8 Enter Units as follows:

- Length (ft.)
- Temperature (C)
- Flow Rate (cfs – BMPs / Mgal - ISM)
- Flow Volume (cf)
- Velocity (fps)

7.9 Select the Mode of Operation based on the hardware configuration selected in 8.3 and the site installation (unique to site; subsequent detailed information required):

- Bubbler Flow Module 730
  - V-Notch Weir (most common):
    - Specify V-Notch angle (Ex. 90°)
  - Data Points (less common – orifice plates and ISM storm water)
    - New Set
    - Clear Data Set
    - Change Name

        - Edit Data Points (enter up to 50 data points; level and cfs)
    - Flume (uncommon)

- Area*Velocity Flow Module 750
    - Flow Meter
    - Area*Velocity
    - Channel Shape
    - Enter Type
        - Round Pipe (most common)
    - Pipe Diameter (ft.) (Eg. 18 inch pipe = 1.5 ft. diameter)

7.10 Enter Current Level (ft.).

- For BMP sites - storm flow only.
    - Bubbler
        - Enter water depth from bubbler to bottom of V-Notch in weir (ft.)
            - Water level below bubbler
                - Distance from bubbler to invert of V-notch weir (negative ft.)
            - Water level above bubbler
                - Difference between water level and invert of V-notch weir (negative ft. – below invert; 0.0 ft. at invert; positive ft. above invert)

Note: Measure distances in inches and divide by 12 to determine distances in ft. Eg. Water level is below bubbler; bubbler is set 1 inch below V-notch weir. Set water depth at -0.08 ft. (1 inch divided by 12 inches/ft. = 0.08 ft.)

    - Area*Velocity
        - Enter (0.000 ft.) when no flow is present.
        - If flow is present, consult the Monitoring Team Supervisor.

- For Stream sites - flow present.
    - Determine current water level from USGS internet website.
    - Enter level (ft.).

7.11 Enter Offset (0.000 ft.) if prompted.

7.12 Enter Data Interval (5 minutes).

7.13 Enter sample collection container information.
- Bottles (1).
- Volume (18.9 L).
- Suction Line (Length of sampler tubing (ft.)).

- Auto Suction Head
- 0 Rinse
- 0 Retry

7.14 Select One-Part Program.

7.15 For Pacing;

- Flow Paced
- Flow Module Volume
- Enter (cf) - unique to site; based upon drainage area, forecast precipitation volume, professional judgment and experience.
- No Sample at Start.

7.16 Run Continuously? - No.

7.17 Enter number of aliquots to Composite (90).

7.18 Enter Sample Volume (200 ml).

7.19 Select "Enable"

- Bubbler Module.
  - Select "Level".
  - For BMP sites;
    - Water level below invert
      - Enter (>0.001 ft.).
    - Water level at or above invert
      - Enter current water level + (0.01 ft.).
  - For Stream sites; Enter (current water level + 0.05 ft.) - current level + margin of safety before sampler enable.

- Area*Velocity Module.
  - Select "Level".
  - For dry pipe;
    - Enter (>0.005 ft.)
  - For pipe with flow;
    - Enter (current water level + 0.02 ft.) - current level + margin of safety before sampler enable.

7.20 Enable.

- Repeatable Enable.
- No Sample at Enable.
- No Sample at Disable.

7.21 Countdown Continues While Disabled.

7.22 No Delay to Start.

7.23 Run This Program.

8.0 Auto-Sampler Composite Retrieval

8.1 Stop Program and View "Sampling Report".

8.2 Scroll through the sampling report and record the time and date of the last aliquot sampled. Enter this information on the Lab COC.

8.3 Connect ISCO RTD 581 to the auto-sampler's Interrogator port. Disconnect RTD when "Download Complete" is indicated by steady green light.

8.4 Turn off the auto-sampler "Power".

8.5 Disconnect the battery leads to the auto-sampler.

8.6 Replace the cap on sample collection carboy.

8.7 Remove the sample collection carboy from the auto-sampler's refrigerated sample compartment and put in cooler for transport to the composite bottling staging area.

9.0 Auto-Sampler Composite Bottling

9.1 Print the appropriate COC forms required for the event.

9.2 Coordinate the sample collection event details with required staff resources and with the CMU lab (number of sites, parameters for analysis, etc.)

9.3 Assemble the required sample collection bottles for each site to be sampled. Pre-print all known information on self-adhesive sample collection bottle labels. Make sure to leave the Sample Collection Time blank (this will be completed when the last aliquot collection time is determined).

9.4 Label the sample collection bottles with the approximate <u>Sample Collection Time</u> (+/- 5 minutes).

9.5 Remove the sample collection bottle cap(s) and place the bottle(s) on a level, stable surface.

9.6 Shake the auto-sampler composite carboy to thoroughly mix the sample.

9.7 Fill the sample collection bottle(s) to the bottom of the neck or to the indicated mark with the auto-sampler composite, approximately 80-90% full. Be careful not to overfill the sample collection bottles!

9.8 Replace the sample collection bottle cap(s).

10.0 Auto-Sampler Grab Sample Collection (pump-grab)

Note: Pump grabs are not commonly collected, but may be utilized in special circumstances, as required.

10.1 Turn on the auto-sampler "Power".

10.2 Select "Other Functions", "Manual Functions", "Grab Sample".

10.3 Enter sample <u>Volume</u> (ml), based on collection container.

10.4 Disconnect large diameter sample collection tubing from the peristaltic pump housing on the front, left-side of the auto-sampler unit.

10.5 Carefully open the sample collection bottle cap. Be sure not to contact any inside surface of the bottle cap or the bottle.

10.6 Press Enter when ready to collect the sample.

10.7 Allow a small amount of sample water to flow through the tube, onto the ground to clear the line.

10.8 Direct the flow from the large diameter sample collection tubing into the sample collection bottle, but do not contact any surfaces of the collection bottle.

10.9 Fill the sample collection bottle to the indicated volume. Do not overfill bottle.

10.10 Replace the sample collection bottle cap.

10.11 Re-connect the large diameter sample collection tubing.

11.0 Post-Sample Collection

11.1 For failed events, document reason for failure (power fail, pacing…) in WQD and forward to Monitoring Team Lead for review.

11.2 Place all sample collection bottles (and blanks) upright in the cooler. Do not submerge sample bottles in ice-melt water as indicated in 4.3.

11.3 For potential valid samples, give RTD to Monitoring Team Lead for pre-sample screening.

11.4 Monitoring Team Lead will download RTD to Flowlink software.

11.5 Validate sample by determining if ≥70% of hydrograph collected. If <70% of the hydrograph was represented, discard the sample and follow 11.1.

11.6 Complete the COC.

11.7 Deliver all sample bottles in the cooler on ice to the CMU Lab for analysis.

11.8 Monitoring Team Lead will enter field data and Flowlink software data into WQD and forward to WQ Data Manager for final review.

11.9 Submit a copy of the completed COC form to the WQ Data Manager.

12.0 Field QC Blank Collection (when required)

12.1 When required by a project or program element, assemble one set of sample collection bottles for QC blanks.

12.2 When QC blanks are required, fill a certified-clean 4-liter bottle with lab distilled/de-ionized reagent grade water for each auto-sampler.

12.3 Replace the small diameter auto-sampler sample collection tubing on the back, left-side of the unit with a short section of clean, new tubing.

12.4 Remove the cap from the distilled/de-ionized reagent grade water or the sterilized buffered bacteriological blank solution as appropriate.

12.5 Insert the short section of new sample collection tubing into the distilled/de-ionized reagent grade water to draw the blank solution up through the auto-sampler unit.

12.6 Turn on auto-sampler “Power”.

12.7 Select “Other Functions”, “Manual Functions”, “Grab Sample”.

12.8 Enter sample <u>Volume</u> (2500 ml required min for full parameter suite analysis).

12.9 Press Enter when ready to collect the sample.

12.10 Collect the required volume of sample blank in the sample collection carboy.

12.11 Remove the blank collection bottle cap(s).

12.12 Shake the auto-sampler composite carboy to thoroughly mix the sample (blank).

12.13 Place the blank collection bottle(s) on level, stable surface. Fill the blank collection bottle(s) to the bottom of the neck or to the indicated mark with the appropriate blank solution, approximately 80-90% full. Be careful not to overfill the blank collection bottles!

12.14 Replace the blank collection bottle cap(s).

12.15 Refer to Section 11.0 for Post Sample Collection procedures.

13.0 References

13.1 ISCO 6712 Avalanche Operating Manual.

APPENDIX E

Pilot SCM Data Analysis Protocol

Charlotte-Mecklenburg Storm Water Services (CMSWS) conducts routine BMP Performance Monitoring for both regulatory and non-regulatory purposes. Regulatory monitoring may be utilized to ensure BMP compliance with water quality standards or performance criteria mandated by State or local government, as required by Phase I and Phase II NPDES permits, the Charlotte-Mecklenburg Post-Construction Ordinance, etc. Non-regulatory monitoring is generally utilized to satisfy grant requirements for Capital Improvement Projects as well as assessing the general performance and efficiency of select BMPs.

BMP monitoring may include both inter-site and intra-site comparisons, depending on the monitoring goals. Inter-site comparisons (site to site) can test varying BMP designs on similar land-use types, and test varying land-use types on one specific BMP design. Intra-site comparisons can test long term efficiency, maintenance intervals, site stabilization, etc. at one site over a specified time period. Both inter-site and intra-site analysis of BMP performance can be utilized to optimize BMP design and to conserve limited resources.

Charlotte-Mecklenburg Storm Water Services will base routine BMP Performance Monitoring and analysis on guidance provided in the October 2009 publication, *Urban Stormwater BMP Performance Monitoring* prepared by Geosyntec Consultants and Wright Water Engineers under contract with the EPA. In addition to the EPA, the guidance preparation was sponsored by the American Society of Civil Engineers (ASCE), the Water Environment Research Foundation (WERF), and the Federal Highway Administration. The published guidance recommends that BMP performance monitoring be analyzed utilizing what is termed the **Effluent Probability Analysis** method. Each section below describes components of the Effluent Probability Analysis approach in detail, where applicable.

A great deal of environmental data is reported by analytical laboratories as "below detection limit" (nondetect). This does not mean that the target pollutant was not present, it simply means that the level of pollutant was too small to quantify given the limits of the analytical test procedure. There is still valuable information in a reported nondetect. However, traditionally, analysts have simply substituted the detection limit or some arbitrary number (like ½ the detection limit) for these unspecified values. This introduces an invasive pattern in the data, artificially reduces variability and subsequently narrows the error measurement range. This can affect hypothesis testing and increase the likelihood of accepting incorrect conclusions. Therefore, in an effort to improve the accuracy of calculated estimates and hypothesis testing results, and to ensure that the results of all analysis are considered "defensible" to the larger scientific community, CMSWS will treat nondetect data in accordance with published guidance from Dr. Dennis Helsel, formerly of the United States Geologic Survey (USGS) and currently director of *Practical Stats*. Dr. Helsel published *Nondetects and Data Analysis; Statistics* *for Censored Data* in 2005, specifically addressing the issues of non-detect data and how to best treat such data during analysis. This book will serve as guidance on handling nondetect values encountered in CMSWS BMP performance monitoring data.

At a minimum, a complete performance analysis report will include a review and qualification of the storm events sampled, descriptive statistics and calculated pollutant removal efficiencies for each analyte of interest. All statistical analysis will be performed using some combination of Minitab 16 with add-in macros from Dr. Helsel (NADA – Practical Stats), Analyze-It for Microsoft Excel, DOS-based software developed by the USGS, or other commercially available software. Each section below includes an example analysis based on data previously collected by CMSWS.

5.2.1 Storm Event Criteria Qualification

Not every storm event is suitable for sampling; nor is each sampled storm event suitable for use in performance analysis. In fact, some storm events sampled are not submitted to the lab for analytical results in an effort to conserve resources. These are complex decisions based on various factors, including: storm duration, intensity, precipitation amount, antecedent weather conditions, the volume of discharge collected, and the percentage of the storm hydrograph captured. Each of these factors plays a very important role in storm event qualification.

It is important to note that storm event qualification occurs prior to review of the analytical data. It is also important to note that analytical data quality control is an independent process completely separated from event qualification. This process was not intended or expected to bias results, but rather simply to control exogenous variables and therefore minimize variability in the dataset. The overall goal of this approach is to use only events that meet specified data quality objectives in order to achieve statistically significant (or non-significant) results from the smallest dataset possible in order to conserve resources.

In general, CMSWS does not monitor an event unless it has been dry weather for 3 days prior to the target storm event. CMSWS defines an acceptable "dry" weather period preceding monitored events as 3 consecutive 24 hour periods during which no more than 0.1 inches of precipitation fell during any one period. This antecedent dry weather period is consistent with guidance from the State of North Carolina Department of Environment and Natural Resources (NC DENR) and is thought to be the minimum sufficient time for pollutants to "build up" on a site between storm events.

CMSWS also does not monitor storm events that exceed the 2-year design storm. For the Charlotte-Mecklenburg area of the NC Piedmont, the 2-year design storm is approximately 3.12" in 24 hours. For BMP efficiency monitoring analysis, CMSWS utilizes only storms that meet BMP design criteria. For many BMPs the specified design criteria is a 1-inch rain event in a 24 hour period. However, this does not apply to many proprietary "flow-thru" devices and other BMPs designed to different or specific standards. In this way, storm flow bypasses, which may introduce additional uncertainty in an analysis, are excluded. Events monitored that exceed the BMP design capacity would be utilized for watershed level land use estimates of loading only.

CMSWS only submits storm samples to the lab for analysis if there were enough aliquots collected in the composite to provide the laboratory with sufficient sample volume to analyze any identified critical parameters. The typical target is 15 aliquots minimum; however sufficient volume can be produced from fewer aliquots and should be reviewed case-by-case. On the other end of the spectrum, no storm samples will be analyzed if the auto compositor finishes its cycle of 90 aliquots before the storm ends, unless at least 70% of the hydrograph was represented. The criterion to sample a minimum of 70% of the hydrograph is intended to ensure that the composite sample is representative of the overall storm flow discharge. This threshold is consistent with Technology Acceptance Reciprocity Partnership (TARP) Tier II protocols (July 2003, Sect. 3.3.1.2 – Identifying Storms to Sample). Any noted flow problems, power failure or other equipment related interferences may result in a discarded sample. Only samples that are deemed suitable for analysis by these criteria are utilized in the determining the overall performance of a BMP.

Special situations or certain projects may arise that require lower standards for acceptable storm event criteria. Any deviations from the aforementioned criteria will be noted in the associated performance report in order to clearly identify which criteria were compromised, why the standards were lowered, and what bias or influence may be realized, if known. It is again important to note that these storm event criteria will be applied to data sets prior to any exploratory analysis and without preconceived ideas or goals for the outcome. In this way, bias to an objective outcome will be minimized.

5.2.2 Characterizing Discharge (Storm Volume Reduction)

BMP performance analysis begins with understanding the nature of the storm events sampled. Once the storm events have been reviewed and qualified as approved for analysis, discharge data will be used to determine if practice level storm volume reduction has been realized. It should be noted that this component of the analysis is not appropriate for all BMPs. Those BMPs designed as flow-thru devices, with no expectation of storm water retention or infiltration will be treated accordingly. Many such BMPs are equipped with influent flow measurement equipment only. In these cases, the influent storm volume is assumed to equal the effluent storm volume, with treatment realized in pollutant concentration reduction only.

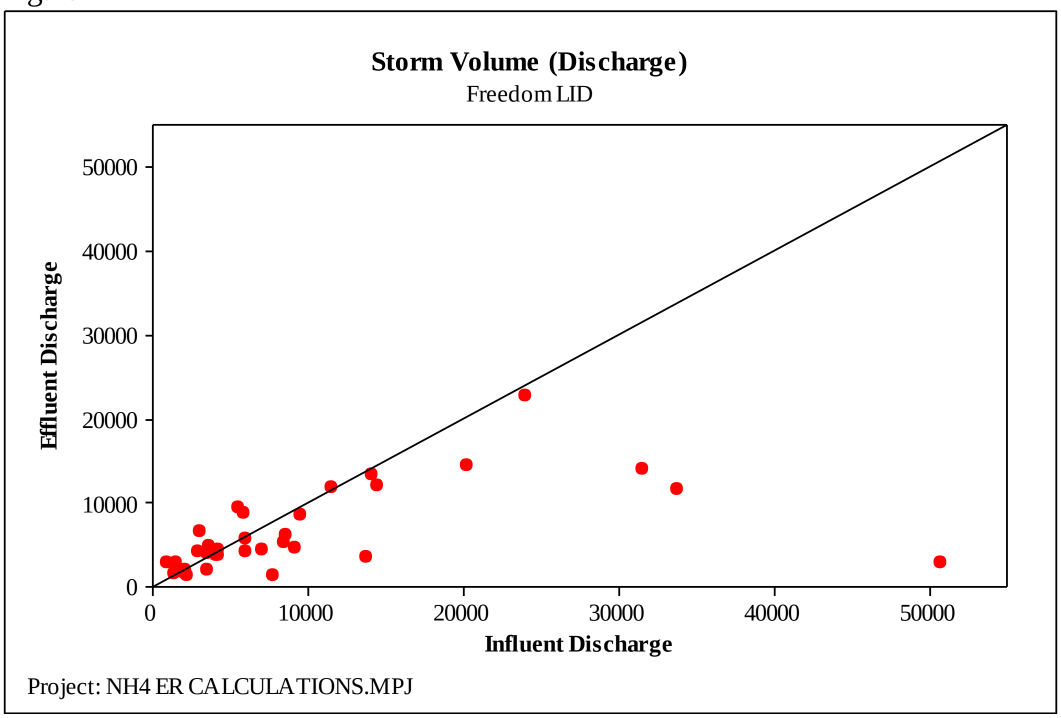
For those BMPs with some expectation of storm water retention or infiltration, characterization and analysis of the storm events and the discharged storm volume is critical. There are five relatively simple ways that this analysis can be conducted and storm events characterized; presence/absence of effluent discharge, absolute volume reduction, relative volume reduction, discharged volume per area and discharged volume per impervious area. The metrics themselves are fairly self-explanatory and simple to calculate.

The most practical of these approaches is likely the absolute volume reduction, realized over time. For this analysis, only paired influent-effluent discharge data can be utilized. For data sets where there are fewer paired observations, the error in estimates will be greater. Essentially, each paired observation is evaluated as:

Absolute Volume Reduction = Influent Volume – Effluent Volume

The volume reductions are then summed over the period of observation. Once the data have been summed, the relative reduction will also be evident, if any. The graphic created in Figure 4 can be helpful to understanding and interpreting this concept visually. Absolute storm flow volumes for the paired influent and effluent samples are plotted as independent (x-axis) and dependent variables (y-axis), respectively. The diagonal line represents the point at which influent volume is equal to effluent volume. Events represented in the lower and right portion of the graphic indicate that influent volume exceeded effluent volume, and consequently some reduction in absolute volume was realized. If a majority of the events fall in this area, as in this example, it is likely that long term reductions will be realized as well.

Figure 4



Discharge data and volume reductions should be tested for statistical significance. Hypothesis testing for paired discharges, influent and effluent, should utilize the Sign test to determine if any reductions in storm volume discharge realized were statistically significant. In this example, the paired influent and effluent samples were found to be significantly different ($p=0.0326$). If paired discharges are not available, other suitable nonparametric hypothesis tests, such as the Mann-Whitney test should be utilized on the pooled event data; influent vs. effluent. Specifics about hypothesis testing are covered in Section 5.2.4.

5.2.3 Descriptive Statistics

For each analyte of interest, the following information will be provided, where appropriate: n (number of observations), Mean, 95% Confidence Interval (CI) of the mean, Standard Error (SE), Standard Deviation (SD), Minimum value observed, 1st Quartile value, Median, 95% Confidence Interval (CI) of the median, 3rd Quartile value, Maximum value observed, and the Inter-Quartile range (IQR). Descriptive statistics are often accompanied by a graphic indicating the data distribution and any identified outliers.

Figure 5 indicates an example of descriptive statistics, which provide basic parametric and nonparametric information on the distribution of the data collected.

Figure 5

ROS Estimated Statistics for FLIDU-NH4

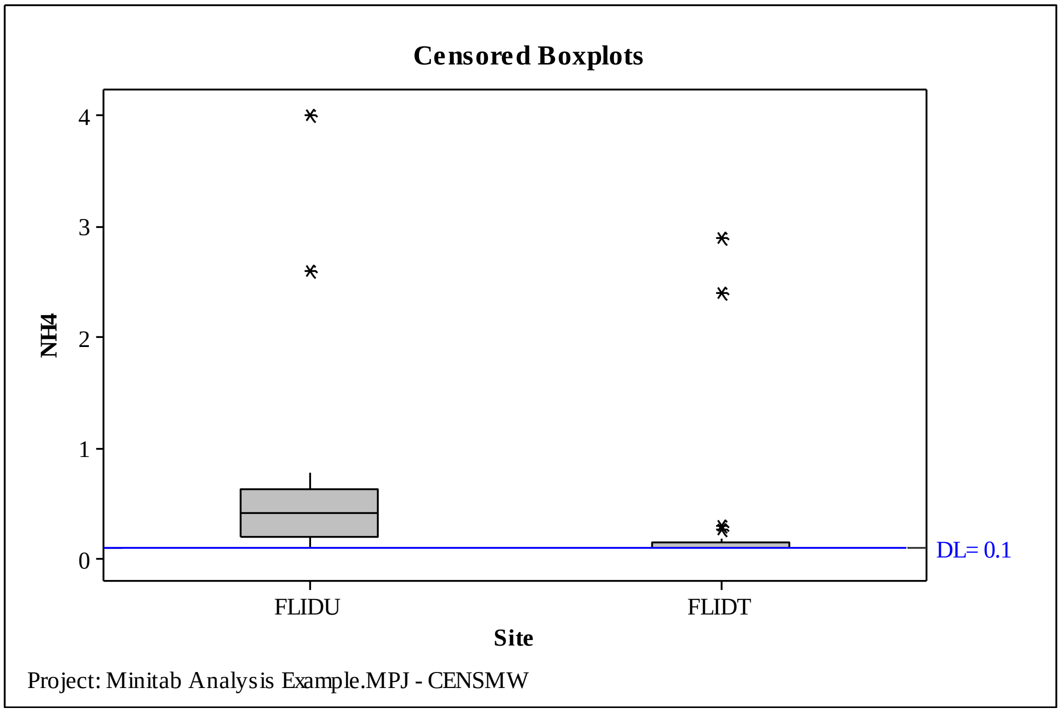
```
Variable    N  N*    Mean  SE Mean  StDev  Minimum     Q1  Median     Q3
Maximum
ESTIMATE   36   0   0.540    0.122  0.734    0.042  0.195   0.410  0.635
4.000

Variable    IQR
ESTIMATE  0.440
```

ROS Estimated Statistics for FLIDT-NH4

```
Variable    N  N*    Mean  SE Mean  StDev  Minimum     Q1  Median     Q3
Maximum
ESTIMATE   36   0   0.212    0.101  0.608    0.001  0.007   0.030  0.155
2.900

Variable    IQR
ESTIMATE  0.148
```

These descriptive statistics are represented graphically in Figure 6 below, in order to gain a visual understanding of the data distribution. A box plot can be utilized to quickly identify relative differences between the sampling sites.

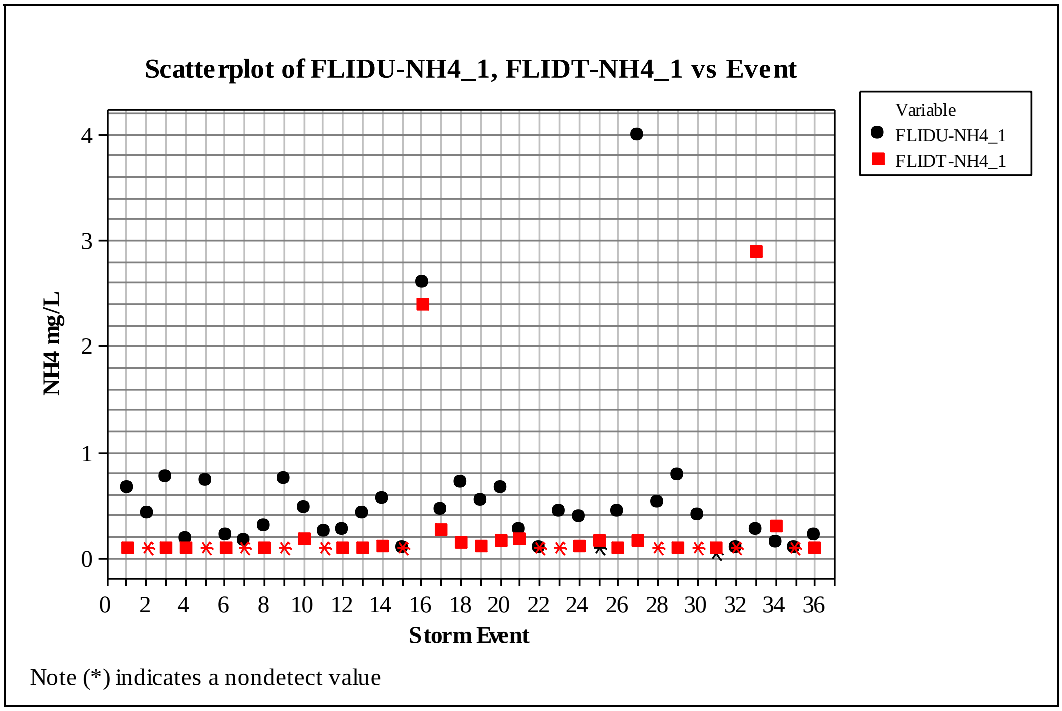
Figure 6



The top of each box represents the 3rd Quartile value (75th percentile), whereas the bottom of each box represents the 1st Quartile (25th percentile). The difference between the top and the bottom of a box represents the Inter-quartile Range. The "waist" or central line within a box represents the Median. The upper and lower line extending from the box often represent the extent of the observed data within 1.5 IQRs of the upper and lower quartile. The example plot in Figure 6, displays outliers beyond 1.5 IQRs as asterisks (*). In some cases, outliers beyond 3 IQRs are represented as plus signs (+). It is important to note that outliers could be removed for the purposes of visualization, but should not be removed from the dataset prior to analysis. The blue horizontal line in Figure 6 marked as "DL=0.1" indicates the laboratory detection limit for NH_4, which in this analysis was 0.10 mg/l. Data below the laboratory detection limit cannot be accurately represented in a box plot.

The graphic in Figure 7 can also be helpful to visualize the data set in relation to the individual storm events that produced the runoff. Influent and effluent concentrations are paired by storm event, where possible. In this particular graphic, numerous values were reported as nondetect and 1 value (FLIDU - event #31) was reported at 0.04 mg/l (*) which is well below the typical detection limit of 0.10 mg/l. Any values that appear at or below the specified detection limit should be treated and viewed only as unspecified values occurring anywhere below that value.

Figure 7



5.2.4 Hypothesis Testing: Pairs or Groups

In general, environmental data is not normally distributed and in most cases, non-parametric hypothesis tests are utilized to test the difference in median location of two or more populations. However, in the event that data sets are found to be normally distributed, parametric statistical tests could be utilized for analysis, if advantageous.

The most common parametric tests utilized will be the Student's T-Test and the Analysis of Variance (ANOVA) for comparison of means. However, the occurrence of normally distributed data and the use of parametric analysis techniques will likely be the exception, rather than the rule. For this reason, the examples and discussion to follow will focus on typical, non-parametric analysis techniques for non-normally distributed environmental data sets.

The first step in selecting the most appropriate nonparametric test method is to determine if there are a sufficient number of data pairs for analysis. For sites with large numbers of unpaired observations, the use of the hypothesis tests for groups (pooled data) would be most appropriate. However, for sites where there are significant numbers of paired observations, hypothesis tests designed for paired data will have more power to detect differences.

5.2.4.1 Hypothesis Testing – Group (Pooled) Data

The most commonly utilized non-parametric hypothesis tests for **pooled** datasets are the Mann-Whitney U test for 2 groups (also known as the Wilcoxon Rank Sum test) and the Kruskal-Wallis test for 3 or more groups. Both tests utilize rank or rank scores, rather than raw data observations, so there is no need to transform data. These 2 tests are analogous to the traditional T- tests utilized for parametric data, with the exception that the non-parametric tests compare the location of the median score, rather than the mean, and are appropriate for small data sets with non-normal distributions. Both the Mann-Whitney U test and the Kruskal-Wallis test are appropriate for small data sets; however a minimum of 12-15 observations are often required to discern statistical differences. Unless otherwise specified, p-values <0.05 will be considered significant.

Figure 8 represents an example output from a Mann-Whitney non-parametric test, when applied to an example **pooled** Ammonia-Nitrogen data set. Based on the box plot constructed for the dataset (see Figure 6), the influent NH_4 concentration appeared to be much greater than the effluent concentration. Therefore, the hypothesis tested was directional; H_O: Influent>Effluent. The corresponding 1-tailed p-value (p=0.0000) indicated that the observed difference between the influent and the effluent was highly significant.

If 3 test groups had been present, for example, Influent, Fore bay and Effluent, the Kruskall-Wallis test could have been utilized to test all 3 groups against a control or against each other. Such contrasts can provide additional useful information. In this example, it may be interesting to determine if there is a significant pollution concentration difference between the influent sample and the fore bay.

Figure 8

```
Mann-Whitney Test and CI: FLIDU, FLIDT

        N   Median
FLIDU  36   0.4100
FLIDT  36  -1.0000

Point estimate for ETA1-ETA2 is 1.1900
95.1 Percent CI for ETA1-ETA2 is (0.3399,1.3900)
W = 1729.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)

Use tie adjustment.  All values below 0.1 were set = -1.
If a median = -1, it means the median is <0.1
```

5.2.4.2 Hypothesis Testing – Paired Data

The most commonly utilized non-parametric hypothesis tests for **paired** datasets are the Sign test and the Wilcoxon Signed Ranks test. The main difference between these 2 tests is that the Wilcoxon Signed Ranks test assumes that the 2 groups have a similar shape or distribution of data. The Sign test makes no assumptions about the shape of the data distribution, and therefore is more often utilized. Both tests are appropriate for small datasets and unless otherwise specified, p-values <0.05 will be considered significant.

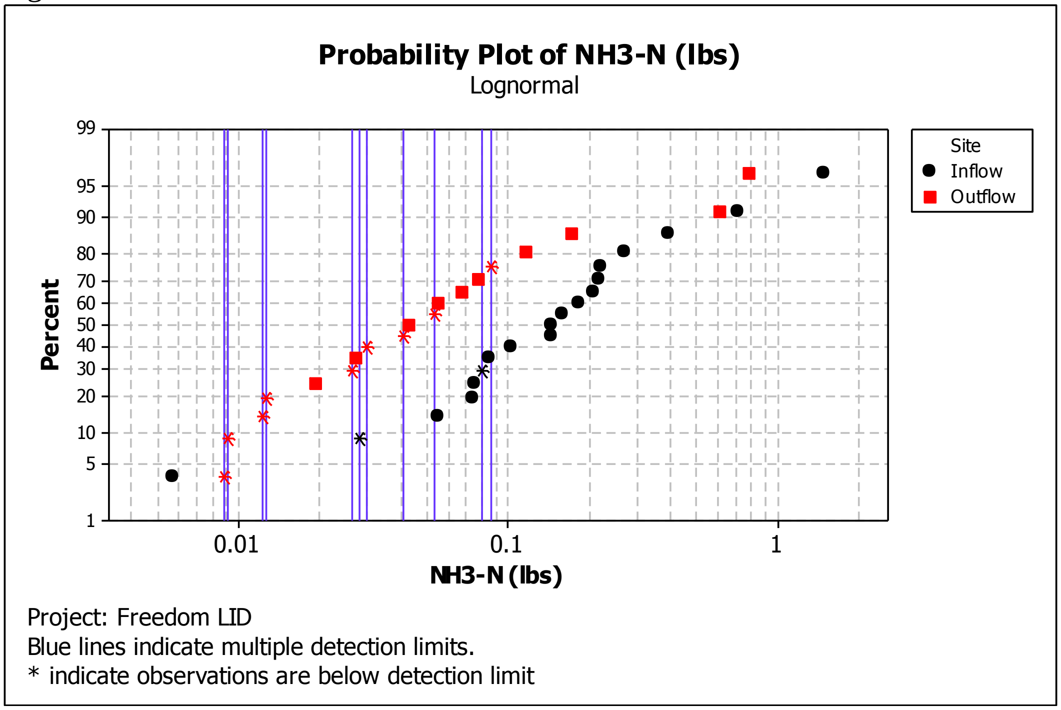
Figure 9 represents an example output from a Sign test, when applied to an example Ammonia-Nitrogen **paired** data set (Influent-Effluent for each event sampled). Based on the box plot constructed for the dataset (see Figure 6), the influent NH_4 concentration appeared to be much greater than the effluent concentration. Therefore, the hypothesis tested was directional; H_O: Influent>Effluent. The corresponding 1-tailed p-value (p=0.0007) indicated that the observed difference between the influent and the effluent was highly significant.

Figure 9

```
Sign Test for Median: FLIDU-NH4_1-FLIDT-NH4_1

Sign test of median =  0.00000 versus not = 0.00000

                          N  Below  Equal  Above        P
Median
FLIDU-NH4_1-FLIDT-NH4_1  36      4      4     28   0.0000
0.2400

p-value (adjusted for 'Equal' ties) = 0.0007

Median difference adjusted for nondetects = 0.28
```

The box plot referenced in Figure 6 indicates one traditional way to visually explore the difference between the influent NH_4 concentration and the effluent concentration. A second way to visually explore the differences is to generate a probability plot based on the observed values at various percentiles. Figure 10 represents a probability plot generated from the example data set, and indicates that reduced effluent concentrations were observed over the range of observations.

Figure 10



In some cases when there is a single detection limit, the observations may "flatten" out and form straight, vertical-dropping lines. This typically indicates that the analytical Detection Limit (DL) has been realized. In this particular case, there were multiple detection limits for NH_4 storm water dilutions below 0.10 mg/l. Although there are points represented in this graphic as asterisks (*), they represent nondetects and should be treated as unspecified values with a true location anywhere between the y-intercept and the x-axis.

5.2.5 BMP Efficiency

BMP Efficiency is commonly reported and there are many recognized metrics. CMSWS will typically report BMP efficiency by analyte in 1 of 3 ways; Pollutant Concentration Removal, Summation of Load [Reduction], or Individual Storm Load [Efficiency]. Each of these methods for calculating BMP efficiency is based on varying assumptions and each has both strengths and limitations. As a consequence, each metric may yield differing results when applied to the same dataset. An *a priori* effort will be made to utilize the most appropriate metric(s), based on the detailed pros and cons of each as published in Appendix B of the *October 2009 Guidance*.

5.2.5.1 Efficiency Ratio – Pollutant Concentration

Where appropriate, the calculated Efficiency Ratio (ER), which is sometimes referred to as the Pollutant Removal Efficiency, will be provided for each analyte of interest. ER is typically expressed as a percentage of the analyte concentration removed from the influent, when compared to the effluent sample. Ideally, ERs are calculated based on complete data pairs; however, there are situations where sample results are aggregated or grouped as “influent” and compared to grouped “effluent” samples.

The formula typically used to calculate the pollutant concentration ER utilizes the average influent and effluent Event Mean Concentration (EMC) for each analyte of interest. However, because the EMC data in the example data set is not normally distributed, the average or mean concentration has very little real value. Simply averaging the influent EMCs and the effluent EMCs presents a potentially biased result. According to the *October 2009 Guidance*, “The median EMC may be more representative of the typical or average site storm event discharge concentration because the value is more robust in the presence of outliers, when compared to the mean. The mean EMC for a site, on the other hand, may be completely biased by a single event that had an abnormally high discharge concentration due to an anomalous point source mass release (e.g., a silt fence failing at a construction site).” Therefore, the formula used for calculating Efficiency Ratio will be:

$$\text{Efficiency Ratio (ER)} = \frac{\text{Median Influent EMC} - \text{Median Effluent EMC}}{\text{Median Influent EMC}}$$

In the specific case of the example NH_4 data set, the ROS median of the influent concentration was 0.410 mg/l, whereas the median effluent concentration was 0.030 mg/l. Using this calculation, the ER for the example data set NH_4 would be 0.93, or approximately 93% NH_4 concentration removed.. The ROS median was used in this case because analytical values for NH_4 were often reported as nondetect. Simply using the detection limit for these values greatly biases the dataset and produces inaccurate results. The ROS procedure determines the most accurate, least biased median score in the presence of nondetect data even when the percentage of non-detect data exceeds 50% of the total observations. When there are no nondetect values are present in the dataset, the true median (50^{th} percentile observation) should be utilized.

5.2.5.2 Summation of Load (Reduction) - SOL

For some BMPs, the pollutant load reduction may be of more interest than the pollutant concentration reduction. This is especially true when the BMP is designed for infiltration so that the total discharge volume is significantly less than the influent volume (see section 5.2.2). A pollutant “load” is simply the mass of a pollutant, determined from the pollutant concentration and the total storm volume discharge, adjusted for units. Essentially, pollutant concentration (mass per volume) multiplied by storm volume produces a result of pollutant mass. The pollutant mass (load) is typically reported in pounds.

The Summation of Loads (SOL) is one methodology that will most likely be utilized when paired influent and effluent events are limited or altogether unavailable. In these cases, all influent load values will be summed, even if there is no corresponding effluent load data for that event. Likewise, all effluent load data will be summed. SOL is then calculated as follows:

$$\text{Sum of Loads (SOL)} = 1 - \frac{\text{Sum of Effluent Loads}}{\text{Sum of Influent Loads}}$$

Calculating a load based on a nondetect observation is problematic. The most conservative approach is to use the method detection limit (DL) as the concentration value for the calculation, but carry the nondetect qualifier with it. For example, if an observed concentration of NH_4 in a sample was reported at <0.10 mg/l (non-detect) for a discharged volume of 10,000 cubic feet, the converted load would be reported as <0.062 lbs.; derived as follows:

$10,000\ ft^3 \times 28.317\ liters/ft^3 = 283,168.5\ liters$

$283,168.5\ liters \times <0.10\ mg/l\ NH_4 = <28,316.85\ mg\ NH_4$

$<28,316.86\ mg\ NH_4 \times 2.204 \times 10^{-6}\ mg/pound = <0.062\ lbs.\ NH_4$

The observation of <0.062 lbs. NH_4 represents only 1 load from 1 event. If there are 15 events, each of these loads must be summed. If there are more than a few nondetects in the dataset, the answers become less certain. The most conservative approach at this point is to present the load as a range to encompass the uncertainty inherent in the nondetect data. The range minimum would be calculated based on the assumption that all of the nondetect observations were true zero (0) observations. The range maximum would be calculated based on the assumption that all nondetect observations were equal to the reporting limit. Because of this limitation, the Summation of Load methodology is less useful in the presence of significant nondetect data.

In the example of the FLID Ammonia dataset, the Summation of Load pollutant reduction was determined to be SOL = **70.4**%, calculated as follows:

Summation of Load Calculations - FLID

Sum Influent Load 446,791.9 pounds NH_4
Sum Effluent Load 132,298.1 pounds NH_4

$$SOL = 1 - \frac{132,298.1}{446,791.9} = 0.704$$

SOL = 70.4% NH_4 removed

5.2.5.3 Individual Storm Load (Efficiency) – ISL

$$\text{Storm Efficiency} = 1 - \frac{\text{Effluent Load}}{\text{Influent Load}}$$

According to the *October 2009 Guidance*, the average efficiency of all of the paired events represents the ISL. However, as discussed in other sections, the average is a biased measure in this situation, particularly in the presence of nondetect data. Another complication observed in calculating ISL comes in the form of negative storm efficiencies. Negative efficiencies represent an export of pollutants from a BMP, suggesting that the structure itself is a source or generator. These values may very well be real and cannot be ignored in the calculation. Unfortunately, nonparametric statistics do not tolerate negative values. Therefore several techniques must be combined in order to treat this data in an unbiased manner in order to produce the best result possible.

First, the nondetect qualifiers must be carried along with the individual storm efficiencies when calculated. Second, a positive fixed value, greater than or equal to the absolute value of the most negative individual storm efficiency observed must be added to each, so that all efficiencies are made positive. Third, use Kaplan-Meier statistics to estimate the median efficiency score in the presence of nondetect data. Make sure to use the correct directional qualifier in the test to ensure that the efficiencies are treated as right-censored values where appropriate. Finally, subtract the fixed value added in step 2 from the estimated median to reveal the most accurate, unbiased ISL available for a dataset with both negative efficiencies and nondetect observations present.
Following the 2009 Guidance for the FLID NH_4 dataset, the Average Storm Efficiency was
-25.2% of the pollutant load removed. This produces a highly biased estimate, as discussed, due to the presence of a few extreme observations, negative efficiencies and nondetect data.

In order to develop an unbiased estimate, the values were flipped using a fixed value of 8.0 (most negative value observed was (ISL > -7.712) and running the Kaplan-Meier statistics for right-censored data on the transformed dataset. When the fixed value was subtracted from the KMStats estimate, the unbiased representative storm efficiency was determined to be ISL = **66.5**%.

Figure 11

Statistics using Kaplan-Meier, with Efron bias correction

```
Right-Censored data (+8)

Largest value is censored, so estimated mean is biased low.

Mean ISL+8              8.56851
Standard error          0.108785
Standard Deviation      0.652711
90th Percentile         *
75th Percentile         8.97080
Median                  8.66483
25th Percentile         8.51893
10th Percentile         8.03425

* NOTE * One or more variables are undefined
* NOTE * Subtract 8 from each value in this example
```

A complete statistical analysis will be completed for a site upon request; however a minimum of 12 complete, acceptable sample events must be collected and analyzed first, as described in section 5.2. Assuming 12 events are collected each fiscal year, as is typically requested, an annual analysis and evaluation of each site would be appropriate, if requested.

Identifying statistical significance in storm water samples is inherently difficult, given the dynamic nature of storm events, variable pollutant build-up, lab error, sampling error, etc. All exogenous factors must be minimized in order to tease out subtle differences between sites, over time. Problems with sampling equipment, site installation, and BMP design can easily obscure any differences that may otherwise have been evident. More focused effort on fewer sites has quality benefits that are easy to realize.

It is important to have confidence in the process in order to have confidence in the final product. Adopting standard protocols for site specific sampling has obvious benefits. Limiting the range of storms sampled to those that produce adequate flow / intensity but do not exceed design capacity, and allowing sufficient time for pollutant build-up, along with various other targets increase confidence in the samples and in the data. Following protocols, similar to those set forth in the TARP TIER II project, build confidence in the final product.

The Environmental Analyst will develop a generalized reporting format for BMP Performance Monitoring Data Analysis. This format will likely be modified several times before a final format is approved, but there are numerous components that must be included at a minimum. The following sections will be included in each BMP Monitoring Data Analysis Report, where appropriate:

1. Background
    a. BMP installation purposes
    b. Goal (why installed)
2. Site Characteristics
    a. Land-Use description, drainage area
    b. BMP design / equipment set-up
3. Data Quality Objectives
    a. What indicates good data
    b. Stated performance goals
4. Storm Event Characterization
    a. Storm event criteria
    b. Acceptable events
5. Analytical Results
    a. Discharge
    b. Analytes
    c. Graphics
6. Summary and Conclusions

7. Raw data (attachment)
8. Stats output (attachment)

Additional report sections may be added or modified to suit the purposes of the specific BMP and situation. The target audience for the general reports will be Charlotte-Mecklenburg Storm Water Services staff and stake-holders, unless otherwise specified.

APPENDIX F

Charlotte-Mecklenburg Storm Water Services
Quality Assurance Project Plan (QAPP)

A1. Signature and Approval Sheet

APPROVED BY:

______________________________________ ______________________
Rusty Rozzelle, Water Quality Program Manager Date

______________________________________ ______________________
Jeff Price, QA/QC Officer Date

______________________________________ ______________________
Tony Roux, Bioassessment Lab Supervisor Date

______________________________________ ______________________
David Buetow, Field Measurement Lab Supervisor Date

______________________________________ ______________________
Steve Jadlocki, Charlotte NPDES Administrator Date

______________________________________ ______________________
State of North Carolina Representative Date

A2. Table of Contents

Appendices

A3. Distribution List

A4. Project Organization

All water quality sampling and field measurement collection conducted by the Mecklenburg County Water Quality Program (MCWQP) is performed by permanent or temporary staff of the MCWQP. Data management and Quality Assurance/Quality Control activities are either conducted or supervised by the MCSWQP QA/QC Officer. Field work is performed by staff in each of the three sections, which correspond to three distinct geographic areas of Mecklenburg County. Chemical, physical and bacteriological analyses are performed by the Charlotte Mecklenburg Utilities (CMU) Laboratory. Macro invertebrate and fish sampling and analysis are performed by the Mecklenburg County Bioassessment Laboratory. Results of the MCWQP sampling efforts are provided to several entities; Charlotte-Mecklenburg Storm Water Services, Charlotte Mecklenburg Utilities, the Towns of Davidson, Cornelius, Huntersville, Pineville, Matthews and Mint Hill, the North Carolina Department of Environment and Natural Resources (NC DENR), private developers and the citizens of Mecklenburg County.

An abbreviated organizational chart for the MCWQP indicating all entities involved in the water quality sampling program is provided in Figure A4.1. A complete organizational chart for the entire MCWQP is provided in Appendix 1. Information concerning individuals assigned to each role can be obtained by contacting Rusty Rozzelle at 704-336-5449 or rusty.rozzelle@mecklenburgcountync.gov.

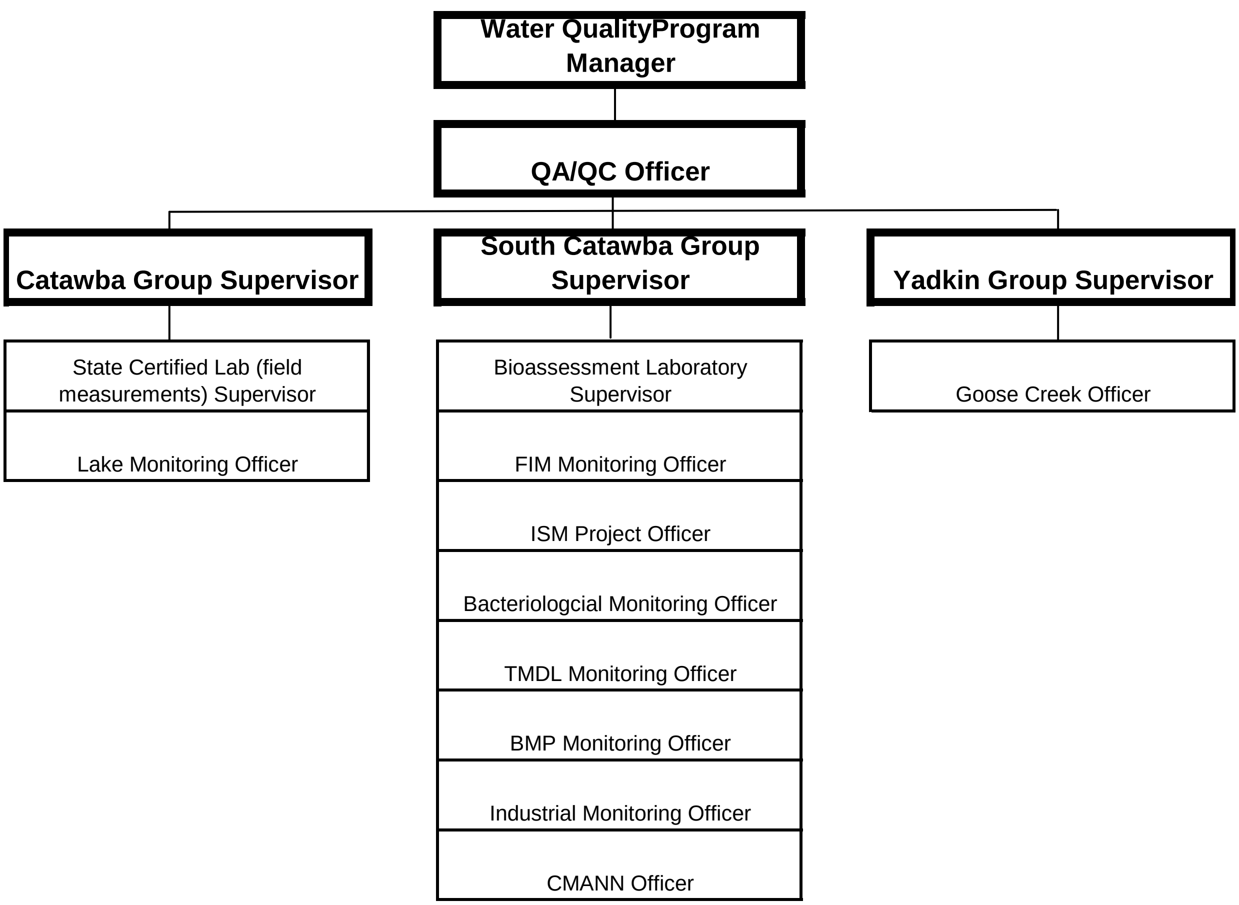


Figure A4.1 – MCWQP Organizational Chart

Project Manager and Supervision

Program Manager
Rusty Rozzelle
MCWQP – Program Manager

- Manages MCWQP
- Supervises QA/QC Officer, Group Supervisors and Administrative Support Staff
- Ultimately responsible for ensuring that the program is conducted in accordance with this QAPP
- Reviews and approves all reports, work plans, corrective actions, QAPP and other major work products and revisions
- Approves changes to program; ensures changes are consistent with program objectives and customer needs
- Program Development
- Reports to Mecklenburg County & Towns elected officials

QA/QC Officer
Jeff Price
MCWQP – Senior Environmental Specialist

- Acts as liaison between program manager and supervisors, project officers and field personnel
- Coordinates logistics of program, including sampling schedule, production and maintenance of forms and station database
- Responds to issues raised by program manager, customers or citizens. Recommends response action or change when necessary.
- Performs all aspects of data management for MCWQP monitoring program
- Fulfills requests for raw data
- Assists in training field staff
- Conducts periodic field audits to ensure compliance with QAPP and SOP
- Calculates SUSI index and communicates results to staff, elected officials and general public
- Performs data screening and action/watch reports and communicates results to MCWQP Supervisors to assign follow-up activities

Water Quality Supervisor
David Caldwell – Catawba Group
John McCulloch – South Catawba Group
Richard Farmer – Yadkin Group

- Supervise project officers and field staff ensuring that deadlines are met and tasks are completed in a timely manner
- Assign follow up activities when action/watch levels are exceeded (communicated to the supervisors by QA/QC Officer)
- Assign staff resources as necessary to complete monitoring activities
- Conduct sampling as necessary to fulfill work plan requirements
- Supervise Bioassessment Laboratory Supervisor
- Supervise State Certified Laboratory Supervisor (field measurements)

- Supervise all activities of MCWQP in their respective geographic area of responsibility
- Act as follow-up, emergency response and service request monitoring project officer for their geographic area

Field Activities

Project Officers

Meredith Moore	TMDL Stream Walks
	Industrial Monitoring
Olivia Edwards	CMANN
Jon Beller	FIM
	Bacteriological Monitoring
	ISM Monitoring
	BMP Monitoring
David Buetow	Lake Monitoring
Tony Roux	Biological Monitoring

- Coordinate and conduct sampling events
- Ensure staff are properly trained in procedures for individual project area
- Compile annual reports
- Act as point of contact for individual project area
- Calculate Lake Water Quality Index (David Buetow)
- Review automated CMANN data for threshold exceedances (Olivia Hutchins)
- Work with QA/QC Officer to ensure deadlines and other project requirements (such as specific parameters) are met
- Responsible for maintaining specialized sampling equipment for assigned projects

Field Staff
Chris Elmore
Don Cecerelli
Amber Lindon
Jason Klingler
Ron Eubanks
Heather Davis
Catherine Knight
Tara Stone
Brian Sikes
Michael Burkhard
Corey Priddy
Heather Sorensen
Andrew Martin
Vacant Inspector Position

- Perform sampling events in accordance with QAPP and SOPs
- Notify supervisor or QA/QC Officer of any issues encountered

Laboratory Analysis

Bioassessment Laboratory Supervisor- Biological Certificate Number - 036
Tony Roux – Senior Environmental Specialist

- Manage MCWQP Bioassessment Laboratory
- Responsible for oversight of all biological sample collection (fish and macro invertebrates)
- Responsible for developing training materials and training staff on proper biological sampling techniques
- Responsible for oversight of all biological sample analysis and reporting of results and indexes
- Responsible for maintaining North Carolina State Certification for MCWQP Bioassessment Laboratory
- Responsible for maintaining all sampling equipment

State Certified Laboratory (Field Parameter Only) Supervisor – Certificate No. 5235
David Buetow – Senior Environmental Specialist

- Responsible for ensuring that all chemical/physical monitoring equipment and procedures are in compliance with state certified laboratory requirements
- Responsible for training staff in the proper use of field instruments
- Responsible for maintenance of field instruments
- Responsible for ensuring that field parameter check-in/check-out procedures and forms are properly used and are in compliance with state certified laboratory requirements.

Primary Data End-Users

Charlotte Storm Water Services
Steve Jadlocki – Charlotte's NPDES Phase I Permit Administrator – 704-336-4398

- Responsible for ensuring that all monitoring conducted to fulfill the requirements of Charlotte's Phase I NPDES permit are completed. MCWQP is under contract with the City of Charlotte to conduct monitoring and other activities.
- Provides parameter lists, sampling schedule and basic requirements of monitoring program
- Reviews data

Mecklenburg County Phase II Jurisdictions
Anthony Roberts – Cornelius Town Manager – 704-892-6031
David Jarrett – Huntersville Public Works Director – 704-875-7007
Ralph Massera - Director of Public Works – 704-847-3640
Brian Welch – Mint Hill Town Manager – 704-545-9726
Mike Rose – Pineville Town Manager – 704-889-4168
Leamon Brice – Davidson Town Manager – 704-892-7591

- MCWQP is under contract with each of Mecklenburg County's Phase II jurisdictions to provide water quality monitoring services to fulfill requirements of the Phase II permits held by each of the towns.

State of North Carolina
319 Grant Administrator
Alan Clark – NCDENR – 919-733-5083
Clean Water Management Trust Fund Administrator
Bern Schumak – CWMTF – 336-366-3801

- MCDWP and Charlotte-Mecklenburg Storm Water Services have received several grants for the installation of BMPs, creation of stream restoration projects, watershed studies and TMDL implementation projects. Each project has specific monitoring requirements to demonstrate the effectiveness of the project. Data are typically reported on an annual basis to each grant's administrator.

A5. Problem Definition and Background

Introduction

The City of Charlotte and Mecklenburg County are located along a drainage divide between the Catawba River Basin and the Yadkin River Basin. Therefore, approximately 98% of the streams in Charlotte and Mecklenburg County originate within the county borders. Streams located in the western portion of the county, as indicated in the map below, drain to the Catawba River in North Carolina. The Catawba River along the western border of the county has been damned to form Lake Norman, Mountain Island Lake and Lake Wylie. Each of the lakes is utilized for water supply purposes for various communities and industries throughout the region. Streams located in the eastern portion of the county drain to the Yadkin River, which has been designated as potential future habitat for the Carolina Heelsplitter, a federally endangered freshwater mussel. Streams located in the southern portion of the county drain to the Catawba River in South Carolina. These streams drain the most developed portion of Charlotte and Mecklenburg County, which is predominated by the City of Charlotte. Strong development pressure throughout Mecklenburg County has led to increased degradation of surface water from non-point source runoff.

The Mecklenburg County Water Quality Program (MCWQP) was created in 1970 under the umbrella of the Mecklenburg County Health Department. Recently, the MCWQP has been merged with several other entities to form Charlotte-Mecklenburg Storm Water Services. The MCWQP is engaged in water quality monitoring efforts on reservoirs, streams and ponds. Moreover, the MCWQP enforces storm water pollution prevention ordinances, enforces erosion control ordinances, conducts NPDES permit holder inspections and conducts watershed planning. The MCWQP is a storm water fee funded program of the Mecklenburg County Government. Its purpose is to ensure the safety and usability of Mecklenburg County's surface water resources including; ponds, reservoirs and streams. Stream and lake monitoring are a critical component of ensuring the safety and usability of Mecklenburg County's surface water resources and elected officials and citizens rely upon communication of the monitoring results to determine the conditions of those resources.

The MCWQP conducts several water quality monitoring programs. These programs include the fixed interval monitoring network (FIM), in-stream storm water monitoring (ISM) program, biological monitoring program (macro invertebrates and fish – these activities are conducted by the Bioassessment Lab), lake monitoring program, best management practice (BMP) monitoring program and bacteriological monitoring. Monitoring sites for the FIM program were located in order to determine the water quality of a particular basin or sub-basin. Figure A5.1 shows the distribution of watersheds in Charlotte and Mecklenburg County. Sites for the BMP program were selected based upon BMP type in order to assess performance of many different types and designs of BMPs. Monitoring sites for the lake monitoring program were selected to determine the general water quality in the three reservoirs of the Catawba and to, more specifically, target swimming areas and areas of intense development.

The MCWQP has created this document to ensure that all data collected conforms to strict QA/QC guidelines in the collection of samples, management of information and communication of results. It is also intended to communicate the policies and procedures of the MCWQP so that data it collects may be considered by other entities in local, regional or national studies.

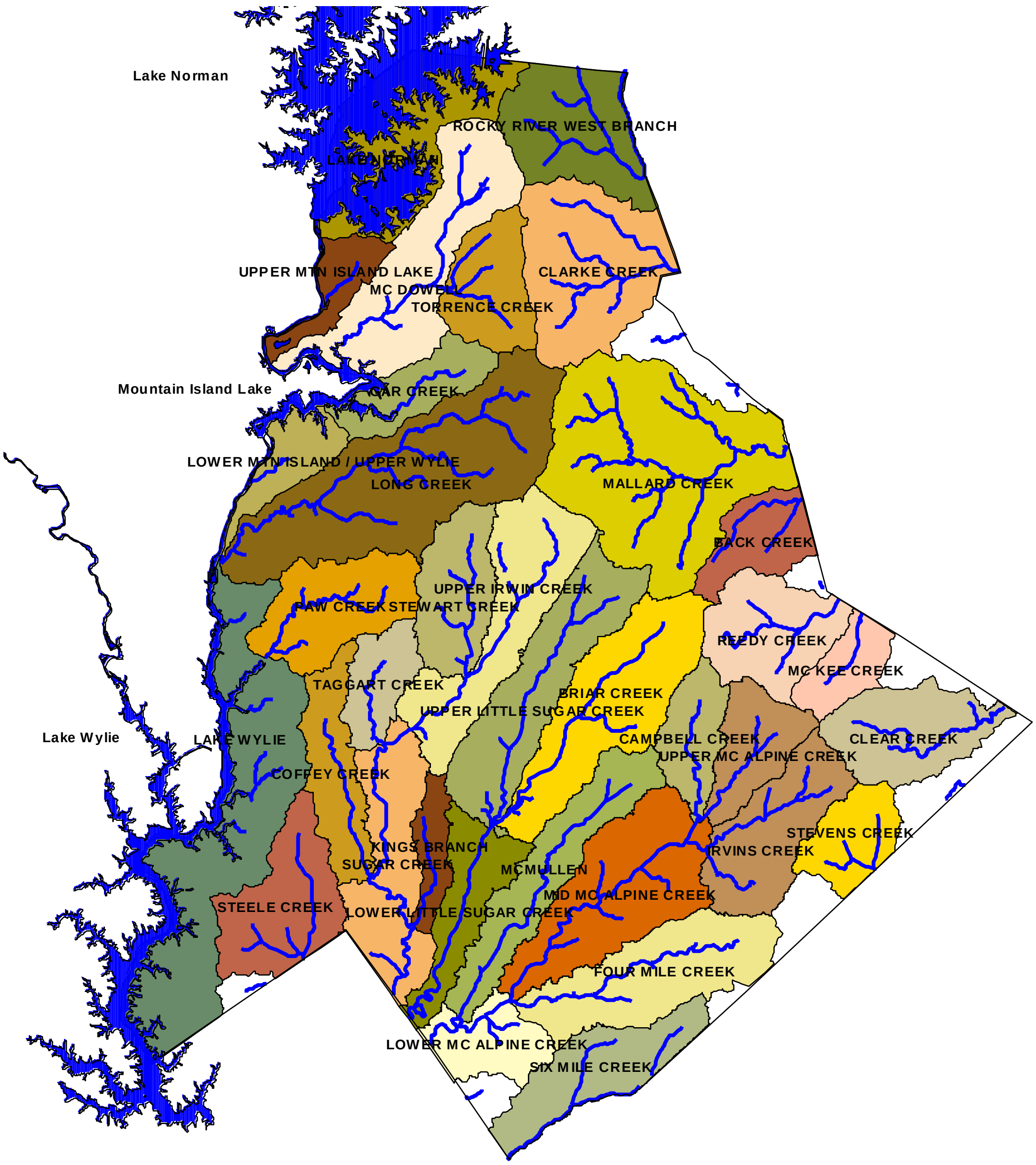


Figure A5.1 – Mecklenburg County Watersheds and Reservoirs

Stream classifications and water quality standards

The state of North Carolina has developed water quality standards for many parameters dependent upon the classification of the stream. All named water bodies in the state have been classified by intended use. Mecklenburg County has Class B, C and WS IV water bodies. Monitoring results are compared to the water quality standards by MCWQP to determine compliance with the standard for communication of results and assessment of the usability of the water for its intended use.

MCWQP Monitoring Program Objectives

There are several objectives of the MCWQP monitoring program; however, the primary objective is to ensure the safety and usability of Mecklenburg County's surface water resources. Samples are collected to determine compliance with applicable state standards and to locate sources of water quality impairment (such as broken sanitary sewer lines). In addition to safety and usability, the MCWQP collects and analyzes samples to determine the effectiveness of watershed planning efforts (BMP monitoring and habitat assessments).

A6. Project/Task Description and Schedule

The MCWQP and its predecessors have conducted monitoring of Mecklenburg County's surface waters since the early 1970s. The program has evolved into many different projects with distinct purposes and desired outcomes. A Standard Administrative Procedure (SAP) has been developed for each specific monitoring project conducted by the MCWQP. The SAPs are included with this document as Appendix 2.

Fixed Interval Monitoring Program

The primary focus of the fixed interval monitoring program is to monitor the overall health of the streams within the Charlotte and Mecklenburg County and to identify chronic pollution problems at the watershed scale. The purpose of the program is to provide on-going baseline data that can be used to determine the long-term condition of Charlotte and Mecklenburg County streams. Fixed Interval monitoring is conducted monthly at 29 sites throughout Mecklenburg County. Sites were located to monitor all of the major watersheds in the County. Monitoring events are typically conducted on the third Wednesday of each month; however, events may be postponed if unsafe conditions exist in the streams.

FIM samples are collected by hand (grab samples) and are delivered to the CMU laboratory in less than 6 hours (fecal coliform hold time). Physical parameters (field parameters) measured at the time of sample collection include temperature, dissolved oxygen, pH and conductivity. These parameters are measured using a YSI Multiprobe instrument, which has sensors for each of the parameters to be measured. Most FIM sites are located at USGS gauging stations and the stage of the stream is recorded from the USGS Internet website. The level of the stream at the time of collection and comments pertaining to the stream flow are noted on the field sheets along with the field parameter readings. Samples are submitted to the CMU laboratory for all other parameters including fecal coliform bacteria, *E-Coli* bacteria, Ammonia Nitrogen (N-NH3), Nitrate + Nitrite (NO2+NO3), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Suspended Solids (TSS), USGS Suspended Sediment Test (SSC), Turbidity, Copper, Zinc, Chromium and Lead. The sample analysis results along with the physical measurements are used in the calculation of the Stream Use Support Index (SUSI), which is a programmatic level reporting tool developed by Charlotte-Mecklenburg Storm Water Services.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The primary focus of the bacteriological monitoring program is to identify sources of fecal coliform in Charlotte-Mecklenburg streams. Several of these streams are listed on North

Carolina's 303(d) list for fecal coliform, which has caused the MCWQP to focus efforts on finding and eliminating sources of fecal coliform. Samples are collected monthly from 72 locations throughout the county during base flow (minimum 72 hours prior without rain) conditions. In addition to the monthly sampling, 5 sites are sampled 5 times per month for fecal coliform. These locations correspond to NC DENR compliance points in watersheds listed for fecal coliform impairment on North Carolina's 303(d) list. These sites are sampled under all conditions in order to assess compliance with the fecal coliform standard.

Bacteriological samples are collected by hand (grab samples) and are delivered to the CMU laboratory in less than 6 hours (fecal coliform hold time). In addition to the fecal coliform sample, temperature of the stream at the time of sample collection is measured and recorded in the field data sheet.

In-Stream Storm Water Monitoring Program

The primary focus of the in-stream storm water monitoring program is to characterize the quality of receiving streams during rainfall events to support various Charlotte-Mecklenburg water quality projects. Samples are collected during runoff events on a regular basis (2 sites are sampled 2 times per month and 2 sites are sampled monthly for a total of 72 samples).

Automated sampling equipment collects the samples during the runoff event, set to start based upon the level of the stream. A flow-weighted composite sample is compiled by the sampler as prescribed by a site specific program uploaded to the sampler, which is based upon estimations of rainfall and runoff. Individual aliquots are collected at site specific volume (discharge) intervals during a runoff event. After the runoff event has ceased the samplers are retrieved and the sample transferred to sample bottles and turned into the CMU laboratory. Parameters analyzed by the laboratory include N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead.

Service Request/Emergency Response/Follow-up Monitoring Program

Water quality samples are occasionally collected during investigation of a citizen request for service. Samples may be collected from any location along any stream pond or reservoir within Charlotte and Mecklenburg County. Most of the samples collected are for fecal coliform along with measurements for physical parameters. Typically, samples are collected to "bracket" or otherwise identify a pollution source. Frequently, physical parameters alone are enough to identify a pollution source, which can be visually identified.

TMDL Stream Walk Monitoring Program

The TMDL stream walk program is conducted to identify pollution sources in the streams in Charlotte and Mecklenburg County with existing TMDLs for fecal coliform. Teams of 2 staff members wade or float sections of streams and collect samples from small tributaries, storm water outfalls and drainage ditches for the purpose of identifying whether a source of fecal coliform is located upstream. If fecal coliform is detected in the sample above 3000 c.f.u./100 ml, follow-up activities are initiated to identify and eliminate the source.

Grab samples are collected at each confluence, storm water outfall and drainage ditch exhibiting dry weather flow (stream walks are only performed during dry weather). The samples are submitted to the CMU laboratory no more than 6 hours (hold time for fecal coliform) from the time of sample collection. Samples are analyzed for fecal coliform and nutrients. YSI multiprobes are used to collect field measurements for turbidity, dissolved oxygen, turbidity, pH and temperature. Field tests are also performed to detect the presence of chlorine.

BMP Monitoring Program

The monitoring of BMP's is conducted to research the effectiveness of various kinds of BMP, such as bioretention, storm water wetlands, wet ponds, grassed swales and dry detention basins. BMPs are installed to improve the quality of urban storm water runoff before the water entering local streams and lakes. Monitoring is conducted using automatic sampling equipment during rain events (similar to in-stream monitoring). Physical and chemical monitoring takes place at both the inlets and outlets of these BMPs to determine their pollutant removal efficiency. Flow into and out of the device is usually assessed using a bubbler meter or Doppler flow meter.

Automated sampling equipment collects the samples during the runoff event, set to start based upon the initiation of runoff. A flow-weighted composite sample is compiled by the sampler as prescribed by a site specific program uploaded to the sampler, which is based upon estimations of rainfall and runoff. Individual aliquots are collected at site specific discharge intervals during a runoff event. After the runoff event has ceased the samplers are retrieved and the sample transferred to sample bottles and turned into the CMU laboratory. Parameters analyzed by the laboratory include N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead.

Lake Monitoring Program

The reservoirs comprising Mecklenburg County's western border are monitored on a routine basis to assess their and usability for water supply and recreation. Samples are collected more frequently in the summer months when recreational use of the reservoirs increases.

Grab samples and depth integrated samples are collected from various locations throughout the reservoirs. Physical parameters are measured throughout the water column for temperature, DO, Specific Conductivity, turbidity and pH, as well as in situ chlorophyll *a*. Secchi Depth is also recorded at each sample collection site. Samples are submitted to the CMU laboratory for several parameters including NO3-N, Total Phosphorus, Alkalinity, and Chlorophyll-*a*. From nine of these parameters, a WQI rating is determined, which summarizes the overall quality of the water. The WQI values are primarily used to communicate the overall lake water quality conditions to the citizens of Mecklenburg County. Several of the local marine commissions utilize the WQI values in their evaluations of reservoir conditions.

Industrial Facility Monitoring Program

The industrial facility monitoring program is conducted to satisfy an element of the City of Charlotte's Phase I NPDES permit. Samples are collected from industrial facilities during runoff events where previous inspections have identified poor material handling or storage practices at the site. Only sites with NPDES permits are inspected and sampled. Typically, approximately 15 sites are sampled each year.

Grab samples are collected from storm water outfalls or drainage swales during runoff events. Special care is taken to ensure the runoff sampled originated from the site or facility in question. Field measurements are collected using a YSI multiprobe for dissolved oxygen, pH, temperature and conductivity. Samples are submitted to the CMU laboratory to be analyzed for fecal coliform, *E-coli* bacteria, N-NH3, NO2+NO3, TKN, TP, TSS, SSC, Turbidity, Copper, Zinc, Chromium and Lead and any other parameters specifically identified in a facilities' NPDES discharge permit (if one exists). Additional parameters may be added to the list of analytes if those materials are suspected to be stored or used on site.

Continuous Monitoring and Alert Notification Network

The Continuous Monitoring and Alert Notification Network (CMANN) program along with the NC DOT Long Creek project are a system of automated monitoring units used to detect illicit connections and other in-stream pollution sources. The units are semi-permanently installed at locations throughout Charlotte and Mecklenburg County, typically at USGS stream flow gauging stations corresponding to FIM sites. The units continuously monitor the stream for pH, turbidity, DO, conductivity and temperature and transmit the readings via cell modem to a database server housed and maintained by a private vendor (NIVIS). The data collected for the Long Creek DOT project is maintained on an in-house server. The data is then accessible through a website. The system also has an alert notification component, which sends specified individuals email messages when certain parameter thresholds have been exceeded.

Goose Creek Recovery Program Monitoring

Water quality monitoring for fulfillment of the Goose Creek Recovery Program is comprised of 3 elements; fecal coliform monitoring at NC DENR compliance point, land-use monitoring for fecal coliform and stream walks to identify sources of fecal coliform. Compliance point monitoring is covered under the bacteriological monitoring program (5 samples collected in 30 days) and the stream walks are covered under the TMDL stream walk monitoring program. The land-use monitoring is a requirement of the Goose Creek Recovery Program intended to categorize the amount of fecal coliform produced by various land-uses in the Goose Creek Watershed. Land uses to be monitored during FY07-08 are 0.25 – 0.5 acre residential, commercial, institutional, 0.5 – 1 acre residential and I-485.

Grab samples are collected from storm water outfalls or drainage swales during runoff events from each individual land-use. Special care is taken to ensure the runoff sampled originated from the land-use in question. Field measurements are collected using a thermometer for temperature. Samples are submitted to the CMU laboratory to be analyzed for fecal coliform. Estimates of rainfall depth for each runoff event sampled are obtained from the nearest USGS rain gauge.

Biological Monitoring

Biological monitoring is performed at 48 stream sites throughout Charlotte and Mecklenburg County. Macro invertebrate samples are collected and habitat assessments are performed at all 48 sites. Fish population samples are collected at 8 sites. Biological sampling and analysis is conducted by the Mecklenburg County Bioassessment Laboratory under a Standard Operating Procedure submitted to NC DENR and accepted in 2004. Biological monitoring is included in this QAPP to document sampling locations and data reporting mechanisms.

Sampling Schedule

Each of the monitoring projects has a specific sampling schedule. The individual project sampling schedule by program element and by site is provided in the SAP, which are in Appendix 2. The following is a general discussion of the sampling interval for each monitoring project.

Fixed Interval Monitoring Program

Samples under the FIM program are collected the third Wednesday of each month. This results in 12 samples per year per site. The FIM monitoring program is intended to provide long-term data on the health of stream water quality at the watershed scale; however SUSI values are calculated from the results on a monthly basis.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The bacteriological monitoring program is intended to provide short term data on the presence of sources of fecal coliform in the streams of Charlotte and Mecklenburg County. The sites are sampled once per month, usually during the first available sampling day with a minimum of 72 hours without rainfall preceding. The reason for the 72 hours preceding is to ensure base flow conditions in the streams. An additional component of the bacteriological monitoring program is to collect five fecal coliform samples during any given 30 day period at NC DENR TMDL compliance points within watersheds with fecal coliform TMDL implementation strategies in place. The purpose of this component is to assess the effectiveness of the implementation strategies. Typically, one sample will be collected during each of the four weeks during a month with an additional sample collected during the third week of the month.

In-Stream Storm Water Monitoring Program

The ISM program is intended to provide information on the characteristics of stream flow during runoff events in the City of Charlotte. This monitoring used to support various watershed and BMP projects within Charlotte and Mecklenburg County. Monitoring is conducted quarterly during a runoff event with a minimum of 72 hours dry weather preceding.

Service Request/Emergency Response/Follow-up Monitoring Program

The SR/ER/follow-up monitoring program is intended to provide information during the investigation of a water quality pollution source. As such, it is performed on an as needed basis to attempt to 'bracket' or locate a pollution source. Many samples or field measurements may be performed over a very short time period to locate a pollution source.

TMDL Stream Walk Monitoring Program

The TMDL stream walk monitoring program is intended to provide information on sources of fecal coliform impairment in Mecklenburg County streams. Stream walks are performed year round with the only requirement being safety (walks are not performed during swift water conditions). No set schedule is in place for conducting stream walks, rather a goal of the number of miles to be walked during a given year is set. The project officer is responsible for setting a loose schedule with milestones of the number of miles to be walked during a given quarter (3 month period).

BMP Monitoring Program

The BMP Monitoring program is intended to provide information on the efficiency of various BMPs at removing water quality pollutants from runoff. A total of 12 samples are typically collected from the inflow and outflow of each BMP in the program during each year during runoff events. An effort is made to spread sample collection across all seasons; however extended dry periods are unavoidable.

Lake Monitoring Program

The lake monitoring program has been designed to provide data on the long term water quality conditions in Lake Norman, Mountain Island Lake and Lake Wylie and to provide short term information on the usability of these lakes for recreation (swimming). Samples are collected monthly during the warm months (May – September) and every other month during the colder months. Additional fecal coliform sampling sites are monitored from May through September to coincide with peak usage time on the lakes.

Industrial Facility Monitoring Program

The industrial facility monitoring program is designed to assess the runoff from individual NPDES Discharge Permitted facilities. Samples are collected during a runoff event once during the fiscal year in which the facility is inspected. If water quality standards or permit limits are exceeded, additional sampling may be initiated under the follow-up monitoring program.

Continuous Monitoring and Automated Notification Network

The CMANN program has been designed to provide real time (or near real time) data on the health of Charlotte and Mecklenburg county's streams. Field measurements are automatically collected once per hour, year round. Collection intervals are occasionally temporarily reduced to once per 15 minutes if necessary.

Goose Creek Recovery Program Monitoring

The Goose Creek recovery program monitoring effort is a requirement of the Goose Creek Water Quality Recovery Program for fecal coliform. The TMDL stream walks in Goose Creek are covered under the TMDL stream walks section, the 5/30 monitoring and compliance point monitoring are covered under the bacteriological monitoring section. Land-use samples are collected 12 times per year from each site during runoff events. An effort is made to spread the samples out evenly over each of the four seasons during a year; however extended dry periods may make monthly sampling impractical.

Biological Monitoring

Typically biological samples are collected once per year during the period of time between May and September; however occasionally samples are collected in October because of scheduling issues. Samples are collected during base flow conditions.

Measurement methods overview

Field Measurements

Measurements made in the field include water temperature, specific conductance, stream flow (or pipe flow), chlorine, Secchi depth, DO, turbidity and pH. Field measurements are discrete and are to be made *in situ* by field staff at the time of sample collection. All field activities are to be performed in accordance with the YSI Multiprobe Calibration and Field Data Collection (Short-term Deployment) SOP, which is included in Appendix 3.

Analytical Methods

Samples are submitted to the CMU laboratory for analysis for fecal coliform bacteria, *E-coli* bacteria, ammonia nitrogen, nitrate + nitrite, TKN, total phosphorus, TSS, suspended sediment, turbidity (lab), copper, zinc, chromium and lead. Other specific parameters may be analyzed on a case by case basis (such as industrial sampling).

Data management

All results are to be sent to the QA/QC officer, who is responsible for the compilation, review, verification, validation, and warehousing of all water quality monitoring data products by the MCWQP. Field staff provides completed field data sheets and copies of COCs to the QA/QC officer on the same day the samples and field measurements are collected. The CMU laboratory will provide finalized data electronically and in hard copy to the QA/QC officer within 45 days of sample collection. The only exception to this is the CMANN program. CMANN data is reviewed and quality assured by the CMANN project officer and submitted to the QA/QC officer electronically.

On at least a monthly basis, data will be compiled, quality assured and added to the Water Quality Data Repository (WQDR).

Reporting

Annual Reports

Annual reports are prepared for each monitoring program (specifically, an annual report for each program element will be prepared – most monitoring programs are comprised of several program elements). At a minimum, the annual report will include basic descriptive statistics (minimum, maximum, median, 25th percentile and 75th percentile) of the sample results from the CMU laboratory and the field measurements collected under the program. Additionally, a count of the number of action/watch and state standard exceedances are prepared for each parameter analyzed or measured. Current year results are compared to previous years and, where applicable, water quality trends are identified. These reports are submitted to the customer and are available to citizens and outside agencies by contacting Rusty Rozzelle at 704-336-5449 or rusty.rozzelle@mecklenburgcountync.gov.

Water Quality Indexes and Program Measures

Two primary indexes are calculated using MCWQP monitoring results and subsequently reported to elected officials and the citizens of Mecklenburg County. The Stream Use Support Index (SUSI) is an index developed by Charlotte/Mecklenburg Storm Water Services to communicate the health of Mecklenburg County's streams. It takes into account FIM, biological monitoring and CMANN results. The lake water quality index (LWQI) is calculated for each of the reservoirs in Mecklenburg County. The LWQI takes into account lab analysis and physical parameters of lake water quality. Documentation of both indexes is included with this document in Appendix 4. Several other program measures use results from water quality data collection for their calculation. These are described in Appendix 5.

Program Indicators

Several program indicators are also calculated using MCWQP data. Program indicators are used to assess MCWQP progress toward meeting programmatic goals, which are required by the Mecklenburg County Manager. They are part of the county manager's M4R program. Goals are set for each program indicator at the beginning of each fiscal year and progress on meeting the goal is determined at the end of the fiscal year. These results are used by the county manager to judge the effectiveness of the MCWQP. The indicators include miles suitable for human contact, assessment of TMDL implementation strategies and turbidity levels in McDowell Creek. A description of the program indicators determined from water quality monitoring is included in Appendix 4 and Appendix 5.

A7. Quality Objectives and Criteria

Precision, accuracy and sensitivity

Results from the MCWQP monitoring program are compared to the NC water quality standards and internal action/watch levels (Appendix 6), so reporting limits for these parameters should be at or below these critical values. All of the reporting limits used by the CMU Laboratory meet these criteria.

Bias

The MCWQP monitoring program is based in judgmental sampling design, so by definition bias will exist due to station locations. However, this is acceptable given that stations are generally established for targeted long term monitoring of known or suspected areas of concern; identification of temporal patterns at these static locations are major objective or the program.

Other sources of bias include:

- Grab sampling is performed only during the weekly business day.
- Stations are only sampled on Monday – Thursday.
- Almost all stations are located at road crossings.

Use of consistent sampling methods, SOPs, and analytical methods minimizes bias from other sources.

Representativeness

Environmental monitoring data generally show high variation due to natural conditions such as precipitation, seasonal and diurnal patterns, and biological activity. It is important to ensure that the variations over time and/or space that are seen in the results are truly representative of the system under study. Monitored water bodies must have sufficient flow year-round at the specified sampling point to allow for the sampling of well-mixed areas (as required by SOP) of the water body. Sampling of BMPs must focus upon representative (or average) storm events within the device's design standard. This allows the samples to represent an "average" condition of the water body at that point in time. Careful selection of station locations on larger perennial water bodies (higher-order streams and rivers, estuaries, and reservoirs) allows representative samples to be obtained year-round.

Comparability

Fixed station locations and standardized operating procedures for sampling and analytical methods ensure that comparable samples are taken at each site visit.

Completeness

It is expected that some site visits or samples will be missed due to problems such as inclement weather, temporary station inaccessibility due to bridge construction, equipment problems, and staff issues such as illness or vacant positions. Many of these impediments are unavoidable. However, under anything but extraordinary circumstances it is expected that at least 90% of scheduled station visits and samples be completed annually.

A8. Special Training/Certification

Field Staff

Since new employees can vary greatly in their background, experience, and knowledge, field staff's direct supervisor should determine training needs on a case-by-case basis and ensure that these needs are met. At the time of hiring, each field staff member is assessed by a Group Supervisor and provided with an appropriate amount of training specific to their assignments. At a minimum, all field staff are to be trained in the methods described in the appropriate SOPs (Appendix 3), this QAPP, and the appropriate SAPs (Appendix 2) pertinent to their work plan (assigned tasks). Every new field employee will be trained in YSI calibration, safety, required documentation, sampling methods, sample handling, safety and other field activities. Training activities at time of hire are documented on the Employee Training Form, which is included in this document at Appendix 7. This training is generally performed by Senior Environmental Specialists, Group Supervisors and experienced Environmental Specialists. This is augmented by the QA/QC Officer, particularly concerning data management, documentation and problem identification. Completed Employee Training Forms are retained by the QA/QC Officer during the employee's term of employment with MCWQP. Experienced field staff will continue to accompany all new field staff during sampling activities until the new staff member exhibits proficiency in the field, as determined by the trainer's observations.

After initial training at the time of hire, refresher training is conducted at least annually for all monitoring activities. A sign-in sheet is circulated at the time of annual training. Staff not present at the training are responsible for scheduling make up training with the trainer. Sign-in sheets will be retained by the QA/QC Officer. At a minimum, each field staff member will receive the following refresher training annually:

- YSI Calibration and Operation
- Grab sample collection
- Proper sample documentation (COC and field data sheets)
- Bacteriological sample collection

Field staff are assessed on an ongoing basis by the direct supervisor and the QA/QC Officer to ensure field staff are performing activities in accordance with SOPs, SAPs and this QAPP. Results of the field audits are retained by the QA/QC Officer for each project and employee.

Laboratory (analytical) staff

All analytical samples are submitted to the CMU Laboratory, which is a North Carolina certified analytical lab. CMU Laboratory staff training is performed in accordance with the requirements inherent in this Certification. If another laboratory is used, it must have North Carolina certification for all analysis performed.

A9. Documentation and Records

Quality assurance information, SOPs, and other support documentation

Once all approval signatures have been obtained, the QA/QC Officer will electronically distribute copies of the approved QAPP to persons on the distribution list in Section A3 of this document. Copies must be disseminated within 30 days of final approval. The original hard copy with approval signatures will be kept on file in the QA/QC Officer's office at the Hal Marshall Center, 700 North Tryon Street, Charlotte, NC 28202.

The QA/QC Officer is to be notified of changes made to SOPs, SAPs, analytical methods, or any other documentation referenced by this QAPP. The QA/QC Officer will then be responsible for distributing the information, as described above. The QA/QC Officer will also be responsible for keeping current copies of all these documents on file at the Hal Marshall Center (address above). Since the MCWQP monitoring program is ongoing, this QAPP will be reviewed on at least an annual basis by the QA/QC officer, and, if appropriate, any changes or updates made at that time. However, critical revisions can be made at any time. The QA/QC Officer is responsible for completing revisions, obtaining signatures of approval, and disseminating the revised document to those on the distribution list within 30 days of final approval. The version or revision number and date shall be easily identifiable by the document control information on each page. A complete list of all revisions/updates will be provided with each annual update.

Program records

The records produced by the MCWQP monitoring program, their location, retention time, format, and disposition at the end of the required retention time are summarized in Table A9.1.

Table A9.1: Program Records

	Minimum Retention Time	Format	Disposition
QA/QC Officer			
Field data sheets	5 years	Hard copy	TBD
Field data electronic	5 years	SQL	TBD
Analytical Reports – hard copy	5 years	Hard copy	TBD
Analytical Reports – electronic	5 years	SQL	TBD
CMANN Data electronic submittals	5 years	SQL	TBD
CMU Laboratory			
Analytical Reports – hard copy	5 years	Hard Copy	TBD
Analytical data - electronic	5 years	SQL	TBD

Data assessment reports

An annual assessment of the monitoring data generated by the MCWQP is prepared annually. It is prepared to document issues with the previous year's data set and to document format, data qualifiers and any know issues that may affect the quality of the year's dataset.

SECTION B: DATA GENERATION AND ACQUISITION

B1. Sampling Process Design

The design of the MCWQP monitoring program is based upon specific project requirements. Each project has unique goals and criteria, therefore each project will be addressed in turn.

Fixed Interval Monitoring

The FIM program was designed as a long-term, watershed scale monitoring project. Portions of the FIM network of stations have been in existence since the 1970s. There are currently 29 monitoring stations throughout Charlotte and Mecklenburg County.

<u>Station Locations</u>

Stations are established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Sites must drain at least 6 square miles. There has been much speculation regarding the ability of 1st order streams to support diverse macro invertebrate and fish populations. In order to ensure comparability of all results, sites draining less than 6 square miles have been excluded

- Fairly uniform coverage of all Watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites with established USGS Stream Gages were given greater importance.

- Sites corresponding to NC-DENR compliance points were given greater importance.

- Single geographic features, such as the Charlotte Douglas Airport were not given greater importance.

A complete current site list and site map is provided in the Fixed Interval Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 15 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Not directly below large amounts of debris or other temporary impoundments

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as specific conductance are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit. All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Fixed Interval Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Fixed Interval Monitoring SAP, which references the appropriate SOPs.

Bacteriological Monitoring Program (Including 5/30 Monitoring)

The bacteriological monitoring program was designed as a short-term, base flow, watershed and catchments' scale monitoring project focused on identifying sources of fecal coliform.

Station Locations

Stations are typically established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed, catchment or known source of fecal coliform (such as a WWTP effluent). The following criteria were considered during the site selection process:

- Fairly uniform coverage of all watersheds.
- Sites with established USGS Stream Gages were given greater importance.
- Sites corresponding to NC-DENR compliance points were given greater importance.

A complete current site list and site map is provided in the Bacteriological Monitoring Program SAP, which is included with this document as Appendix 2.

The short term nature of the bacteriological monitoring program necessitates that sites move frequently and are added and subtracted. Generally, the network is stable during an entire fiscal year, however mid-year changes do occur. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Suspected source of fecal coliform
- Changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

<u>Indicators measured and sampling frequency</u>

The only routine indicator monitored for the Bacteriological Program is fecal Coliform, however *E-coli* is monitored at all TMDL compliance points. The fecal coliform standard by stream classification is included in Appendix 6. There currently is no state water quality standard for *E-coli*, however the samples are collected and analyzed with the expectation that a standard is forthcoming.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit.

All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Fixed Interval Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

<u>Sampling and measurements</u>

Field measurements and samples are taken and handled in accordance with the Bacteriological Monitoring SAP, which references the appropriate SOPs.

In-Stream Storm Water Monitoring Program

The ISM program was designed to assess the impacts of non-point source pollution on stream water quality. Portions of the ISM network of stations have been in existence since the mid 1990's. There are currently 4 monitoring stations in the City of Charlotte.

<u>Station Locations</u>

Stations are established at publicly accessible, fixed locations, generally at bridge crossings. It is a requirement that ISM stations be located at USGS stream gauging stations. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed or development.

A complete current site list and site map is provided in the In-stream Monitoring SAP, which is included with this document as Appendix 2.

Requests from MCWQP staff for station establishment and/or discontinuation of a site will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy
- Changes to program needs or direction

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Samples are collected automatically using ISCO samplers. Actual sampling points (tubing influent) are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

<u>Indicators measured and sampling frequency</u>

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as specific conductance are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit.

All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The In-stream Monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

<u>Sampling and measurements</u>

Field measurements and samples are taken and handled in accordance with the In-stream Monitoring SAP, which references the appropriate SOPs.

Service Request/Emergency Response/Follow-up Monitoring Program

The service request monitoring program was designed as a short term, catchment scale monitoring project. The service request monitoring program is designed to identify active sources of water quality pollution.

Station Locations

There is no established network of sites or sampling locations. Sites are sampled based solely on the discretion of the field staff engaged in the investigation. An attempt is made to 'bracket' or narrow down the possible sources of a pollution problem through intensive sampling in the immediate vicinity of a suspected pollution source. Typically, service request monitoring is initiated after a citizen complaint or discovery of an action/watch exceedance from the FIM or bacteriological monitoring programs.

Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those suspected of being released to surface water by the pollution source. Field staff determine indicators based upon professional judgment and knowledge of the incident (action/watch report or citizen provided information).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Service Request Monitoring SAP, which references the appropriate SOPs.

TMDL Stream Walk Monitoring Program

The TMDL stream walk monitoring program was designed as a short term, catchment scale monitoring project. The program is designed to identify active sources of fecal coliform in TMDL watersheds.

Station Locations

There is no established network of sites or sampling locations. Sites are sampled based solely on the discretion of the field staff engaged in the investigation and guidance provided in the TMDL Stream Walk SAP (Appendix 2). Typically, all tributaries and storm water outfalls and swales encountered during a TMDL stream walk are sampled. Other suspected sources, such as straight pipes, are also sampled.

Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The indicators measured are listed in the TMDL Stream Walk Monitoring SAP (Appendix 2).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the TMDL Stream Walk Monitoring SAP (Appendix 2), which references the appropriate SOPs.

BMP Monitoring Program

The BMP monitoring program was designed as a short term, individual device scale monitoring project. The program is designed to characterize the pollution removal efficiency of certain BMPs in Charlotte, NC. Currently there are 18 BMP devices being monitoring.

Station Locations

There is no established network of sites or sampling locations. BMPs are generally selected for sampling by Charlotte Storm Water Services. Factors such as upstream land-use, impervious area and drainage area size are considered. A complete list of the sites sampled is included in the BMP Monitoring Program SAP, which is included in Appendix 2. BMP locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The indicators measured are listed in the BMP Monitoring Program SAP (Appendix 2).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the BMP Monitoring Program SAP (Appendix 2), which references the appropriate SOPs.

Lake Monitoring Program

The lake monitoring program was designed as a long-term and short term watershed scale monitoring project. Portions of the lake monitoring network of stations have been in existence since the 1970s. There are currently 32 monitoring stations in the five impoundments (3 reservoirs) of the Catawba River in Mecklenburg County. Stations are visited at the regular intervals outlined in the Lake Monitoring Program SAP (Appendix 2).

Station Locations

Most lake stations are established at publicly accessible, fixed locations that are accessible by boat. However, in several instances where launching a boat is problematic, samples are collected off of the end of private docks (Lake Cornelius and Lake Davidson primarily). Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific section or cove of a reservoir or impoundment. The following criteria were considered during the site selection process:

- Sites should be indicative of overall water quality.
- Sites should be located along the primary flow path through the reservoir. Additionally, sites should be located in major coves along the Mecklenburg County shoreline.

A complete current site list and site map is provided in the Lake Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 30 years and the focus on long-term data is integral to identifying temporal patterns within a reservoir and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points may be in open water, coves, or near the confluence with tributaries of interest that enter the reservoir at points determined by field staff as representative of the water body or subsection of the water body.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those with NC water quality standards that can be cost-effectively analyzed. Additional indicators are also included that may not have specific standards associated with them but are useful for interpretation of other measurements. Others, such as Secchi depth are of themselves useful for identifying long-term trends. A summary of standards by stream classification is included in Appendix 6.

Field staff are encouraged to use their discretion to sample for any additional indicators they feel may be of concern due to unusual circumstances encountered on a station visit. All measurements and samples are taken on whole water samples, i.e., no analyses for dissolved fractions are performed. The Lake Monitoring Program SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the lake monitoring SAP, which references the appropriate SOPs.

Industrial Facility Monitoring Program

The industrial facility monitoring program was designed as a short term, site scale monitoring project to determine an NPDES discharge permit holder's compliance with state water quality standards and permit requirements.

Station Locations

There is no established network of sites or sampling locations. Sampling locations are situated at sites with poor material handling and housekeeping procedures discovered during the industrial inspection program. Sites are usually storm water outfalls conveying runoff from the industrial facility in question. Stations are established by field staff as field conditions necessitate. Locations and their latitude and longitude are generally determined using GPS units or ESRI GIS software.

Indicators measured and sampling frequency

The selection of indicators is primarily focused on those suspected of being released to surface water by the industrial facility in question. At a minimum, indicators identified in the NPDES discharge permit are selected. Field staff determines additional indicators based upon professional judgment and knowledge of the industrial facility (generally, the staff member completing the industrial inspection will collect the samples from the site runoff).

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Industrial Facility Monitoring SAP, which references the appropriate SOPs.

Continuous Monitoring and Automated Notification Network

The CMANN program was designed as a short-term, watershed and catchment scale monitoring project to identify sources of pollution in Charlotte and Mecklenburg County Streams. Subsequently, the program has evolved into a long-term project with 39 stations (4 mobile stations and 35 fixed stations) used to identify water quality trends for the parameters measured.

Station Locations

Fixed stations are established at publicly accessible, fixed locations, generally at bridge crossings. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Fairly uniform coverage of all watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites with established USGS Stream Gages were given greater importance.

- Sites corresponding to NC-DENR compliance points were given greater importance.

Mobile stations are established downstream of suspected sources of water quality pollutants. By nature, these locations are moved frequently (approximately monthly) to monitor other suspected sources of surface water pollution.

A complete current site list and site map is provided in the CMANN SAP, which is included with this document as Appendix 2.

Many of the current fixed stations have been active for over 2 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally mid-channel, or as determined by field staff as representative of the water body:

- Flow should be significant enough to ensure a relatively well-mixed, homogenous sample
- Outside of effluent mixing zones
- Upstream side of bridge whenever possible
- Not directly below large amounts of debris or other temporary impoundments

Mobile stations can be moved at the discretion of field staff to locations downstream of suspected sources of surface water pollution.

Indicators measured and sampling frequency

The nature of the equipment limits the indicators to field measurements (conductivity, pH, turbidity, temperature and DO). A summary of standards by stream classification is included in Appendix 2.

The CMANN SAP (Appendix 2) lists the frequency of measurement.

Sampling and measurements

Measurements are collected in accordance with the CMANN SAP, which references the appropriate SOPs.

Goose Creek Recovery Program Monitoring

The Goose Creek Recovery program was designed as a long-term, catchment scale monitoring project to characterize the fecal coliform loading rates of certain land-uses in the Goose Creek Watershed. The monitoring sites are to be established during FY07-08.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at storm water outfalls. Locations and their latitude and longitude will be identified using GPS units or ESRI GIS software. Stations are strategically located to monitor a specific land-use. Monitoring stations will be located downstream of specific land-uses, including; 0.25 – 0.5 acre residential, commercial, institutional, 0.5 – 1 acre residential and I-485.

A complete current site list and site map is provided in the Goose Creek Recovery Program SAP, which is included with this document as Appendix 2.

Requests from MCWQP staff for station establishment and/or discontinuation of monitoring stations will be assessed on the value gained from a land-use characterization perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added. Actual sampling points are generally end of pipe, or as determined by field staff as representative of the runoff from the land-use.

Indicators measured and sampling frequency

The only indicator is fecal coliform bacteria.

The Goose Creek Recovery Program SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Field measurements and samples are taken and handled in accordance with the Fixed Interval Monitoring SAP, which references the appropriate SOPs.

Biological Monitoring

The biological monitoring program was designed as a long-term, watershed scale monitoring project. Portions of the biological monitoring network of stations have been in existence since the 1980s. There are currently 48 macro invertebrate and habitat monitoring stations and 8 fish monitoring stations throughout Charlotte and Mecklenburg County. The Mecklenburg County Bioassessment Laboratory is a State of North Carolina Certified Biological Lab (Certificate Number 036). It conducts all biological sampling for the MCWQP in accordance with its certification requirements.

Station Locations

Stations are established at publicly accessible, fixed locations, generally at bridge crossings corresponding to a FIM location. Locations and their latitude and longitude were originally identified using USGS topographic maps or ESRI GIS software. Stations are strategically located to monitor a specific watershed. The following criteria were considered during the site selection process:

- Sites must drain at least 6 square miles (unless a specific project site). There has been much speculation regarding the ability of 1st order streams to support diverse macro invertebrate and fish populations.

- Fairly uniform coverage of all watersheds. Sites were not focused up and downstream of treatment plants, nor were they place at restoration or BMP sites.

- Sites corresponding to NC-DENR compliance points were given greater importance.

- Single geographic features, such as the Charlotte Douglas Airport were not given greater importance.

A complete current site list and site map is provided in the Biological Monitoring SAP, which is included with this document as Appendix 2.

Many of the current stations have been active for over 20 years and the focus on long-term data is integral to identifying temporal patterns within a watershed and to gaining an understanding of the variability within each system. Consequently, requests from MCWQP staff for station establishment and/or discontinuation will be assessed on the value gained from a long-term perspective. Changes to station locations and sampling regimens may be made with sufficient reason, such as:

- Safety concerns of field staff
- Other changes to location accessibility
- The reason for sampling is no longer valid (i.e., a discontinued discharge)
- Emergence of new water quality concerns
- Resource constraints, particularly funding
- Redundancy

If any of these concerns arise, the QA/QC Officer, project officer and program manager will collectively decide if it is appropriate for a station to be discontinued, moved or added.

Indicators measured and sampling frequency

Samples are collected for macro invertebrates and fish. Field measurements are made for habitat assessment.

The biological monitoring SAP (Appendix 2) lists the frequency of measurement and the indicators measured.

Sampling and measurements

Biological samples are collected, handled and analyzed in accordance with the Biological Laboratory Certification requirements.

B2. Sampling Methods

Samples and measurements are to be taken in accordance with all SOPs (Appendix 3). Any irregularities or problems encountered by field staff should be communicated to the QA/QC

Officer, either verbally or via email, who will assess the situation, consult with other project personnel if needed, and recommend a course of action for resolution.

The SAPs (Appendix 2) identify sampling methods to be used for each monitoring program. The SOPs (Appendix 3) describe specific sampling and measurement techniques. Table B2.1 displays the types of samples and measurements collected for each monitoring program.

Table B2.1: Sample Collection Matrix

Monitoring Program	Grab Samples	ISCO Samples	Field mmts	Fish & Bug
Fixed Interval Monitoring Program	X		X	
Bacteriological Monitoring Program (Including 5/30 Monitoring)	X		X	
In-Stream Storm Water Monitoring Program		X	X	
Service Request/Emergency Response/Follow-up Monitoring Program	X		X	
TMDL Stream Walk Monitoring Program	X		X	
BMP Monitoring Program	X	X	X	
Lake Monitoring Program	X		X	
Industrial Facility Monitoring Program	X	X	X	
Continuous Monitoring and Automated Notification Network			X	
Goose Creek Recovery Program Monitoring	X			
Biological Monitoring				X

B3. Sample Handling and Custody

All samples are to be handled by field staff in accordance with the applicable SAPs (Appendix 2) and SOPs (Appendix 3).

Sample preservation

Chemical preservation of water samples occurs instantaneously, in that MCWQP utilizes pre-preserved sample collection containers for all direct-grab surface water samples. Samples should then be place in coolers with ice. The chemical preservatives utilized for each sample are listed in Table XX. Biological samples are preserved according to their approved SOP.

Sample submission forms

Sample submission forms (also known as chain of custody forms or COCs) are developed by the QA/QC Officer for all monitoring programs with the exception of the Biological Monitoring Program. The biological monitoring program follows the sample submission protocol outlined in their approved SOP. Each sheet corresponds to one monitoring event for one monitoring program (samples collected for multiple monitoring programs must be submitted to the laboratory under separate forms).

Examples of COCs for each monitoring program are provided in the SAP (Appendix 2) for the program. Typically, they will include the following information:

- Sample collectors initials
- Date and time of sample collection
- Depth (for lake samples)
- Notes

Field data is recorded on the field data sheets for the monitoring program. Example field data sheets are provided in the SAP (Appendix 2) for the program.

Sample bottle labels

Sample bottle labels for each program are provided in the SAP (Appendix 2) for the program. They should be filled out using waterproof ink or be pre-printed with the equivalent information. The bottle labels are printed from the special printer in the tech area on water proof, self-adhesive stock. Bottles labels should be affixed to the sample containers prior to departure for the field.

Sample Transport

Immediately after sampling, labeling, and chemical preservation, samples are placed in coolers on ice along with a "super" (trip, field, equipment) blank. Coolers are then hand delivered by field staff to the CMU Laboratory for check-in and subsequent analysis.

Laboratory

Once samples are checked into the CMU Laboratory, laboratory staff handles the samples in accordance with the procedures outlined in their laboratory certification. Samples submitted by field staff that are either out of hold time or fail the check-in temperature test may be rejected by the CMU Laboratory.

B4. Analytical Methods

Field measurements

Refer to the YSI Multiprobe Calibration and Field Data Collection SOP (Appendix 3) or appropriate YSI manual for field measurement analytical methods.

Lab analyses

Samples are submitted for analysis to the CMU Laboratory in Charlotte, NC. Results should be reported to the QA/QC Officer within 30 days of sample submission.

A summary of methods and PQLs (the Laboratory Section's minimum reporting limit) are listed below in Table B4.1.

Table B4.1: Analytical method references and lower Reporting Levels (RLs)

Analyte	RL	Units	Reference	Samp Vol	Hold Time	Preservative
ALKALINITY	3.00	mg/L	SM 2320-B	100	14	None
AMMONIA-NITROGEN	0.10	mg/L	SM 4500-NH3H	30	28	H_2SO_4
CHLOROPHYLL A	1.00	ug/L	SM 10200	250	14 days	None
CHROMIUM	5.00	ug/L	EPA 200.8	*500	180	HNO_3
COPPER	2.00	ug/L	EPA 200.8	*500	180	HNO_3
E. COLI	1.00	MPN /100 ml	SM 9223-B	125	0.25	$Na_2S_2O_3$
FECAL COLIFORM	1.00	CFU/100 ml	SM 9222-D	125	0.25	$Na_2S_2O_3$
LEAD	3.00	ug/L	EPA 200.8	*500	180	HNO_3
MANGANESE	10.00	ug/L	EPA 200.8	*500	180	HNO_3
MERCURY	0.20	ug/L	EPA 200.8	*500	180	HNO_3
NITRATE/NITRITE	0.05	mg/L	EPA 353.2	30	28	H_2SO_4
ORTHO-PHOSPHATE	0.01	mg/L	SM 4500-PF	30	2	None
SUSPENDED SEDIMENT CONCENTRATION	2.00	mg/L	ASTM D3977-97	250	7	None
TOTAL KJELDAHL NITROGEN	0.25	mg/L	EPA 351.2	30	28	H_2SO_4
TOTAL PHOSPHORUS	0.01	mg/L	SM 4500-PF	30	28	H_2SO_4
TOTAL SOLIDS	5.00	mg/L	SM 2540-B	100	7	None
TOTAL SUSPENDED SOLIDS	1.00	mg/L	SM 2540-D	250	7	None
TURBIDITY	0.05	NTU	SM 2130-B	100	2	None
VOC	VAR	ug/L	EPA 8620	80	14	HCl
ZINC	10.00	ug/L	EPA 200.8	*500	180	HNO_3

*500 ml = sufficient volume for all metals requested

p = Plastic

pS = Sterile Plastic

pO = Opaque Plastic

g = glass

B5. Quality Control

The Mecklenburg County Water Quality Program implements a comprehensive Quality Control (QC) program designed to monitor the integrity of both field measurements and laboratory samples. The program consists primarily of blanks, but also equipment blanks and field checks of know standards to ensure that all field data and samples collected are of the highest quality.

A majority of the routine monitoring run blanks (i.e. direct surface water grab samples) are considered by MCWQP to be “super-blanks”, or high-level scoping blanks that cover the practical extent of our sampling efforts. These blanks encompass error introduced from a number of common sources; including reagent water (or buffer solution for bacteriological parameters), pre-preserved sample containers, field methods and cooler / trip blanks. In the event that a parameter “hit” is observed in a super-blank, additional investigations must be initiated in order to determine the source of the contamination. This will result in additional work and consequently additional expense when contamination is discovered. Over a period of years, however MCWQP has determined that contamination problems of this nature are almost non-existent.

Any combination of the following traditional blanks and any other means deemed necessary to identify a source of sample contamination may be employed at any time.

- Bottle blank
- Field blank
- Reagent blank
- Sample container blank
- Transport, storage (cooler)

- Equipment (ISCO) blank

In general, one super-blank is included with each routine sampling run. A sampling run generally consists of approximately 10 sites on average. ISCO automated sample collection containers are blanked at least annual to ensure the cleaning procedures are adequate.

The Charlotte-Mecklenburg Utilities Laboratory (CMU), contracted by MCWQP for all sample analysis, is a NC State Certified lab for water and wastewater sample analysis. CMU lab is certified as EPA NC00125. The CMU lab conducts thorough and complete quality control in accordance with EPA and State standards for Certified Laboratory Practices. The CMU lab routinely conducts the following:

- Matrix spike
- Matrix spike replicate
- Analysis matrix spike
- Surrogate spike
- Analytical (preparation + analysis) bias
- Analytical bias and precision
- Instrument bias
- Analytical bias
- Zero check
- Span check
- Mid-range check
- Calibration drift and memory effect
- Calibration drift and memory effect
- Calibration drift and memory effect
- Replicates, splits, etc.
- Field co-located samples
- Field replicates
- Field splits
- Laboratory splits
- Laboratory replicates
- Analysis replicates
- Sampling + measurement precision
- Precision of all steps after acquisition
- Shipping + inter-laboratory precision
- Inter-laboratory precision
- Analytical precision
- Instrument precision

Annually, MCWP reports all instances of Quality Control violations. All violations are investigated and corrective actions are implemented wherever possible to eliminate additional sources of contamination.

B6. Instrument/Equipment Testing, Inspection, and Maintenance

Field Equipment

All field staff are responsible for regular cleaning, inspection, and maintenance of equipment they use for sampling activities. All equipment should be visually inspected daily for damage or dirt, and repaired or cleaned if needed before use. If meters are stored for long periods (> 1 week) without being used, it is recommended that they be calibrated and inspected at least weekly to keep them in good working order. Other required maintenance on field meters is conducted in accordance with the MCWQP Field Parameter Laboratory certification.

Laboratory analytical equipment

Laboratory analytical equipment is maintained in accordance with CMU Laboratory's Analytical Laboratory Certification requirements.

B7. Instrument Calibration and Frequency

Field meters

All field meters are to be inspected and calibrated at a minimum at the beginning and end of each day and checked at the end of each day they are used (Note: field meters are not re-calibrated at the end of use, rather they are checked). Field staff should record calibration information on the appropriate form (located in the meter calibration area of the tech room). Calibration and documentation should occur in accordance with the YSI Multiprobe Calibration and Field Data Collection SOP (Appendix 3).

Meters should also be checked against standards periodically throughout the day and recalibrated if needed if any of the following occur:

- Physical shock to meter;
- DO membrane is touched, fouled, or dries out;
- Unusual (high or low for the particular site) or erratic readings, or excessive drift;
- Extreme readings (e.g., extremely acidic or basic pH; D.O. saturation >120%);
- Measurements are outside of the range for which the meter was calibrated.

Laboratory instrument calibration

CMU laboratory instrument calibration shall occur in accordance with their analytical laboratory certification.

B8. Inspection/Acceptance Requirements for Supplies and Consumables

The CMU laboratory performs quality assurance of sample bottles, reagents, and chemical preservatives that are provided to field staff. Containers that are purchased as pre-cleaned should be certified by the manufacturer or checked to ensure that the parameters tested are below the published reporting limits. Containers should be stored in a manner that does not leave them susceptible to contamination by dust or other particulates and should remain capped until use. Any containers that show evidence of contamination should be discarded. Certificates for glass containers certified by the manufacturer should be kept on file by the CMU Laboratory.

Field staff shall inspect all bottles before use. Any bottles that are visibly dirty or those with lids that have come off during storage should be discarded.

Certificates of purity for all preservatives obtained from an outside source should be provided when purchased, and these certificates kept on file by the CMU Laboratory. Any preservatives that show signs of contamination, such as discoloration or the presence of debris or other solids, should not be used and should be discarded. A summary of inspections to be performed by field staff is presented in Table B8.1.

Table B8.1: Consumable inspections and acceptance criteria

Item	Acceptance Criteria
Sample Bottles	- No visible dirt, debris or other contaminants
pH standards	- No visible discoloration, debris or other contaminants
Conductivity Standards	- No visible discoloration, debris or other contaminants
Acid preservatives	- No visible debris or other contaminants
Distilled or deionized water	- No visible discoloration, debris or other contaminants

B9. Non-Direct Measurements

All data will be generated through program field and activities and consequent lab analyses, with two exceptions:

- Precipitation: Data are to be obtained from the USGS database through their website at http://nc.water.usgs.gov/char/. Currently there are data available from more than 50 sites in and around Charlotte and Mecklenburg County. Data should be obtained from the nearest rain gauge. Figure B9.1 shows the distribution of rain gauges in and around Charlotte and Mecklenburg County
- USGS Flow data: Charlotte-Mecklenburg Storm Water Services has a cooperative agreement to help the US Geological Survey fund approximately 54 stream gages for the measurement of stream flow in and around Charlotte and Mecklenburg County. Data should be obtained from the stream gauge at the site at http://nc.water.usgs.gov/char/. Figure B9.2 shows the distribution of stream gauges in and around Charlotte and Mecklenburg County.

Figure B9.1: USGS Rain gauge network in and around Mecklenburg County

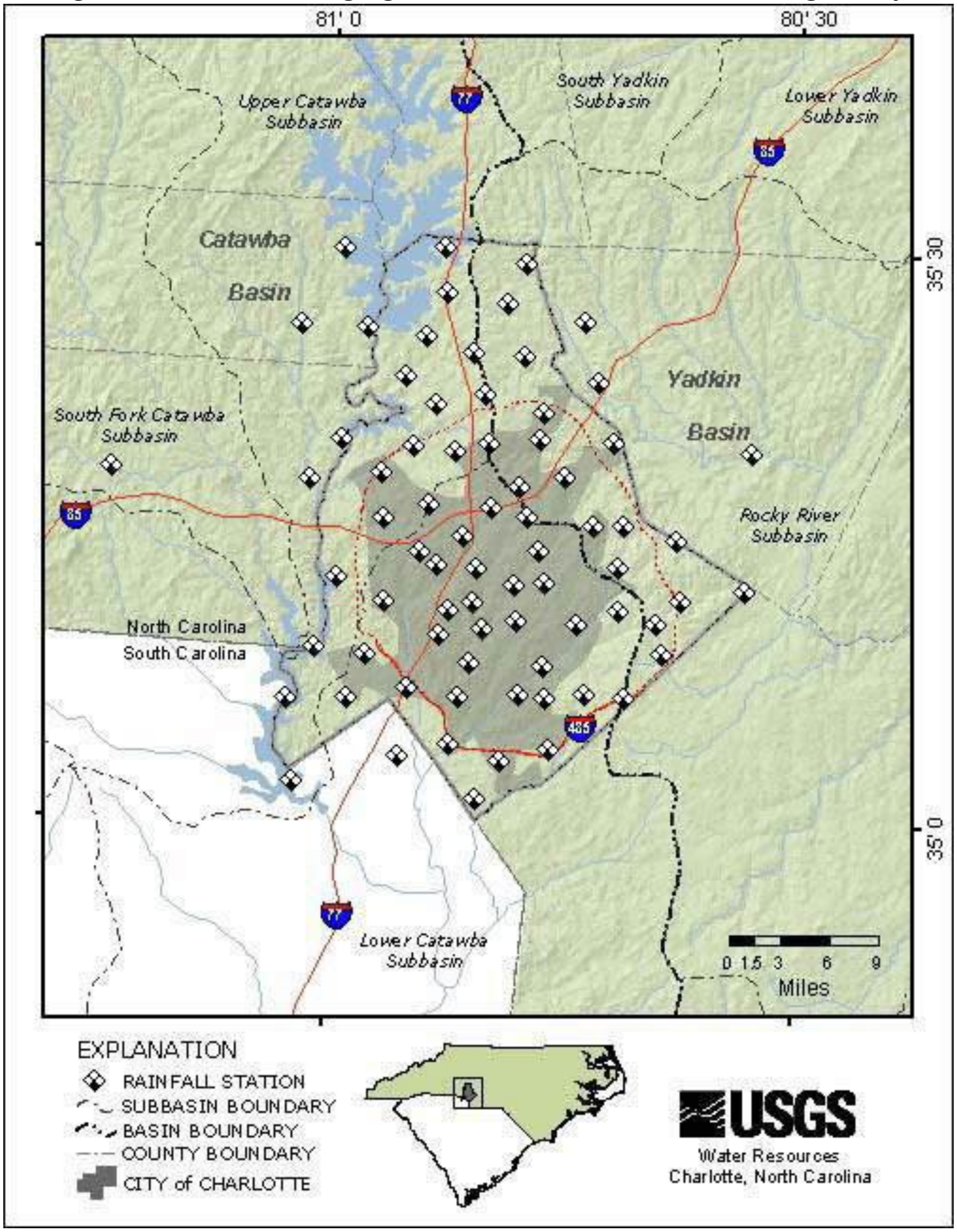
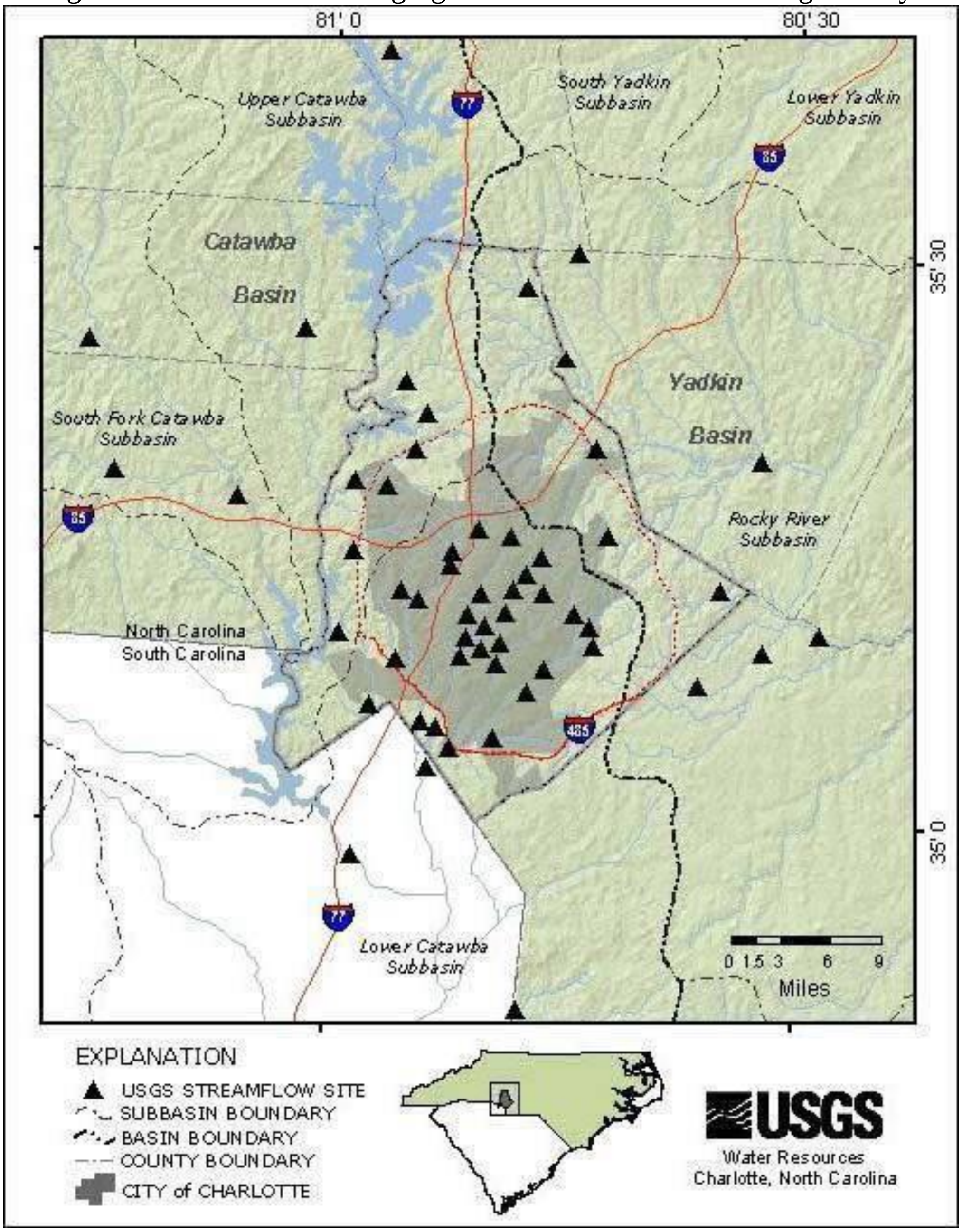


Figure B9.2: USGS Stream gauges in and around Mecklenburg County.



B10. Data Management

MCWQP produces approximately 17,000 analytical data points annually. In addition there are numerous Macro invertebrate assessments, fish counts, and habitat scores, as well as approximately $1.7x10^6$ remote water quality data points produced every year. Due to the quantity and complexity of information being produced, organized data management is critical. An overview of the data flow is given in Figure B10.1.

Analytical results are submitted to the Data Manager electronically and in hard copy format from the CMU laboratory. Occasionally samples are subcontracted by the CMU lab to outside sources. All outside sub-contract labs must be State Certified and provide data to MCWQP in both electronic and hard copy formats.

Field data is submitted in hard-copy on formatted field data sheets. Hard copy formatted original field data must be hand-key entered into electronic format for use and storage. Remote data from CMANN automated water quality sondes and USGS flow and precipitation data are routinely downloaded from the respective internet servers in .csv file format.

Individual data points are uniquely identified using a combination of Program Element Code, Location Code, Location Description, Date/Time Collected and analyte. All data received are reviewed by the Data Manager / QC Officer for completeness, data entry errors, unlikely or impossible values, etc., prior to approval.

All approved data is then uploaded into a secured SQL database utilizing a custom, web-interface application, the Water Quality Data Repository (WQDR). Approved data is available to MCWQP staff through the Environmental Data Management System (EDMS), or through Open Database Connectivity (ODBC) using Microsoft Access.

SECTION C: ASSESSMENT AND OVERSIGHT

C1. Assessments and Response Actions

The QA/QC Officer acts as the liaison between field staff, the CMU Laboratory, program management and data end users. Issues with any aspect of the program noted by any of these should report them as soon as possible to the QA/QC Officer, who will assess the issue, consult with other parties as needed, and determine the course of action to be taken.

The QA/QC Officer will conduct field audits of each monitoring program at least annually. The main purpose of these audits is to ensure that field staff are performing activities in accordance with current SOPs and to determine if there are any other issues that need to be addressed. Concerns or irregularities noticed by the QA/QC Officer will be discussed with the field staff and project officer. If significant issues arise, the QA/QC Officer will notify the Program Manager, and the field staff member's direct supervisor and issue a corrective action report. If the issue continues after the notification, the QA/QC officer will prepare a memorandum, describing the issue and providing recommendations for correcting the issue. The field staff member's direct supervisor is responsible for ensuring that these significant issues are resolved.

C2. Reports to Management

The QA/QC Officer reports significant issues to the Program Manager verbally and/or via written updates. The QA/QC Officer also maintains a database of the sampling schedule, which includes an accounting of all samples collected, samples to be collected and any issues with samples collected to date. The QA/QC Officer delivers periodic updates to the supervisors, project officers and field staff on the status and schedule of the monitoring program. These updates occur at monthly staff meetings and monthly supervisor meetings.

SECTION D: DATA VALIDATION AND USABILITY

D1. Data Review, Verification and Validation

Data verification and validation occurs at every step of water quality data generation and handling. Field staff, laboratory staff, project officers and the QA/QC Officer are each responsible for verifying that all records and results they produce or handle are completely and correctly recorded, transcribed, and transmitted. Each staff member and project officer is also responsible for ensuring that all activities performed (sampling, measurements, and analyses) comply with all requirements outlined in the SAPs and SOPs pertinent to their project. The QA/QC Officer is responsible for final verification, validation and acceptance of all results. One exception is the CMAN program where the CMANN project officer reviews all measurements and performs final verification, validation and acceptance of results.

D2. Validation and Verification Methods

Field staff

Field staff will visually check the following items as produced to ensure that they are complete and correct:

- Sample bottle labels
- COCs
- Field data sheets

Laboratory staff

CMU laboratory staff will perform data validation and verification in accordance with their Analytical Laboratory Certification requirements.

If circumstances arise where samples or analysis do not meet laboratory criteria, the Laboratory Section will report this using a text comment field attached to the result record.

QA/QC officer

The MCWQP QA/QC Officer (QCO) is responsible for data review, validation, and verification. These duties are conducted on an ongoing basis. As received, the QCO reviews hard copy lab reports and electronic data transfers from the CMU Lab, remote databases (CMANN) and from outside vendors (subcontracted labs). The QCO also reviews data that has been hand-key entered by MCWQP staff.

The QCO consults with the CMU Laboratory Manager and / or designated staff for clarification or corrections as needed. When errors or omissions are discovered or suspected, a focused investigation will be conducted. In the event that errors are discovered in electronic data transfers from CMU or CMANN, the QCO will contact the CMU Lab Manager, the CMU QC Lab Coordinator, or the designated MCWQP staff for resolution. In the event that errors are discovered in hand-key entry data, the QCO will consult hard-copy field data sheets and / or staff to resolve any identified issues. Final decisions on qualified or rejected data are the responsibility of the QCO.

Results in question that are found to be in error when compared to the original documentation will be corrected by the QCO. “Impossible” values (e.g., pH of 19) will be rejected or corrected if a value can be determined from original documentation. "Unusual" values that are confirmed by original documentation are left intact and unqualified.

Validated and verified data are uploaded to the Water Quality Data Repository by the QCO.

Data end-users

The individuals that request data from the MCWQP may note odd or possibly incorrect values. These questionable data should be brought to the attention of the QA/QC officer for focused verification. For most data, original lab reports and field data submissions are on file at the Hal Marshall Center (700 North Tryon Street, Charlotte, NC 28202). These will be consulted to determine if correction or deletion of any records in WQDR is required, using the same criteria as described above for data reviews. If original documentation for data collected is not available, confirmation and/or correction are not possible. This historic data will remain unchanged in the main warehouse and it is up to each data user to determine the proper handling of these results.

D3. Reconciliation with User Requirements

Section 7.0 – Performance Acceptance Criteria of each individual SAPs (Appendix 2) for each monitoring project outlines the acceptance criteria for each project.

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