Efficiency Assessment of BaySeparator and BayFilter Systems in the Richard Montgomery High School

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Summary

The detrimental effects of urban rainfall runoff have received increasing attention for several decades. Consequently, implementation of various in-situ structural stormwater BMPs is becoming more widespread and has been further accelerated by the application of March 2003 enactment of NPDES Storm Water Phase II regulations. As new stormwater regulations go into effect for Phase II communities, many state and local agencies are asking for field performance data. To comply with the requirements, field tests were implemented in April 2008 to evaluate the effectiveness of the BaySeparator and BayFilter systems in removing pollutants from stormwater runoff at Richard Montgomery High School parking lots located in Rockville, Maryland. The test systems with total drainage areas of 3.62 acres were used as targeted watersheds for samplings at flow paced intervals. ISCO automatic samplers collected runoff samples at the BaySeparator inlet, BaySeparator outlet and BayFilter outlet during the storm events for analysis of suspended sediment concentrations (SSC), total suspended solids (TSS), total phosphorus (TP) and turbidity (NTU). Rainfall depths of the first 20 monitored storm events ranged from 0.24 to 3.04 inches.

As a treatment train, BaySeparator and BayFilter removed 92.2% and 89.6% of the incoming SSC and TSS respectively for total 20 monitored events. The independent SSC removal efficiencies of the BaySeparator and BayFilter alone reached 46.3% and 85.6%, respectively. The independent TSS removal efficiencies of the BaySeparator and BayFilter alone reached 33.6% and 84.4%, respectively. The independent TP removals of the BaySeparator system and BayFilter system were 19.4% and 55.4%, respectively. The TP removal by the treatment train reached 64.0%. In addition, The BaySeparator system and BayFilter system were found to be able to achieve an overall reduction of 6.9% and 64.4% of turbidity (NTU) reduction, respectively. Furthermore, the treatment train achieved 66.9% turbidity reduction. In spite of the fact that influent concentrations are generally highly influential in determining the projected removal efficiency, the BayFilter system was consistently effective in reducing pollutants to nearly irreducible levels (less than 20 mg/L of TSS) in most events (18 of 20), which proved that the BayFilter is a feasible and reliable stormwater treatment system for reduction of sediments and total phosphorus.

Introduction

Urban stormwater runoff has been recognized as a specific source of contamination potentially impacting receiving aquatic systems. Rainfall runoff can mobilize and transport a wide gradation of particulate matter in source area watershed, which is a potential concern not only because of the environmental and ecological issues related to the particulate matter, but also because many pollutants such as phosphorus, nitrogen, metals, oil and hydrocarbons etc. can be bound to the surface of the particles during the transportation. Phosphorus has been long recognized as the limiting nutrient for eutrophication, and as the pollutant of primary concern for the ecological health of fresh waters (Correll, 1998).

Since 1997, BaySaver Technologies™ has been addressing the issues in relation to the pollutants transported in urban environment and protecting lakes, streams, and waterways from environmental problems. Two of BaySaver Technologies' most innovative products developed to control non-point source pollution have been the BaySeparator system and BayFilter system. These systems have been installed in over 1,500 locations in commercial, industrial, and residential applications worldwide, and have been used in projects as varied as parking lots, gas stations, service stations, maintenance facilities, and highways. BaySeparator has often been used as a pretreatment for filtration system and designed to remove the coarser sediments and the floating debris, oil and grease. BayFilter is a stormwater filtration device designed to remove fine sediments, heavy metals, and phosphorus from stormwater runoff.

As new stormwater regulations go into effect for Phase II communities, many state and local agencies are asking for field performance data. To comply with the requirements, field tests were implemented by Mid-Atlantic Stormwater Research Center (MASWRC) in April 2008 to evaluate the effectiveness of the BaySeparator and BayFilter systems in removing pollutants at the request of BaySaver Technologies, Inc. In addition, an added third party evaluation was accomplished by University of Maryland to audit and examine the sampling procedures, laboratory methods and testing result reporting etc.

Background overview

The BaySeparator system

The BaySeparator™ system relies on gravity sedimentation and flotation to remove and retain the collected contaminants. The system is comprised of three main components: the primary manhole, the high-density polyethylene (HDPE) BaySeparator unit and the storage manhole. Figure 1-1 displays a schematic of the BaySeparator™ system. Influent flow containing pollutants enters the system by first passing through the Primary Manhole (PM). In the PM, coarse sediment settles while the flow passes over a weir in the BaySeparator™ unit and is routed to the storage manhole. The influent flow, at this point, still contains pollutants of concern, such as fine sediments, oil, grease, floating trash, and other debris. In the storage manhole floatable trash, oils, and grease float to the surface, while fine sediments settle out and the influent separated flow returns to the outfall of the system back through the separator unit.

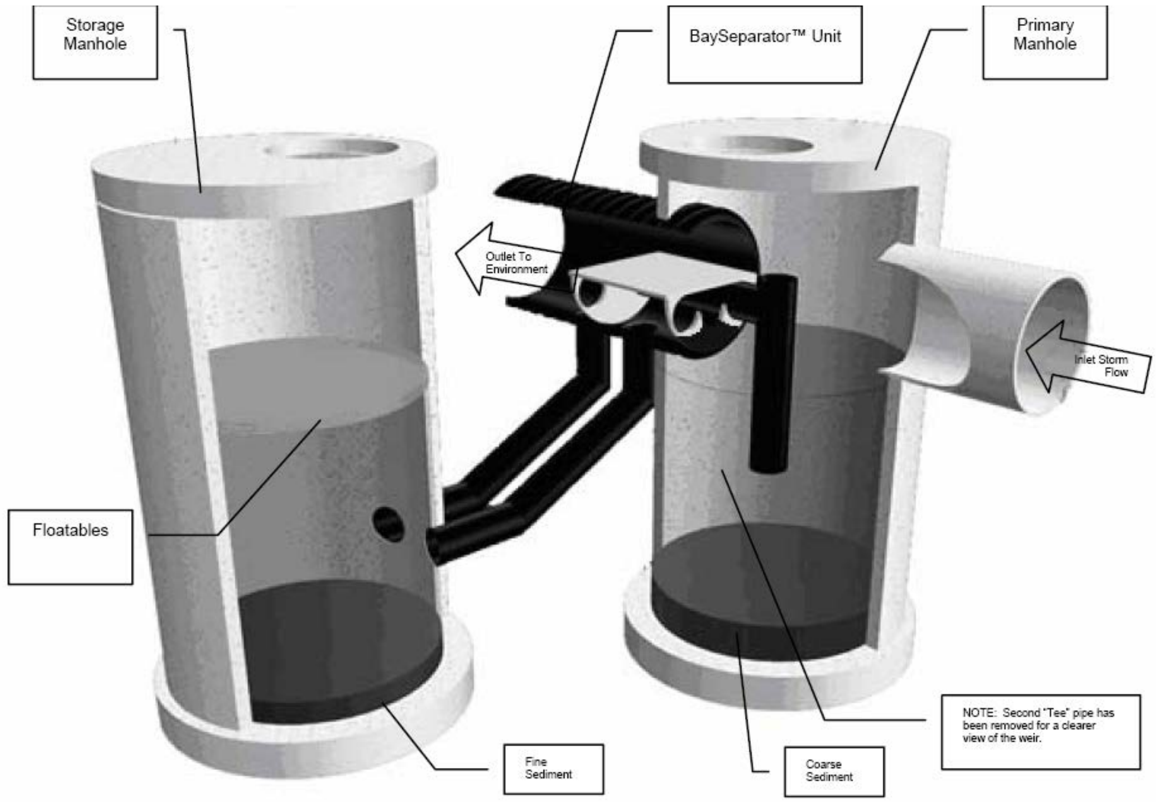

Figure 1- 1 Schematic of BaySeparator system

As the rate of flow increases through the system, the BaySeparator™ system acts as a dynamic control to route the influent flow through the most effective flow path for treatment. Under low flow conditions the entire influent flow is treated as described above. Under moderate flows and up to the maximum treatment flow, water is continuously treated through both the primary and storage manholes, with the surface flow directed to the storage manhole and subsurface flow directed to the outlet. This flow path allows for full treatment of floatable pollutants, while still treating sediments under moderate flow conditions. During maximum flow conditions, the influent flow passes over the bypass plate and will only be treated for larger sediment particles.

The BayFilter system

The BayFilter™ system removes contaminants from stormwater runoff via media filtration and absorption. This technology has proven effective at removing sediments, nutrients, heavy metals, and a wide variety of organic contaminants. BayFilter™ removes pollutants from water by physical straining, interception and attachment. In addition, the BayFilter™ system uses a proprietary media containing activated alumina to enhance adsorption of anions such as orthophosphates.

The main building block of the BayFilter™ stormwater filtration system is the BayFilter™ cartridge (BFC), shown in Figure 1-2. The BFCs are housed in either a vault, manhole, or other structure. This structure contains the inlet and outlet pipes, as well as an internal manifold that delivers treated water to the outlet of the BayFilter™ system.

Stormwater runoff enters the manhole or concrete structure via an inlet pipe and begins to fill the structure. When the water surface elevation in the vault/manhole reaches operating level, water flows through the BFC driven by hydrostatic head. Within the BFC, the water flows through a proprietary filter media and drains via a vertical pipe. The vertical drain is connected to the underdrain system which conveys filtered water to the outfall.

The BayFilter™ has been extensively tested in the laboratory. This testing has been carried out using SIL-CO-SIL 106 as a sediment source. SIL-CO-SIL 106 is a silica product containing approximately 90% fine sediments (d_{50} = 23 microns), and is widely accepted as a surrogate sediment source for stormwater simulations by regulatory agencies such as the Washington State Department of Ecology's Technology Assessment Protocol – Environmental (TAPE) program, the New Jersey Department of Environmental Protection's Technology Assessment and Reciprocity Program (TARP), as well as other leading agencies.

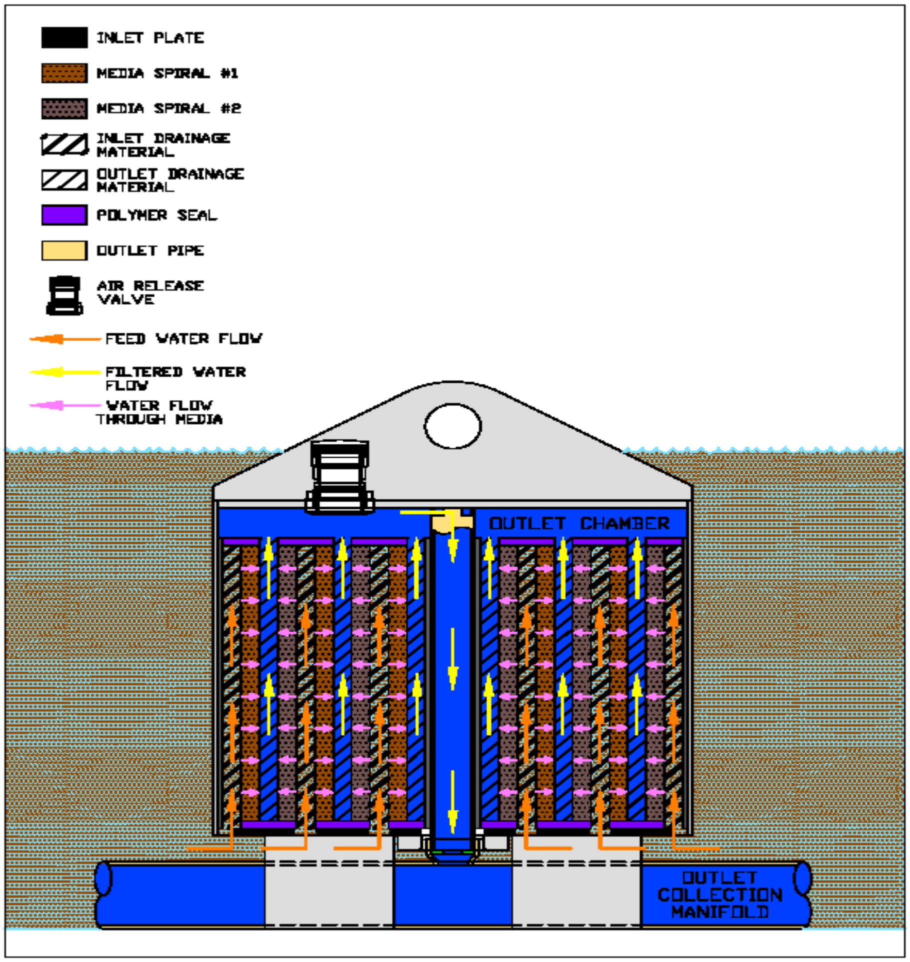

Figure 1- 2 Schematic of BayFilter™ Cartridge.

Field Testing Program Evaluation

Site Description

The BaySeparator and BayFilter systems monitored treat the stormwater runoff from the Richard Montgomery High School parking lots located in Rockville, Maryland. The majority of the site is paved with asphalt. The test site contains a total drainage area of 3.62 acres with 83% impervious cover including the building roof and 17% managed vegetated area (Figure 1-3, Figure 1-4). During the day, car and bus parking spaces are provided to serve 1,900 students. Heavy traffic and activity are often seen in early morning, noon and middle afternoon daily.

Topographically, the test site slopes gently from north to south towards the stormwater drains. Surface runoff is collected in the existing stormwater drainage system and delivered to the drain manhole at the south end of the parking lots where the test units are installed. The treated water from the test site is discharged into a riprap protection area and then drained to a low area, a stormwater management pond maintained by the City of Rockville.

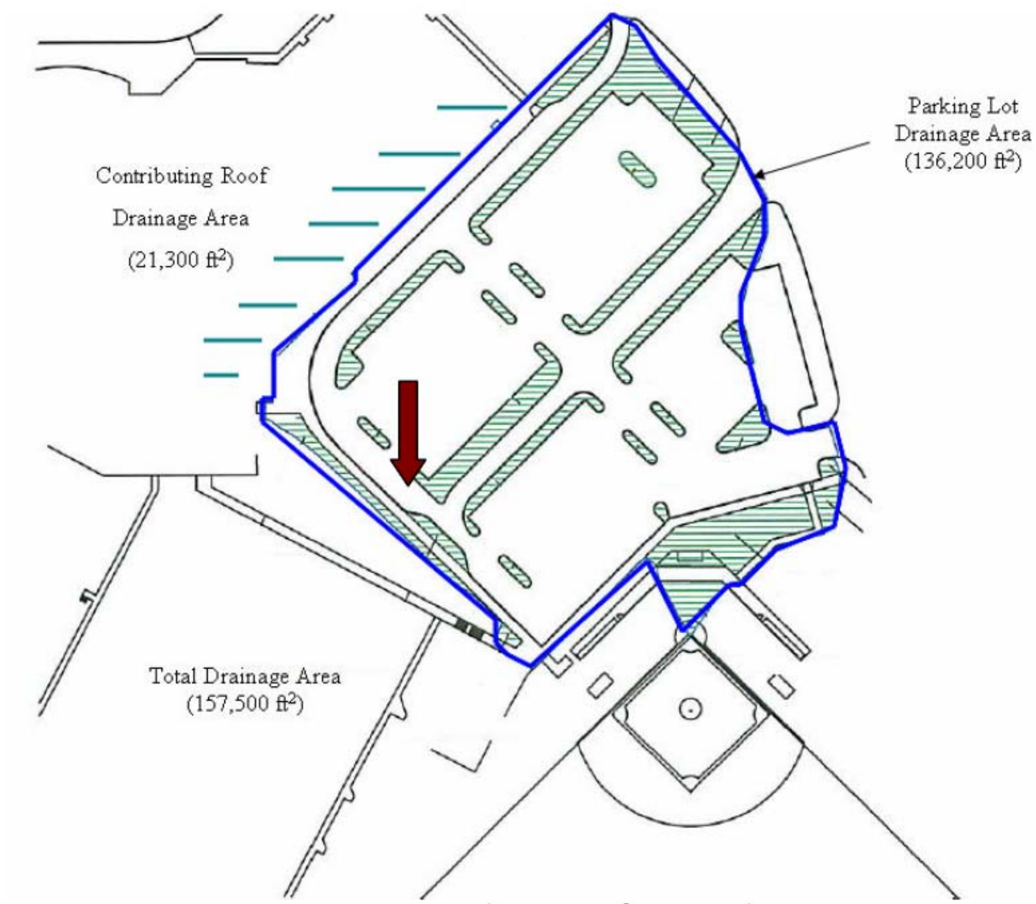

Figure 1- 3 Drainage area layout of test site. Arrow points the location of treatment system.

Figure 1- 4 View of Richard Montgomery High School test site. Arrow points the location of treatment system.

System Description

As a part of the Stormwater Management plan for Richard Montgomery High School, a water quality treatment system was required to treat the first 1 inch of rainfall according to MDE. The test system incorporates a treatment train approach using a pretreatment system (BaySeparator 3K), a water quality diversion structure, and a volume based filtration system containing an underground water quality CMP storage system, 5 BayFilter cartridges and 1 drain down cartridge connected by PVC manifold. The stormwater runoff is collected by inlets in the parking lot and flow is carried to the BaySeparator. Flow from the BaySeparator™ goes into a diversion structure, a precast concrete manhole, then into an underground storage system in conjunction with a precast 8 by 12 foot concrete vault where 5 BayFilter cartridges and 1 draindown cartridge (or 5 drain down modules) are installed (Figure 2-1). This test is configured to enable a determination of the efficiency of BaySeparator system and BayFilter system separately and the entire treatment train as a whole. The test system is detailed as follows.

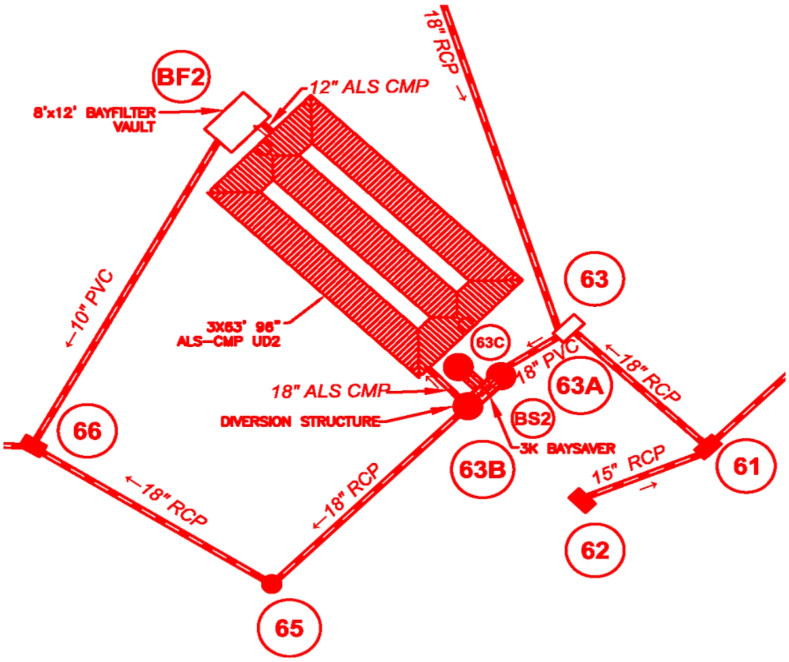

Figure 2- 1 BaySeparator and BayFilter system layout for system A.

BaySeparator system

Runoff from the test site is conveyed into a 3K BaySeparator unit via an 18” diameter RCP. Water then flows into a 3K BaySeparator unit which serves as a pretreatment structure with a maximum treatment capacity of 3.4 cfs (Figure 2-2).

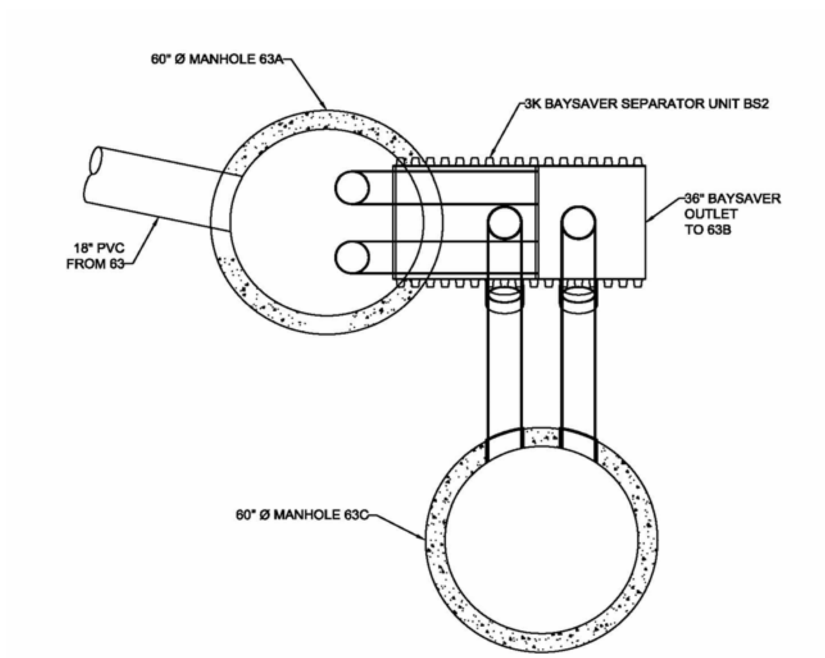

Figure 2- 2 Layout of the BaySeparator system

Diversion structure

Effluent from the BaySeparator enters a water quality flow diversion structure which diverts flows into an underground water quality detention system. The diversion structure is directly downstream of the outlet of the BaySeparator. There is an approximately 2' drop to the invert of the water quality diversion pipe into the storage system. The invert of the bypass in the flow split structure controls the water level in the storage system. Bypass can only occur when the storage system is full (1 inch storm, about 10, 938 cf). Unless there is bypass, all of the BaySeparator effluent enters the storage system and cannot leave that system unless it passes through the BayFilter.

Storage system

The water quality storage consists of 205' of 8' diameter corrugated metal pipe (CMP) with a 6" dead storage capacity (Figure 2-3). The volume of the storage system is based on 75% of the water quality volume for the site in accordance with Maryland stormwater regulations. The CMP discharge pipe is 6" above the invert of the storage system and there is a 2' drop into the BayFilter vault.

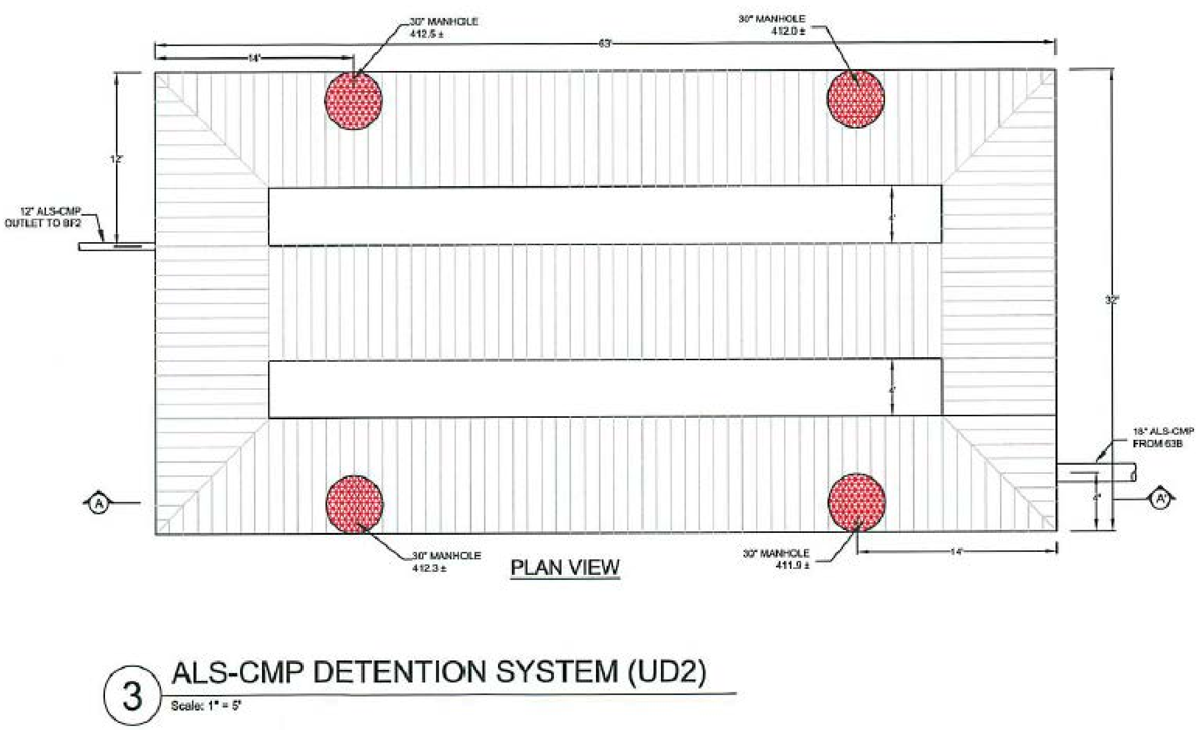

Figure 2- 3 Layout of the Storage system

Filtration system

A total of 5 BayFilter cartridges (BFC) and 1 drain down cartridge (DDC) were housed inside of an 8'x12' precast vault. This vault contains an energy dissipater/level spreader at the inlet and a PVC underdrain system that connects the BayFilter filter cartridges to the outlet pipe. A layout drawing of the system can be found in Figure 2-4 and Figure 2-5. Each cartridge has a design flow rate of 15 gpm and the test system is designed to drain down in 40 hours. The discharge time is after the cessation of inflow.

The initial testing was done using 5 BFC and 1 DDC. Because of some advances in the design, in June the test DDC was disconnected in favor of the new drain down module (DDM). There is 1 DDM used for each BFC, so the revised configuration includes the same 5 BFCs and 5 DDMs (Figure 2-6). Since these components only account for small fraction of the flow and are primarily designed to drain the vault after the cartridges have backwashed, the impact of this change was expected to be insignificant.

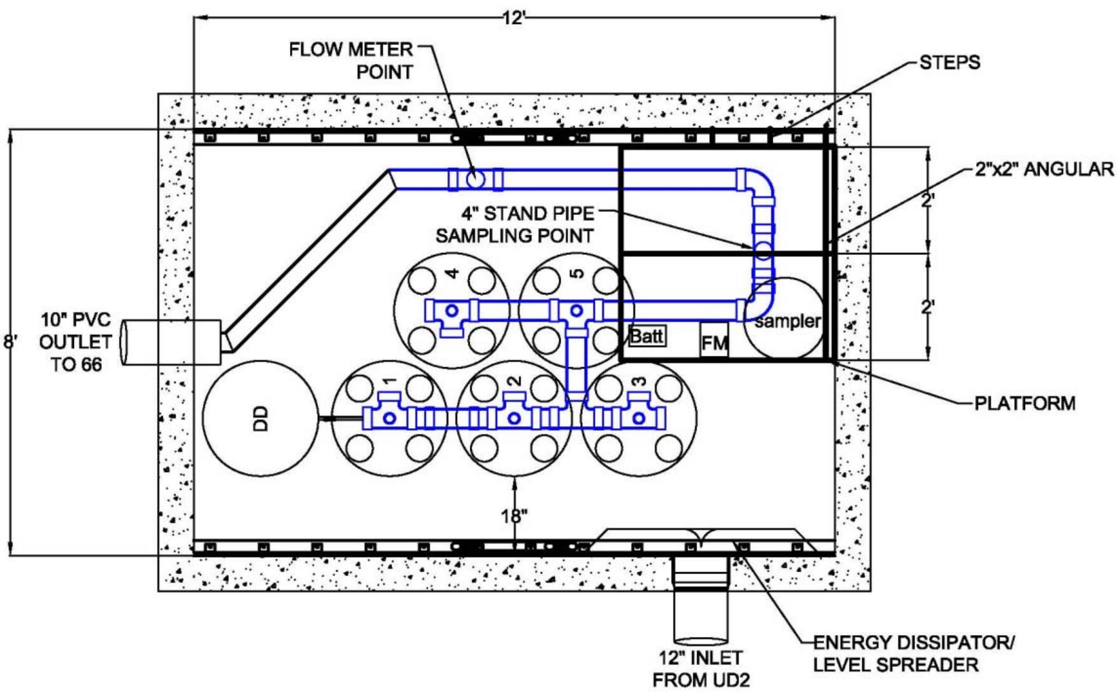

Figure 2- 4 Layout of the BayFilter filtration system with DDC (top view)

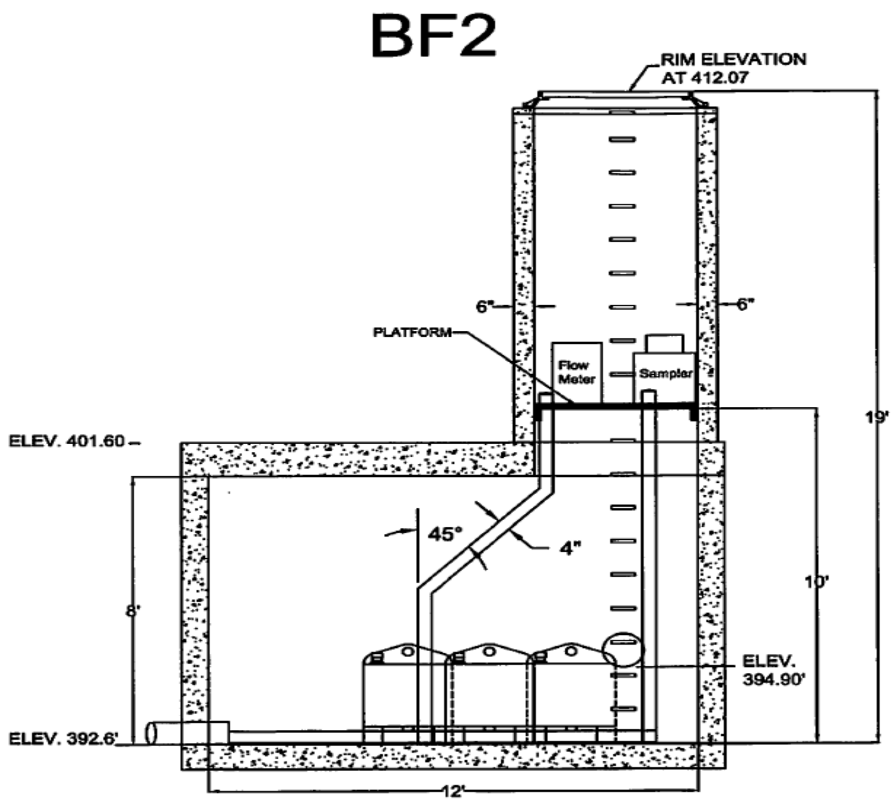

Figure 2- 5 Layout of the BayFilter filtration system (side view)

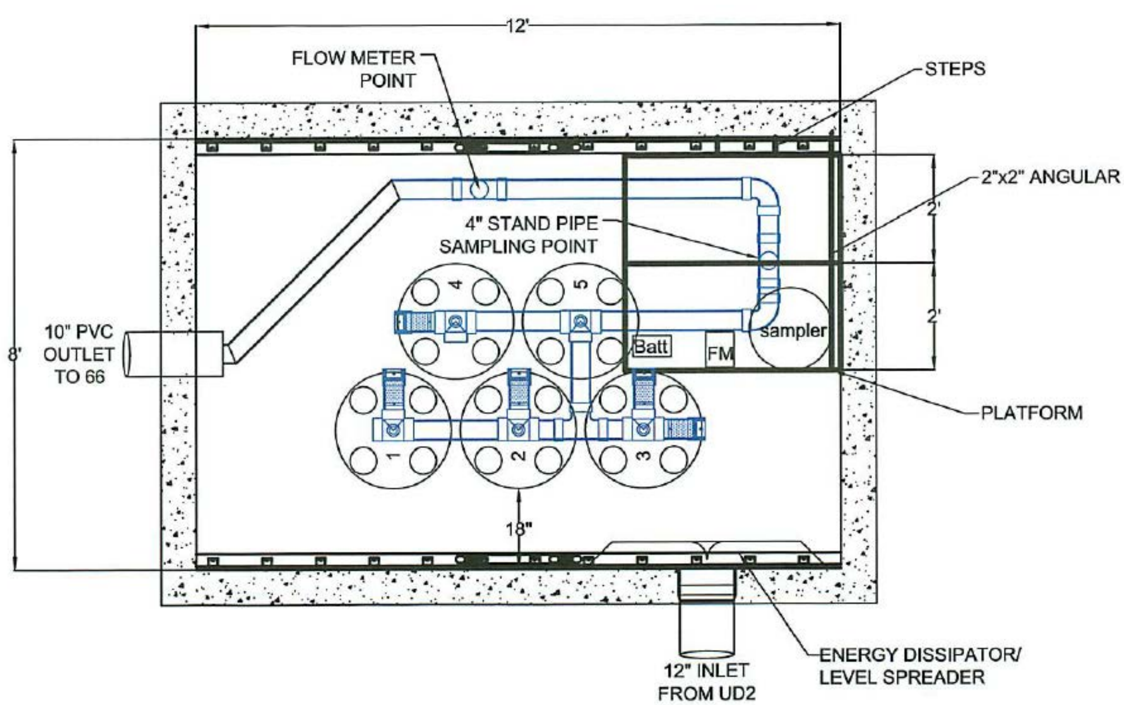

Figure 2- 6 Layout of the BayFilter filtration system with DDM (top view)

Field testing

Hydrologic data collection

Precipitation was measured and recorded in intervals of 0.01 inch by a tipping bucket rain gauge (Rainwise) with an event data logger (HOBO) installed on the site. Flow through the BaySeparator system and BayFilter system were measured and recorded by ISCO 4250 Flow Meters which utilize a submerged area/velocity sensor to measure the flow rate and water level in the influent or effluent pipe of the device. The rainfall and flow monitoring equipments were installed, calibrated and maintained according to the manufacturer's specifications. A single flow meter was sufficient for measuring both influent and effluent flow rates for the BaySeparator system since the hydraulic retention time of the BaySeparator is relatively short.

Stormwater runoff sampling

Flow paced samples were collected using ISCO 3700 portable automatic samplers at the BaySeparator inlet, BaySeparator outlet and Bayfilter outlet. This enabled analysis of the independent performance of the BaySeparator, and the BayFilter (although the BayFilter influent had already had the larger particles removed), as well as an analysis of the entire treatment train. The two ISCO 4250 area velocity flow meters were used to trigger samplers in both the BaySeparator and BayFilter systems. The samplers pull discrete flow aliquots in an individual sample container when the flow meter has recorded a specified volume of flow. One bottle will contain 4 aliquots to ensure the collection of a more representative sample. This volume pace was determined based on the minimum sample volume, the total predicted rainfall depth, and the contributing drainage area. The information required to establish these values was developed prior to deployment of the sampling equipment. Deep cycle marine batteries were used to supply electricity for the sampler and flow meter. All sampling equipment was installed, calibrated and maintained according to the manufacturer's recommendations.

All samplers, flow meters and ancillary equipment were installed within a manhole or vault and positioned above the high-water level (Figure 3-1 and Figure 3-2). A landing platform was equipped in the manhole or vault to provide safety for the equipment operation and maintenance. Sampling equipment was held securely in place by a pair of L-shaped bracket supports mounted to the concrete wall of the manhole or vault. This feature aids the deployment, sample recovery and other associated activities. The sampler intakes and flow meter sensors are secured to the stormwater conduit using mounting straps. A 3/8 inch diameter suction line was mounted slightly off center bottom of the inlet or outlet pipes to allow the collection of a representative sample.

Figure 3-1 View of sampler and flow meter set up in BaySeparator outlet manhole

Figure 3-2 View of sampler, flow meter, ultrasonic sensor set up in BayFilter vault

Targeted Pollutants Analysis

After each event, all samples were collected and returned to the laboratory for analysis within 24 hours (or as close to this as feasible) since many water quality parameters are time sensitive. A pipette aliquot sub-sample was then taken of each sample to establish a composite sample for analysis of metals and PSD while well mixing. Another aliquot (60 ml) was then taken from each sample for analysis for TP and turbidity. The balance remaining of each sample was then analyzed for TSS and SSC. Because of the variations in test protocols, between TAPE, TARP, and others, as well as the inherent variations in results generated from the aliquot TSS testing, the SSC data has been broken down into two subsets. The first is all of the solids found in the sample including the coarser particles (sand), and the second is the same data set but with a screening off of all of the particles greater than 250 μm.

The TSS (SM2540D, APHA/AWWA) and SSC (ASTM D3977-97B) were measured by filtering the sample through a nominal 1.5 μm glass fiber filter. The SSC concentration was determined by filtering the entire sample whereas the TSS was determined by filtering an aliquot of a sample taken by the samplers. The composite samples then had aliquots again taken for PSD analysis.

Although SSC data is often described as whole sample TSS data, the basic distinctions are that the TSS sampling method utilizes mixing of the sample and taking an aliquot extraction, whereas the SSC method involves filtering of the entire sample. Because the mixing during the TSS aliquot extraction is very difficult to maintain the particles in uniform suspension, even extractions from the same original sample can have significant data variation between samples. In order to ensure the representative of the original sample, subsamples were taken by moving the pipette up and down in the water column while the sample was well-mixing to overcome the stratification and the settling out of heavier particles. The SSC method on the other hand will include those particles that were not suspended during the TSS aliquot extraction, and therefore will generally be higher since the total sample is filtered, which means that the data is far more reliable.

This testing is designed to meet both the TAPE and TARP protocols, which define TSS in different ways. Commonality can exist in that the TAPE protocol considers TSS and SSC to be equal if the particles larger than 500um are excluded from the SSC data. To further this concept and generate accurate and repeatable data acceptable to both protocols, the particles greater than 250um were sieved off from the samples and reported this as such.

The PSD analysis was done on an aliquot of each of the composite samples using laser diffraction, with a Sequoia LISST PSD analyzer by Particle Engineering Research Center (PERC), University of Florida.

Turbidity measurements (SM2130B, APHA/AWWA) were performed with a nephelometric turbidimeter.

For the total phosphorus (TP) determination, the sample was thoroughly mixed and a suitable portion (20 mL) was transferred into a flask for digestion prior to the phosphorus analysis. Phosphorus acid digestion followed the Persulfate Digestion Method (SM4500-P, APHA/AWWA). The analysis of phosphorus was performed using the ascorbic acid molybdenum blue method (EPA 365.2) using a HACH DR-2800 Spectrophotometer.

The composite samples were analyzed for copper and zinc by using nitric acid-hydrochloric acid digestion first and copper analysis was based on porphyrin method and zinc adapted from SM 3500 Zn –B approved by USEPA.

Sample data quality assurance and control

As per the test QA plan and sampling and analysis plan, the following quality control samples and activities were used to assess the quality of sampling and analysis in both field and laboratory.

Field quality control

Samples are collected within 24 hours of the end of the rainfall event and are transported to the MASWRC laboratory for analysis of water quality parameters. The sample bottles are replaced with clean sample bottles after each event. The sample bottles are washed and prepared with an Alconox solution (non-phosphorus containing detergent) and rinsed with deionized water three times. Field blank and rinsate blank were analyzed and the results were below 1 mg/L for SSC and 0.1 mg/L for TP (Figure 5-1). The Univariate Statistics analysis showed that SSC mean and TP mean are not significantly different from zero ($\alpha = 0.05$, $p = 0.384$ and $p = 0.732$ for SSC and TP respectively). All samplers, flow meters, rain gauge and ultrasonic sensor were calibrated according to manufacturer’s recommendation. Field log and Chain of Custody form were attached in Appendix B.

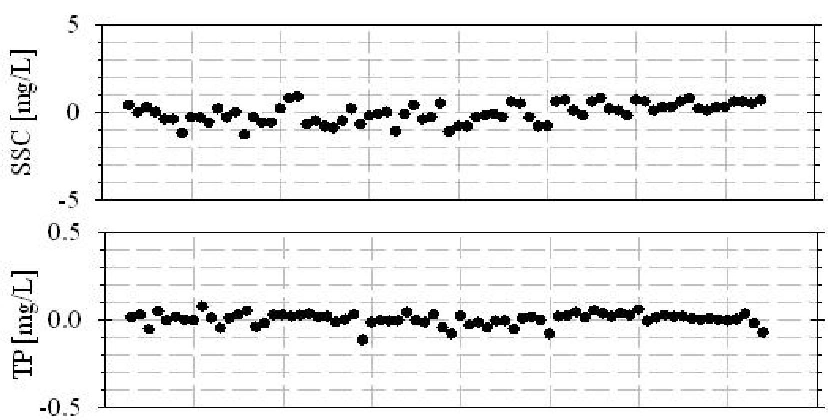

Figure 5-1 Field blank results for SSC and TP

Laboratory quality control

To be more descriptive, color coded dots (one on each side of sample bottle) and a computer generated label with the sample ID and date are affixed to the sample bottles; to avoid potential cross-contamination, pipette was rinsed between samples and changed between sample sets. Because of the time sensitive analysis for many parameters, turbidity, TSS/SSC samples were run immediately after they were transported back to the laboratory. TP samples were preserved using sulfuric acid if analysis was not being done immediately. Method blanks were used for each set of sample. Duplicate samples were collected and analyzed for TSS, TP and turbidity (not including the split samples by UMD).

All replicates (A and B) were paired and plot in Figure 5-2. Replicate A was sorted in order from the lowest value to the highest value. In general, the overall agreement between the replicates was satisfactory except the TSS of BaySeparator Influent since it was challengeable to take two identical samples while the coarse sediment present.

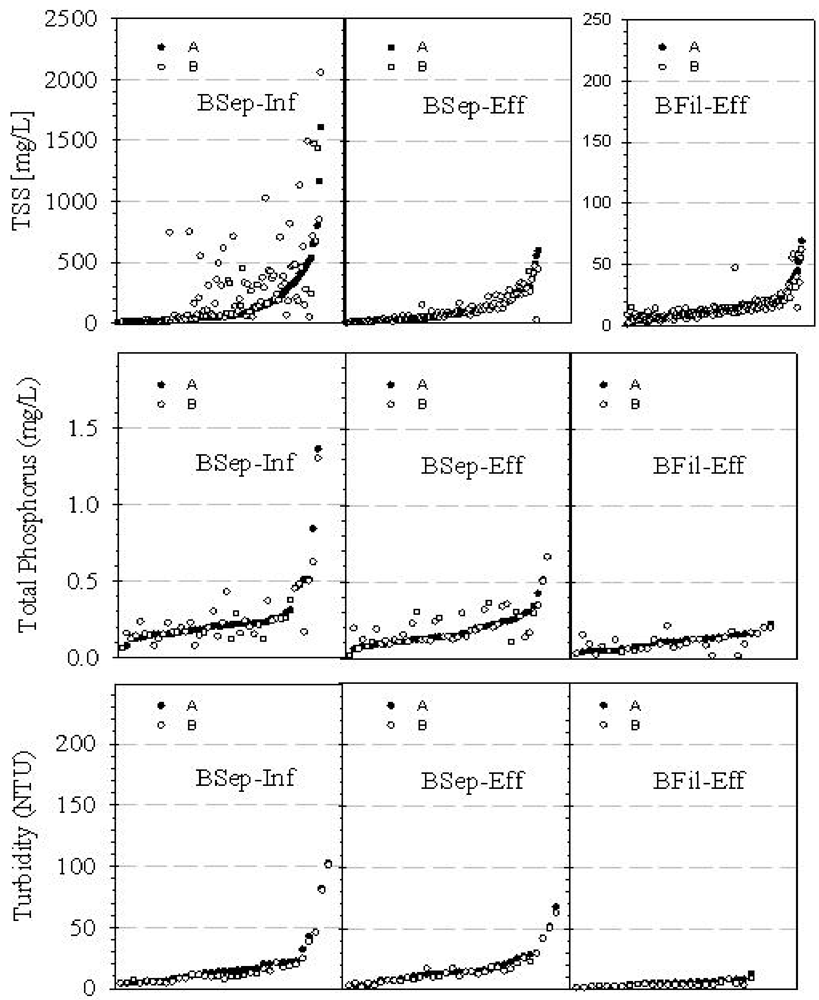

Figure 5-2 Replicates (A and B) of TSS, TP and turbidity samples for BaySeparator influent, BaySeparator effluent and BayFilter effluent.

As one of the common indicator to measure the precision, the relative percentage difference (RPD) was defined as following formula:

$$RPD(\%) = \frac{|A - B|}{(A + B)/2} \times 100$$

Figure 5 –4 shows the RPDs of TSS, TP and turbidity replicate samples for BaySeparator influent, BaySeparator effluent and BayFilter effluent. Boxes represent the range from the lower bound of the second quartile to the upper bound of the third (a distance sometimes described as the interquartile range), with the line between marking the median. Only the boxes of BaySeparator influent TSS and BayFilter effluent TP showed the upper bound was over the 50% line, likely due to the less representative of coarser sediments in BaySeparator influent subsamples and many of the BayFilter effluent TP was too close to detect limit (for example, 0.01 mg/L and 0.02 mg/L may generate a 100% RPD).

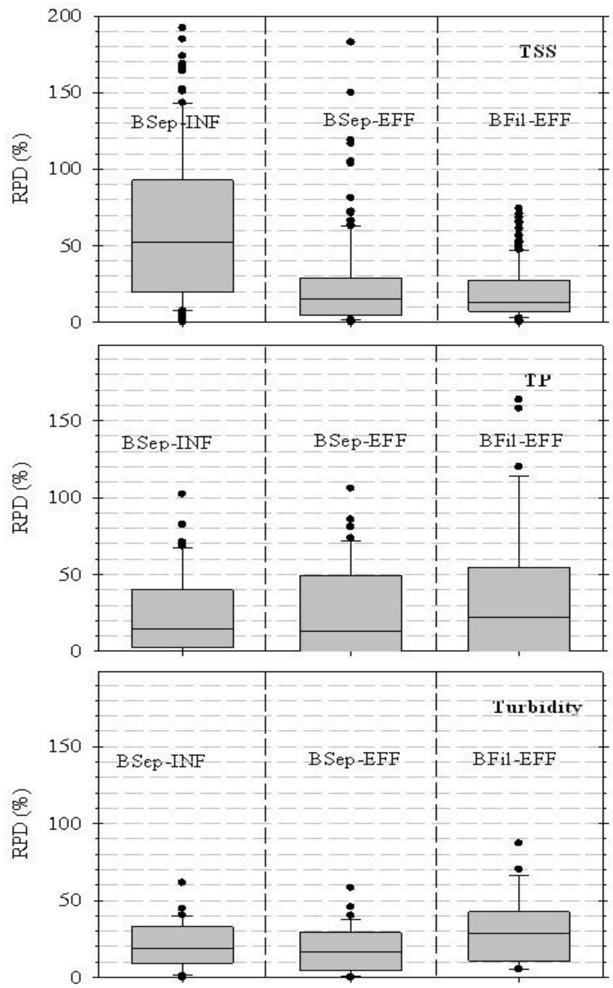

Figure 5-4 Box plots of Relative percentage differences (RPD, %) for TSS, TP and turbidity replicates. BSep-INF, BSep-EFF and BFil-EFF represent BaySeparator influent, BaySeparator effluent and BayFilter effluent respectively.

Evaluation of testing program by UMD

Three flow-paced discrete samples from BaySeparator inlet, BaySeparator outlet and BayFilter outlet were split in the field immediately after collection by UMD personnel for two selected events (October 25, 2008 and November 13, 2008). Both MASWRC and UMD analyzed the split samples from the site separately and the results of SSC, TP and turbidity were demonstrated in Figure 5-5. Generally, the correlations of the analysis between UMD and MASWRC are reasonably high, according to the coefficient of determination 0.975, 0.854 and 0.992 for SSC, TP and turbidity respectively. On average, SSC analysis by MASWRC tends to be 11.4% higher than UMD SSC data and TP analysis by MASWRC is about 8.6% higher than UMD TP analysis. The discrepancies were primarily attributed to the sampling procedures to obtain aliquots or subsamples by pouring or pipetting, particularly when larger sediments are present. However, the turbidity data showed that MASWRC analysis exhibit 17.5% lower compared to the UMD analysis, most likely due to the variance between the different turbidity meters, in addition to the sampling error. In general, the variability in values between MASWRC and UMD was contributed by sample splitting, different laboratory equipment and slight difference in sample handling and analysis.

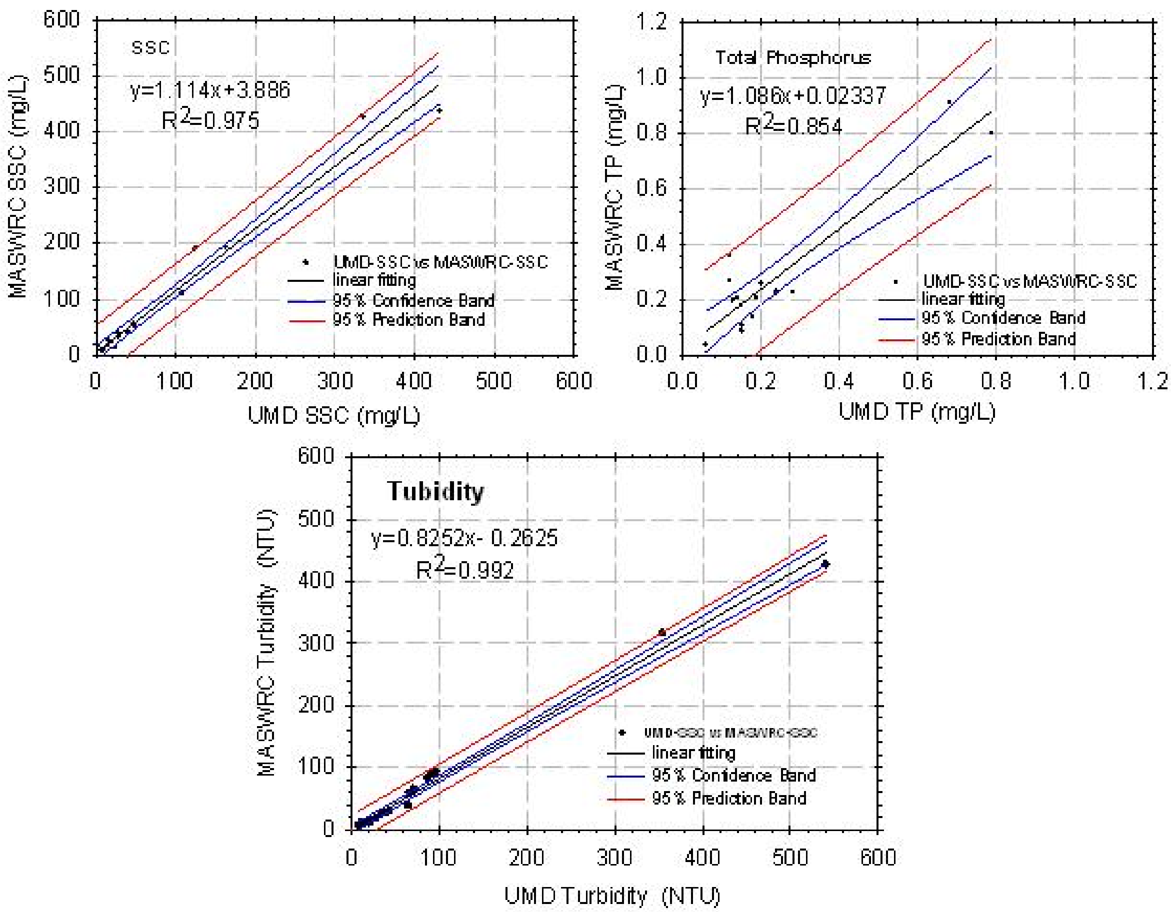

Figure 5-5 Split samples between UMD and MASWRC

Performance evaluation

Summary of Rainfall Events

Twenty storm events were monitored and examined from April to December 2008 at Richard Montgomery High School (RMHS) during the course of this study. Significant hydrologic characteristics associated with constituent loadings for all events are summarized in Table 6-1 through Table 6-9. The observed storms varied in duration from 180 minutes to 2098 minutes and the average rainfall intensity ranged from 0.03 to 0.51 inch/hour. The previous dry hours (PDH) for eleven monitored evens were longer than 96 hours (4 days), indicating a significant load of pollutants possibly accumulated on the pavement surface, while three events had a PDH less than one day. The PDH was 22 hours during the back-to-back storm events (April 26, 2008 and April 28, 2008). For all events except April 20, 2008, water quality samples covered over 90% of the total storm flow. Only 30% of the flow was covered by sampling during April 20, 2008 event so that it was marked as non-qualified (N) events in Table 6-1. In order to quantify the mass load received by the treatment systems, this event was also included in the performance evaluation but only the sampling period was counted.

In general, the events sampled were able to characterize the broad range of storm events typical of Rockville, Maryland and fulfilled the project criteria for storm events of the TARP protocols (minimum 0.10 inch total rainfall depth, minimum 6-hour dry period between events) and TAPE protocols (minimum 0.15 inch total rainfall depth, minimum 6 hour dry period between events and minimum 1 hour event duration).

Removal efficiencies for twenty monitored events were also summarized in the following tables. Both event mean concentration (EMC) and mass load were summarized in Table 2-2 to Table 2-9 for TSS, TP, and turbidity. In general, the efficiency of the BayFilter system was higher in the twenty events monitored given the varied flow and influent loading conditions, compared to the efficiency of BaySeparator. Six of the twenty events had a SSC removal by BayFilter system below 80%; however the Separator effluent (the incoming SSC to BayFilter system) for those six events all showed a very low EMC (< 50 mg/L). Additionally, in spite of the fact that influent concentrations are generally highly influential in determining the projected removal efficiency, the BayFilter system was consistently effective in reducing pollutants to nearly irreducible levels (less than 20 mg/L of TSS) in most events (18 of 20), which proved that the BayFilter is a feasible and reliable stormwater treatment system for reduction of sediments. Sixteen of twenty events monitored showed a 40 % or above TP reduction and fourteen of twenty events showed a 50% turbidity reduction by BayFilter system.

Table 6- 1 Hydrological indices for 20 storm events treated by the BaySeparator and BayFilter systems in system A at Richard Montgomery High School parking lot in Rockville, MD

Event	PDH (hr)	D (min)	P_s (in)	BSep Q_{ave} (gpm)	BSep Q_{peak} (gpm)	BFil Q_{ave} (gpm)	BFil Q_{peak} (gpm)	I_{ave} (in/hr)	I_{max} (in/hr)	TARP	TAPE
04/11/2008	129	183	0.29	69.2	546.7	38.9	57.0	0.51	4.50	Y	Y
04/20/2008	174	1759	3.04	112.0	1398.2	46.7	89.0	0.11	6.00	N	N
04/26/2008	121	560	0.58	57.2	566.6	30.0	50.0	0.10	1.11	Y	Y
04/28/2008	22	813	0.62	69.4	524.5	26.3	52.5	0.05	1.44	Y	Y
05/31/2008	231	228	0.26	73.1	888.0	15.0	46.0	0.07	1.14	Y	Y
06/03/2008	53	678	0.55	44.7	2265.0	28.3	57.9	0.047	72.0	Y	Y
06/04/2008	10	550	0.62	65.0	2393.0	17.1	55.0	0.068	72.0	Y	Y
06/16/2008	43	346	0.40	69.4	881.0	19.4	36.4	0.069	1.76	Y	Y
06/23/2008	117	378	0.24	33.0	263.0	11.9	15.5	0.038	0.81	Y	Y
06/27/2008	91	208	0.36	211.9	4285.0	25.6	68.2	0.104	5.14	Y	Y
07/09/2008	65	281	0.44	83.2	1243.0	21.5	32.0	0.094	2.12	Y	Y
07/13/2008	67	836	0.94	63.7	857.0	23.9	40.7	0.067	2.40	Y	Y
07/23/2008	230	776	0.46	39.7	398.0	19.6	28.0	0.036	0.60	Y	Y
08/02/2008	93	180	0.26	88.8	944.0	10.4	15.5	0.087	1.80	Y	Y
08/14/2008	170	404	0.28	33.1	1081.0	6.9	13.0	0.042	3.43	Y	Y
08/28/2008	322	2098	1.75	49.4	1065	18.6	33	0.05	1.36	Y	Y
10/25/2008	558	942	1.16	125	2977	24	54	0.074	4.50	Y	Y
11/13/2008	183	402	0.75	103.3	367	15.8	41.5	0.16	0.45	Y	Y
11/30/2008	124	1255	0.64	44.7	888	40.6	79	0.031	0.30	Y	Y
12/11/2008	10	1662	1.57	65.4	889	49.7	82.3	0.05	1.67	Y	Y
Mean	140.7	727.0	0.8	75.1	1236.0	24.5	47.3	0.1	9.2	N/A	N/A
Median	119.0	555.0	0.6	67.3	888.5	22.7	48.0	0.1	1.8	N/A	N/A
SD	127.7	562.7	0.7	40.8	1009.3	11.8	21.7	0.1	21.5	N/A	N/A

PDH, D, P_s, BSep Q_{ave}, BSep Q_{peak}, BFil Q_{ave}, BFil Q_{peak}, I_{ave}, I_{max} represent previous dry hour, event duration, precipitation, BaySeparator event mean flow, BaySeparator event peak flow, BayFilter event mean flow, BayFilter event peak flow, peak rainfall intensity and event mean rainfall intensity, respectively.

Table 6-2 Summary of SSC removals for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ [mg/L]	$BSep_{out}$ [mg/L]	$BFil_{out}$ [mg/L]	BSep Δ (%)	BFil Δ (%)	System Δ (%)
04/11/2008	718.1	169.8	19.4	76.4	88.6	97.3
04/20/2008	3742.4 (200.1)	90.3 (90.3)	15.0 (15.0)	97.6 (54.9)	83.4 (83.4)	99.6 (92.5)
04/26/2008	128.8	64.8	8.6	49.7	86.7	93.3
04/28/2008	47.3	19.8	5.7	58.1	71.2	87.9
05/31/2008	168.1	103.8	11.8	38.3	88.6	93.0
06/03/2008	184.6	97.5	6.2	47.2	93.6	96.6
06/04/2008	184.1	104.6	13.2	43.2	87.4	92.8
06/16/2008	27.8	37.9	8.3	-36.3	78.1	70.1
06/23/2008	47.4	50.1	12.8	-5.7	74.5	73.0
06/27/2008	224.7	137.7	18.2	38.7	86.8	91.9
07/09/2008	349.7	200.5	22.6	42.7	88.7	93.5
07/13/2008	100.3	40.3	16.7	59.8	58.6	83.3
07/23/2008	81.4	45.2	17.3	44.5	61.7	78.7
08/02/2008	412.0	173.8	19.7	57.8	88.7	95.2
08/14/2008	642.1	285.6	26.2	55.5	90.8	95.9
08/28/2008	149.2	73.0	11.4	51.7	84.4	92.4
10/25/2008	272.5	183.1	18.9	32.8	89.7	93.1
11/13/2008	25.0	34.8	11.3	-39.2	67.5	54.8
11/30/2008	18.9	n/a	2.4	n/a	n/a	87.3
12/11/2008	26.1	31.8	3.0	-21.8	90.6	88.5

$BSep_{in}$, $BSep_{out}$, $BFil_{out}$, BSep Δ, BFil Δ and overall Δ represent BaySeparator inlet, BaySeparator outlet, BayFilter outlet, BaySeparator removal, BayFilter removal and overall system removal, respectively. The values with underline are removals of the systems for any particles less than 250 microns.

n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-3 Summary of TSS removals for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ [mg/L]	$BSep_{out}$ [mg/L]	$BFil_{out}$ [mg/L]	BSep Δ (%)	BFil Δ (%)	System Δ (%)
04/11/2008	262.8	153.5	18.2	41.6	88.1	93.1
04/20/2008	294.3	92.2	18.6	68.7	79.8	93.7
04/26/2008	97.7	52.5	10.1	46.3	80.8	89.7
04/28/2008	48.5	21.6	7.3	55.5	66.2	84.9
05/31/2008	148.2	96.6	12.7	34.8	86.9	91.4
06/03/2008	48.2	74.1	6.2	-54.0	91.6	87.1
06/04/2008	122.8	90.3	13.3	26.4	85.2	89.1
06/16/2008	25.8	35.8	8.2	-38.9	77.2	68.3
06/23/2008	47.1	47.5	13.1	-0.8	72.4	72.2
06/27/2008	227.8	131.8	18.2	42.2	86.2	92.0
07/09/2008	260.7	247.5	23.1	5.0	90.7	91.2
07/13/2008	69.2	37.3	17.0	46.0	54.5	75.4
07/23/2008	76.6	44.2	17.0	42.4	61.5	77.8
08/02/2008	365.6	169.9	19.1	53.5	88.8	94.8
08/14/2008	519.1	275.1	27.3	47.0	90.1	94.7
08/28/2008	89.4	70.6	12.3	21.0	82.6	86.2
10/25/2008	209.9	178.4	19.0	15.0	89.3	90.9
11/13/2008	23.6	35.2	11.7	-49.1	66.8	50.5
11/30/2008	10.9	n/a	2.7	n/a	n/a	75.0
12/11/2008	23.8	40.0	2.9	-68.0	92.7	87.7

$BSep_{in}$, $BSep_{out}$, $BFil_{out}$, BSep Δ, BFil Δ and overall Δ represent BaySeparator inlet, BaySeparator outlet, BayFilter outlet, BaySeparator removal, BayFilter removal and overall system removal, respectively. The values with underline are removals of the systems for any particles less than 250 microns.

n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-4 Summary of TP removals for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	**$BSep_{in}$ [mg/L]**	**$BSep_{out}$ [mg/L]**	**$BFil_{out}$ [mg/L]**	**BSep Δ (%)**	**BFil Δ (%)**	**System Δ (%)**
04/11/2008	0.46	0.34	0.27	26.1	20.6	41.3
04/20/2008	0.28	0.28	0.10	0.0	64.3	64.3
04/26/2008	0.47	0.44	0.01	6.4	97.7	97.8
04/28/2008	0.16	0.08	0.04	50.0	50.0	75.0
05/31/2008	0.29	0.27	0.12	6.9	55.6	58.6
06/03/2008	0.41	0.35	0.26	14.6	25.7	36.6
06/04/2008	0.56	0.25	0.11	55.4	56.0	80.4
06/16/2008	0.16	0.18	0.07	-12.5	61.1	56.3
06/23/2008	0.30	0.23	0.11	23.3	52.2	63.3
06/27/2008	0.42	0.41	0.07	2.4	82.9	83.3
07/09/2008	0.45	0.46	0.14	-2.2	69.6	68.9
07/13/2008	0.49	0.18	0.06	63.3	66.7	87.8
07/23/2008	0.28	0.15	0.07	46.4	53.3	75.0
08/02/2008	1.35	0.63	0.13	53.3	79.4	90.4
08/14/2008	0.82	0.55	0.30	32.9	45.5	63.4
08/28/2008	0.29	0.36	0.17	-24.1	52.8	41.4
10/25/2008	0.34	0.35	0.21	-2.9	40	38.2
11/13/2008	0.15	0.22	0.16	-46.7	27.3	-6.7
11/30/2008	0.04	n/a	0.05	n/a	n/a	-25
12/11/2008	0.27	0.21	0.11	22.2	47.6	59.3

$BSep_{in}$, $BSep_{out}$, $BFil_{out}$, BSep Δ, BFil Δ and overall Δ represent BaySeparator inlet, BaySeparator outlet, BayFilter outlet, BaySeparator removal, BayFilter removal and overall system removal, respectively.
n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-5 Summary of turbidity removals for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ (NTU)	$BSep_{out}$ (NTU)	$BFil_{out}$ (NTU)	BSep Δ (%)	BFil Δ (%)	System Δ (%)
04/11/2008	44.3	43.6	13.3	1.6	69.5	70.0
04/20/2008	34.4	35.6	7.5	-3.5	78.9	78.2
04/26/2008	22.8	25.6	5.4	-12.3	78.9	76.3
04/28/2008	9.1	12.5	6.7	-37.4	46.4	26.4
05/31/2008	36.9	38.3	10.4	-3.8	72.8	71.8
06/03/2008	29.2	26.6	9	8.9	66.2	69.2
06/04/2008	69.8	62	9.4	11.2	84.8	86.5
06/16/2008	15.7	16.3	9.8	-3.8	39.9	37.6
06/23/2008	20.7	23.2	10.1	-12.1	56.5	51.2
06/27/2008	65.8	69.6	23.4	-5.8	66.4	64.4
07/09/2008	44	51.3	17.8	-16.6	65.3	59.5
07/13/2008	24.1	20.5	13.3	14.9	35.1	44.8
07/23/2008	29.3	28.3	19.2	3.4	32.2	34.5
08/02/2008	126	78	15.9	38.1	79.6	87.4
08/14/2008	162	100.7	28.2	37.8	72.0	82.6
08/28/2008	33.1	34.7	10.9	-4.8	68.6	67.1
10/25/2008	163.9	148.0	57.5	9.7	61.1	64.9
11/13/2008	13.3	17.3	12.3	30.1	28.9	7.5
11/30/2008	7.0	n/a	2.6	n/a	n/a	62.9
12/11/2008	18.1	19.3	6.9	-6.6	64.2	61.9

$BSep_{in}$, $BSep_{out}$, $BFil_{out}$, BSep Δ, BFil Δ and overall Δ represent BaySeparator inlet, BaySeparator outlet, BayFilter outlet, BaySeparator removal, BayFilter removal and overall system removal, respectively.
n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-6 Summary of SSC mass for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ (g)	$BSep_{out}$ (g)	$BFil_{out}$ (g)	Rainfall (in)	Flow (gallon)
04/11/2008	39506.43	9341.584	1067.295	0.29	14535
04/20/2008	43221.33	19504.68	3239.98	3.04	57067*
04/26/2008	15667.46	7882.386	1046.119	0.58	32138
04/28/2008	6898.193	2887.616	831.2833	0.63	38531
05/31/2008	10588.6	6538.35	743.2807	0.26	16642
06/03/2008	21253.4	11225.39	713.8195	0.55	30418
06/04/2008	25008.8	14209.24	1793.135	0.62	35890
06/16/2008	2616	3566.417	781.036	0.4	24861
06/23/2008	2246.8	2374.782	606.7308	0.24	12523
06/27/2008	37839.5	23188.69	3064.882	0.72	44491
07/09/2008	30816.96	17668.86	1991.602	0.44	23282
07/13/2008	19637.64	7890.297	3269.676	0.94	51728
07/23/2008	8553.105	4749.39	1817.798	0.46	27761
08/02/2008	24661.91	10403.49	1179.222	0.26	15815
08/14/2008	32900.56	14633.86	1342.462	0.28	13537
08/28/2008	58731.09	28735.72	4487.496	1.75	104000
10/25/2008	61917.76	41604.19	4294.479	1.16	60032
11/13/2008	3850.509	5359.908	1740.43	0.75	40692
11/30/2008	4537.753	N/A	576.2226	0.64	63433
12/11/2008	11486.63	13995.21	1320.303	1.57	116275
SUM	**461940.4**	**245760.1**	**35907.25**	15.6	823652

Note: * April 20 2008 event only caught 1/3 of the storm because of the shorter sampling pace. For other 19 events, sampling covered over 90% of the storm.

$BSep_{in}$, $BSep_{out}$ and $BFil_{out}$ represent BaySeparator inlet, BaySeparator outlet and BayFilter outlet, respectively.

n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-7 Summary of TSS mass for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ (g)	$BSep_{out}$ (g)	$BFil_{out}$ (g)	Rainfall (in)	Flow (gallon)
04/11/2008	14457.9	8444.8	1001.3	0.29	14535
04/20/2008	63568.4	19915.1	4017.6	3.04	57067*
04/26/2008	11884.5	6386.2	1228.6	0.58	32138
04/28/2008	7073.2	3150.1	1064.6	0.63	38531
05/31/2008	9335.1	6084.8	800.0	0.26	16642
06/03/2008	5543.9	8537.0	715.2	0.55	30418
06/04/2008	16675.7	12267.6	1813.4	0.62	35890
06/16/2008	2428.9	3372.7	768.8	0.4	24861
06/23/2008	2231.1	2249.8	620.9	0.24	12523
06/27/2008	38369.5	22189.5	3058.6	0.72	44491
07/09/2008	22971.7	21812.9	2031.7	0.44	23282
07/13/2008	13548.1	7312.3	3327.6	0.94	51728
07/23/2008	8052.5	4640.5	1787.5	0.46	27761
08/02/2008	21885.1	10167.7	1142.9	0.26	15815
08/14/2008	26596.7	14097.7	1400.1	0.28	13537
08/28/2008	35184.9	27809.1	4844.9	1.75	104000
10/25/2008	47689.5	40525.2	4328.1	1.16	60032
11/13/2008	3639.7	5425.1	1802.4	0.75	40692
11/30/2008	2627.0	n/a	656.5	0.64	63433
12/11/2008	10471.0	17590.0	1291.3	1.57	116275
SUM	**364234.6**	**241978.3**	**37701.9**	15.6	823652

Note: * April 20 2008 event only caught 1/3 of the storm because of the shorter sampling pace. For other 19 events, sampling covered over 90% of the storm.

$BSep_{in}$, $BSep_{out}$ and $BFil_{out}$ represent BaySeparator inlet, BaySeparator outlet and BayFilter outlet, respectively.

n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-8 Summary of TP mass for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ (g)	$BSep_{out}$ (g)	$BFil_{out}$ (g)	Rainfall (in)	Flow (gallon)
04/11/2008	25.31	18.71	14.85	0.29	14535
04/20/2008	60.48	60.48	21.60	3.04	57067*
04/26/2008	57.17	53.52	1.22	0.58	32138
04/28/2008	23.33	11.67	5.83	0.63	38531
05/31/2008	18.27	17.01	7.56	0.26	16642
06/03/2008	47.20	40.30	29.93	0.55	30418
06/04/2008	76.07	33.96	14.94	0.62	35890
06/16/2008	15.06	16.94	6.59	0.4	24861
06/23/2008	14.22	10.90	5.21	0.24	12523
06/27/2008	70.73	69.04	11.79	0.72	44491
07/09/2008	39.66	40.54	12.34	0.44	23282
07/13/2008	95.94	35.24	11.75	0.94	51728
07/23/2008	29.42	15.76	7.36	0.46	27761
08/02/2008	80.81	37.71	7.78	0.26	15815
08/14/2008	42.02	28.18	15.37	0.28	13537
08/28/2008	114.16	141.71	66.92	1.75	104000
10/25/2008	77.26	79.53	47.72	1.16	60032
11/13/2008	23.10	33.88	24.64	0.75	40692
11/30/2008	9.60	n/a	12.00	0.64	63433
12/11/2008	118.83	92.42	48.41	1.57	116275
SUM	**1038.62**	**837.50**	**373.82**	15.6	823652

Note: * April 20 2008 event only caught 1/3 of the storm because of the shorter sampling pace. For other 19 events, sampling covered over 90% of the storm.

$BSep_{in}$, $BSep_{out}$ and $BFil_{out}$ represent BaySeparator inlet, BaySeparator outlet and BayFilter outlet, respectively.

n/a: effluent sampler distributor jammed on November 30 2008 event

Table 6-9 Summary of Turbidity mass for 20 storm events treated by BaySeparator and BayFilter systems at Richard Montgomery High School in Rockville, MD

Event	$BSep_{in}$ (NTU)	$BSep_{out}$ (NTU)	$BFil_{out}$ (NTU)	Rainfall (in)	Flow (gallon)
04/11/2008	2437.2	2398.7	731.7	0.29	14535
04/20/2008	7430.4	7689.6	1620.0	3.04	57067*
04/26/2008	2773.4	3114.0	656.9	0.58	32138
04/28/2008	1327.1	1823.0	977.1	0.63	38531
05/31/2008	2324.3	2412.5	655.1	0.26	16642
06/03/2008	3361.9	3062.5	1036.2	0.55	30418
06/04/2008	9481.9	8422.3	1276.9	0.62	35890
06/16/2008	1477.4	1533.8	922.2	0.4	24861
06/23/2008	981.2	1099.7	478.7	0.24	12523
06/27/2008	11080.7	11720.6	3940.6	0.72	44491
07/09/2008	3877.5	4520.8	1568.6	0.44	23282
07/13/2008	4718.5	4013.7	2604.0	0.94	51728
07/23/2008	3078.7	2973.6	2017.4	0.46	27761
08/02/2008	7542.2	4669.0	951.8	0.26	15815
08/14/2008	8300.7	5159.8	1444.9	0.28	13537
08/28/2008	13029.5	13659.3	4290.7	1.75	104000
10/25/2008	37241.5	33628.7	13065.2	1.16	60032
11/13/2008	2048.5	2664.6	1894.5	0.75	40692
11/30/2008	1680.6	n/a	624.2	0.64	63433
12/11/2008	7965.8	8493.9	3036.7	1.57	116275
SUM	**132159.1**	**123060.1**	**43793.4**	15.6	823652

Note: * April 20 2008 event only caught 1/3 of the storm because of the shorter sampling pace. For other 19 events, sampling covered over 90% of the event.

$BSep_{in}$, $BSep_{out}$ and $BFil_{out}$ represent BaySeparator inlet, BaySeparator outlet and BayFilter outlet, respectively.

n/a: effluent sampler distributor jammed on November 30 2008 event

Particle Size Distribution

Particle size distribution analysis was conducted on samples collected from four events (April 11, 2008, April 20, 2008 and April 26-28, 2008 events). Figure 6-1 demonstrated the percentage finer by mass for the combined average of four events. In addition, the cumulative probability function of gamma distribution was modeled for BaySeparator influent, BaySeparator effluent and BayFilter effluent. In general, the models fit pretty well and the shape factor and scale factor of gamma model are summarized in Table 6-10. Additionally, results showed that the average d_{50} values are 62 μm, 48 μm and 19 μm for BaySeparator influent, BaySeparator effluent and BayFilter effluent, indicating the reduction of the sediment size by BaySeparator and BayFilter systems.

According to the soil texture triangle widely used by many agencies to categorize the PSD for stormwater sediments, the percentages of sand, silt and clay was developed based on the results as shown in Figure 6-1 and the values were summarized in Table 6-10. The texture plot in Figure 6-2 showed that the sediments in BaySeparator influent and effluent were all sandy loam although there was some reduction on coarser sand materials by BaySeparator. On the contrast, BayFilter effluent was a silt loam, which further demonstrated the BayFilter system was effective to remove the fine sediments and other pollutants (nutrients, metals etc.) bound to the sediments as well.

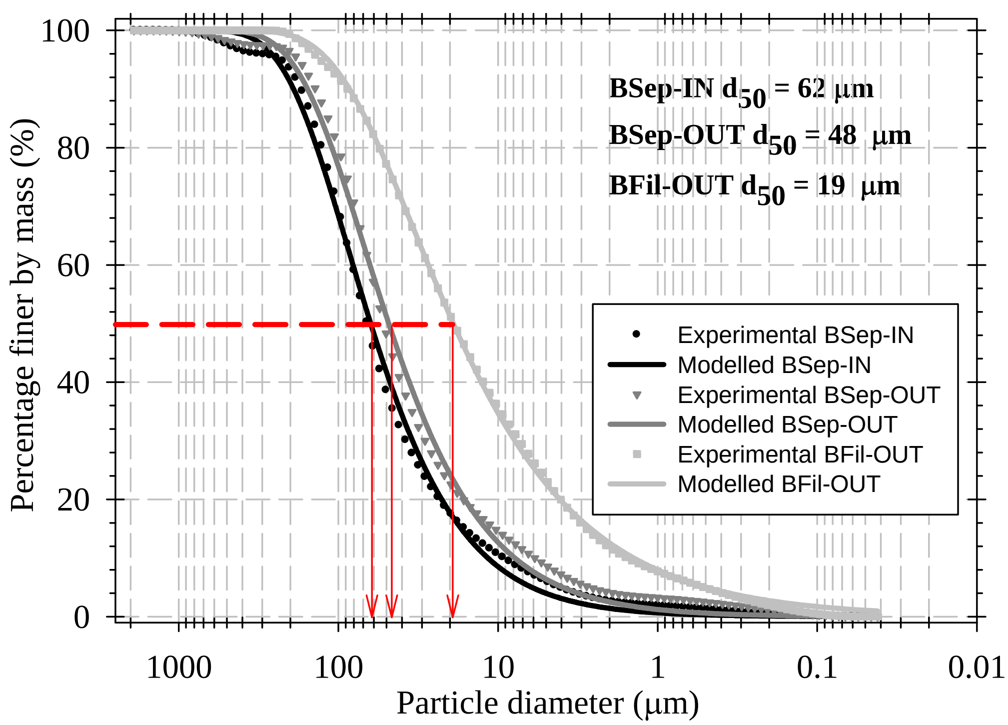

Figure 6-1 The average PSD and gamma models for BaySeparator influent, BaySeparator Effluent and BayFilter effluent

Table 6-10 Characteristics of PSD for BaySeparator influent, BaySeparator Effluent and BayFilter effluent

	BSep-IN	BSep-OUT	BFil-OUT
	Granulometry		
d_{10}	11 µm	8 µm	1.5 µm
d_{50}	62 µm	48 µm	19 µm
d_{90}	189 µm	154 µm	85 µm
	Gamma model parameter		
α	1.15	1.05	0.67
β	74.4	65.5	50.1
	Texture		
Sand (> 50 µm)	58.1 %	48.6 %	22.6 %
Silt (2-50 µm)	40.4 %	48.8 %	64.4 %
Clay (< 2 µm)	1.5 %	2.6 %	13.0 %
	Sandy loam	Sandy loam	Silt loam

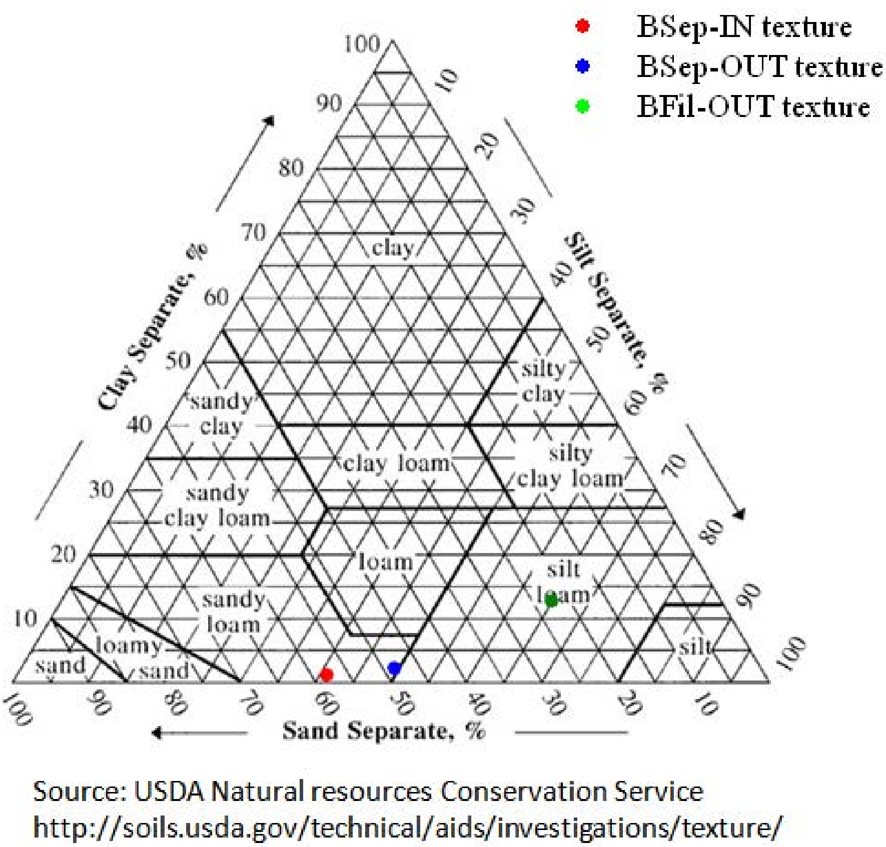

Figure 6-2 The PSD texture of BaySeparator influent, BaySeparator Effluent and BayFilter effluent

System removal efficiency

The storm water BMP efficiency can be evaluated in a number of ways. In accordance with the NJCAT TARP protocol and the Technical Memorandum on determining removal efficiencies for stormwater BMPs published by ASCE and EPA, the efficiency ratio method, the summation of load method (recommended by TARP) and regression of EMC method are presented as following to determine the removal rates of SSC, TSS, TP and turbidity by BaySeparator system, BayFilter system and the treatment train.

<u>*Efficiency ratio*</u>

The average inflow and outflow event mean concentration (EMC) values for each pollutant were used to calculate a BMP efficiency ratio (ER):

$$ER = 1 - \frac{average \cdot outlet \cdot EMC}{average \cdot inlet \cdot EMC}$$

The ER and average of EMCs were summarized in the following bar plots based on results summarized in Tables 6-2 through 6-5.

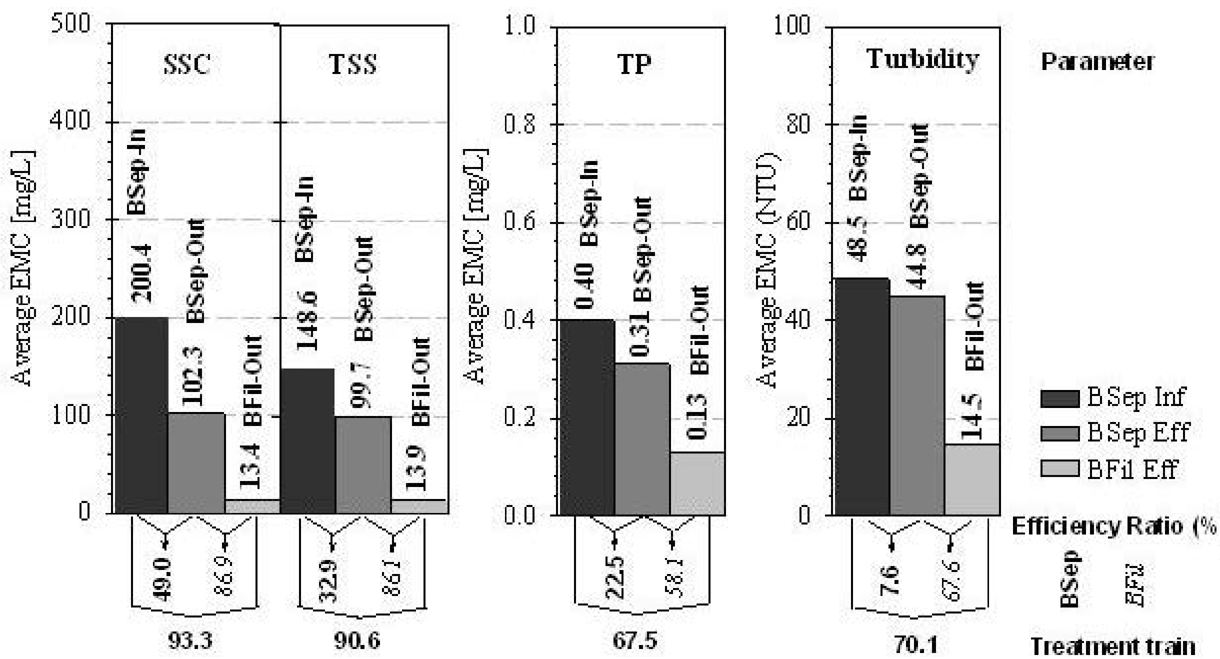

Figure 6- 3 The average EMCs and efficiency ratios (ER)

According to the ER values, SSC removal by the Separator system and the BayFilter system reached to 49.0% and 86.9%, respectively. TSS removal by the Separator system and the BayFilter system reached to 32.9% and 86.1%, respectively. The treatment train showed a 93.3% and 90.6% removal on SSC and TSS respectively. The removals of TP and turbidity are generally lower (22.5% and 7.6%), but the BayFilter system showed a 58.1% and 67.6% removals on TP and turbidity, respectively. The removals by treatment train are 67.5% and 70.1% for TP and turbidity, respectively.

Summation of loads

The summation of loads method defines the efficiency based on the ratio of the summation of all incoming loads to the summation of all outlet loads as shown in the formula below:

$$SOL = 1 - \frac{sum \cdot of \cdot outlet \cdot loads}{sum \cdot of \cdot inlet \cdot loads}$$

The summation of loads of SSC, TSS, TP and turbidity are summarized in Table 6-11:

	SSC	TSS	TP	Turbidity
Sum of Loads In	461940.4 g	364234.6 g	1038.6 g	132159.1 NTU
Sum of loads BSep Out	245760.1 g	241978.3 g	837.5 g	123060.1 NTU
Sum of Loads BFil Out	35907.3 g	37701.9 g	373.8 g	43793.4 NTU
BSep Efficiency	46.8 %	33.6 %	19.4 %	6.9 %
BFil Efficiency	85.4 %	84.4 %	55.4 %	64.4 %
Treatment train Efficiency	92.2 %	89.6 %	64.0 %	66.9 %

Table 6-11 showed that BaySeparator and BayFilter systems removed 92.2% of the incoming SSC for total 20 monitored events as a treatment train. The independent SSC removal efficiencies of the BaySeparator and BayFilter alone reached 46.8% and 85.4%, respectively. The independent TP removals of the BaySeparator system and BayFilter system were 19.4% and 55.4%, respectively. The TP removal by the treatment train reached 64.0% on average. In addition, The BaySeparator system and BayFilter system were found to be able to achieve an overall reduction of 6.9% and 64.4% of turbidity (NTU) reduction, respectively. Furthermore, the treatment train achieved 66.9% turbidity reduction.

Regression of EMCs

The regression of EMCs defines the regression efficiency as the slope (a) of a least squares linear regression of inlet EMCs and outlet EMCs of pollutants. Based on the EMCs summarized in Tables 6-2 through 6-5, the regression efficiencies were plot in Figures 6 -4 to 6-7.

It should ne noted that the regression statistics suggest the higher removal efficiencies compared to the removals calculated based on other methods. The SSC and TSS removals by Separator system only are 68.1 % and 51.8 %. The BayFilter system can remove 93.1 % of SSC and 93.3 % of TSS according to the regression line. In addition, BayFilter system showed a 76.1 % of TP reduction and 70 % of turbidity reduction. However, this method cannot be universally applied to monitoring data in the field since the assumptions of the method are very rarely valid. Therefore, it is not recommended by EPA according to EPA urban stormwater BMP performance monitoring annual.

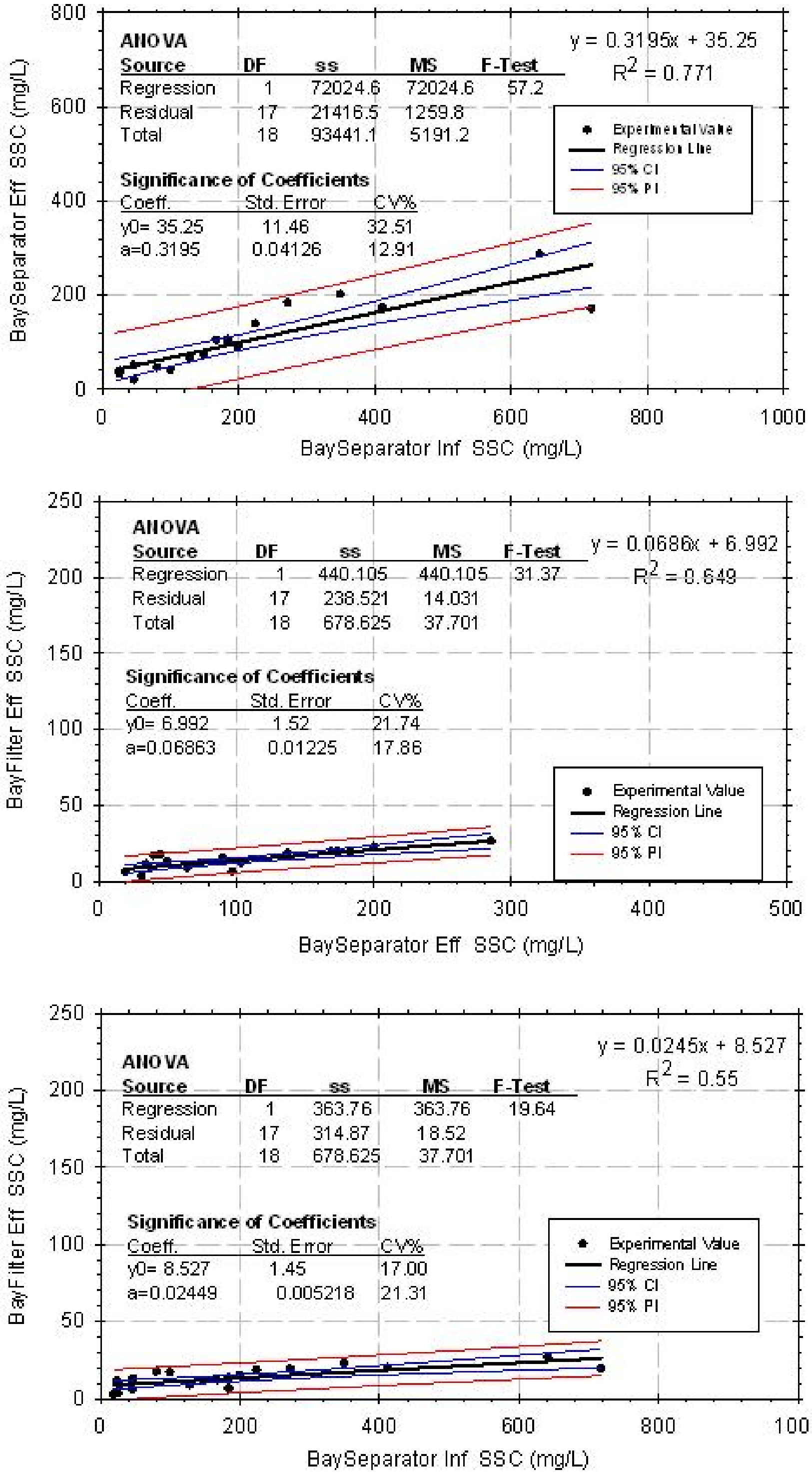

Figure 6-4 Regression of EMCs for efficiency evaluation of BaySeparator system, BayFilter system and treatment train on SSC removal

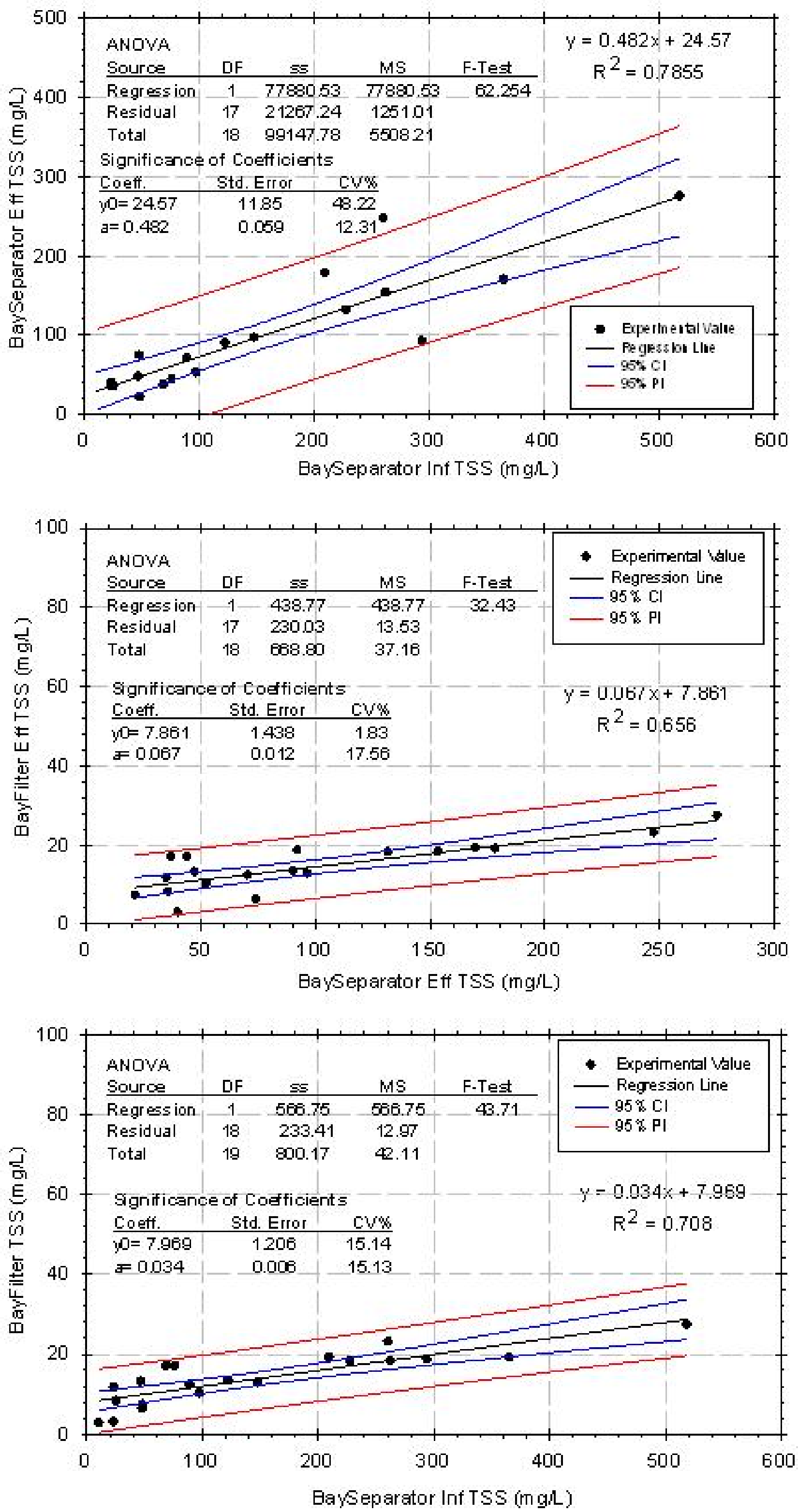

Figure 6-5 Regression of EMCs for efficiency evaluation of BaySeparator system, BayFilter system and treatment train on TSS removal

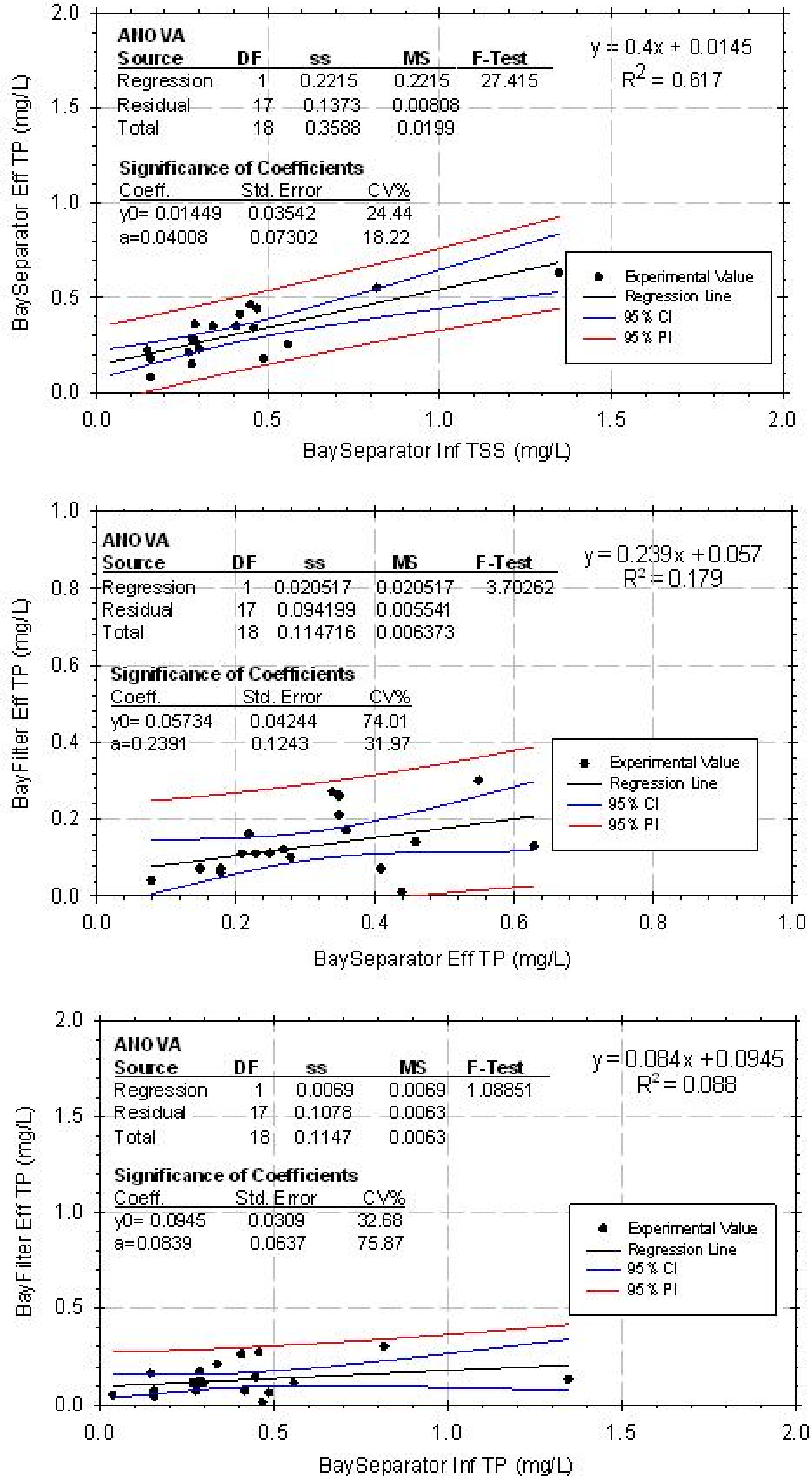

Figure 6-6 Regression of EMCs for efficiency evaluation of BaySeparator system, BayFilter system and treatment train on TP removal

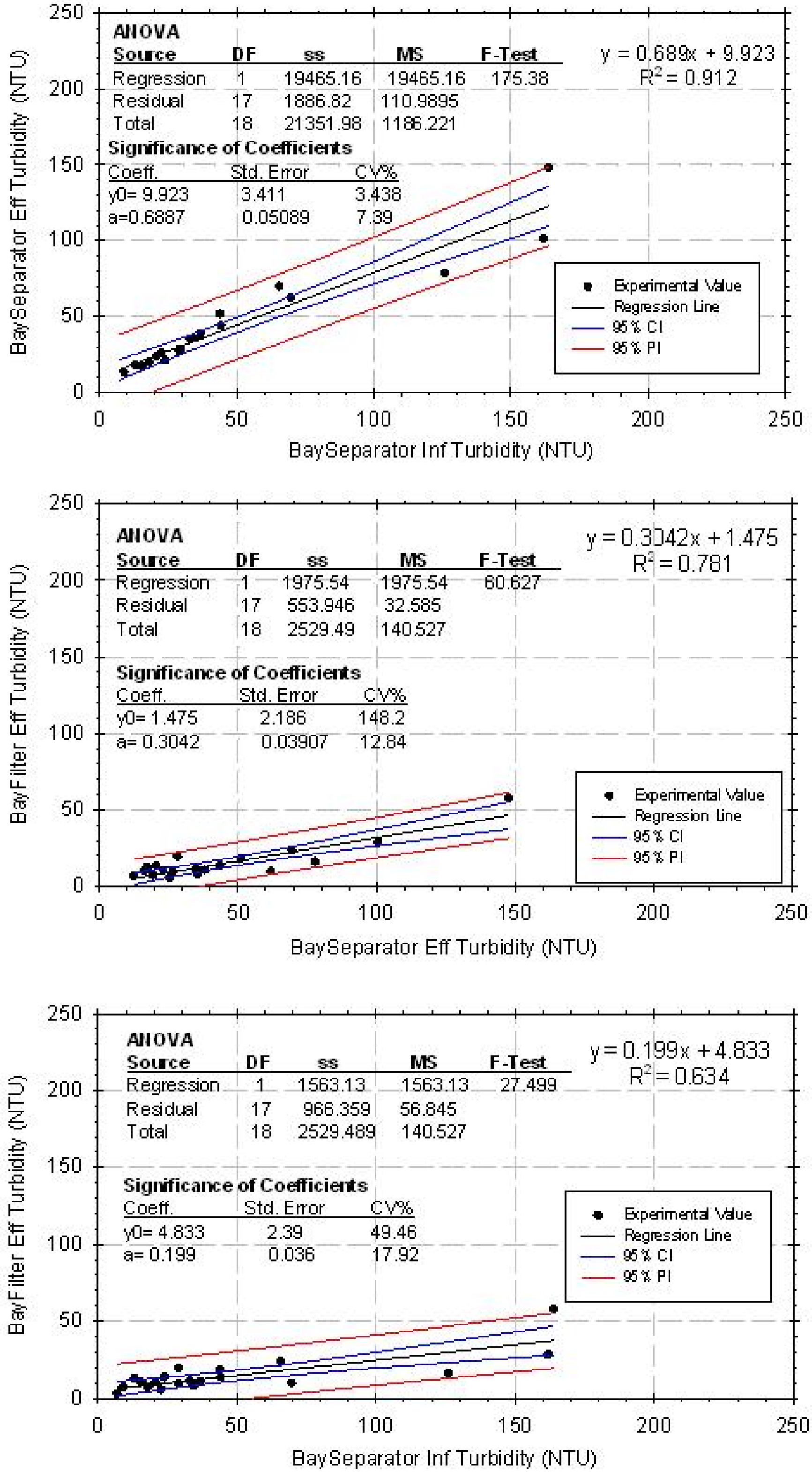

Figure 6-7 Regression of EMCs for efficiency evaluation of BaySeparator system, BayFilter system and treatment train on turbidity removal

Conclusion

The Richard Montgomery High School site field performance for SSC was compared to two nationally recognized certification protocol guidelines for manufactured stormwater treatment systems. Each program uses different approaches for SSC removal requirements. The Technology Acceptance and Reciprocity Partnership (TARP), an eight state consortium administered by the New Jersey Department of Environmental Protection (NJDEP), requires that a filtration system should achieve 80 percent removal regardless of influent concentration and that designated field testing use a site exhibiting 100 to 300 ppm SSC with median particle sizes of less than 100 microns in diameter. The Richard Montgomery High School site meets the SSC removal and particle size requirement; however, the Richard Montgomery High School site had SSC influent concentrations in the 1000's mg/L and SSC dropped to 220.1 mg/L without considering the particles above 250 microns in April 20, 2008 event. The BayFilter system was proved to be able to remove 85.4% of SSC, 84.4% of TSS and 55.4% TP and the removal efficiencies increased to 92.2%, 89.6% and 64.0% for combined BaySeparator and BayFilter system in terms of SSC, TSS and TP, respectively. So the BayFilter system and treatment train meet the 80% TARP SSC removal criteria for manufactured systems. The other protocol program is the Technology Assessment Protocol-Ecology (TAPE) developed by the Washington State Department of Ecology. The TAPE protocol specifies 80 percent SSC removal if influent concentrations exceed 100 ppm (TAPE 2004). If influent concentrations are less than 100 ppm then the target effluent concentration is 20 ppm. The TAPE criteria are independent of particle size. Seven out of the twenty events monitored had the SSC/TSS influent values below 100 ppm but all seven events had the BayFilter effluent SSC below 20 ppm, thus the BaySeparator and BayFilter system meets TAPE criteria for a manufactured system.