Technical Evaluation Report

BaySeparator™ System

Woodinville Sammamish River Outfall, Woodinville, Washington

Prepared by

Bo Liu, P.E., Ph. D.
BaySaver Technologies, LLC
1207 Park Ridge Drive
Mount Airy, Maryland

November 1, 2017

Revised: December 19, 2017
Revised: August 29, 2018

Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BaySaver	BaySaver Technologies, LLC
BMP	Best Management Practice
CAS	Columbia Analytical Services, Inc
cfs	Cubic Feet per Second
CULD	Conditional Use Level Designation
d_{10}	Diameter of Particles that Comprise 10 Percent or Less of the Mass
d_{50}	Diameter of Particles that Comprise 50 Percent or Less of the Mass
d_{90}	Diameter of Particles that Comprise 90 Percent or Less of the Mass
DOE	Department of Ecology
gpm	Gallons per Minute
GULD	General Use Level Designation
HDPE	High Density Polyethylene
in/hr	Inches per Hour
Isco	Teledyne Isco

MASWRC	Mid-Atlantic Stormwater Research Center
ug/L	Micrograms per Liter
mg/L	Milligrams per Liter
mL	Milliliter
MTR	Maximum Treatment Rate
ND	Non-Detect
%	Percent
PSD	Particle Size Distribution
PULD	Pilot Use Level Designation
PVC	Poly Vinyl Chloride
QAPP	Quality Assurance Project Plan
QA/QAC	Quality Assurance/Quality Control
site	BayFilter™ System Drainage Area
SSC	Suspended Sediment Concentration
TAPE	Technology Assessment Protocol – Ecology
TARP	New Jersey Department of Environmental Protection Technology Assessment and Reciprocity Program
TER	Technical Evaluation Report
TP	Total Phosphorus
TSS	Total Suspended Solids
WC-RMD	West Consultants River Measurement Division

1.0 Introduction

BaySaver Technologies, LLC, is seeking approval from the State of Washington Department of Ecology (WADOE) for the BaySeparator™ system for use as a storm water treatment device. A field monitoring program was conducted from November, 2013 to January, 2017 at Woodinville Sammamish River Outfall in Woodinville, Washington to assess the compliance of the separator with DOE Technology Assessment Protocol – Ecology (TAPE) requirements on pretreatment Total Suspended Solids (TSS) removal. Site precipitation, flow rate, and influent and effluent data from the system were collected over a series of twelve qualifying rainfall events. This report contains these data and an evaluation of BaySaver's treatment performance claims.

Since 1997, BaySaver has been protecting lakes, streams, and waterways from the harmful effects of polluted stormwater. One of BaySaver's most innovative products to control non-point source pollution has been the BaySeparator™ system. Since its creation, the BaySeparator™ has been installed on over 5,000 locations in commercial, industrial, and residential applications worldwide, and has been used in various projects such as parking lots, gas stations, service stations, maintenance facilities, and highways. This separator has also been used as pretreatment for many types of stormwater technologies such as filters, ponds, infiltration systems, etc.

This Technical Evaluation Report (TER) is a comprehensive compilation and evaluation of monitoring and analytical data collected from a field monitoring program in Woodinville, Washington. It includes data summaries from each individual rainfall event, a statistical evaluation of the collected data (bootstrap method with 95% confidence interval), a detailed discussion of the analytical and field monitoring results, and conclusions regarding the removal capabilities of the BaySeparator™ system. These field monitoring activities were conducted under the guidelines set by the Woodinville Sammamish QAPP, which was submitted to the WADOE on September 28, 2013 and revised February, 20 2014 (**Appendix A**).

During this field testing program, twelve qualified rainfall events were monitored and sampled. The test equipment was installed by BaySaver and all sampling and analysis was performed by an independent third party in accordance with the QAPP. Based on the analytical results reported, the BaySeparator™ exceeded the requirements for a GULD in pretreatment TSS removal. For all twelve qualified events, the lower one-sided 95% confidence interval around the removal rate is 55.9%. For the qualified events with influent concentrations between 50-100 mg/L, the upper one-sided 95% confidence interval around the effluent concentration is 33.3 mg/L. The BaySeparator achieved, on average, a 56.4% removal rate (influent TSS >100 mg/L) and 24.9 mg/L average effluent TSS concentration (influent TSS between 50 and 100 mg/L). The overall average removal efficiency for all twelve qualified events was 62.7%.

In light of these findings, it is recommended that the WADOE grant the BaySeparator™ system a General Use Level Designation (GULD) approval for pretreatment TSS removal.

2.0 Roles

BaySaver LLC and the Mid-Atlantic Storm Water Research Center (MASWRC) managed the field monitoring activities. Collection of influent and effluent stormwater samples, rainfall data, and flow data was conducted by field personnel from Terracon, located in Mountlake Terrace, WA. Influent and effluent stormwater samples were submitted by Terracon to the ALS Life Science Division and analyzed at the ALS Laboratory in Everett, WA.

3.0 Site Description

Field testing occurred at the Woodinville Sammamish test site located near the intersection of NE 175th Street and 131st Ave NE in Woodinville, Washington. The treatment area spans 52 acres, 49 of which are occupied by completely constructed office, commercial, and transportation facilities. The remaining three acres are covered by ground vegetation. **Appendix C** shows the project site and the three major drainage basins (A, B, and C). The region highlighted in red was identified by the city as a 100% infiltration area, and is labeled as such.

Soil boring data provided by Perteet, Inc. from January 2009 indicated that the groundwater level is approximately 21 feet above sea level (**Appendix C**). The Sammamish River high water mark at the project location is at 21.4 ft. The available maximum drop (head drop) between the inlet of the new facility and the discharge point (elevation 21.75 ft) is approximately 2.6 ft. The NRCS Soil Survey maps revealed that the underlying soil is in hydrologic soil group A, which has a high infiltration capacity.

Stormwater runoff from the Woodinville site is directed into a 5K BaySeparator™ unit via high density polyethylene (HDPE) corrugated stormwater inlet pipe. After passing through the separator, effluent flow is diverted to the BayFilter™ EMC system where it is treated and released to an outlet structure through a single HDPE pipe. High flows bypass the BayFilter™ system to prevent sediment re-suspension and are conveyed through the BaySeparator™ to a manhole downstream. A set of site plans is included in **Appendix C** and details regarding the BaySeparator™ and BayFilter EMC systems installation can be found in **Figure 7**.

4.0 BaySeparator™ Treatment Technology

The BaySeparator™ relies on two historically successful mechanisms to remove pollutants from influent stormwater: sedimentation and flotation. Sedimentation is gravity-driven, and relies on the density difference between solid particles and the surrounding water. Particles, depending on their specific gravity, size, and the amount of time, settle to the bottom of the separator unit and accumulate on the floor. Flotation works by a similar principle but in reverse: Free oils and debris rise to the surface and are trapped in the storage manhole until maintenance is performed.

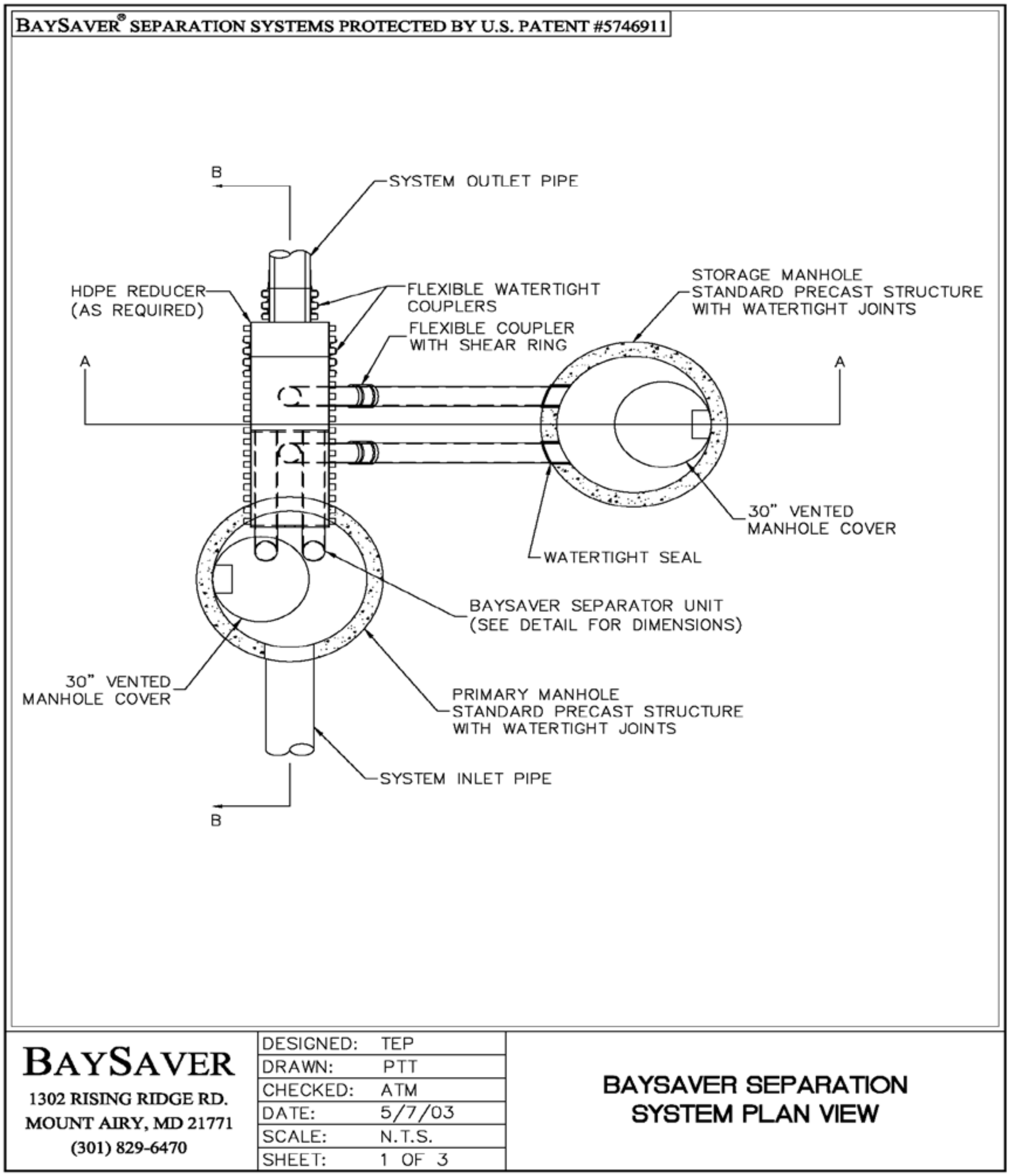

Figure 1 Simple Schematic of a BaySeparator™ System

4.1 BaySeparator™ Treatment System

Runoff from the Woodinville Sammamish site is conveyed into a 5K BaySeparator™ unit via one 48" diameter Corrugated Polyethylene Stormwater inlet pipe. Low effluent flows from the separator are diverted into the BayFilter EMC system via one 18" diameter High-Density Polyethylene (HDPE) inlet pipe, while high-flow bypass is conveyed into a 4' manhole downstream. Plan view and profile view illustrations of the BaySeparator™ are provided in **Figures 5** and **6**.

4.1A BaySeparator™ Component Construction Materials

The BaySeparator™ unit is made entirely of high-density polyethylene (HDPE) infused with UV-resistant carbon-black. HDPE is non-brittle, chemically inert, and corrosion-resistant, and is commonly used in landfills, chemical plants, and storm drains worldwide. The separator is connected to the two manholes using flexible pipe-to-manhole connectors (i.e., rubber boots) installed by the precast manufacturer. Because these connections are submerged during normal operation, they must be watertight. The connector pipes are joined to the BaySeparator™ using Fernco seals with shear rings for additional structural strength and rigidity. The separator unit is joined to the system outfall pipe with a reducer/adaptor provided by BaySaver Technologies.

The primary and storage manholes are standard precast structures that can be purchased from local concrete distributers. The primary manhole is used to remove coarse sediments, and is generally installed in line with the storm drain. It can be used as a multiple inlet structure. The precast manholes are purchased from local concrete distributors. The storage manhole acts as a secondary treatment device for the collection and offline storage of oils, fine sediments and floatables. It is also a standard precast manhole that is purchased locally. The storage manhole is a key component that sets the BaySeparator™ system apart from other systems: storing the pollutants offline prevents re-suspension during high flows.

4.1B BaySeparator™ Component Dimensions

The BaySeparator™ 5K model that was installed at the Woodinville Sammamish site has a nominal diameter of 48", a maximum treatment rate (MTR) of 11.1 cfs and a maximum hydraulic rate (MHR) of 50 cfs. The manhole diameter (length of flow-based system) is 72" and the manhole sump depth is 8'from the invert.

4.1C BaySeparator™ Component Capacity

The BaySeparator™ system can function with approximately 4 feet of sediment buildup in each manhole, although maintenance is recommended after 2 feet of sediment accumulation. The system must be maintained if the solids are within 1 foot of the bottom of the vertical pipes in the primary manhole or the pipes entering or exiting the storage manhole, if there is more than 2 feet of floating trash and debris, or if there is more than 12 inches of free oil floating on the surface. The BaySeparator™ System Technical and Design Manual (**Appendix E**) contains detailed sizing information and design details.

4.1D BaySeparator™ Treatment Functions

As water enters the BaySeparator™ system's primary manhole, coarse sediments (e.g., gravel and sand) quickly fall to the floor. The influent water, carrying floatables and finer sediments, flows through the separator and into the storage manhole. When water enters the storage manhole from the submerged inlet pipe, oils and other floatables rise to the top, while fine sediments settle to the floor. The influent water displaces clean water from the center of the column, which is forced back up the return pipe to the system outfall. In this way, all of the water that reaches the system outfall has been treated in both the primary and storage manholes.

During larger storms with high influent flow rates, the BaySeparator™ continues to divert surface flows (which contain the majority of suspended sediments, oils, and floatables) from the primary manhole to the storage manhole. Excess flows associated with the larger storm are treated by separation in the primary manhole. Additionally, an internal bypass plate directs bypass flow directly through the unit.

The BaySeparator™ system uses the weir plate to limit flows into the storage manhole, which minimizes the risk high flows disturbing sediment and other debris. Offline storage by the BaySeparator™ hydraulically isolates the contaminants from high-energy influent flows, effectively eliminating the risk of re-suspension.

4.2 BaySeparator™ Pretreatment Requirements

The BaySeparator™ is often used as a pretreatment device, and since its design accommodates a wide range of flow rates including peak flows in excess of 50 cfs, it can also act as a flow-splitting structure and requires no pretreatment.

4.3 BaySeparator™ Installation Requirements

The BaySeparator™ is installed as part of the storm drain. To begin, grout the BaySeparator™ unit and the system inlet pipe into the primary manhole. Alternatively, use a watertight seal where local regulations specify. The parallel pipes entering and leaving the storage manhole require watertight connections – these are made by using standard boots or other seals. Flexible watertight couplers join BaySeparator™ to the parallel inlet and outlet pipes from the storage manhole. These flexible seals prevent system failure in the event of differential settling between the two concrete structures. Cover the pipes with gravel or any type of flowable fill.

4.4 BaySeparator™ Sizing Methodology

The BaySeparator™ can be sized following different criteria. Flow-based sizing applies when there is an established minimum treatment rate requirement the separator has to treat together with the maximum hydraulic rate (MHR) associated with a peak design storm. In some cases, a treatment volume is given which then needs to be converted to a flow using approved methods. Annual aggregate removal (AAR) bases sizing of hydrodynamic separators upon a given suspended solids removal performance.

To determine the size of the BaySeparator to be installed, three factors must be considered:

1. The anticipated maximum flow rate of the site
2. The anticipated sediment load of the site
3. Specific sizing requirements of the jurisdiction (ex: water quality volume)

Each of the above factors, when evaluated, will determine the size of BaySeparator required to address each design parameter. Calculations for all three factors need to be done to determine which design factor is limiting.

When sizing in Western Washington, the Western Washington Hydrology Model (WWHM) is used. The WWHM sizes a BMP based on the water quality volume or the flow rate. We will utilize the WWHM software to calculate sizing for different sites based on the drainage area, soil characteristics, vegetation cover and local rainfall patterns. Stormwater treatment systems installed downstream of the detention system, will be sized to handle full 2-year release rates. Runoff from the stormwater technology will be compared with pre-development to comply with the Ecology standard.

When sizing in Eastern Washington, we will utilize the methods outlined in the "Stormwater Management Manual for Eastern Washington". According to this document, each treatment BMP will be sized based on a water quality design volume or water quality design flow rate. Specific jurisdictions will adopt criteria for sizing. For water quality design flow rates, the design will depend on whether the stormwater treatment is located downstream or upstream of the detention system. For regions 1 and 4, the runoff flow rate will be predicted for the proposed development condition from the short duration storm with at 6-month return frequency. For regions 2 and 3, the runoff flow rate will be predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency.

4.5 BaySeparator™ Expected Treatment Capabilities

The BaySeparator™ stormwater treatment unit shall be sized to remove between 50% and 80% of the suspended solids on an annual aggregate removal basis, depending on local requirements and such things as particle size and pollution loading into the device.

4.6 BaySeparator^{TM} Maintenance Procedures

The system was maintained at the start of testing. The system remains functioning to date with no maintenance having been required or performed during testing or after the completion of testing.

4.6A BaySeparator^{TM} Maintenance Inspections

Like any other structural stormwater BMP, the BaySeparator^{TM} system requires routine maintenance to operate at its design capability. Inspection is the key to effective maintenance, and it particularly useful to keep a record of each inspection. It should be noted that sediment accumulation may be especially variable during the first year after installation as construction disturbances and landscaping stabilize.

During inspections, the depth of solids in the primary manhole, the depth of solids in the storage manhole, and the amount of trash and oil floating in the storage manhole should be noted.

4.6B BaySeparator^{TM} Maintenance Operations

Maintenance of the BaySeparator^{TM} system is recommended when inspection reveals that 2 feet (0.6 meters) of sediment has accumulated on the bottom of either manhole, although the system can function with approximately 4 feet of sediment buildup in each manhole. This determination of sediment depth can be made by lowering a pole into the manhole until it hits the sediment and measuring the distance.

5.0 Sampling Procedures

All samples taken over the course of this study were collected by Terracon and sent to ALS Life Sciences Division (ALS) for analysis.

Stormwater influent and effluent samples for water quality analysis were collected during the qualifying rainfall events by field personnel from Terracon/West Consultants River Measurement Division (WC-RMD). Water quality samples were submitted to the ALS/Columbia Analytical Services, Inc. (CAS) Laboratory for analysis. The collection procedures, sampling equipment, analytical methods, quality control and quality analysis, and statistical goals used as part of the field monitoring program are described below.

5.1 Sample Collection Procedure

Influent and effluent water quality samples were collected by two ISCO auto-samplers. The samplers collected flow-paced samples by withdrawing approximately 230 milliliters (mL) per aliquot for a pre-programmed volume. The volume of pacing was predetermined based upon the expected total volume of the rainfall event. Each 1000 mL sample bottle contained a composite 4 aliquots for a total of around 920 mL. A minimum of 10 aliquots were collected and submitted to ALS/CAS from each rainfall event.

The sample bottles were collected by Terracon/WC-RMD (field personnel wore nitrile or latex disposable gloves to prevent the introduction of outside contamination or cross contamination) within 24 hours of the end of the rainfall event. In some instances, such as in the case of weekend storm events, sample bottles were collected within 48 hours. The sample bottles were placed on ice in a cooler kept below 4 degrees Celsius and were transported to the ALS/CAS Laboratory under a chain of custody for analysis of the selected water quality parameters.

In accordance with protocol, ALS/CAS sub-sampled the influent and effluent composite samples immediately after compositing for each of the selected individual water quality constituents. Preservation methods for sub-samples depended on the type of testing they were selected to undergo, but were enacted according to protocol. ALS/CAS also prepared duplicate water quality samples by sub-sampling the influent and effluent composite samples.

The sample bottles from each rainfall event were collected by Terracon/WC-RMD and brought to ALS/CAS. Old sample bottles were replaced and cleaned according to ALS/CAS protocol after each rain event.

5.2 Sampling Equipment

The site was equipped with a RainWise® rain gauge (RAINEW 111) and HOBO® data logger. The rain gauge collected and recorded precipitation data in 0.01-inch increments using the tipping bucket method. The data was downloaded from each device by Terracon/WC-RMD after each rainfall event.

The flow-paced water quality samples were collected using four Teledyne Isco (Isco) auto-samplers (Isco 6712) that were connected to Isco 750 flow modules. The auto-samplers and flow meters were mounted with L-brackets inside the influent manhole. The influent flow meter sensor and influent sampling tubing were located in the inlet pipe to the influent manhole. This flow meter sensor controlled the flow-paced sampling by the influent auto-sampler.

The influent and effluent stormwater samples were collected using a 3/8-inch diameter Teflon tubing suction line, which was positioned approximately 0.5 inches off the bottom of the pipe (invert). The auto-samplers were programmed to purge and rinse the suction line between samples, reducing the potential for cross contamination between aliquot collections. Terracon/WC-RMD personnel downloaded flow and sampling data after each rainfall event.

Terracon/WC-RMD calibrated the flow meters and auto-samplers prior to installation. There was no set schedule to replace flow meters and check calibration, but program settings were visually inspected after each rainfall event, even in the case of unqualified storms. The deep cycle marine batteries used to power the monitoring and sampling instruments were checked and replaced regularly.

A schematic showing the treatment system and monitoring equipment locations is detailed in **Figure 7**. A plan view and profile view of the sampling system are illustrated in **Figure 8** and **9,** respectively.

A cellular sampler controller system developed by Micro Systems Engineering, LLC, provided remote control and status monitoring capability for Teledyne ISCO 6712 series samplers. The system consisted of a single programmable GSM cellular base unit and 1 wireless remote unit for each sampler. The base unit provided both the cellular network connection and a local wireless link to each sampler. The base unit allowed authenticated users to initiate programs and retrieve data and status from each sampler via simple SMS text messages. A reply SMS message was sent with either the requested data or command execution status.

The effluent flow meter sensor and effluent sampling tubing were located inside the 18" HDPE pipe which flowed to the filter vault in the downstream manhole.

5.3 Analytical Methods

The ALS laboratory in Everett, Washington is a Washington DOE-certified laboratory for drinking water, wastewater water, and solid/hazardous waste analyses. Water quality samples were submitted to ALS for analysis. Reporting limits and other details are listed in **Table 1**.

Table 1 - Constituents, Analytical Methods, and Method Reporting Limits
Woodinville, Washington

Constituents	Analytical Method	Unit	Method Reporting Limit
TPH-Diesel Range	NWTPH-DX	ug/L	130
TPH-Oil Range	NWTPH-DX	ug/L	250
Total Suspended Solids	SM2540D	mg/L	5.0
pH	SM4500H	S.U.	1.00
Orthophosphate as P	EPA-300.0	mg/L	0.10
Copper	EPA-200.8	ug/L	2.0
Hardness	EPA-200.8	mg/L	1.0
Zinc	EPA-200.8	ug/L	2.5
Copper (Dissolved)	EPA-200.8	ug/L	2.0
Zinc (Dissolved)	EPA-200.8	ug/L	2.5
Ammonia as N	EPA-350.1	mg/L	0.05
Total Kjedahl Nitrogen (TKN)	EPA-351.1	mg/L	0.40

Total Phosphorus	EPA-365.1	mg/L	0.010
Nitrate/Nitrite as N	EPA-353.2	mg/L	0.050
Suspended Sediment Concentration	ASTM D3977-97	mg/L	1.0
Total Nitrogen	351.4/350.1	mg/L	0.10

5.4 Quality Assurance/Quality Control

The QAPP (**Appendix A**) was developed by BaySaver to provide guidance to Terracon/WC-RMD field personnel when conducting the field testing of the BaySeparator™ system. The QAPP was site-specific and was meant to ensure that sampling and analysis of field data was done safely and accurately. In accordance with the QAPP, Terracon/WC-RMD conducted quality assurance/quality control (QA/QC) on the water quality samples throughout the duration of the field testing program. Specific QA/QC measures are described in detail below.

5.4A Equipment Field Blanks

Equipment field blanks (termed "field blanks" in the QAPP) were used to evaluate whether contamination was introduced during field sampling activities. Three rounds of field blanks were conducted throughout the testing period (10/31/13, 7/15/14, and 9/18/15). Reagent-grade water was pumped through the influent and effluent auto-samplers at all four sampling locations to mimic an event without introducing TSS. Samples were taken, handled, and transported according to protocol for storm water samples. If the results of the field blanks showed TSS concentrations above the method-reporting limit, introduction of sediment from the auto-samplers would be the likely cause, as reagent-grade water contains no suspended solids.

The ALS/CAS Laboratory determined a method-reporting limit for each constituent, above which it can be routinely detected. There are often minor variations in precision, sensitivity, accuracy, and variability in instruments and among multiple instruments that are used for analysis. When the ALS/CAS Laboratory did not detect a constituent concentration greater than their method-reporting limit, a value of non-detect (ND) was recorded.

Results of the field blanks can be found in **Tables 2**, **3**, and **4** with lab reports in **Appendix K**. Field blanks showed trace amounts of metals in the reagent water, resulting in concentrations above the method-reporting limit. These trace amounts are not expected to affect the associated stormwater samples.

Table 2 – Field Blank Analytical Results (October 31, 2013)

Constituents	Unit	Method Reporting Limit	Sep-IN	Sep-OUT	Bypass
TPH-Diesel Range	ug/L	130	ND	ND	ND
TPH-Oil Range	ug/L	250	ND	ND	ND
Total Suspended Solids	mg/L	5	ND	ND	ND
pH	S.U.	1	4.42	4.92	4.29
Orthophosphate as P	mg/L	0.29	ND	ND	ND
Copper	ug/L	2	12	8.9	2.9
Hardness	mg/L	1	ND	2.9	1.1
Zinc	ug/L	2.5	ND	2.8	ND
Copper (Dissolved)	ug/L	2	12	8.5	3
Zinc (Dissolved)	ug/L	2.5	ND	2.7	ND
Total Phosphorus	mg/L	0.01	ND	ND	ND
Suspended Sediment Concentration	mg/L	1	ND	ND	ND

Table 3 – Field Blank Analytical Results (July 15, 2014)

Constituents	Unit	Method Reporting Limit	Sep-IN	Sep-OUT	Bypass
TPH-Diesel Range	ug/L	130	ND	ND	ND
TPH-Oil Range	ug/L	250	ND	ND	ND
Total Suspended Solids	mg/L	5	ND	ND	ND
pH	S.U.	1	5.6	5.65	5.79
Orthophosphate as P	mg/L	0.1	ND	ND	ND
Copper	ug/L	2	ND	ND	ND
Hardness	mg/L	1	ND	ND	ND
Zinc	ug/L	2.5	4	4.2	12
Copper (Dissolved)	ug/L	2	ND	ND	ND
Zinc (Dissolved)	ug/L	2.5	5	3.5	9.9
Total Phosphorus	mg/L	0.01	ND	ND	ND
Suspended Sediment Concentration	mg/L	1	ND	ND	ND

Table 4 – Field Blank Analytical Results (September 18, 2015)

Constituents	Unit	Method Reporting Limit	Sep-IN	Sep-OUT	Bypass
TPH-Diesel Range	ug/L	130	ND	ND	ND
TPH-Oil Range	ug/L	250	ND	ND	ND
Total Suspended Solids	mg/L	5	ND	ND	ND
pH	S.U.	0.01	5.95	6.17	6.10
Orthophosphate as P	mg/L	0.1	ND	ND	ND
Copper	ug/L	2	ND	ND	ND
Hardness	mg/L	1	ND	ND	ND
Zinc	ug/L	5	ND	ND	ND
Copper (Dissolved)	ug/L	2	ND	ND	ND
Zinc (Dissolved)	ug/L	5	ND	ND	ND
Total Phosphorus	mg/L	0.01	ND	ND	ND
Suspended Sediment Concentration	mg/L	1	ND	ND	ND

5.4B Duplicate Samples

Influent and effluent water quality samples were collected on a flow-paced basis and composited by the CAS/ALS Laboratory. CAS/ALS sub-sampled the influent and effluent composite containers for specific constituents. At the same time, CAS/ALS collected laboratory duplicate samples and analyzed them along with the original composite samples. The duplicate samples' and composite samples' analytical results were compared to detect variations in the compositing process and subsequent sub-sampling procedures. Laboratory duplicate samples were collected for some of the composite samples submitted by Terracon/WC-RMD. However, all batches of samples being analyzed, including these monitoring samples, had a laboratory duplicate analyzed and reviewed for relative percent difference (RPD) with the original sample. Even if the original and duplicate samples were not one of the influent or effluent samples submitted, the batch they were being analyzed in was subject to the analytical laboratory's QA/QC program. More details are provided in **Appendix F.**

5.4C Laboratory QA/QC

The CAS/ALS Laboratory is an EPA certified analytical laboratory. As such, it is required to maintain its own QA/QC procedures. These include checking for analytical anomalies and conducting data validation. Method blanks, laboratory control samples (LCS), and matrix spike samples and duplicates (MS/MSD) were prepared and analyzed as part of each analytical batch of water quality samples. The analytical laboratory provided BaySaver with Tier III analytical reports (**Appendix F**). These reports included all the raw data, quality control results, and water quality samples' analytical results.

5.5 Removal Rate Calculations

The removal efficiency calculations are based on the event mean concentration (EMC) and TSS values which are derived from the flow-weighted composite samples. Removal efficiency was calculated for each qualifying event using equation 7-1. A bootstrap statistical analysis was performed on the complete data set to determine overall average removal efficiency at the lower 95% confidence level.

$$E = 100\left(1 - \frac{EMC_{Effluent}}{EMC_{Influent}}\right)$$

Individual storm reduction in pollutant concentration was calculated as:

$$E = \left(-\frac{100[A - B]}{A}\right)$$

Where:

A = flow proportional influent concentration

B = flow proportional effluent concentration

6.0 Qualified Events

Overall, TAPE requires at least 12 qualified rainfall events be analyzed to assess the performance of a stormwater treatment technology. The criteria for qualified events, the field-monitoring requirements of TAPE, the hydrological data, and the analytical results for individual rainfall events are discussed below. BaySaver provided the rainfall, flow, and analytical data for evaluation and analysis to determine the treatment capabilities of the BaySeparator™ system. Copies of these data are included in **Appendix G**.

A qualified event was defined as:

- having at least 6 hours with less than 0.04 inches of rain prior
- having an average rainfall intensity that was greater than 0.03 inches per hour (in/hr) for at least 50% of the duration
- having a minimum duration of 1 hour
- having greater than 0.15 inches of precipitation

Additionally, events were included only if more than 75% of the stormwater runoff volume was sampled and no fewer than 10 aliquots were collected for analysis. Four aliquots were collected per sample bottle during each rainfall event, so any event during which 3 sample bottles were collected met this requirement.

Hydrologic data for twelve events were collected and recorded as part of this study. Events are identified and organized by the date that precipitation began, and are displayed in **Table 5** along with their respective hydrological data (precipitation amount, antecedent dry period, duration, and mean rainfall intensity) and the TAPE guidelines for each parameter. The general sampling characteristics (influent and effluent volume sampled, influent and effluent aliquots collected, and volume of the rainfall event treated) for each of the rainfall events is provided in **Table 6**.

Table 5 – Rainfall Event Hydrological Data

Rainfall Event	Precipitation (Inches)	Antecedent Dry Period (hours)	Rainfall Duration (hours)	Mean Rainfall Intensity (in/hr)
18-Nov-13	0.26	84	3	0.09
13-Dec-13	0.2	336	6	0.04
17-Dec-13	0.24	48	4	0.06
23-Dec-13	0.34	96	4	0.10
25-Feb-14	0.43	216	7	0.06
27-May-14	0.46	84	8	0.06
30-Jul-14	0.21	48	6	0.03
17-Mar-15	0.22	168	6	0.04
30-Mar-15	0.31	120	7	0.06
27-Jun-16	0.18	127	5	0.04
2-Sep-16	0.16	720	3	0.06
10-Jan-17	0.16	186	3	0.05
TAPE Guideline	**0.15**	**6**	**1**	**0.03**

Table 6 – Rainfall Event Sampling Requirements
Woodinville, WA

Rainfall Event	Volume of Influent Sampled (percent)	Volume of Effluent Sampled (percent)	Influent Sample Aliquots (number)	Effluent Sample Aliquots (number)	Volume of Stormwater Treated (percent)[1]
18-Nov-13	100	100	28	21	91
13-Dec-13	100	100	36	32	100
17-Dec-13	97	95	48	48	100
23-Dec-13	100	100	36	40	100
25-Feb-14	100	100	40	40	100
27-May-14	100	100	32	32	100
30-Jul-14	100	100	22	31	100
17-Mar-15	100	100	29	29	100
30-Mar-15	100	100	48	48	100
27-Jun-16	100	100	29	29	100
2-Sep-16	100	100	24	23	100
10-Jan-17	100	100	22	24	100
TAPE Guideline	**75**	**75**	**10**	**10**	**75**

1. Volume of stormwater runoff calculated using precipitation data, since limited power supply at the site did not allow for the continuous collection of flow data.

Table 7 – Rainfall Event Flow Summary

Event Date	Rainfall Depth	Influent Peak Flow Rate	Influent Volume	Effluent Peak Flow Rate	AVG Effluent Flow Rate	Effluent Volume	Bypass Peak Flow Rate	Bypass Volume
	(in)	(gpm)	(gallons)	(gpm)	(gpm)	(gpm)	(gpm)	(gallon)
11/18/2013*	0.26	--	--	3544	550	214877	904	19801
12/13/2013	0.2	2098	141743	1753	300	130383	112	2633
12/17/2013	0.24	2302	184468	2356	482	209330	79	416
12/23/2013	0.34	2671	279147	2085	726	320670	--	--
2/25/2014*	0.43	--	--	2614	872	511942	--	--
5/27/2014	0.46	3358	401918	3164	752	430731	--	--
7/30/2014	0.21	2030	177867	1828	640	238198	--	--
3/17/2015	0.22	915	145159	903	333	140581	--	--
3/30/2015	0.31	1346	240020	1234	414	235788	--	--
6/27/2016	0.18	849	148867	842	359	145437	--	--
9/2/2016	0.16	1455	123501	1487	539	119062	--	--
1/10/2017	0.16	840.3	110453	886	493	121171	--	--

*For events 11/18/13 and 2/25/14, flow data for Separator-IN is missing due to the failure of the internal battery located inside the sampler. The flow was recorded and samples were collected during the storm. However, the sampler memory was erased when the marine battery was replaced after the storm. Consequently, it caused the sampler to revert to the default setting, but caused no disruption of flow-paced sample collection.

7.0 BaySeparator™ Analytical Results

The analytical results (influent and effluent concentrations and removal efficiency) for each qualified rainfall events are compiled by constituent and summarized in **Table 8**. The individual rainfall event summaries, which include the general rainfall event information, recorded hydrologic data, flow data, sampling information, analytical results, and constituent removal efficiencies are summarized and included as **Appendix H**. The mean value of the original and duplicate sample results are reported in the tables below.

Bootstrap analyses were conducted for TSS and can be found in **Appendix I**. The column labeled "P5" in the bootstrap analysis tables indicates the lower 95% confidence level for the statistical analysis, while the column labeled "P95" in the bootstrap analysis tables indicates the upper 95% confidence level for the statistical analysis.

7.1 TSS

Pretreatment by the BaySeparator™ system involves reducing the sediment concentration in the influent stormwater flow. TAPE's requirements state that if the influent TSS concentration is greater than 100 mg/L, an approved pretreatment device must achieve a minimum removal efficiency of 50%. If the influent TSS concentration is between 50 and 100 mg/L, the device must produce an effluent TSS concentration 50 mg/L or less.

Twelve rainfall events qualified for inclusion based on their compliance with TAPE requirements for influent TSS concentrations. For the five events with influent TSS concentrations above 100 mg/L, the average removal efficiency was 56.4%. For the remaining seven events with influent TSS concentrations between 50 and 100 mg/L the average effluent TSS concentration was 24.9 mg/L. Results are presented in detail in **Table 8**.

Table 8 - Total Suspended Solids Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
18-Nov-13	66	20	69.7%
13-Dec-13	195	120	38.5%
17-Dec-13	130	51	60.8%
23-Dec-13	88	7	92.0%
25-Feb-14	79	22	72.2%
27-May-14	82	35	57.3%
30-Jul-14	190	90	52.6%
17-Mar-15	250	55	78.0%
30-Mar-15	230	110	52.2%
27-Jun-16	56	12	78.6%
2-Sep-16	98.5	54.5	44.7%
10-Jan-17	54	24	55.6%
12 Qualified Events		**Average**	**62.67%**

The bootstrap analysis conducted on the TSS removal efficiencies for the twelve qualifying events are shown in **Table 9**. The removal rate associated with the upper 95% confidence interval (CI) is 69.3% while the removal rate associated with the lower 95% CI is 55.9%. The results show the estimated mean removal rate to be 62.7% with a standard deviation of 4.21. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range. More detailed bootstrap results are included in **Appendix I**.

Table 9 – Bootstrap Results TSS Removal for All Qualifying Events

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	53.023	55.948	59.725	62.683	65.225	69.278	71.878	4.2116	5.5
median	52.398	52.6	56.45	59.05	65.25	72.2	78	6.3451	8.8
midrange	55.35	58.25	61.35	65.25	68.35	72.1	73.8	4.3872	7
mode	38.5	44.7	52.5	62.683	72.1	78.6	92	12.039	19.6
mode k.dens	42.236	47.773	53.182	58.549	64.055	77.139	85.111	9.4984	10.874

The bootstrap analysis conducted on the BaySeparator^{TM} influent TSS concentrations for the twelve qualifying events are shown in **Table 10.** The estimated mean was 126.5 mg/L (89.6 – 161.2 mg/L, 95% CI), with a standard deviation of 21.30. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range. More detailed bootstrap results are included in **Appendix I**.

Table 10 – Bootstrap Results TSS Influent Concentrations

Estimation Results of Bootstrap									
Statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
Mean	81.235	89.577	112.3	126.54	139.86	161.21	173.09	21.298	27.563
Median	65.95	72.325	85	93.25	114.25	190	195	35.113	29.25
Midrange	92.99	122.95	142	152	152	158	164.5	12.407	10
Mode	54	55	79	126.54	152.98	230	250	55.34	73.975
mode k.dens	55.351	58.21	69.247	76.166	86.215	214.46	232.29	47.284	16.968

Table 11 shows the bootstrap results for TSS effluent concentrations for the events with influent concentrations between 50-100 mg/L. The concentration associated with the upper 95% confidence interval (CI) is 33.3 mg/L while the concentration associated with the lower 95% CI is 17.3 mg/L. The results show the estimated mean concentration to be 24.9 mg/L with a standard deviation of 5.09. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range. More detailed bootstrap results are included in **Appendix I**.

Table 11 – Bootstrap Results for TSS Effluent Concentrations (Events with Influent Concentrations 50-100 mg/L)

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	15.421	17.279	20.982	24.929	28.518	33.286	38.076	5.0897	7.5357
median	12	12	20	22	24	35	35.195	6.0193	4
midrange	15.5	15.5	21	30.75	30.75	37.25	37.25	6.0107	9.75
mode	7	7	16.75	24.929	33.25	54.5	54.5	11.824	16.5
mode k.dens	7.6854	9.6157	18.558	19.856	22.641	35	54.445	7.9553	4.083

Table 12 shows the bootstrap results for TSS effluent concentrations for all twelve events. The concentration associated with the upper 95% confidence interval (CI) is 70.4 mg/L while the concentration associated with the lower 95% CI is 34.8 mg/L. The results show the estimated mean concentration to be 50.0 mg/L with a standard deviation of 10.54. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range. More detailed bootstrap results are included in **Appendix I**.

Table 12 – Bootstrap Results for TSS Effluent Concentrations for All Twelve Events

Estimation Results of Bootstrap									
Statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
Mean	29.635	34.821	43.948	50.042	59.24	70.392	73.266	10.54	15.292
Median	21	22	29.5	43	54.5	72.5	90.1	15.376	25
Midrange	31	48.5	58.5	63.5	66	70	71	6.2964	7.5
Mode	7	12	24	50.042	68.062	110	120	28.716	44.062
mode k.dens	12.266	15.926	19.823	24.296	48.155	97.771	115	23.203	28.332

7.2 Statistical Analysis

Figure 2 below compares the influent and effluent TSS values for the twelve (12) storm events. While no definitive trend can be determined from the plot, it does appear that generally, effluent TSS values increase as influent TSS values increase.

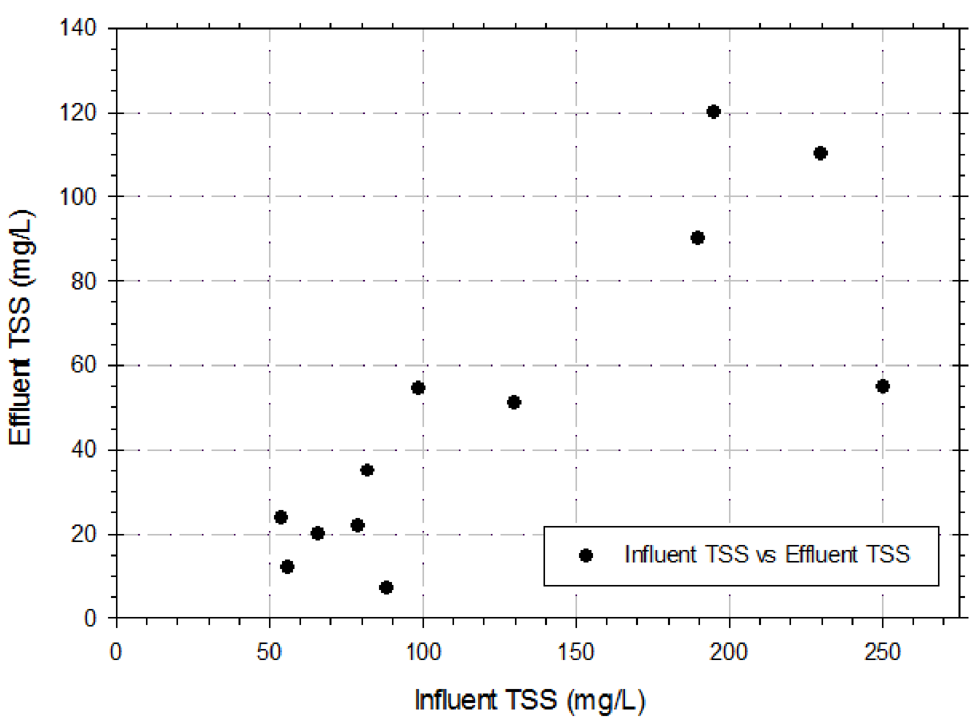

Figure 2 Comparison of Influent TSS vs. Effluent TSS

Table 13 – Statistical Analysis of Influent and Effluent Concentrations Using Wilcoxon 1-Tailed Signed Rank Test

Significance Level 0.05					
Treatment 1	**Treatment 2**	**Sign**	**Abs**	**R**	**Sign R**
66	20	1	46	4	4
195	120	1	75	7	7
130	51	1	79	8	8
88	7	1	81	9	9
79	22	1	57	6	6
82	35	1	47	5	5
190	90	1	100	10	10
250	55	1	195	12	12
230	110	1	120	11	11
56	12	1	44	2.5	2.5
98.5	54.5	1	44	2.5	2.5
54	24	1	30	1	1

Result Details			
W-Value	0	Z-Value	-3.0594
Mean Difference	6.54	Mean (W)	39
Sum of Positive Ranks	78	Standard Deviation (W)	12.75
Sum of Negative Ranks	0	Sample Size (N)	12

A 1-Tailed Wilcoxon Signed Rank Test was performed to determine if a statistical difference exists between the influent and effluent TSS concentration datasets. Results of this analysis are shown in **Table 13**. The critical value of *W* for a sample size of 12 events at p≤ 0.05 is 17. As shown in the table above, the W-value is 0. Therefore, the result is significant at p≤ 0.0 5 and the two datasets are shown to be statistically different.

As shown in **Figure 3** below, TSS removal is plotted as a function of flow rate. All data points, with the exception of two events, show a TSS removal of at least 50% regardless of flow rate.

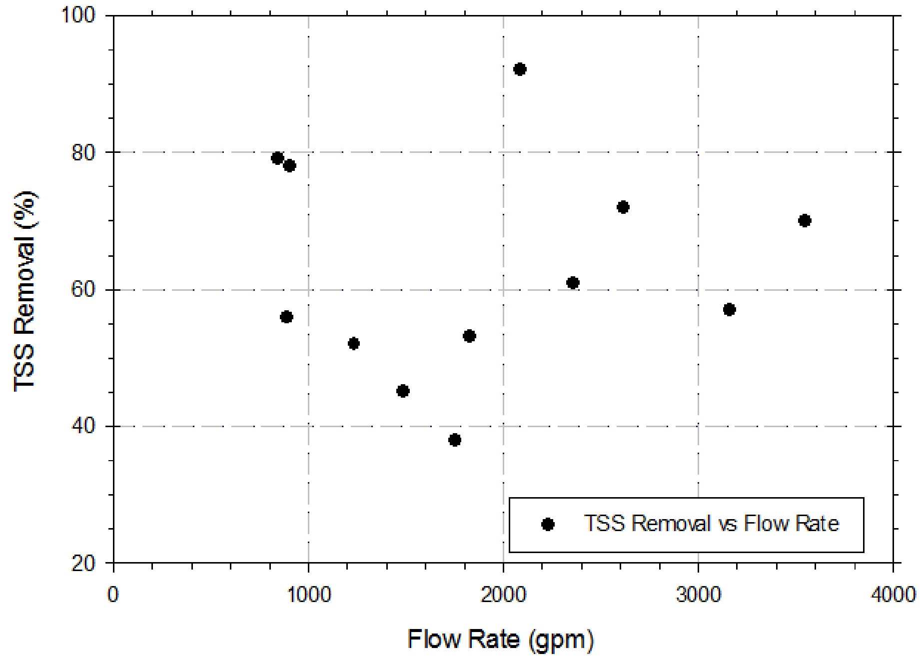

Figure 3 TSS Removal as a Function of Flow Rate

In **Figure 4,** TSS removal is analyzed over time. As shown in the figure, there seems to be no definitive trend represented by the comparison. In the field, it is difficult to establish a trend over time due to variation in rainfall frequency, duration, and volume, which can all cause significant variation in removal.

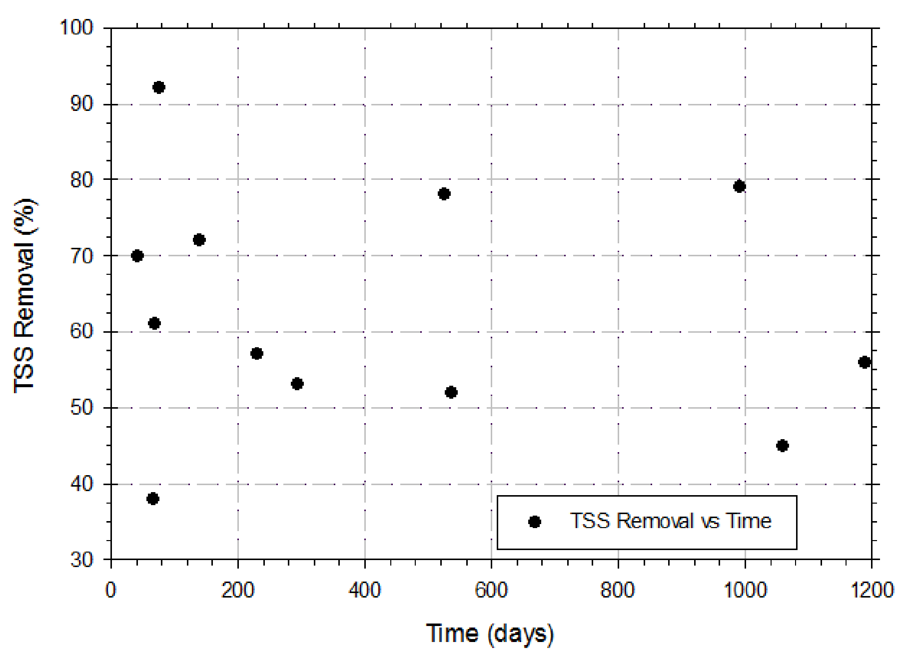

Figure 4 TSS Removal Analyzed Over Time

7.3 Field Duplicate Results

Field Duplicates were collected at Woodinville site for analysis and comparison for quality assurance. Field duplicates were compared against the field duplicate relative percent difference (RPD) in order to ensure that data adhered to the method quality objectives. The field duplicate results are presented below in **Table 14** and the average RPD values are shown in **Table 15**. Lab reports can be found in **Appendix K**.

Table 14 – Field Duplicates Results

Event Date	Analysis	Unit	Detection Limit	Sep-IN	Sep-IN	Sep-OUT	Sep-OUT
12/13/2013	**TSS**	mg/L	5	200	190	120	120
	Total P	mg/L	0.01	0.44	0.5	0.32	0.32
	SSC	mg/L	1	130	150	110	140
4/26/2016	**TSS**	mg/L	5	13	10	2.5	2.5
	Total P	mg/L	0.01	0.088	0.09	0.005	0.01
	SSC	mg/L	2	18	13	1	1
11/23/2016	**TSS**	mg/L	5	27	29	27	26
	Total P	mg/L	0.01	0.11	0.11	0.13	0.14
	SSC	mg/L	1	31	30	32	32

Table 15 – Field Duplicates RPD in Woodinville, WA

Analysis	Average RPD Sep-IN	Average RPD Sep-OUT	MQO
TSS	12.8%	1.3%	**<20%**
Total P	5.0%	24.7%	**<25%**
SSC	16.6%	8.0%	**<30%**

7.4 Particle Size Distribution (PSD)

PSD analysis was conducted on the influent stormwater samples collected from eight rainfall events as part of these field testing activities (data in **Appendix J**, summarized below). Under TAPE guidelines, rainfall events with influent TSS concentrations that contain particles less than 500 microns in diameter meet the requirement for determining pretreatment (TSS removal). Medium sands, according to the United States Department of Agriculture (USDA) soil classification system, have an upper diameter size limit of 500 microns. Generally, according to TAPE, TSS from rainfall events in the Pacific Northwest consists of silts, clays, and fine sands. **Table 16** contains the USDA soil classification system designations for soil particle size.

Table 16 – Soil Classification

Classification	Particle Size (microns)
Colloids	<1
Clay	1 to 2
Silt	2 to 50
Very Fine Sand	50 to 100
Fine Sand	100 to 250
Medium Sand	250 to 500
Coarse Sand	500 to 1,000

Notes:

1. Soil classification based on United States Department of Agriculture soil system.

The rainfall events that were analyzed for PSD had a TSS influent concentration that consisted primarily of silts and fine sands. The diameter of particles that comprise ten percent or less of the sample (d_{10}) was 10.51 microns (flow-weighted basis). The diameter of the particles that comprise ninety percent or less of the sample (d_{90}) was approximately 236 microns. The median diameter (particle that comprise fifty percent or less of the sample) (d_{50}) was 51.53 microns (silts).

Table 17 shows the mean particle size distribution for the influent TSS particles entering the BaySeparator™ system. Stormwater runoff is a mixture of sediment and organic particles, which are all measured based on their optical properties (assumed to be spherical, isotropic, and homogeneous). However, the PSD analysis does not account for the presence of organic particles, which are often irregularly shaped, heterogeneous, and can have darker coloration than sediments. This can cause large organic particles being represented in the data as large diameter sediments, which can skew the reported particle sizes (diameters). By extension these organic particles are reported with a higher mass when the specific gravity of sediments (nominally 2.65) is used in conjunction with the reported diameter.

Table 17 – Particle Size Distribution Influent Concentration

Parameter	Mean	Flow-Weighted Mean
Median Particle Size (microns)	53.81	54.22
d^{10} (microns)	9.49	9.30
d^{50} (microns)	53.81	54.22
d^{90} (microns)	200.97	192.25

7.5 Screening Parameters

Composite samples were collected during the evaluation period and screened for parameters (pH, hardness, total copper, dissolved copper, total zinc, and dissolved zinc) as required by TAPE for a GULD for pretreatment. **Table 18** below lists the results of the screening analyses.

Table 18 – Screening Parameter Results

Sample	pH (s.u.)	Hardness (mg/L)	Total Copper (ug/L)	Dissolved Copper (ug/L)	Total Zinc (ug/L)	Dissolved Zinc (ug/L)
Sep-IN 11/18/13	6.46	18	30	28	150	81
Sep-OUT 11/18/13	6.50	25	15	27	100	78
Sep-IN 12/17/13	6.82	60	48	12	350	140
Sep-OUT 12/17/13	6.63	70	29	14	240	160
Sep-IN 02/25/14	6.62	17	24	8.0	170	74
Sep-OUT 02/25/14	7.00	21	12	6.5	100	67
Sep-IN 05/27/14	6.73	47	50	25	260	150
Sep-OUT 05/27/14	7.13	93	28	16	130	85
Sep-IN 03/30/2015	7.01	36	50	7.0	330	62
Sep-OUT 03/30/2015	6.74	52	55	6.5	360	86

Under TAPE guidelines, rainfall events with influent TSS concentrations that contain particles less than 500 microns in diameter meet the requirement for determining pretreatment (TSS removal). Data in **Table 19** demonstrate that the PSD screened samples meet this guideline.

Table 19 – PSD Screening Results

Sample	D10 (um)	D50 (um)	D90 (um)
Sep-IN 11/18/13	13.9	58.3	186
Sep-IN 12/17/13	8.8	53.7	284.5
Sep-IN 02/25/14	7.5	28.5	51.1
Sep-IN 05/27/14	10.3	48.8	161.5
Sep-IN 3/30/15	N/A	N/A	N/A

*PSD analysis was not performed for the storm event 3/30/15. All other screening parameters were analyzed for this event.

8.0 Data Validation

A review of the ALS/CAS analytical laboratory reports (**Appendix F**) was conducted to identify any deviations of the testing procedure from the QAPP. The ALS laboratory used the analytical methods for screening and test parameters specified in the QAPP. In the case of TSS, ALS/CAS had a method reporting limit of 5 mg/L rather than the QAPP's 1 mg/L (**Table 20**). However, because the method reporting limit was still well below the DOE's effluent concentration limit of 50 mg/L, this inconsistency did not affect the reported data.

Field duplicates were collected for both influent and effluent samples at a rate of 10 percent of the stormwater samples collected. Further information on specific collection procedures can be found in the QAPP.

Table 20 – Constituents Method Reporting Limits and QAPP Reporting Limits Woodinville Sammamish, Woodinville, Washington

Constituents	Unit	Method Reporting Limit	QAPP Reporting Limit
Orthophosphate	mg/L	0.10	0.01
Total Phosphorus	mg/L	0.01	0.01
Total Hardness as $CaCO_3$	mg/L	1.0	2
TSS	mg/L	5.0	1
pH	SU	1.0	--
SSC	mg/L	1.0	--
Total Copper	ug/L	2.0	0.1
Total Zinc	ug/L	2.5	0.5
Dissolved Copper	ug/L	2.0	1.0
Dissolved Zinc	ug/L	2.5	0.5
PSD	--	--	--

9.0 Conclusion

Over the course of this field testing program, BaySaver monitored and sampled 12 rainfall events in Woodinville, WA, that met TAPE's guidelines for precipitation amount, duration, and intensity, as well as qualifications for influent TSS concentrations. Testing took place from November 2013 to January 2017, and demonstrated the ability of the BaySeparator™ system to meet DOE TAPE requirements for pretreatment (TSS removal).

For a system to receive a GULD for pretreatment, it must achieve a minimum average removal rate of 50% when influent TSS concentrations exceed 100 mg/L and a maximum effluent concentration of 50 mg/L when influent concentrations are below 100 mg/L. For this testing program the lower one-sided 95% confidence interval around the removal rate (for all twelve qualified events) is 55.9%. For the qualified events with influent concentrations between 50-100 mg/L, the upper one-sided 95% confidence interval around the effluent concentration is 33.3 mg/L. The data from this field testing program demonstrates that the BaySeparator™ system exceeds the TAPE requirements for pretreatment and, as a result, meets the qualifications for a GULD.

9.1 Additional Considerations

The system was maintained at the start of testing. The site underwent visual inspections upon each site visit to determine if maintenance was required (Appendix L). The system remains functioning to date with no maintenance having been required or performed during testing or after the completion of testing.

Like any other structural stormwater BMP, the BaySeparator™ system requires routine maintenance to operate at its design capability. Inspection is the key to effective maintenance. It should be noted that sediment accumulation may be especially variable during the first year after installation as construction disturbances and landscaping stabilize.

During inspections, the depth of solids in the primary manhole, the depth of solids in the storage manhole, and the amount of trash and oil floating in the storage manhole should be noted.

Maintenance of the BaySeparator™ system is recommended when inspection reveals that 2 feet (0.6 meters) of sediment has accumulated on the bottom of either manhole, although the system can function with approximately 4 feet of sediment buildup in each manhole. This determination of sediment depth can be made by lowering a pole into the manhole until it hits the sediment and measuring the distance.

When sizing in Western Washington, the Western Washington Hydrology Model (WWHM) is used. The WWHM sizes a BMP based on the water quality volume or the flow rate. We will utilize the WWHM software to calculate sizing for different sites based on the drainage area, soil characteristics, vegetation cover and local rainfall patterns. Stormwater treatment systems installed downstream of the detention system, will be sized to handle full 2-year release rates. Runoff from the stormwater technology will be compared with pre-development to comply with the Ecology standard.

When sizing in Eastern Washington, we will utilize the methods outlined in the "Stormwater Management Manual for Eastern Washington". According to this document, each treatment BMP will be sized based on a water quality design volume or water quality design flow rate. Specific jurisdictions will adopt criteria for sizing. For water quality design flow rates, the design will depend on whether the stormwater treatment is located downstream or upstream of the detention system. For regions 1 and 4, the runoff flow rate will be predicted for the proposed development condition from the short duration storm with at 6-month return frequency. For regions 2 and 3, the runoff flow rate will be predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency.

10.0 References

BaySaver Technologies, Inc. (BaySaver). 2007. Washington State Department of Ecology Technology Assessment Protocol – Environmental BayFilter™ Conditional Use Designation Application. March.

BaySaver. 2007. BayFilter™ System Technical and Design Manual (Version 1.4). February 15.

BaySaver. 2008. BayFilter™ Performance Evaluation and Data Supplement. April 3.

BaySaver. 2013. QAPP for Woodinville Sammamish BayFilter™ EMC and BaySeparator™. October 28.

BaySaver. BayFilter™ System Technical and Design Manual. BaySaver, Mount Airy, MD.

Clark, S. and Pitt, R. (2008). "Comparison of Stormwater Solids Analytical Methods for Performance Evaluation of Manufactured Treatment Devices. " *J. of Env. Eng.* , (134), 259-264.

Davis, A. and Janoch, R. (2008). Evaluation of MASWRC Sample Collection, Sample Analysis, and Data Analysis. December 22.

John, R., Gray, G., Glysson, D. Turcios, L. M. , and Schwarz, G. E. (2000). "Comparability of Suspended-Sediment Concentration and Total Suspended Solids Data. " *USGS Water-Resources Investigations Report 00-4191*, United States Geological Survey.

Washington State Department of Ecology. 2008. Technology Assessment Protocol Ecology (TAPE) Guidance for Evaluating Emerging Stormwater Treatment Technologies.

Wessa, P. (2014), Free Statistics Software, Office for Research Development and Education, version 1.1.23-r7, URL http://www.wessa.net/