Technical Evaluation Report

BayFilter™ EMC and BaySeparator™ Systems

Grandview Place Apartments, Vancouver, Washington and Woodinville Sammamish River Outfall, Woodinville, Washington

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Acronyms and Abbreviations

AAR	Annual Aggregate Removal
ASTM	American Society for Testing and Materials
BayFilter EMC	BayFilter Enhanced Media Cartridge
BaySaver	BaySaver Technologies, LLC.

BFC	BayFilter™ Cartridge
$CaCO_3$	Calcium Carbonate
CAS	Columbia Analytical Services, Inc.
CFS	Cubic Feet per Second
CULD	Conditional Use Level Designation
d_{10} Sample	Diameter of Particles that Comprise 10 Percent or Less of the mass
d_{50} Sample	Diameter of Particles that Comprise 50 Percent or Less of the mass
d_{90} Sample	Diameter of Particles that Comprise 90 Percent or Less of the mass
DOE	Department of Ecology
E	Removal Efficiency
EMC	Event Mean Concentration
EMC_{inf}	Influent Event Mean Concentration
EMC_{eff}	Effluent Event Mean Concentration
EPA	United States Environmental Protection Agency
gpm	Gallons per Minute
GULD	General Use Level Designation
HDPE	High Density Polyethylene
in/hr	Inches per Hour
Isco	Isco, Inc.
LCS	Laboratory Control Sample
MASWRC	Mid-Atlantic Stormwater Research Center
mg/L	Micrograms per Liter
mg/L	Milligrams per Liter
MHR	Maximum Hydraulic Rate
mL	Milliliter
MTR	Maximum Treatment Rate
MS/MSD	Matrix Spike/Matrix Spike Duplicate
ND	Non-Detect
OSHA	Occupational Safety and Health Administration
%	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
RPD	Relative Percent Difference
Site	BayFilter™ System Drainage Area
SM	Standard Methods
SSC	Suspended Sediment Concentration
SU	Standard Units
TAPE	Technology Assessment Protocol – Ecology
TARP	Technology Acceptance Reciprocity Partnership
TER	Technical Evaluation Report
Terraphase	Terraphase Engineering, Inc.
TP	Total Phosphorus
TSS	Total Suspended Solids
WC-RMD	West Consultants River Measurement Division

1.0 Introduction

This interim Technical Evaluation Report ("TER") was prepared by Charles Gaines, Senior at Dickinson College, for BaySaver Technologies, LLC. ("BaySaver") of Mount Airy, Maryland as a summer intern project. BaySaver is seeking approval from the State of Washington Department of Ecology ("DOE") for the BayFilter™ EMC System and BaySeparator System for use as stand-alone stormwater treatment devices. The field monitoring programs were conducted between April 5, 2011 and November 1, 2011 at the Grandview Place Apartments in Vancouver, Washington and from November 11, 2013 to May 27, 2014 with testing still continuing at Woodinville Sammamish River Outfall in Woodinville, Washington. The field monitoring programs were designed to assess whether the BayFilter EMC System and BaySeparator System were capable of meeting the DOE Technology Assessment Protocol – Ecology ("TAPE") requirements for Total Suspended Solids ("TSS"), Total Phosphorus ("TP"), enhanced treatment (dissolved copper, dissolved zinc), and oils and grease. Precipitation data, flow data, and influent and effluent analytical data were evaluated from a series of eighteen rainfall events for the BayFilter EMC System at the Grandview Place Apartments and Woodinville Sammamish. The data for the BaySeparator system were collected from a series of ten rainfall events at the Woodinville Sammamish River Outfall site. This report contains the data collected as part of the field monitoring activities and an evaluation of the manufacturer's (BaySaver) treatment performance claims.

Since 1997, BaySaver Technologies™ has been protecting lakes, streams, and waterways from environmental problems. One of BaySaver Technologies' most innovative products to control non-point source pollution has been the BaySaver® Separation System. The system 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.

In 2006, BaySaver introduced the BayFilter stormwater treatment system, which was designed to remove fine sediments, dissolved metals, phosphorus, and other pollutants from stormwater runoff. The historical use of sand filters in water and wastewater treatment is the basis for the design of the original BayFilter Cartridge ("BFC"). The BFC is a spiral-wound media filter cartridge. The BayFilter System, which was tested as part of the 2010 field monitoring program, consisted of three BFCs housed in a containment structure that evenly distributes the flow between the cartridges. Stormwater flow through the BFCs is gravity-driven and self-regulating, which makes the BayFilter System a low maintenance, high performance stormwater treatment technology.

In 2010, BaySaver introduced the Enhanced Media Cartridge (BayFilter EMC) BayFilter stormwater treatment system, a stormwater filtration device designed to remove fine sediments, dissolved metals, phosphorus, and other pollutants from stormwater runoff. BayFilter™ EMC is a spiral wound media filter cartridge with approximately 90 square feet of active filtration area. The filter cartridges are housed in a concrete structure that evenly distributes the flow between cartridges. System design is typically off-line with an external bypass that routes high intensity flows away from the system to prevent sediment re-suspension. Flow through the filter cartridges is gravity-driven and self-regulating, which makes the BayFilter™ EMC system a low-maintenance, high-performance stormwater treatment technology.

Previously, BaySaver had applied for and received approval of the BayFilter System at the Pilot Use Level Designation ("PULD"), included as Appendix B, and Conditional Use Level Designation ("CULD"), included as Appendix C and Appendix D. Based on a review of the field monitoring program data from Grandview in accordance with the QAPP, and TAPE requirements, the BayFilter EMC System was granted a General Use Level Designation ("GULD") by the State of Washington DOE for basic treatment (TSS).

This interim TER is a comprehensive compilation and evaluation of monitoring and analytical data collected from the field monitoring programs. This TER includes data summaries from each individual rainfall event, a statistical evaluation of the collected data, a detailed discussion of the analytical and field monitoring results, and conclusions regarding the removal capabilities of the BayFilter EMC System and BaySeparator System. These field monitoring activities were conducted under the guidelines set by the Grandview Apartments Quality Assurance Project Plan ("QAPP") submitted to the DOE on July 11, 2008 and the Woodinville Sammamish Quality Assurance Project Plan submitted to DOE on September 28, 2013, and revised February, 20 2014 (Appendix A).

BaySaver's field testing program consisted of monitoring and sampling eight qualified rainfall events in Grandview and ten qualified rainfall events in Woodinville. The test equipment was installed by BaySaver and all sampling and analysis was performed by an independent third party, associated to each site in accordance with their respective QAPPs. Based on the analytical results reported, BaySaver achieved 93 percent ("%") removal of TSS when influent stormwater TSS concentrations were greater than 50 milligrams per liter ("mg/L"). Over the course of 13 qualifying rainfall events, the BayFilter EMC achieved a mean TP removal efficiency of 75.4%. In addition, the BayFilter EMC system achieved a mean 54%

removal efficiency of the dissolved zinc from the influent stormwater during rainfall events with an influent dissolved zinc concentration greater than 20 μg/L. The BayFilter system achieved average removal efficiency for TPH Oil Range of 88.1%, with all effluent samples being below 0.3mg/L. One sample was ruled out as an outlier due to data inconsistency.

Based on the results just mentioned, it is recommended the Washington DOE grant the BayFilter a GULD approval for TSS/basic, TP, Zinc/enhanced, Oils and Grease, and Copper (pending).

2.0 Roles

Woodinville Sammamish River Outfall, Woodinville, Washington

BaySaver and the Mid-Atlantic Stormwater Research Center ("MASWRC") managed the field monitoring activities. Collection of the influent and effluent stormwater samples, the 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 located in Everett, WA.

Grandview Place Apartments, Vancouver, Washington

BaySaver and the MASWRC managed the field monitoring activities. Collection of the influent and effluent stormwater samples, the rainfall data, and flow data was conducted by field personnel from WEST Consultants, Inc. River Measurement Division ("WC-RMD") from their Vancouver, Washington office. Influent and effluent stormwater samples were submitted by WC-RMD to Columbia Analytical Services, Inc. ("CAS") and analyzed at CAS' analytical laboratory in Kelso, Washington.

Charles Gaines in conjunction with Dr. Bo Liu of the MASWRC, received the analytical results, flow, and rainfall data from BaySaver and prepared this TER.

3.0 Site Description

Grandview Place Apartments

The field testing occurred at the Grandview Place Apartments located at 19420 Southeast 20th Street in Vancouver, Washington, which is a populated, suburban environment located west of the Cascade Mountain Range. Grandview Place Apartments, which consists of residential apartments, paved parking lots, controlled intersection, and an entrance road is a 9.9 acre parcel surrounded by open space and other residential areas. Stormwater runoff from a 1.35 acre sub-area, which is mainly a paved parking lot, ("Site") drains to the BayFilter™ System via an underground conveyance system. Five catch basins collect the stormwater runoff from the Site and convey the stormwater runoff to the BayFilter System for treatment prior to discharge. The remainder of the stormwater runoff at Grandview Place Apartments is collected and treated through other methods prior to discharge. A set of site plans is included in Appendix E.

Woodinville Sammamish River Outfall

The 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 area to be treated is a 52 acre site that consists of 49 acres of impervious area and only three acres of vegetation cover. Stormwater runoff from the Woodinville Sammamish site is conveyed in to a 5K BaySeparator unit via High Density Polyethylene (HDPE) Corrugated Stormwater inlet pipe. Flows of effluent from the BaySeparator unit are diverted in to the BayFilter EMC system where they are treated by the BayFilter Cartridges and released to an outlet structure via one HDPE inlet pipe. High flows and bypass beyond the capacity of the BayFilter are conveyed through the BaySeparator to a manhole downstream. A set of site plans is included in Appendix E.

4.0A BayFilter Treatment Technology

The BayFilter™ EMC system removes dissolved pollutants and fine sediments from stormwater runoff via media filtration. Media filtration has long been used in drinking water and wastewater treatment processes. This technology has proven effective at removing sediments, nutrients, heavy metals, and a wide variety of organic contaminants. The BayFilter™ EMC removes pollutants from water by four mechanisms: 1) separation 2) interception, 3) attachment, and 4) adsorption. Separation is the differential density settlement, sedimentation, which occurs before the water enters the filter cartridge. Interception occurs when a pollutant becomes trapped at the surface layer or within the filter media. A sediment particle, for example, may be carried into the filter media by the water and become stuck in the interstices of the media. Particles will typically remain trapped within the media until the media is removed or through backwash. Attachment occurs when pollutants attach themselves to the surface of the filter media; this happens primarily through absorption. Adsorption is the process by which dissolved ions are removed from a solution and chemically bind themselves to the surface of the media. This occurs when the surface of the filter media particle contains sites that are chemically attractive to the dissolved ions. The BayFilter™ EMC system uses a filter media that consists of a mix of Zeolite, Perlite, and Activated Alumina.

4.1A BayFilter Treatment System

Grandview Place Apartments

Stormwater runoff from the Site is collected in five surface level drop inlets and conveyed via a series of underground pipes to a 4-foot diameter pre-cast concrete manhole (termed the influent manhole). The influent stormwater enters via a 12-inch diameter HDPE influent pipe (invert at 248.76 feet) and fills the influent chamber of the influent manhole. The manhole contains a bypass component, a 3-inch thick concrete weir with a top elevation of 249.67 feet, which divides the influent manhole into two chambers. In the event of a high volume flow, the influent chamber fills to the top of the concrete weir and the excess stormwater flows over the weir into the outlet chamber, which discharges via a 15-inch diameter plastic outlet pipe (invert at 246.63 feet).

Under normal operation conditions (non-bypass), the influent chamber discharges stormwater through the 4-inch diameter inlet pipe (invert at 247.51 feet in the influent manhole) to a 6-foot diameter pre-cast concrete manhole (termed the filter manhole). Stormwater rises in the filter manhole until the water surface elevation reaches the operating level of the two BayFilter EMCs located in the filter manhole. The stormwater is driven through the BayFilter EMCs under hydrostatic head. A 4-inch diameter poly-vinyl chloride ("PVC") piping manifold connects the outlets from the BayFilter EMCs (collectively referred to as the under-drain manifold) to the 4-inch diameter filter manhole outlet pipe (invert at 246.69 feet in the filter manhole). The outlet pipe drains from the filter manhole to the outlet chamber (downstream of the weir) and discharges into the 15-inch diameter outlet pipe. (Figures 1 and 2)

Woodinville Sammamish River Outfall

Runoff from the Woodinville Sammamish site is conveyed into a 5K BaySeparator unit via one 48" diameter Corrugated Polyethylene Stormwater inlet pipe. Low and moderate flows of effluent from the BaySeparator unit are diverted into the BayFilter EMC system via one 18" diameter HDPE inlet pipe. The high flow bypass is conveyed into a 4' manhole downstream. The BayFilter cartridges are housed inside of a 44'x10' precast vault and have a peak flow rate of 4 cfs. This vault contains a PVC underdrain system that connects the BayFilter cartridges to the outlet pipe. (Figure 3 and 4)

4.1.1A BayFilter Component Construction Materials

The BayFilter EMC casing is a polymer cylinder (outer shell constructed out of HDPE) with a vertical fin that has a hole for lifting the BayFilter EMC. A plastic inlet plate (also constructed of HDPE), which allows influent stormwater to enter the BayFilter EMC, is located on the bottom of the BayFilter EMC. Polymer seals are used to attach the spiral-wound filtration layers and outlet drainage channels to the inlet plate (Figure 5).

A 3/8-inch thick layer of media (blend of zeolite, perlite, and activated alumina) is sandwiched between layers of filter fabric. This filtration layer is placed between layers of plastic drainage media, which form inlet and outlet drainage channels in the BayFilter EMC. Influent stormwater fills from the bottom of the cylindrical BayFilter EMC and flows vertically up through the inlet channels. The stormwater is forced horizontally through the inlet filtration layer, which is a 4-ounce filter fabric encasing a 3/8-inch layer of blended media, and the outlet filtration layer, which is a 10-ounce filter fabric encasing a 3/8-inch layer of blended media (Figure 5).

The treated stormwater is conveyed vertically to the top of the BayFilter EMC via the outlet drainage channels. A one-way air release valve, which expels air from the outlet chamber as the water level rises inside the BayFilter EMC, is located on the top of the BayFilter EMC. The outlet chamber is drained by a 2.5-inch diameter outlet pipe in the center of the BayFilter EMC, which conveys treated stormwater through a flow control orifice and to the under-drain manifold.

4.1.2A BayFilter Component Dimensions

Each standard BayFilter EMC is approximately 28 inches in diameter and stands 30 inches in height. The containment structure size is based on the number of BayFilter cartridges to achieve the designed flow rate. In the Grandview Place Apartments, two BayFilter EMCs were installed in a 6-foot diameter pre-cast concrete manhole. In Woodinville Sammamish, 40 BayFilter EMCs were installed in a 10'x44' diameter pre-cast concrete vault.

4.1.3A BayFilter Component Capacity

Stormwater runoff is filtered through the BayFilter EMCs, which each have approximately 90 square feet of surface area available for filtration. The adsorption of dissolved constituents is aided by the high surface area of the particles in the media and the pollutants. The BayFilter cartridges operate at 0.5 gpm per square foot, contain 90 square feet of media, and operate at 45 gpm per cartridge. The BayFilter™ System Technical and Design Manual (Appendix F) contains detailed sizing information and design details.

4.1.4A BayFilter Treatment Functions

When the water level in the containment structure (influent manhole) reaches at least 28 inches (full flow), which is the height of the BayFilter EMCs, the stormwater flows through the spiral-wound media layers. As stormwater flows into the BayFilter EMCs, the air in the BayFilter EMCs is exhausted through the air-release valve (Figure 6). Stormwater then flows horizontally through the engineered media layers. Next, the stormwater flows to the outlet drainage spiral, which is also one single spiral wrap of outlet material. The treated stormwater then flows vertically to the outlet chamber located on the inside top of the filter (Figure 7). Finally the treated stormwater flows to the center outlet drain and through the under-drain manifold below the inlet plate.

Filtration media is a blend of zeolite, perlite, and activated alumina. The media is packaged in a patented spiral wound configuration and contained within layers of polymer fabric (filter fabric) for media containment and additional filtration performance. Two drainage spirals provide for inlet and outlet flow paths.

Filtration of the pollutants, nutrients, organics, sediment, and metals, is driven by gravity through the BayFilter EMC, where the media and filter fabric trap suspended contaminants and dissolved contaminants are adsorbed onto the surface of the media particles. The adsorption is driven by the high surface area of the media particles combined with the ionic interactions between the media particles and the contaminants.

When the inflow of stormwater stops or the rate of inflow is below the rate of outflow (treated stormwater effluent), the BayFilter EMC will continue to operate by siphon. The BayFilter flow rate is gradually reduced by approximately 40 percent toward the end of the siphon cycle. This allows the BayFilter EMC to remain in siphon for an extended period of time. A siphon allows for the treatment of stormwater until the water level in the filter manhole reaches 6 inches in depth, the bottom of the BayFilter housing and media (Figure 8). This siphon operation is critical for the proper functioning of the BayFilter, which drives the BayFilter EMC System during periods of low water level in the manhole.

Once the water level in the manhole falls below the bottom of the BayFilter EMC, air enters the BayFilter EMC thereby breaking the siphon (Figure 9). Upon breaking of the siphon, all water remaining in the BayFilter Cartridge reverses flow and backwashes the intercepted pollutants from the cartridge (Figure 10). This backwash has the effect of dislodging particles captured in the filter media layers and reestablishing filter media porosity. Dislodged particles are transported by the backwash and accumulate on the filter manhole floor.

4.2A BayFilter Pretreatment Requirements

The BayFilter EMC System is a stand-alone treatment technology, which is a flow and volume-based design. Pretreatment will reduce the load on the filter vault as the larger solids will accumulate in the pretreatment system and not build up on the BayFilter Vault Floor. However, the physical configuration of the BayFilter system is such that the use of a pretreatment device will not improve the efficiency of the BayFilter system as the settling area in the BayFilter is substantially higher than that in the BaySeparator or typical pretreatment device. This is better understood when considering that the means of particulate removal from a pretreatment device is gravity settling. Most pretreatment devices operate above 30 gpm/sf of settling area (vault or chamber area). Comparing this to the BayFilter System, at a maximum flow of about 7 gpm/sf, the larger particles will have over 4 times as much time to settle as they did in the pretreatment device. As a result, the particles that settle out during the ¼ the amount of time in the pretreatment device will have settled in the filter chamber, had the pretreatment device been absent. On the other hand, a pretreatment device can be configured to collect the larger pollutants during peak flows that are beyond the treatment capacity of the BayFilter system. The pretreatment, including the BaySeparator, functions to extend the lifespan of the BayFilter EMC System.

4.3A BayFilter Installation Requirements

BayFilter EMCs as part of the BayFilter System are housed in an underground structure, such as a vault, manhole, or other structure. The small footprint of a manhole allows for placement of the BayFilter EMCs without disturbing underground utilities. The addition of BayFilter EMCs to an underground structure such as a pre-cast concrete manhole does not require any additional requirements. The BayFilter System has no electrical components and functions under the principles of gravity flow (drainage and pressure head). In addition, the filter structure must allow for at least 28 inches of water to accumulate (difference between bottom of the structure and invert of the inlet pipe) to drive the filtration process and siphon.

4.4A BayFilter Sizing Methodology

To determine the number of cartridges required for a BayFilter EMC installation, three factors must be considered:

1. The flow capacity of the system
2. Treated sediment load of the system
3. Jurisdiction – specific sizing requirements (water quality volume)

Each of the above factors, when evaluated, will determine a minimum number of cartridges required to address each design parameter. Calculations for all three factors need to be done to determine which design factor is limiting. The system configuration will then become the greatest number of cartridges determined by the above calculations.

4.5A BayFilter Expected Treatment Capabilities

The BayFilter EMC system has been extensively tested in the laboratory. This testing was carried out using SIL-CO-SIL 106 as a surrogate sediment. SIL-CO-SIL 106 is an engineered silica product containing approximately 90% fine sediments (the diameter at which 50% of the particles are smaller ("d_{50}") is 23 microns). It is widely accepted as a sediment source for stormwater laboratory testing by regulatory agencies such as the Washington State DOE TAPE program and the New Jersey Department of Environmental Protection Technology Assessment and Reciprocity Program ("TARP").

The BayFilter EMC system is designed to achieve TSS removal efficiency over 80% at the design flow rate. The 80% sediment removal efficiency is based on laboratory testing using the SIL-CO-SIL 106 sediment gradation. The EMC media removes dissolved metals and dissolved phosphorus through adsorption. As a result of the combined fine particulate removal and dissolved removal ability, TP removal rates greater than 75% are expected. The lab summary report on the BayFilter EMC can be found in Appendix F.

4.6A BayFilter Maintenance Procedures

Grandview Apartment Place

Maintenance was completed prior to the start of testing and after testing; the last maintenance on this site was performed in late 2011 and no maintenance has been required since.

Woodinville Sammamish River Outfall

Maintenance was completed prior to the start of testing; no maintenance was necessary during the testing time frame, and the testing remains ongoing without maintenance.

4.6.1A BayFilter Maintenance Inspections

Like any other structural stormwater Best Management Practices (BMPs), the BayFilter EMC system requires routine maintenance to operate at their design capabilities. Inspection is the key to effective maintenance and it is easily performed. BaySaver Technologies LLC recommends ongoing quarterly inspections of accumulated pollutants. Sediment accumulation may be especially variable during the first year after installation as construction disturbances and landscaping stabilizes. It is very useful to keep a record of each inspection.

4.6.2A BayFilter Maintenance Operations

The maintenance cycle of the BayFilter EMC system is determined by the influent load on the filter cartridges. The system should be periodically monitored to be certain it is operating correctly. When the filter system exhibits flows below design levels or when the system does not completely drain between storm events, the system requires maintenance. Maintenance should also be performed when sediment reaches to the top of the 6” collector pipes to the manifold.

Maintenance of the BayFilter EMC systems should be performed when there is no flow entering the system. For this reason, it is recommended to schedule the cleanout during dry weather or between rainfall events. Maintenance of the BayFilter EMC system, consists of removing the spent cartridge, cleaning out any sediment accumulated in the vault with a vacuum truck, and replacing the spent cartridges with exchange cartridges.

4.6.3A BayFilter Life Span

BaySaver recommends the BayFilter be sized to treat a minimum of at least one year under normal conditions before removal and replacement with new BayFilter EMCs is necessary. If the BayFilter System does not drain down within 24 hours of the conclusion of a rainfall event, the BayFilter EMCs likely need to be replaced. Each site has unique contaminant characteristics and those sites with high sediment, excessive organics, and/or petroleum hydrocarbons will likely require more frequent BayFilter EMC replacement.

4.0B BaySeparator Treatment Technology

The BaySeparator system removes pollutants from the stormwater stream through two mechanisms: sedimentation and flotation. Engineers have relied on these two mechanisms in water and wastewater treatment for years. The BaySeparator system applies these time tested principles to stormwater treatment in a configuration that prevents contaminant release or re-suspension during high flow rates. Sedimentation is the gravity-driven process by which solids suspended in water fall downward. Sedimentation is driven by the difference in density between the solid particles and the water surrounding it, and the size of the settling particles. The effectiveness of sedimentation depends on the specific gravity and size of the settling particles and the length of time the particles are allowed to settle. Flotation works in the same way as sedimentation, but in the opposite direction. Floatable pollutants like free oils and debris rise to the surface and are trapped in the storage manhole until removal by maintenance.

4.1B BaySeparator Treatment System

Woodinville Sammamish River Outfall

Runoff from the Woodinville Sammamish site is conveyed into a 5K BaySeparator unit via one 48" diameter Corrugated Polyethylene Stormwater inlet pipe. Low flows of effluent from the BaySeparator unit are diverted into the BayFilter EMC system via one 18" diameter High-Density Polyethylene (HDPE) inlet pipe. The high flow bypass is conveyed into a 4' manhole downstream. The BayFilter cartridges are housed inside of a 44'x10' precast vault and have a peak flow rate of 4 cfs. This vault contains a PVC underdrain system that connects the BayFilter cartridges to the outlet pipe. (Figure 3 and 4)

4.1.1B BaySeparator Component Construction Materials

The BaySeparator™ unit is fabricated entirely of high-density polyethylene (HDPE) infused with UV-resistant carbon-black. HDPE is a non-brittle, chemically inert material known for its corrosion-resistant properties. It is commonly used in applications that expose it to harsh conditions (landfills and chemical plants, for example) and is used in storm drains throughout the world.

The BaySeparator unit is connected to each of the two manholes with standard storm drain pipe connections. The connecting pipes entering and leaving the storage manhole are submerged during normal operation. Those joints must be watertight, and are typically made using flexible pipe- to-manhole connectors (rubber boots) installed in the storage manhole by the precast manufacturer. These connecting pipes are joined to the BaySeparator unit using Fernco® seals with shear rings. The shear rings provide additional structural strength and rigidity to this joint. The BaySeparator unit is joined to the system outfall pipe with a custom made reducer/adapter provided by BaySaver Technologies.

The Primary Manhole is a standard precast structure used to remove coarse sediments. This manhole is generally installed inline with the storm drain and 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. The BaySeparator system stores the pollutants offline to prevent resuspension (Figure 11).

4.1.2B BaySeparator Component Dimensions

The BaySeparator 5K model was placed at the Woodinville Sammamish site and has a nominal diameter of 48”. The maximum treatment rate (MTR) is 11.1-cfs and the maximum hydraulic rate (MHR) is 50-cfs. The manhole diameter (length of flow based systems) is 72” and the manhole sump depth is 8’.

4.1.3B BaySeparator Component Capacity

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

4.1.4B BaySeparator Treatment Functions

As water enters the BaySeparator system’s Primary Manhole coarse sediments (gravel and sand) immediately fall to the floor of the Primary Manhole. The influent water, carrying floatables and finer sediments, flows through the separator and those that have not settled are conveyed into the Storage Manhole, where it enters below the water surface. When water enters the Storage Manhole from the submerged inlet pipe, oils and other floatables rise to the surface, while fine sediments settle to the floor. These contaminants remain trapped offline and are not resuspended during larger flows. 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, flow rates continue to increase. During these events, the BaySeparator continues to divert surface flows (containing the majority of suspended sediments, as well as the oils and other floatables) from the Primary Manhole to the Storage Manhole as described above (Figure 12).

Additional flows associated with the larger storm are treated by separation in the Primary Manhole. As the pollutants are separated, the influent water displaces treated water from the center of the column and forces it up the "Tee" pipes to the system outfall.

The BaySeparator system also has an internal bypass when inflows exceed the systems treatment capacity. Bypass flows are directed over the bypass plate and directly through the unit. The BaySeparator system uses the weir plate to limit flows into the Storage Manhole, minimizing the risk of the resuspension of captured pollutants because they are stored offline. By storing pollutants offline, the BaySeparator system hydraulically isolates these contaminants from the high-energy influent flows, effectively eliminating the risk of resuspending accumulated contaminants.

4.2B BaySeparator Pretreatment Requirements

The BaySeparator is often used as a pretreatment device, and since its design accommodates a wide range of flow rates up to including peak flows in excess of 100 cfs, it can also act as a flow splitting structure and requires no pretreatment.

4.3B BaySeparator Installation Requirements

The BaySaver Technologies' 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.

4.4B BaySeparator Sizing Methodology

BaySeparators can be sized following different criteria which include:

Flow Based Sizing: this 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) Based Sizing: this is a very common criteria used to size hydrodynamic separators to a given suspended solids removal performance.

4.5B 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 upon local requirements.

4.6B BaySeparator Maintenance Procedures

Woodinville Sammamish River Outfall

The system was maintained at the start of testing and no maintenance has occurred since, and the testing is ongoing at this location.

4.6.1B BaySeparator Maintenance Inspections

Like any other structural stormwater BMPs, the BaySeparator system requires routine maintenance to operate at their design capabilities. Inspection is the key to effective maintenance and it is easily performed. BaySaver Technologies recommends ongoing quarterly inspections of accumulated pollutants. Sediment accumulation may be especially variable during the first year after installation as construction disturbances and landscaping stabilizes. It is very useful to keep a record of each inspection.

There are three points of maintenance limitations for the BaySeparator system, 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. 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 from the bottom of the pole to the water line mark on the pole. By simple inspection, if the solids are within 1 foot of the bottom of vertical pipes in the Primary Manhole, or within 1 foot of the pipes entering or exiting the Storage Manhole, or there is more than 2 feet of floating trash and debris, or more than 12 inches of free oil floating on the surface, the system must be maintained. From a periodic inspection, with the knowledge of when the last maintenance was performed, an estimated next inspection and maintenance data can be projected as well.

4.6.2B BaySeparator Maintenance Operations

Maintenance of the BaySeparator system should be performed when there is no flow entering the system. For this reason, it is recommended to schedule the cleanout during dry weather and between rainfall events. Maintenance of the BaySeparator system requires the cleanout of the two manholes with a vacuum truck, removing the sediment, debris, and a portion of the water from the manholes

Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. In BaySeparator System installations where there is little risk of petroleum spills, liquid contaminants may not accumulate as quickly as sediment. However, known hydrocarbon spill should be cleaned out immediately. All manhole covers should be securely seated following cleaning activities.

Solids recovered from the BaySeparator stormwater treatment devices can typically be land filled or disposed of at an approved facility. Local regulations may prohibit the discharge of solid material into the sanitary sewer system. It is recommended to check with the local sewer authority for permission to discharge the liquid. Many locations treat the pollutants as leachate. Proper disposal must be in accordance with local regulations.

4.6.3B BaySeparator Systems Life Spans

The BaySeparator is constructed using standard precast concrete manholes and HDPE storm drain pipe. The BaySeparator system is expected to last the life of any typical storm drain system, when properly maintained.

5.0 Sampling Procedures

The samples were collected by West Consultants, River Measurement Division (WC-RMD) and sent to The Columbia Analytical Services (CAS) to analyze the samples for Grandview Apartment Place. The sampling procedures were collected by Terracon and sent to ALS Life Sciences Division (ALS) to analyze the samples for Woodinville Sammamish.

Stormwater influent and effluent samples for water quality analysis were collected during 18 rainfall events by field personnel from Terracon/WC-RMD. Collected water quality samples were submitted to the ALS/CAS Laboratory in for analysis of the selected water quality constituents. The sampling equipment, sample collection procedures, 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 the two ISCO auto-samplers in Grandview and four ISCO auto-samplers in Woodinville based on reading from their respective flow meter sensors. The auto-samplers collected flow-paced samples by withdrawing a 230 milliliter (mL) aliquot for a pre-programmed volume. The volume of pacing was predetermined based upon the expected total volume of the rainfall event. Each 500 mL sample bottle contained a composite of 2 aliquots for a total of 460 mL at Grandview and each 1000 mL sample bottle contained a composite 4 aliquots for a total of 920 mL at Woodinville. 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 or cross contamination) within 24 hours of the end of the rainfall event. In some instances (weekend storm events), sample bottles were typically collected within 48 hours. The sample bottles were placed on ice in a cooler (temperature 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.

Influent and effluent samples were composited according to the approved ALS/CAS methods. ALS/CAS sub-sampled the influent and effluent composite samples, immediately after compositing, for each of the selected individual water quality constituents. Preservation of the sub-samples was based on the requirements of the analytical method for the individual water quality constituents. 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. The cleaned sample bottles were replaced in the auto-samplers with clean sample bottles after each rainfall event. The used sample bottles were washed and prepared according to ALS/CAS procedures.

5.2 Sampling Equipment

The Site was equipped with a RainWise® rain gauge (RAINEW 111) and HOBO® data logger to collect and record specific precipitation data. The rain gauge collected and recorded precipitation data in 0.01-inch increments using the tipping bucket method. The data were then downloaded by Terracon/WC-RMD during their site visit after each rainfall event.

The flow-weighted water quality samples were collected using two (Grandview) and four (Woodinville) Isco, Inc. ("Isco") auto-samplers (model was Isco 6712) that were connected to Isco 4250 area/velocity flow meters. 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 silicon tubing suction line, which was set 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. Terracon/WC-RMD visually inspected and checked the programmed settings after every rainfall event, even if the flow was less than 0.1 inches, a non-qualifying rainfall event. The deep cycle marine batteries used to power the monitoring and sampling instruments were checked and exchanged regularly.

5.2.1 Grandview Sampling Equipment

The effluent flow meter sensor and effluent sampling tubing were located in a 4-inch diameter PVC pipe that extended from the 4-inch diameter outlet pipe from the filter manhole into the 15-inch diameter outlet pipe in the influent manhole. The 4-inch diameter extension prevented stormwater that bypassed the filter manhole due to high flow rates from mixing with treated stormwater effluent.

5.2.2 Woodinville Sampling Equipment

A Cellular Sampler Controller system developed by Micro Systems Engineering, LLC, provides remote control and status monitoring capability for Teledyne ISCO 6712 series samplers. The system consists of a single programmable GSM cellular base unit and 1 wireless remote unit for each sampler. The base unit provides both the cellular network connection and a local wireless link to each sampler. The base unit allows authenticated users to initiate programs and retrieve data and status from each sampler via simple SMS text messages. A reply SMS message is 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 filter vault outlet pipe access through the downstream manhole.

5.3 Analytical Methods

The CAS analytical laboratory in Kelso, Washington is a Washington DOE-certified laboratory (certification number C1203) for drinking water, wastewater water, and solid/hazardous waste analyses. Water quality samples were submitted to CAS for analysis of 10 individual constituents.

Table 1 - Constituents, Analytical Methods, and Method Reporting Limits
Grandview Place Apartments, Vancouver, Washington

Constituents	Analytical Method	Unit	Method Reporting Limit
Orthophosphate	EPA 365.3	mg/L	0.010
Total Phosphorus	EPA 365.3	mg/L	0.010
Total Hardness as $CaCO_3$	SM 2340 C	mg/L	2.0
TSS	SM 2540 D	mg/L	5.0
pH	SM 4500-H+ B	SU	--
SSC	ASTM D 3977-97 B	mg/L	5.0
Total Copper	EPA 200.8	µg/L	0.1
Total Zinc	EPA 200.8	µg/L	0.5
Dissolved Copper	EPA 200.8	µg/L	0.1
Dissolved Zinc	EPA 200.8	µg/L	0.5
PSD	Coulter Counter	--	--

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 of 16 individual constituents.

Table 2 - 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 QAPPs (Appendix A and B) were developed by BaySaver to provide guidance to Terracon/WC-RMD field personnel when conducting the field testing of the BayFilter™ EMC and BaySeparator systems. The QAPP was site specific and was meant to ensure that sampling and analysis of field data was done safely and accurately. According to the QAPP, Terracon/WC-RMD was to conduct 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.

5.4.1 Equipment Field Blanks

Equipment field blanks (termed field blanks in the QAPP) are used to quantify the results of sampling contamination or bias. The equipment field blanks are prepared by pumping reagent grade water through the influent and effluent auto-samplers and collecting samples in the sample containers. The equipment field blank samples are handled and transported in the same manner as the water quality samples. The influent TSS concentration from both equipment field blanks was anticipated to be zero, because the reagent grade water does not contain suspended solids. If TSS concentrations were reported above the method reporting limit, the introduction of sediments from the auto-samplers would likely be the cause.

Field blanks are used to evaluate whether contamination is introduced during field sampling activities. Field blanks will be collected before the initial runoff event or at the earliest time possible by passing reagent grade water through the samplers. The samples will be delivered to the laboratory and will be handled in the same manner as event samples. The second set of field blanks will be collected at or near the mid-point of the testing by following the same procedure. Field blanks will be collected by running reagent grade water through both the automatic samplers at all sampling locations.

When the ALS/CAS Laboratory was not able to detect a constituent at a concentration greater than their method-reporting limit, a value of non-detect ("ND") was reported. The ALS/CAS Laboratory establishes the method-reporting limit at the concentration, which the constituent(s) can be routinely detected. There are often minor variations in precision, sensitivity, accuracy, and variability in instruments and between multiple instruments that may be used for analysis. The method-reporting limit is the concentration that the ALS/CAS Laboratory is confident of the analytical results being reported due to the aforementioned causes of variation.

Table 3 – Field Blank Analytical Results (January 12, 2010)
Grandview Place Apartments, Vancouver, Washington

Constituents	Unit	Method Reporting Limit	Influent	Effluent
Orthophosphate	mg/L	0.010	ND	ND
Total Phosphorus	mg/L	0.010	ND	ND
Total Hardness as $CaCO_3$	mg/L	0.4	0.2	0.2
TSS	mg/L	5.0	ND	ND
pH	SU	--	5.21	5.22
SSC	mg/L	1.0	ND	ND
Total Calcium	µg/L	4.0	69.0	60.4
Total Copper	µg/L	0.1	4.1	3.8
Total Magnesium	µg/L	2.0	17.2	10.8
Total Zinc	µg/L	0.5	1.2	2.6
Dissolved Copper	µg/L	0.1	3.6	3.0
Dissolved Zinc	µg/L	0.5	8.6	9.8

Table 4 – Field Blank Analytical Results (October 31, 2013) Woodinville Washington

Constituents	Unit	Method Reporting Limit	Sys-IN	Sep Low-OUT	Sep High-OUT	Filt-OUT
TPH-Diesel Range	ug/L	130	ND	ND	ND	ND
TPH-Oil Range	ug/L	250	ND	ND	ND	ND
Total Suspended Solids	mg/L	5.0	ND	ND	ND	ND
pH	S.U.	1.00	4.42	4.92	4.29	4.38
Orthophosphate as P	mg/L	0.29	ND	ND	ND	ND
Copper	ug/L	2	12	8.9	2.9	5.9
Hardness	mg/L	1	ND	2.9	1.1	ND
Zinc	ug/L	2.5	ND	2.8	ND	2.7
Copper (Dissolved)	ug/L	2.0	12	8.5	3.0	5.9
Zinc (Dissolved)	ug/L	2.5	ND	2.7	ND	ND
Total Phosphorus	mg/L	0.010	ND	ND	ND	ND
Suspended Sediment Concentration	mg/L	1.0	ND	ND	ND	ND

5.4.2 Duplicate Samples

The influent and effluent water quality samples were collected in the field on a flow-paced basis and composited by the CAS/ALS Laboratory. CAS/ALS sub-sampled the influent and effluent composite containers for the 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 used 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 BaySaver. However, all batches of samples being analyzed, which included 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.

5.4.3 Laboratory QA/QC

CAS/ALS are EPA certified analytical laboratories. As such, they have their own QA/QC procedures detailed.

The analytical laboratory (CAS/ALS) has internal QA/QC procedures, including the 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 I), which included all the raw data, quality control results, and submitted water quality samples' analytical results.

5.5 Removal Rate Calculations

The removal efficiency calculation is based on the EMC, TSS values, metals, phosphorus and oil and grease values which are derived from the flow-weighted composite samples. Removal efficiency will be calculated for each qualifying event using equation 7-1. A bootstrap statistical analysis will be performed on the complete data set to determine an overall Removal efficiency at a 95% confidence level. $E = 100\left(1 - \frac{EMC_{Effluent}}{EMC_{Influent}}\right)$

Individual storm reduction in pollutant concentration will be calculated as:

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

Equation 4.5.1

Where:

A = flow proportional influent concentration

B= flow proportional effluent concentration

6.0 Qualified Events

The criteria for qualified events, the field monitoring requirements of TAPE, the hydrological data, and the reported 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 BayFilter™ System. Copies of the data are included in Appendix J.

A qualified event is a rainfall event that:

- had at least 6 hours with less than 0.04 inches of rain prior to rainfall;
- an average rainfall intensity that was greater than 0.03 inches per hour ("in/hr") for at least 50% of the rainfall event;
- a minimum rainfall event duration that was 1 hour; and
- there was greater than 0.15 inches of precipitation (Table 5).

Sampling requirements included that greater than 75% of the stormwater runoff volume had been sampled and 10 aliquots were collected for analysis. In this field monitoring program, two aliquots were collected per sample bottle during each rainfall event. Therefore, rainfall events with 5 sample bottles met the sampling requirement. Overall, TAPE requires at least 12 qualified rainfall events be analyzed to assess the performance of a stormwater treatment technology.

Table 5 – Field Monitoring TAPE Requirements
Grandview Place Apartments, Vancouver, Washington

Requirement	Unit	Guideline
Minimum Precipitation Amount	inches	0.15
Antecedent Dry Period	hours	6
Minimum Rainfall Event Duration	hours	1
Minimum Rainfall Intensity	in/hr	none
Average Rainfall Intensity	in/hr	0.03[1]
Minimum Number of Qualified Rainfall	none	12
Volume of Stormwater Runoff Sampled	percent	75
Minimum Number of Aliquots Collected	none	10

Notes:
1. Should exceed 0.03 in/hr for at least 50% of the rainfall events.

Hydrologic data for eighteen rainfall events were collected and recorded as part of these field monitoring activities. The eighteen rainfall events, which are identified by the date that precipitation began, are displayed below in Table 6 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 7.

Table 6 – Rainfall Event Hydrological Data
Vancouver, WA and Woodinville, WA

Rainfall Event	Precipitation (Inches)	Antecedent Dry Period (hours)	Rainfall Duration (hours)	Mean Rainfall Intensity (in/hr)
April 5, 2011	0.34	54	5	0.07
April 15, 2011	0.23	60	8	0.03
April 26, 2011	0.20	40	6	0.04
May 26, 2011	0.35	33	9	0.04
June 20, 2011	0.39	23	10	0.04
July 18, 2011	0.37	23	3	0.12
September 26, 2011	0.24	11	3	0.08
November 1, 2011	0.30	126	2	0.05
November 11, 2013	0.37	48	5	0.07
November 13, 2013	0.94	72	16	0.06
November 18, 2013	0.26	84	3	0.09
December 13, 2013	0.20	336	6	0.04
December 17, 2013	0.24	48	4	0.06
December 23, 2013	0.34	96	4	0.09
February 25, 2014	0.43	216	7	0.06
April 24, 2014	0.45	54	9	0.05
May 12, 2014	0.45	48	7	0.07
May 27, 2014	0.46	84	8	0.06
TAPE Guideline	**0.15**	**6**	**1**	**0.03**

Table 7 – Rainfall Event Sampling Requirements
Vancouver, WA and 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]
April 5, 2011	95	100	24	18	80
April 15, 2011	100	94	26	24	100
April 26, 2011	100	96	18	24	100
May 26, 2011	100	100	20	10	100
June 20, 2011	100	100	20	20	100
July 18, 2011	100	100	22	16	95
September 26, 2011	87	100	24	18	100
November 1, 2011	82	100	24	18	100
November 11, 2013	100	100	36	20	100
November 13, 2013	81	100	48	20	96
November 18, 2013	100	100	21	12	91
December 13, 2013	100	90	36	24	100
December 17, 2013	97	95	48	24	100
December 23, 2013	100	100	36	18	100
February 25, 2014	100	100	40	18	100
April 24, 2014	100	100	32	20	100
May 12, 2014	100	100	28	14	100
May 27, 2014	100	100	32	22	100
TAPE Guideline	**75**	**75**	**10**	**10**	**91**

Notes:

1. Bypass was not specifically monitored for Grandview events in 2011; however, the pressure sensor indicates the depth of water in the system. These data were correlated to the height of the bypass weir in the influent manhole to determine an estimated bypass flow volume.

7.0A BayFilter Analytical Results

The analytical results (influent and effluent concentrations and removal efficieny) for each of the relevant/qualified rainfall events are compiled by constituent and summarized in the tables below. 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 K. The mean value of the original and duplicate sample results are reported in the tables below.

Bootstrap analysis was conducted for TSS, SSC, TP, dissolved copper, dissolved zinc, TPH Oil Range, and separator only TSS and can be found in Appendix L.

7.1A TSS and SSC

Basic treatment by the BayFilter™ EMC system is accomplished by reducing the sediments in the influent stormwater flow. TAPE has specific requirements, which are based on the influent TSS concentration, for stormwater treatment devices to meet by reducing the suspended solids (measured as TSS for less than 500 microns particles). The influent TSS concentration at 100 mg/L represents the line of division according to TAPE. Treatment devices with an influent concentration greater than 100 mg/L are required to have a minimum of 80% removal efficiency. Treatment devices with an influent concentration less than 100 mg/L are required to achieve an effluent TSS concentration of less than 20 mg/L.

The analytical results (influent and effluent concentrations) for TSS from each rainfall event are summarized below in Table 8. The calculated TSS removal efficiency for each rainfall event is also summarized below in Table 8. Of the eighteen qualified rainfalls, the average TSS removal was 87.8%. Fifteen of these qualified rainfall events had influent concentrations greater than 10 mg/L and nine qualified rainfall events had influent concentrations greater than 50 mg/ L.

Table 8 - Total Suspended Solids Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
April 5, 2011	7.5	ND[1]	66.5%
April 15, 2011	17.3	ND[1]	85.5%
April 26, 2011	7.3	ND[1]	65.8%
May 26, 2011	279	25	91.0%
June 11, 2011	8.5	ND[1]	70.6%
July 18, 2011	39[2]	ND[1]	93.5%
September 26, 2011	103[2]	9.5	90.8%
November 1, 2011	47[2]	7	85.1%
November 11, 2013	42	ND[1]	94.0%
November 13, 2013	41	10	75.6%
November 18, 2013	66	ND[1]	96.2%
December 13, 2013	195	14	92.8%
December 17, 2013	130	10	92.3%
December 23, 2013	88	ND[1]	97.1%
February 25, 2014	79	ND[1]	96.8%
April 24, 2014	45	ND[1]	94.4%
May 12, 2014	65	ND[1]	96.1%
May 27, 2014	82	ND[1]	97.0%
18 Qualified Events		**Average**	**87.8%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.
2. Subject to contamination.

Table 9 below shows the Bootstrap results for TSS at Woodinville and Grandview for all 18 events. These results also show the estimate mean at 87.8% with a standard deviation of 2.4. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 9 – Bootstrap Results TSS for Woodinville and Grandview

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	81.717	83.606	86.376	87.839	89.617	91.757	93.156	2.4259	3.2403
median	85.1	87.95	91	92.55	93.5	94.4	96.1	2.3171	2.5
midrange	80.95	81.25	81.4	81.4	81.85	83.85	91.05	1.4687	0.45
mode	65.7	66.6	85.015	87.839	94.4	97	97.1	8.6824	9.385
mode k.dens	85.3	91.931	93.428	94.562	95.595	96.579	96.814	2.6755	2.1677

The fifteen rainfall events with an influent TSS concentration of greater than 10mg/L had an average removal efficiency of 91.9% (Table 10).

Table 10 - Total Suspended Solids Influent > 10 mg/L Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
April 15, 2011	17.3	ND[1]	85.5%
May 26, 2011	279	25	91.0%
July 18, 2011	39[2]	ND[1]	93.5%
September 26, 2011	103[2]	9.5	90.8%
November 1, 2011	47[2]	7	85.1%
November 11, 2013	42	ND[1]	94.0%
November 13, 2013	41	10	75.6%
November 18, 2013	66	ND[1]	96.2%
December 13, 2013	195	14	92.8%
December 17, 2013	130	10	92.3%
December 23, 2013	88	ND[1]	97.1%
February 25, 2014	79	ND[1]	96.8%
April 24, 2014	45	ND[1]	94.4%
May 12, 2014	65	ND[1]	96.1%
May 27, 2014	82	ND[1]	97.0%
15 Qualified Events		**Average**	**91.9%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.
2. Subject to contamination.

Table 11 below shows the Bootstrap results for TSS at Woodinville and Grandview for the 15 events with influent greater than 10mg/L. These results also show the estimate mean at 91.9% with a standard deviation of 1.5. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 11 - TSS for Woodinville and Grandview – Influent > than 10mg/L

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	88.087	89.346	91.022	91.88	92.94	94.18	94.733	1.4587	1.9183
median	90.8	91	92.8	93.5	94	96.1	96.2	1.2458	1.2
midrange	85.9	86.2	86.3	86.35	91.1	91.3	94	2.4995	4.8
mode	75.6	83.912	90.702	91.88	94.9	97	97.1	4.9121	4.1975
mode k.dens	90.892	91.596	93.328	95.145	96.366	96.815	96.962	1.7988	3.0381

For the nine rainfall events with an influent TSS concentration greater than 50 mg/L The average TSS removal was 94.5% (Table 12).

Table 12 - Total Suspended Solids Influent > 50 mg/L Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
May 26, 2011	279	25	91.0%
September 26, 2011	103	9.5	90.8%
November 18, 2013	66	ND[1]	96.2%
December 13, 2013	195	14	92.8%
December 17, 2013	130	10	92.3%
December 23, 2013	88	ND[1]	97.1%
February 25, 2014	79	ND[1]	96.8%
May 12, 2014	65	ND[1]	96.1%
May 27, 2014	82	ND[1]	97.0%
9 Qualified Events		**Average**	**94.5%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.

Table 13 below shows the Bootstrap results for TSS at Woodinville and Grandview for the nine events with influent greater than 50mg/L. These results also show the estimate mean at 94.5% with a standard deviation of 0.84. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 13 - TSS for Woodinville and Grandview – Influent > than 50mg/L

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	92.6	93.066	93.844	94.456	95.033	95.756	96.211	0.8367	1.1889
median	91	92.3	92.8	96.1	96.2	96.8	97	1.8639	3.4
midrange	93.5	93.8	93.938	93.95	94.012	94.7	94.95	0.32859	0.075
mode	90.8	90.8	92.8	94.456	96.45	97.05	97.1	2.0909	3.65
mode k.dens	90.857	90.933	92.36	96.663	96.811	96.99	97.064	2.449	4.4513

In addition to TSS, SSC was also analyzed for the submitted influent and effluent samples. Examination of the influent SSC concentration was conducted using the TAPE guidelines for TSS. The eighteen qualified rainfall events had an average SSC removal of 85.7%(Table 14). Fifteen of these qualified rainfall events had influent concentrations greater than 10 mg/L and nine qualified rainfall events had influent concentrations greater than 50 mg/L.

Table 14 - Suspended Sediment Concentration Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
April 5, 2011	4.9	1.5	69.4%
April 15, 2011	17.2	1.7	90.2%
April 26, 2011	2.5	1.5	40.0%
May 26, 2011	271	21.7	92.0%
June 11, 2011	8.2	3.3	59.8%
July 18, 2011	40.6	3.2	92.2%
September 26, 2011	99.5	9.2	90.8%
November 1, 2011	49.2	6.5	86.8%
November 11, 2013	46	5.5	88.0%
November 13, 2013	38	8.1	78.7%
November 18, 2013	59	6.6	88.8%
December 13, 2013	140	13.5	90.4%
December 17, 2013	110	9.0	91.8%
December 23, 2013	93	5.0	94.6%
February 25, 2014	80	2.3	97.1%
April 24, 2014	46	2.0	95.7%
May 12, 2014	59.5	2.2	96.3%
May 27, 2014	68	ND[1]	99.3%
18 Qualified Events		**Average**	**85.7%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.

Table 15 below shows the Bootstrap results for SSC at Woodinville and Grandview for all 18 events. These results also show the estimate mean at 85.5% with a standard deviation of 3.5. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 15 - SSC for Woodinville and Grandview

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	77.171	79.45	83.383	85.528	88.032	90.792	92.122	3.4719	4.6486
median	86.8	88	90.1	90.6	91.8	92.1	92.415	1.6393	1.7
midrange	67.85	68.15	69.65	69.65	79.55	84.35	91.95	6.1499	9.9
mode	40	59.8	83.222	85.528	92.306	97.1	99.3	12.445	9.0837
mode k.dens	87.853	89.193	90.582	91.003	91.966	94.783	96.717	2.3334	1.3845

For the fifteen qualified rainfall events with an influent greater than 10 mg/L, the average SSC removal efficiency was 91.5% (Table 16).

Table 16 - Suspended Sediment Concentration Influent > 10 mg/L Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
April 15, 2011	17.2	1.7	90.2%
May 26, 2011	271	21.7	92.0%
July 18, 2011	40.6	3.2	92.2%
September 26, 2011	99.5	9.2	90.8%
November 1, 2011	49.2	6.5	86.8%
November 11, 2013	46	5.5	88.0%
November 13, 2013	38	8.1	78.7%
November 18, 2013	59	6.6	88.8%
December 13, 2013	140	13.5	90.4%
December 17, 2013	110	9.0	91.8%
December 23, 2013	93	5.0	94.6%
February 25, 2014	80	2.3	97.1%
April 24, 2014	46	2.0	95.7%
May 12, 2014	59.5	2.2	96.3%
May 27, 2014	68	ND[1]	99.3%
15 Qualified Events		**Average**	**91.5%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.

Table 17 below shows the Bootstrap results for SSC at Woodinville and Grandview for the 15 events with influent greater than 10mg/L. These results also show the estimate mean at 91.4% with a standard deviation of 1.2. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 17 - SSC for Woodinville and Grandview – Influent > than 10mg/L

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	88.258	89.219	90.585	91.353	92.187	93.234	93.881	1.2214	1.6017
median	88.8	90.1	90.8	91.8	92	92.4	95.7	1.1316	1.2
midrange	87.2	87.5	89	89	92.55	93.65	94.05	2.2004	3.55
mode	78.7	85.398	89.35	91.353	93.831	98.2	99.3	4.0774	4.4812
mode k.dens	87.624	88.744	90.516	91.082	91.958	96.11	96.923	1.7814	1.4421

The nine qualified rainfall events with an influent greater than 50 mg/L, had an average SSC removal efficiency of 93.5% (Table 18).

Table 18 - Suspended Sediment Concentration Influent > 50 mg/L Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
May 26, 2011	271	21.7	92.0%
September 26, 2011	99.5	9.2	90.8%
November 18, 2013	59	6.6	88.8%
December 13, 2013	140	13.5	90.4%
December 17, 2013	110	9.0	91.8%
December 23, 2013	93	5.0	94.6%
February 25, 2014	80	2.3	97.1%
May 12, 2014	59.5	2.2	96.3%
May 27, 2014	68	ND[1]	99.3%
9 Qualified Storms		**Average**	**93.5%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.

Table 19 below shows the Bootstrap results for SSC at Woodinville and Grandview for the nine events with influent greater than 50 mg/L. These results also show the estimate mean at 93.2% with a standard deviation of 1.1. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 19 - SSC for Woodinville and Grandview – Influent > than 50mg/L

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	90.826	91.349	92.456	93.211	93.956	95.078	95.84	1.1292	1.5
median	90.4	90.8	91.8	92	92.4	96.3	97.1	1.7456	0.6
midrange	90.6	92.55	92.95	94.05	94.05	95.05	95.55	0.92486	1.1
mode	88.8	88.8	91.2	93.211	95.15	98.2	99.3	2.7333	3.95
mode k.dens	88.809	90.012	90.866	91.382	92.055	97.349	99.213	2.3064	1.1888

7.2A Phosphorus

The influent TP concentration for the 13 rainfall events ranged from 0.055 mg/L to 0.47 mg/L. The influent and effluent TP concentrations with individual rainfall event removal efficiencies are summarized below in Table 20.

Table 20 - Total Phosphorus Analytical Results

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
April 15, 2011	0.06	0.017	69.1%
April 26, 2011	0.07	0.019	73.6%
May 26, 2011	0.38	0.067	82.2%
November 11, 2013	0.16	0.043	73.1%
November 13, 2013	0.14	0.063	55.0%
November 18, 2013	0.18	0.054	70.0%
December 13, 2013	0.47	0.14	70.2%
December 17, 2013	0.25	0.068	72.8%
December 23, 2013	0.19	0.026	86.3%
February 25, 2014	0.15	0.021	86.0%
April 24, 2014	0.18	0.05	75.0%
May 12, 2014	0.195	0.0365	81.3%
May 27, 2014	0.31	0.045	85.5%
13 Qualified Events		**Average**	**75.4%**

However, while TAPE guidelines require the BayFilter System to be capable of treating influent TP concentrations of greater than 0.1 mg/L, no guidance is supplied for influent TP concentrations less than 0.1 mg/L. Eleven of the 13 rainfall events from these field monitoring activities had an influent TP concentration less than 0.1 mg/L, but these samples were rounded to 0.1. The 13 qualified events listed above had an average TP removal efficiency of 75% (Table 20).

Table 21 below shows the Bootstrap results for TP at Woodinville and Grandview for all 13 qualifying events. These results also show the estimate mean at 75.4% with a standard deviation of 2.3. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 21 - Total Phosphorus for Woodinville and Grandview

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	69.462	71.538	73.883	75.392	76.956	79.169	80.27	2.3102	3.0731
median	70	70.2	73.1	73.6	75	82.2	85.5	3.5319	1.9
midrange	68.15	70.25	70.65	70.65	77.7	78.15	78.25	3.5724	7.05
mode	55	55	71.373	75.392	81.3	86	86.3	7.2441	9.9271
mode k.dens	69.463	69.889	71.53	72.067	82.235	85.807	86.016	5.8998	10.705

7.3A Dissolved Zinc

Enhanced treatment by the BayFilter EMC System is accomplished by absorption of influent dissolved zinc on the filter media. The influent and effluent dissolved zinc concentrations are summarized below in Table 22. Influent dissolved zinc concentrations ranged from 18 µg/L to 285 µg/L. Individual rainfall event removal efficiency ranged from 21.4% to 90.8%. Based on the field monitoring conducted on the Sites, the average dissolved zinc removal efficiency was 61.5% (Table 22).

Table 22 - Dissolved Zinc Analytical Results

Rainfall Event	Influent Concentration (ug/L)	Effluent Concentration (ug/L)	Removal Efficiency
April 5, 2011	18	6.8	62.2%
April 15, 2011	20.7	1.9	90.8%
April 26, 2011	39.3	13.5	65.6%
June 11, 2011	18.8	10.1	46.3%
November 13, 2013	70	36	48.6%
November 18, 2013	81	29	64.2%
December 13, 2013	285	91	68.1%
December 17, 2013	140	110	21.4%
December 23, 2013	120	30	75.0%
April 24, 2014	140	36	74.3%
May 12, 2014	96.5	39.5	59.1%
May 27, 2014	150	57	62.0%
12 Qualified Events		**Average**	**61.5%**

Table 23 below shows the Bootstrap results for Dissolved Zinc at Woodinville and Grandview for all 12 qualifying events. These results also show the estimate mean at 61.5% with a standard deviation of 4.7. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 23 - Dissolved Zinc for Woodinville and Grandview

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	50.075	53.648	58.512	61.467	64.821	68.905	72.451	4.7253	6.3083
median	48.6	55.4	62.1	63.2	64.9	69.25	74.3	3.6629	2.8
midrange	44.75	47.85	56.1	56.1	68.55	69.7	74.95	8.0284	12.45
mode	21.4	21.4	55.512	61.467	68.1	80.159	90.8	13.861	12.587
mode k.dens	46.856	56.562	62.463	63.6	65.568	74.183	74.849	5.3641	3.1052

7.4A Dissolved Copper

Like dissolved zinc, dissolved copper is part of TAPE's enhanced treatment guidelines. The removal of copper by the BayFilter System is accomplished by absorption of influent dissolved copper on the filter media. The influent and effluent dissolved copper concentrations are summarized below in Table 24. Influent total copper concentrations ranged from 9.1 μg/L to 25 μg/L. Individual rainfall event removal efficiency ranged from 22.8% to 52.7%. Based on the field monitoring conducted on the Site, the mean removal efficiency was 36% (Table 24).

Table 24 - Dissolved Copper Analytical Results

Rainfall Event	Influent Concentration (ug/L)	Effluent Concentration (ug/L)	Removal Efficiency
April 5, 2011	9.1	4.3	52.7%
April 15, 2011	9.6	5.2	45.8%
April 26, 2011	15.8	9.1	42.4%
June 11, 2011	9.2	7.1	22.8%
April 24, 2014	18	15	16.7%
May 12, 2014	14.5	9.15	36.9%
May 27, 2014	25	17	32.0%
7 Qualified Events		**Average**	**36%**

Despite only having seven qualified rainfall events for acceptable dissolved copper levels, the small sample size produced an average removal efficiency of 36% (Table 24).

Table 25 below shows Bootstrap results for Dissolved Copper at Woodinville and Grandview for all 7 qualifying events. These results also show the estimate mean at 35.6% with a standard deviation of 4.3. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 25 - Dissolved Copper for Woodinville and Grandview

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	25.614	28.57	32.204	35.614	38.636	42.358	45.101	4.3226	6.4321
median	16.7	22.8	32	36.9	42.4	45.8	45.869	6.6136	10.4
midrange	26.8	29.55	31.25	34.7	37.75	42.35	42.35	3.4513	6.5
mode	16.7	16.7	29.85	35.614	42.4	52.7	52.7	9.5814	12.55
mode k.dens	16.7	19.75	32.489	38.837	44.039	50.624	52.694	8.9328	11.55

7.5A Particle Size Distribution (PSD)

PSD analysis was conducted on the influent stormwater samples collected from eight rainfall events from Woodinville Sammamish and eleven rainfall events from Grandview Place Apartments as part of these field testing activities (data in Appendix M, 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 basic treatment (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, TSS from rainfall events in the Pacific Northwest (according to TAPE) consists of silts, clays, and fine sands. Table 26 below contains the USDA soil classification system designations for soil particle size.

Table 26 – Soil Classification
Grandview Place Apartments and Woodinville Sammamish

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 at had a mean TSS influent concentration that consisted mainly of silts and fine sands. At the Woodinville site 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). At the Grandview site the diameter of particles that comprise ten percent or less of the sample ("d_{10}") was 12.7 microns (flow-weighted basis). The diameter of the particles that comprise ninety percent or less of the sample ("d_{90}") was approximately 142.4 microns. The median diameter (particle that comprise fifty percent or less of the sample) ("d_{50}") was 55.3 microns (silts). Table 27 contains the mean particle size distribution for the influent flow to the

BayFilter EMC and BaySeparator Systems at Woodinville and Table 28 at Grandview. Stormwater runoff is a mixture of sediment and organic particles, which are all measured based on their optical properties (assumed to be spherical, isotropic, 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 27 – Particle Size Distribution Influent Concentration Woodinville, Washington

Parameter	Mean	Flow-Weighted Mean
Median Particle Size (microns)	53.81	54.22
d10 (microns)	9.49	9.30
d50 (microns)	53.81	54.22
d90 (microns)	200.97	192.25

Table 28 – Particle Size Distribution Influent Concentration Vancouver, Washington

Parameter	Mean	Flow-Weighted Mean
Median Particle Size (microns)	55.3	47.0
d10 (microns)	12.7	10.0
d50 (microns)	55.3	47.0
d90 (microns)	142.4	136.7

7.6A TPH Oil Range

Table 29 below shows the ability of the BayFilter to remove TPH Oil. The average removal efficiency for TPH Oil was 88.1% in eight qualified events.

Table 29 – TPH Oil Range Analytical Results

Rainfall Event	Influent Concentration (ug/L)	Effluent Concentration (ug/L)	Removal Efficiency
November 11, 2013	1600	380	76.3%
November 18, 2013	1500	280	81.3%
December 17, 2013	1400	300	78.6%
December 23, 2013	3000	ND[1]	95.8%
February 25, 2014	2100	ND[1]	94%
April 24, 2014	2900	ND[1]	95.7%
May 12, 2014	1900	ND[1]	86.8%
May 27, 2014	3600	ND[1]	96.5%
8 Qualified Events		**Average**	**88.1%**

Notes:

1. Half of the reporting limit concentration used for ND values to determine removal efficiency.

Table 30 below shows the bootstrap data for TPH Oil range removal. These results also show the estimate mean at 69.77% with a standard deviation of 3.9. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 30 - TPH Oil Range for Woodinville

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	82.51	84.01	86.35	88	89.77	91.98	93.32	2.445	3.417
median	78.6	81.3	86.8	88.1	94	95.4	95.7	4.788	7.2
midrange	85.15	85.85	86.05	86.05	87.2	88.55	91.3	1.159	1.15
mode	76.3	76.3	82.7	88	94	95.8	95.8	6.15	11.3
mode k.dens	76.96	78.09	87.05	95.06	95.37	95.68	95.76	6.542	8.321

7.0B BaySeparator Analytical Results

Basic treatment by the BaySeparator system is accomplished by reducing the sediments in the influent stormwater flow. TAPE has specific requirements, which are based on the influent TSS concentration, for stormwater treatment devices to meet by reducing the suspended sediments (measured as TSS for less than 500 microns particles). The influent TSS concentration at 100 mg/L represents the line of division according to TAPE. TAPE guideline requires 50% TSS removal if influent TSS > 100 mg/L, if influent TSS <100 mg/L, and also should meet 50mg/L effluent discharge standard. Treatment devices with an influent concentration less than 100 mg/L are required to achieve an effluent TSS concentration of less than 20 mg/L.

7.1B TSS Removal BaySeparator

Table 31 below shows the BaySeparator alone can remove significant amounts of TSS. Out of the nine qualifying events, eight passed by meeting the minimum requirement of 50% TSS removal. According to Table 26, the BaySeparator system had an average removal efficiency of 70% in six qualifying events when the influent was greater than 50 mg/L.

Table 31 – BaySeparator TSS Removal With Influent > 50 mg/L

Rainfall Event	Influent Concentration (mg/L)	Effluent Concentration (mg/L)	Removal Efficiency
November 18, 2013	66	18.5	72%
December 13, 2013	195	70	64.1%
December 17, 2013	130	51	60.8%
December 23, 2013	88	7	92%
February 25, 2014	79	22	72.2%
May 27, 2014	82	35	57.3%
6 Qualified Events		**Average**	**70%**

Table 32 below shows Bootstrap results for BaySeparator TSS removal at Woodinville Sammamish for all 6 qualifying events. These results also show the estimate mean at 69.77% with a standard deviation of 3.9. The table also shows median, midrange, mode, and mode k. density for each percentile, quartile, and interquartile range.

Table 32 - Separator Only TSS for Woodinville

Estimation Results of Bootstrap									
statistic	P1	P5	Q1	Estimate	Q3	P95	P99	S.D.	IQR
mean	62.39	63.87	66.85	69.77	72.35	76.8	78.51	3.902	5.496
median	60.8	60.8	64.1	70	72	72.2	72.2	4.565	7.9
midrange	63.65	64.65	66.47	74.65	76.4	78.05	81	5.038	9.925
mode	57.3	57.3	64.1	69.77	72.2	92	92	9.047	8.1
mode k.dens	57.56	58.4	62.14	71.04	71.72	72.15	92	5.886	9.579

8.0 Data Validation

A review of the analytical laboratory reports (Appendix J) was conducted for discrepancies and deviations from the QAPP. The method reporting limits and reporting limits listed in the QAPP were evaluated. The collection of field blanks and field duplicate samples is discussed below. Problems encountered during sampling are also discussed and analyzed below.

The Grandview Place Apartments QAPP contains the analytical methods and their respective reporting limits. The analytical laboratory used the same analytical methods as specified in the QAPP, and with the exception of TSS, the same reporting limits (Table 33). The QAPP listed a reporting limit of 1 mg/L though the analytical laboratory had a method-reporting limit of 5.0 mg/L. This difference likely did not affect the results being reported, because a reported value of ND (less than 5 mg/L) was below the effluent TSS concentration limit of 20 mg/L. None of the rainfall events with an influent TSS concentration of greater than 100 mg/L had an ND reported for the effluent TSS concentration, which could potentially have affected the calculated removal efficiency (Table 6).

Table 33 – Constituents Method Reporting Limits and QAPP Reporting Limits Grandview Place Apartments, Vancouver, Washington

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

The Woodinville Sammamish QAPP contains the analytical methods and their respective reporting limits. The ALS laboratory used the same analytical methods as specified in the QAPP, and with the exception of TSS, the same reporting limits (Table 34). The QAPP listed a reporting limit of 1 mg/L though the ALS laboratory had a method reporting limit of 5.0 mg/L. This difference likely did not affect the results being reported, because a reported value of ND (less than 5 mg/L) was below the effluent TSS concentration limit of 20 mg/L. None of the rainfall events with an influent TSS concentration of greater than 100 mg/L had an ND reported for the effluent TSS concentration, which could potentially have affected the calculated removal efficiency (Table 8).

Table 34 – 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	µg/L	2.0	0.1
Total Zinc	µg/L	2.5	0.5
Dissolved Copper	µg/L	2.0	1.0
Dissolved Zinc	µg/L	2.5	0.5
PSD	--	--	--

Some of the data recorded at the Grandview Place Apartments was subject to contamination on June 28, 2011, most likely due to a construction washout. A milky runoff found inside the system and only TSS data was used after this point because of the likelihood of unusual chemistry associated with the runoff.

9.0 Conclusion

BaySaver's field testing program consisted of monitoring and sampling 18 qualified rainfall events under TAPE guidelines for rainfall event precipitation amount, duration, and intensity. The manufacturer's (BaySaver) data shows that the BayFilter™ EMC System can achieve greater than 80% removal of TSS from stormwater and greater than 50% removal of TP. This study evaluated these past results under TAPE guidelines for sites in Vancouver, Washington and Woodinville, Washington.

The TAPE guidelines call for 80% removal of TSS when qualified rainfall events have an influent TSS concentration greater than 100 mg/L. When rainfall events have an influent TSS concentration of less than 100 mg/L, the treatment technology should be capable of removing TSS to a concentration of less than 20 mg/L in the effluent discharge. Based on the analytical results reported, BaySaver achieved 87.8% removal of TSS from all the 18 qualified storms. BaySaver achieved 94.5% removal of TSS in nine qualified events that had an influent greater than 50 mg/L. All filter effluent was less than 20mg/L independent of influent concentration, with the exception of one storm that had an influent of 279 mg/L and effluent of 25 mg/L.

The target treatment goal was greater than 50% removal of influent TP concentrations greater than 0.1 mg/L per TAPE guidelines. The BayFilter EMC System achieved 75% removal efficiency for qualified rainfall events with an influent TP concentration greater than 0.1 mg/L.

According to the TAPE guidelines, enhanced treatment is accomplished by having "significantly higher removal rates" than stormwater treatment devices capable of basic treatment (Washington State Department of Ecology, 2008). Based on the analytical results reported, BaySaver achieved 61.5% removal of dissolved zinc when influent stormwater dissolved zinc concentrations were greater than 20 μg/L. The BayFilter was also able to remove 88.1% of TPH Oil Range in eight qualifying events.

The field monitoring program conducted from November 2011 until May 2014 by BaySaver was designed to assess whether the BayFilter EMC and BaySeparator Systems were capable of meeting DOE TAPE requirements for basic treatment (TSS removal), phosphorus treatment (TP removal), enhanced treatment, and oil and greases. The testing will continue until sufficient qualifying events have been recorded to meet the dissolved copper requirements.

10.0 References

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Figure 1: Plan View of Grandview Place Apartments BayFilter Treatment System

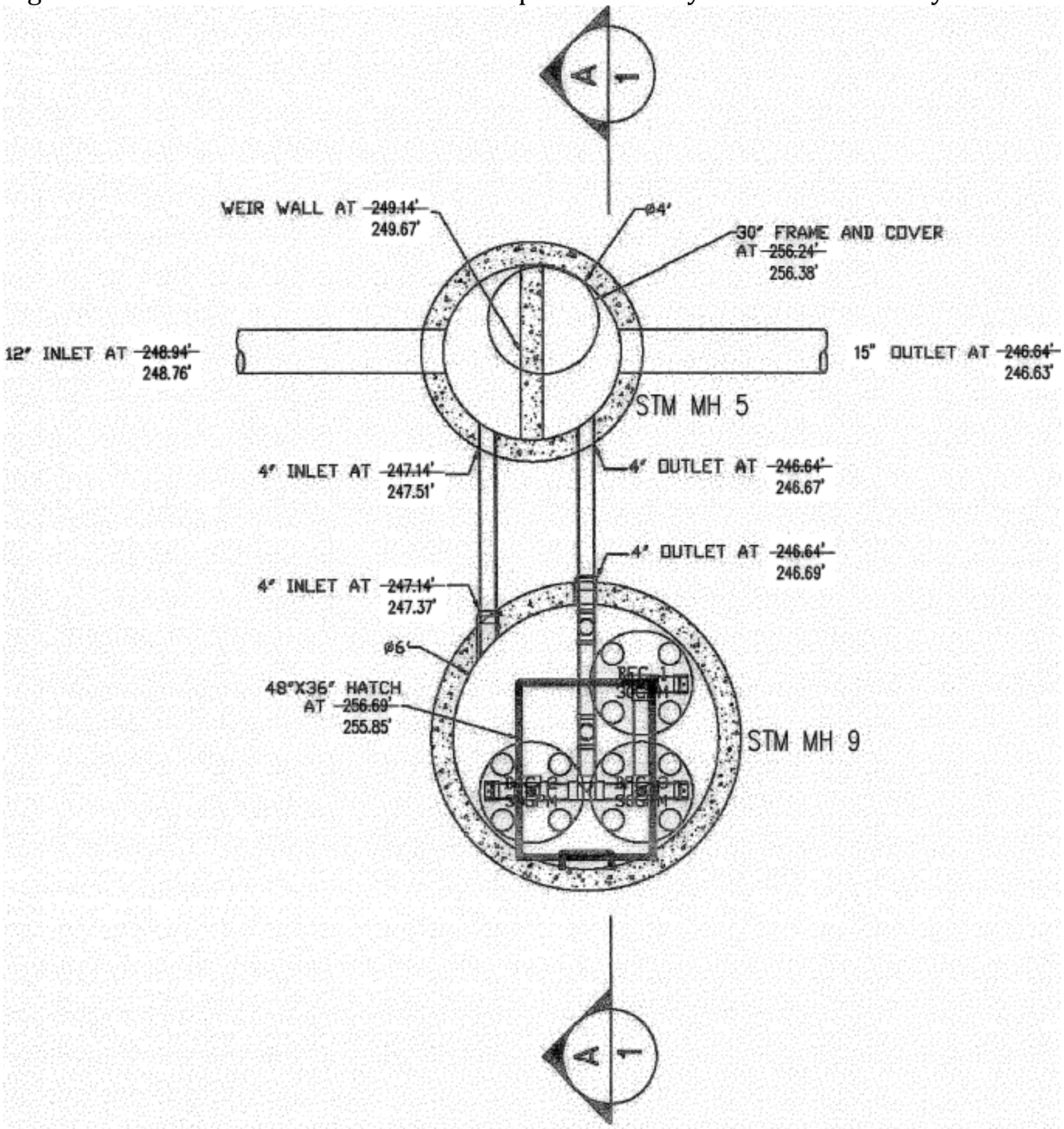

Figure 2: Profile View of Grandview Place Apartments BayFilter Treatment System

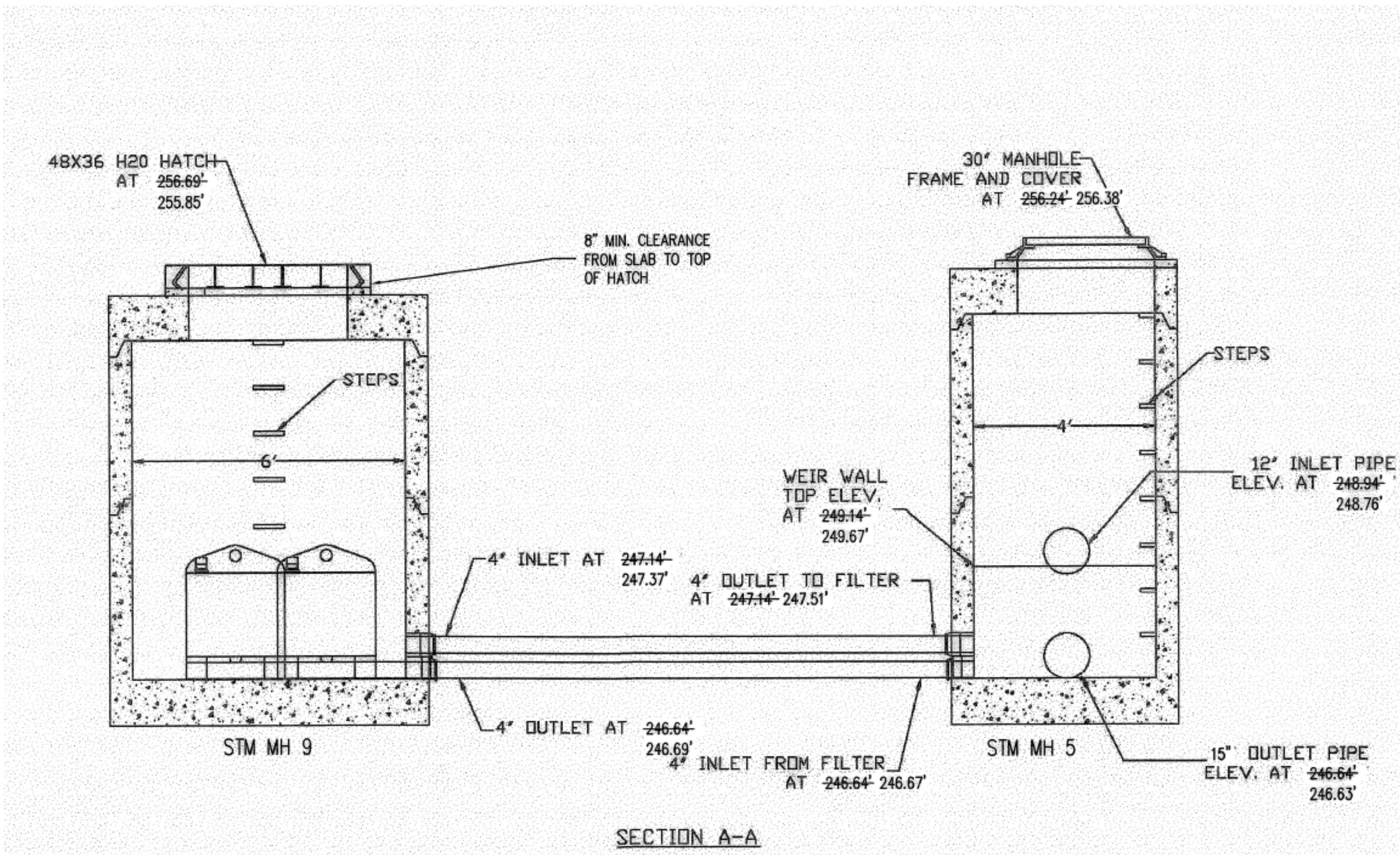

Figure 3: Plan View of Woodinville Sammamish BayFilter Treatment System

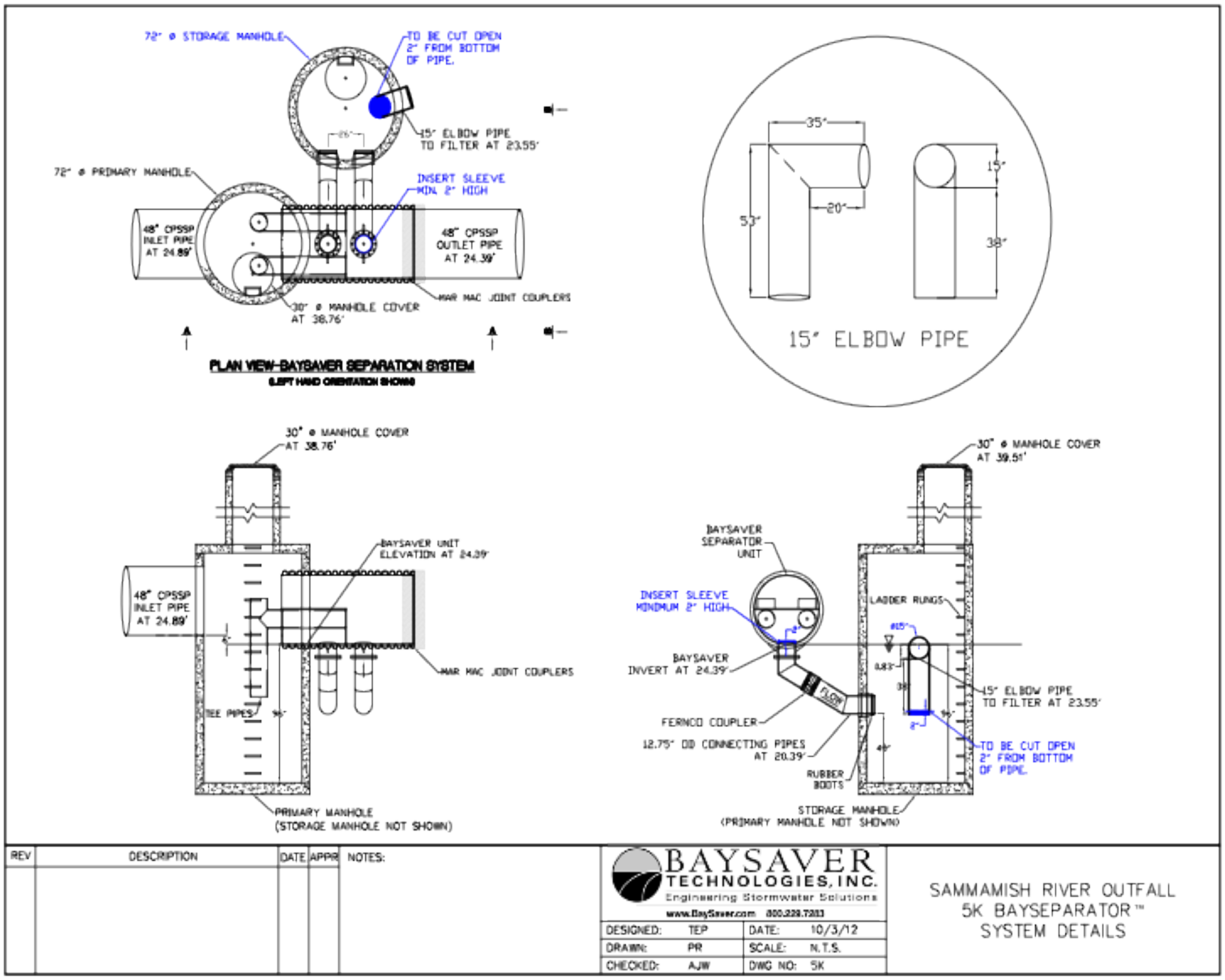

Figure 4: Profile View of Woodinville Sammamish BayFilter Treatment System

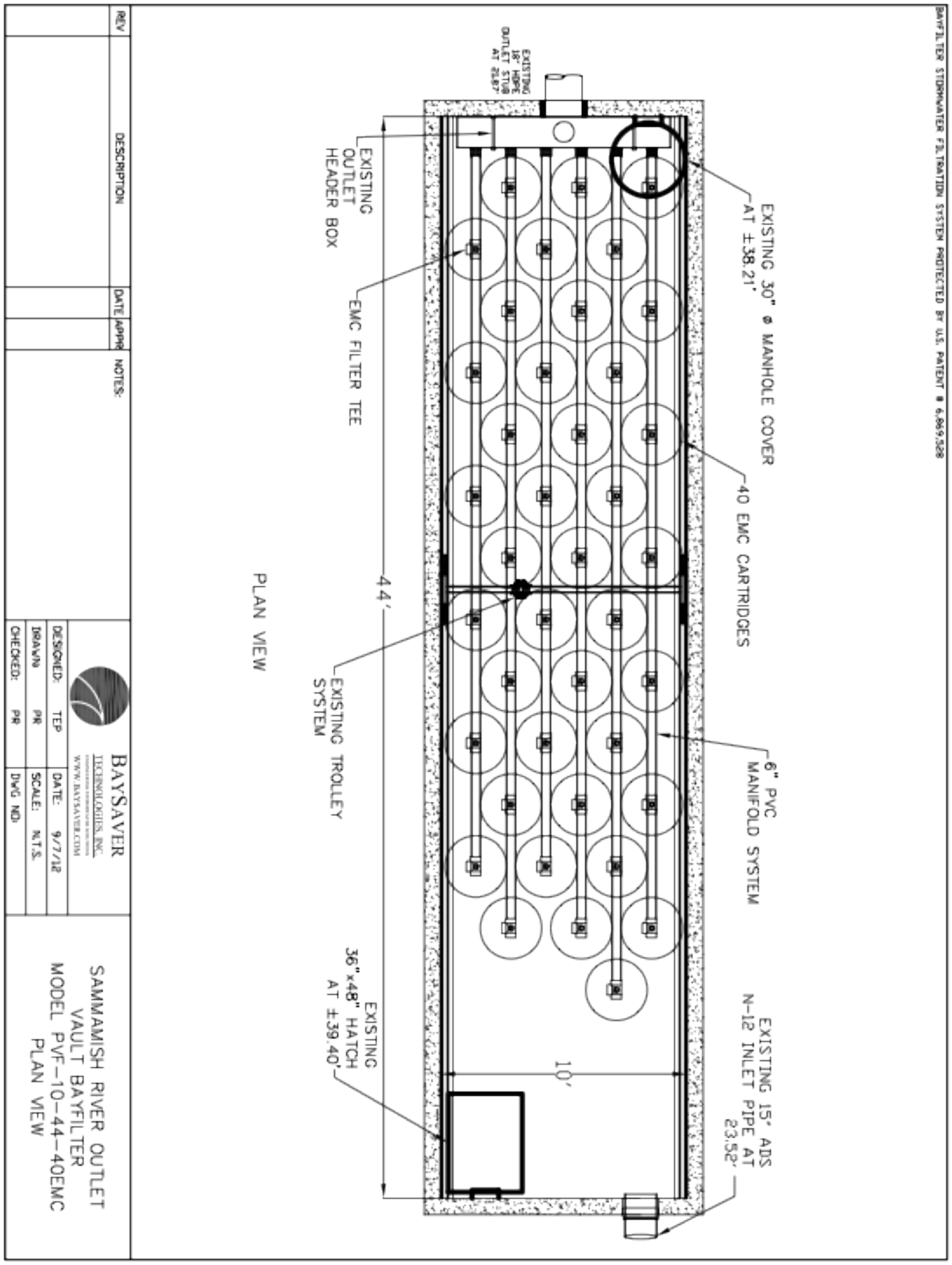

Figure 5: BayFilter Cartridge

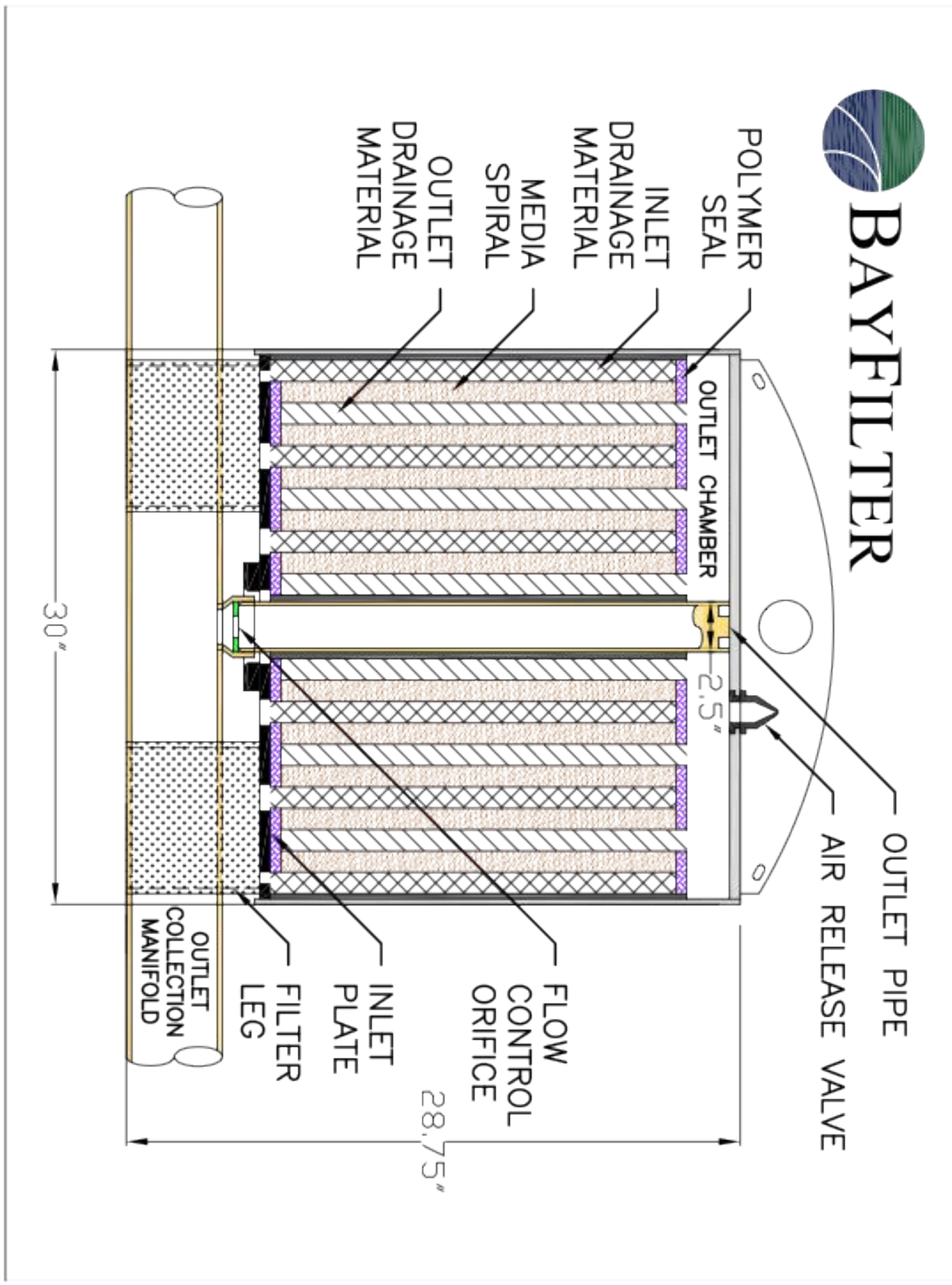

Figure 6: BayFilter Cartridge Fill and Air Release

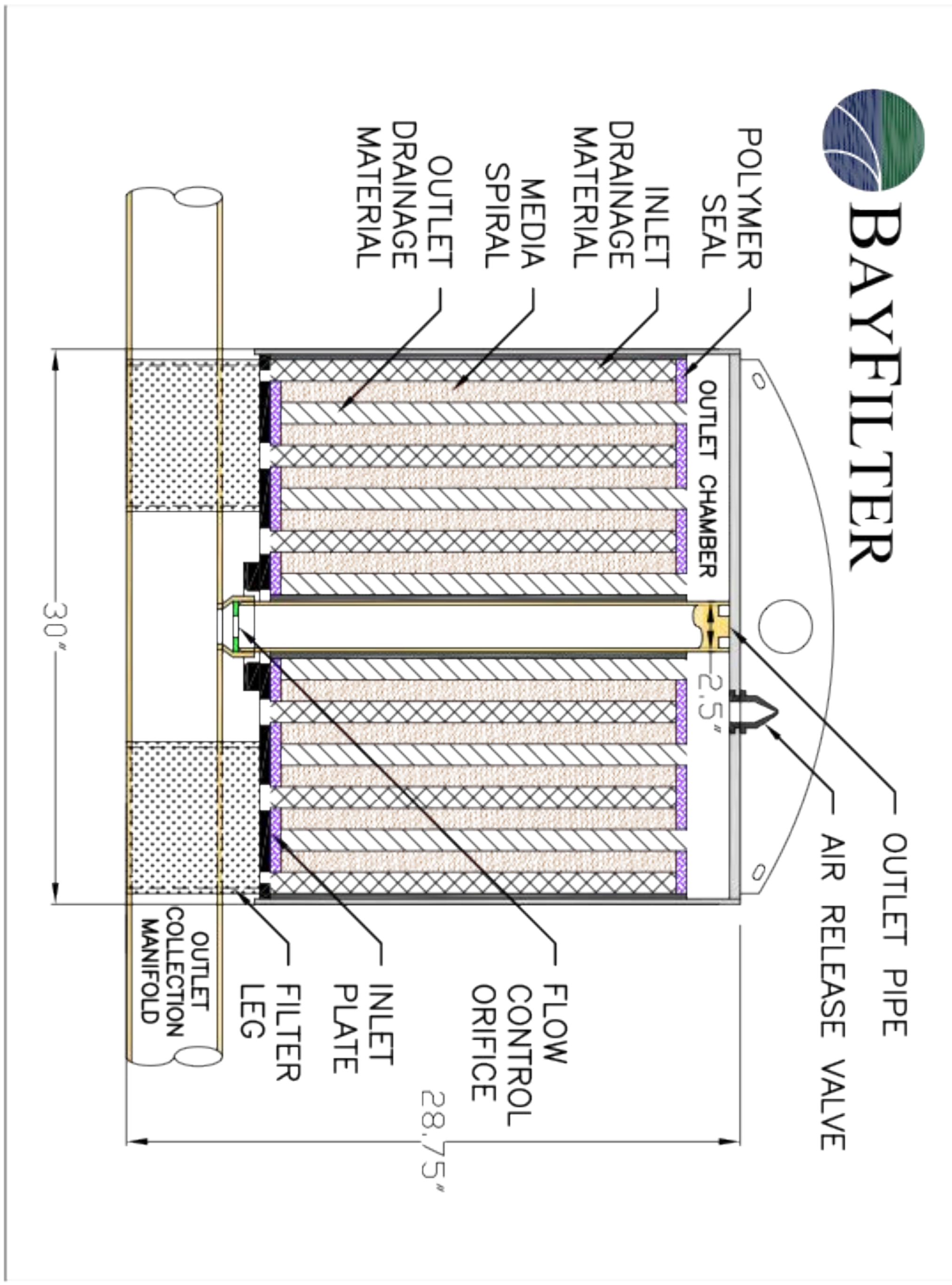

Figure 7: BayFilter Cartridge Operation

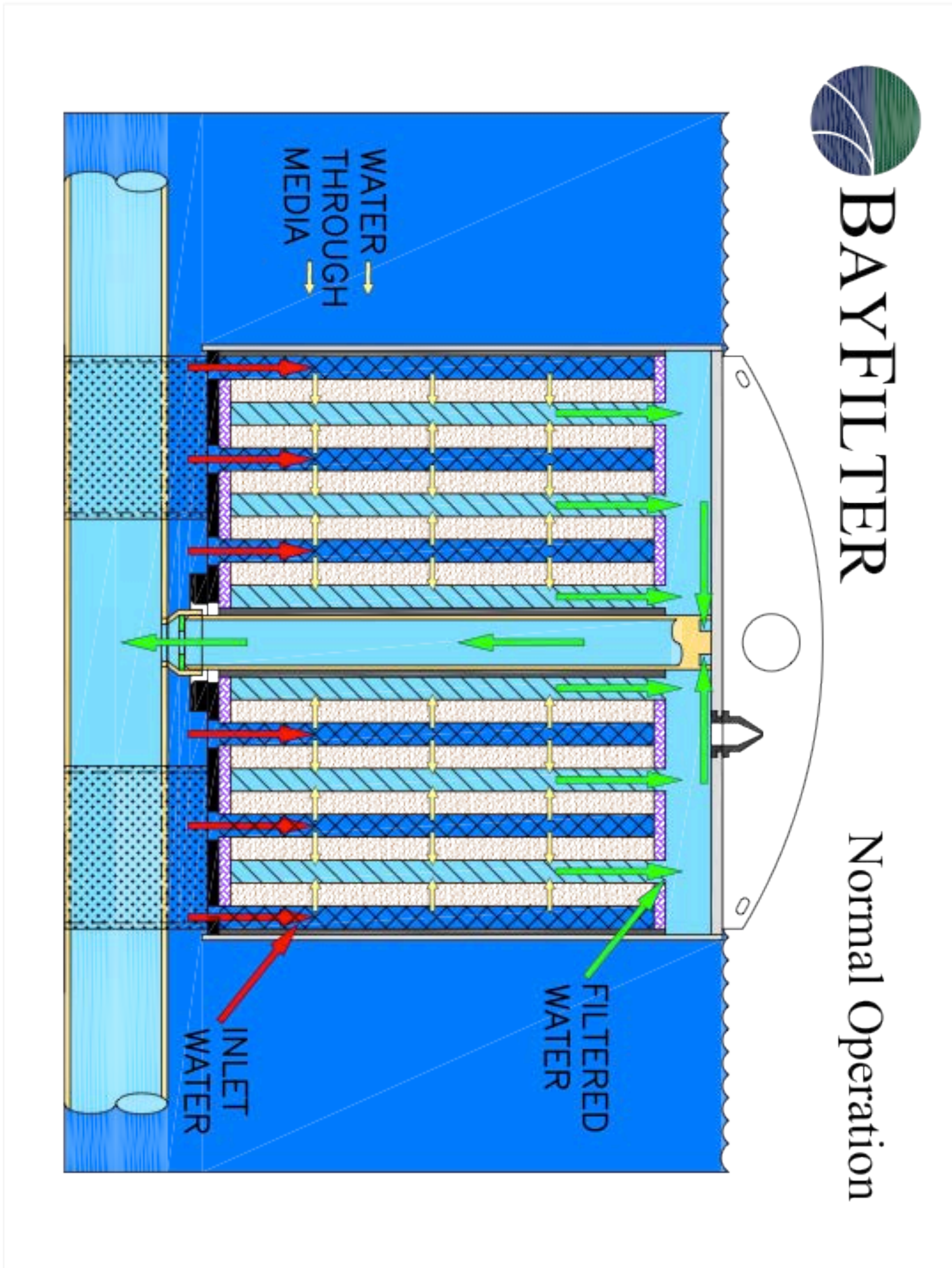

Figure 8: BayFilter Cartridge Siphon Operation

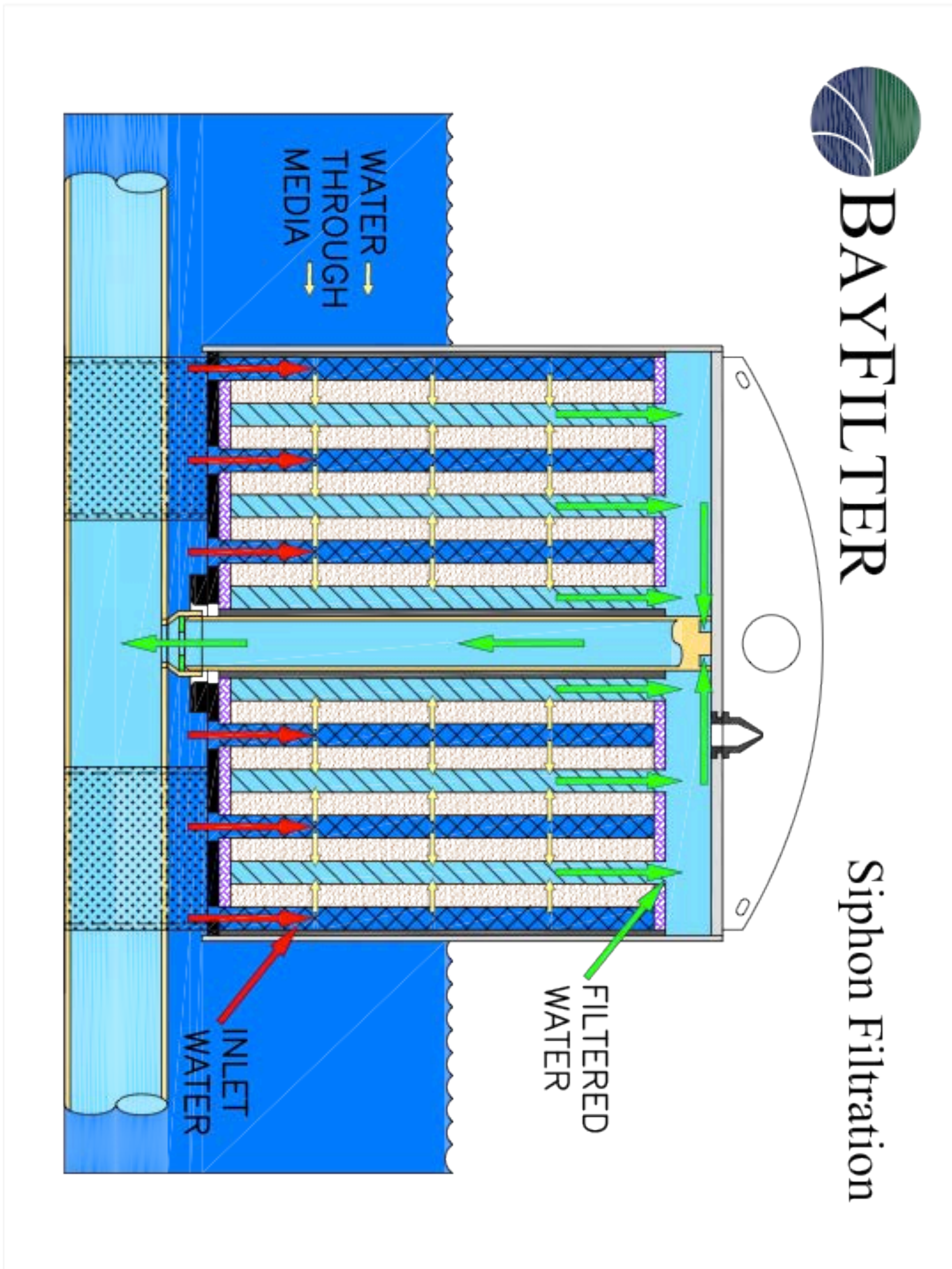

Figure 9: BayFilter Cartridge Siphon Break

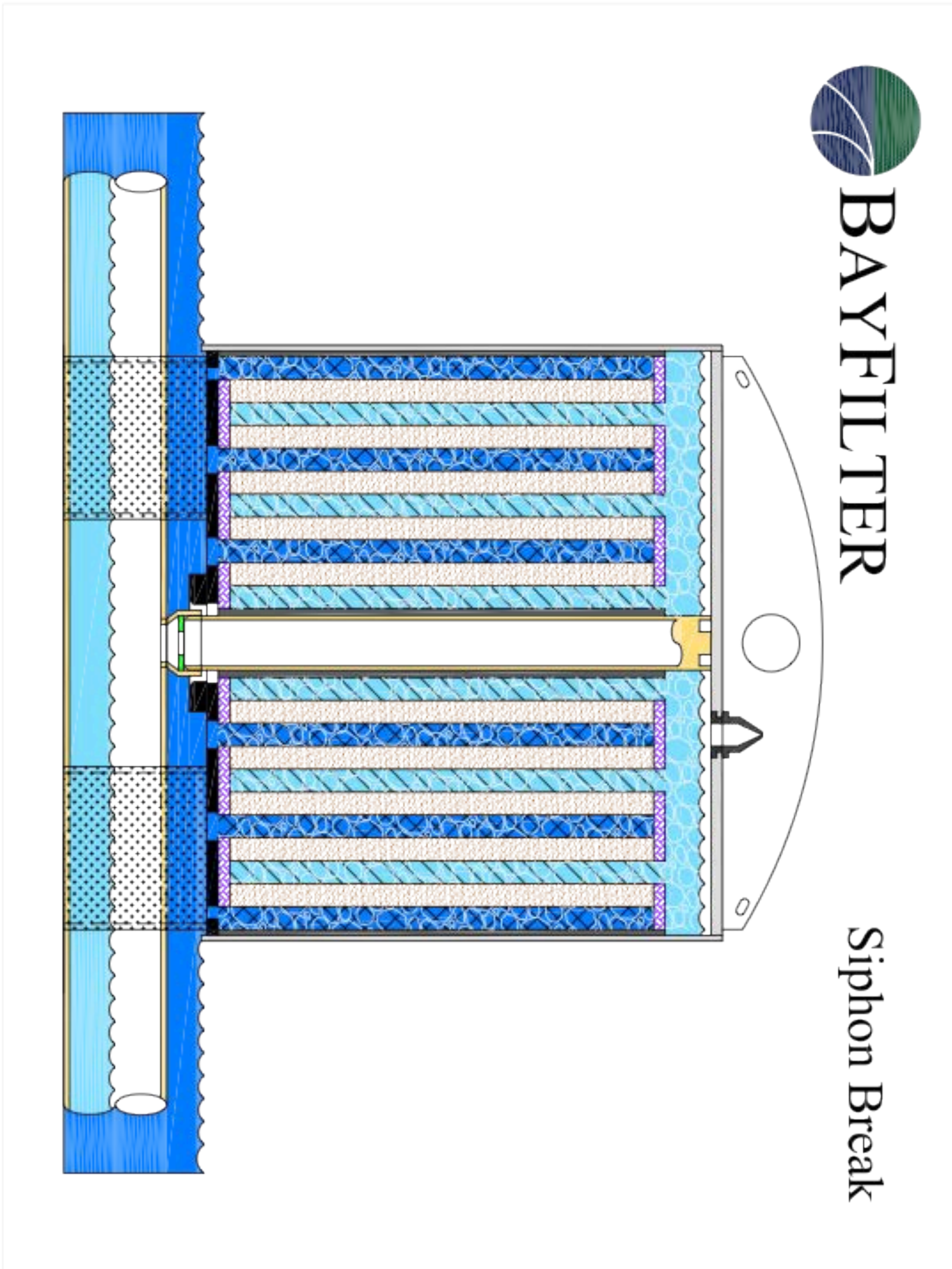

Figure 10: BayFilter Cartridge Backwash

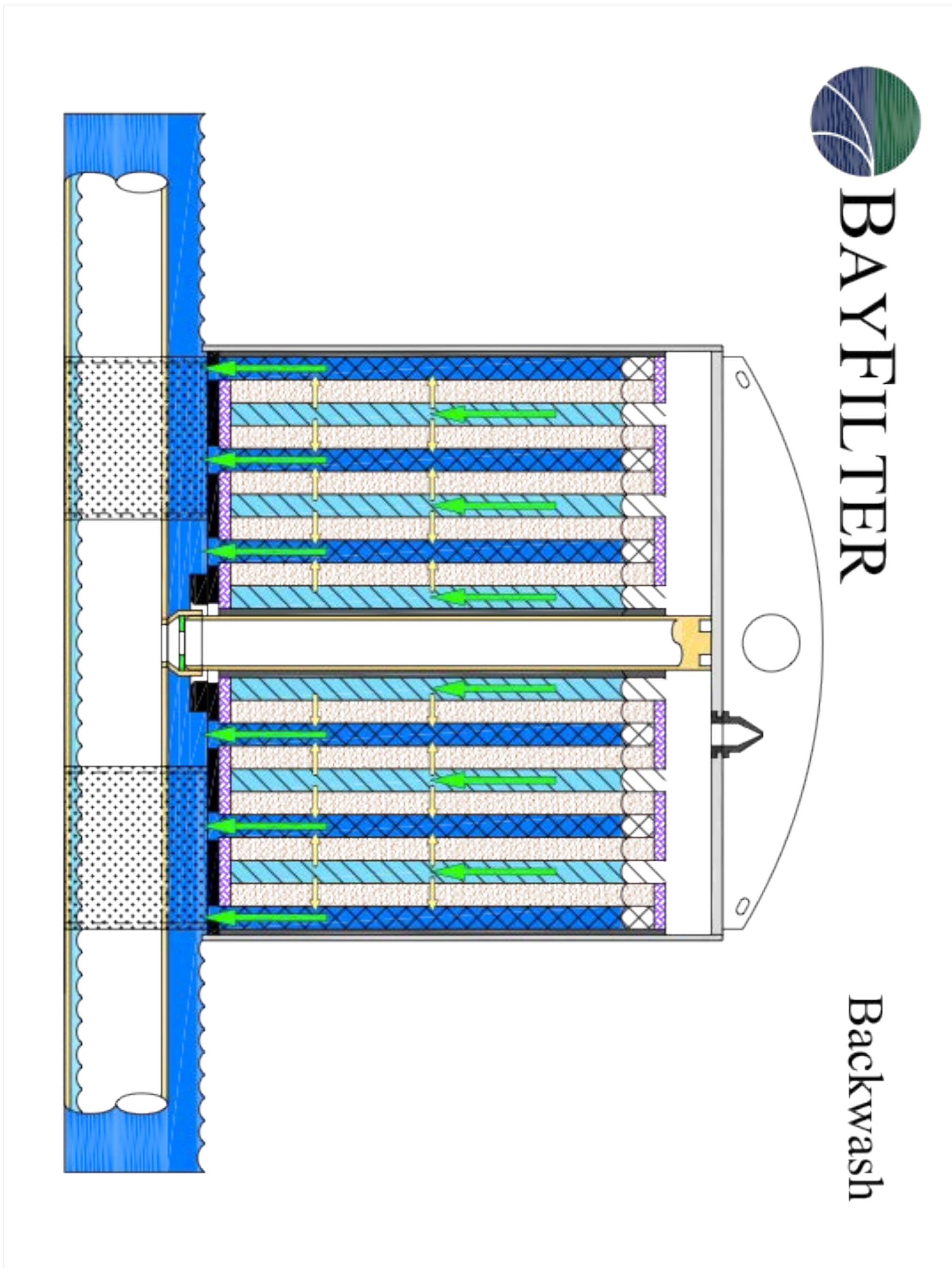

Figure 11: BaySeparator Storage

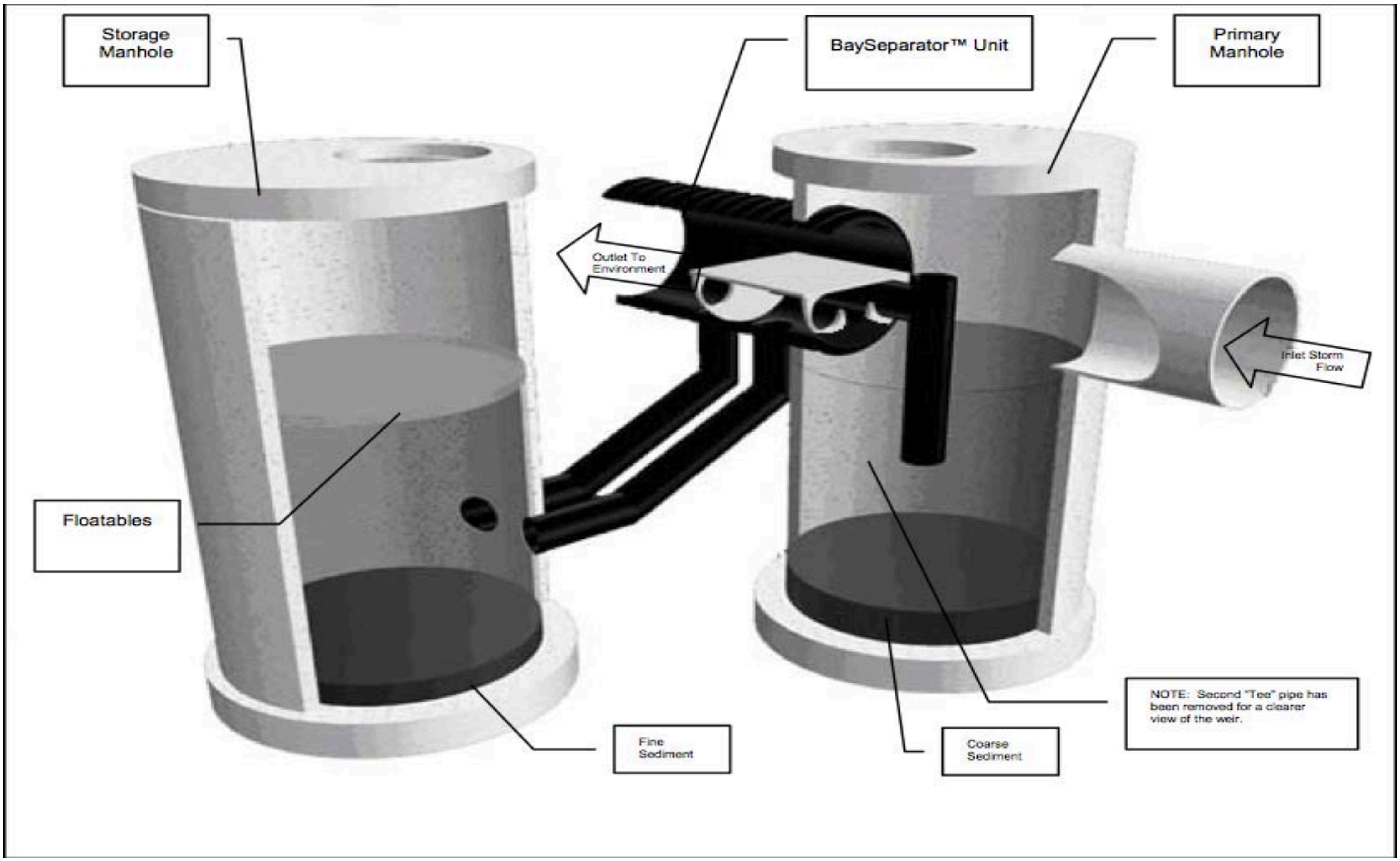

Figure 12: BaySeparator Operation