Eastern Washington Stormwater Effectiveness Studies

Quality Assurance Project Plan

Sand Filter Sidewalk Vault BMP

Study Classification: Structural BMP

Study Objective(s): ☑ Evaluate Effectiveness ☑ Develop New BMP

November 1st, 2018

Prepared For:

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Proposal and QAPP Publication Information

This Detailed Study Design Proposal (Proposal) and Quality Assurance Project Plan (QAPP) will be stored and accessible to the public on the Spokane County's website: https://www.spokanecounty.org/918/Stormwater-Utility. For questions regarding the Proposal, please contact Matt Zarecor by email MZarecor@spokanecounty.org or phone (509) 477-7255.

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Document History

This document was developed following the Eastern Washington (EWA) Detailed Study Design Proposal and Quality Assurance Project Plan Template for Structural Best Management Practices (BMPs). A copy of the template is located on the City of Spokane Valley's website at the following web link: http://www.spokanevalley.org/content/6836/6896/6914/8301/10121/default.aspx

The Detailed Study Design Proposal (Proposal) was submitted to Ecology on June 30, 2017. Ecology approved the Proposal via email to Spokane County on November 8th, 2017. Appendix A contains a copy of the email along with Ecology's comments on the Proposal. Appendix B contains a summary of HDR's responses to Ecology's comments including how the comments were incorporated into the Quality Assurance Project Plan (QAPP).

The draft QAPP was reviewed by members of the Technical Advisory Group (TAG) in April 2018. Appendix C contains a summary of the TAG's comments along with a summary of HDR's response to these comments including how the comments were addressed in this document. The QAPP was submitted to Ecology by the May 8, 2018 deadline for their review and comment. Comments from Ecology on the QAPP were provided via email on August 30th. Appendix D contains a copy of Ecology's QAPP review comments along with HDR's responses to the comments including how the comments were incorporated into the final QAPP document.

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1.0 Table of Contents

2.0 Executive Summary

Constructing BMPs at sites with space constraints creates a challenge for jurisdictions. A viable solution is to develop BMPs that can fit into these built areas, such as the proposed sand filter sidewalk vault. A sand filter sidewalk vault is a variation of the basic sand filter vault BMP that is defined the Ecology stormwater manuals for Washington State. Specifically, a sand filter sidewalk vault is located below grade in a vault that fits underneath the sidewalk. The primary differences between the proposed sand filter sidewalk vault and the basic sand filter vault are, the proposed BMP does not utilize a pretreatment cell and is designed to accept runoff from a larger contributing basin area. The goal for this study is to evaluate the effectiveness of the proposed BMP. Effectiveness will be based upon:

- The ability of the BMP to infiltrate stormwater during 6-month 24-hour storm events without overflowing into the bypass system within the maintenance cycle
- The efficacy of the BMP to reduce the concentrations of total suspended solids (TSS), dissolved copper (Cu) and zinc (Zn), and oils, which will be evaluated to determine whether the BMP can achieve the respective Ecology treatment goals

If these objectives can be met, the results from this study will be used to justify the development of a new BMP that is approved for 'general use' on future projects.

The goals for this study will be achieved by conducting flow-through column testing and field testing the BMP. The column testing was conducted prior to the development of this QAPP. The purpose of this testing was to define BMP design and maintenance guidance. The field testing includes installing the sand filter sidewalk vault at a test-site in Spokane, WA and using automated equipment to collect data. The data to be collected includes pollutant concentrations from water quality samples (influent and effluent), the flow rate (influent, effluent, and overflow), and precipitation depth. Data will be collected from a minimum of 12 qualifying storm events over two wet seasons starting in the fall of 2018.

3.0 Introduction and Background

3.1 Introduction to the Structural BMP

The focus of this study is to evaluate the effectiveness of a new sand filter BMP (referred to as the sand filter sidewalk vault). This BMP will be installed below grade in a sidewalk vault (Figure 3.1). The top of the vault is a section of the sidewalk and runoff enters the vault through a curb cut located in the gutter. The sidewalk vault is 5-feet long and the same width as the sidewalk (4-feet). The primary components of this BMP are a sand filtration layer, an underdrain pipe, and a bypass pipe. The sand filtration layer will consist of an 18-inch layer of coarse sand which is overlaid by an organic material (coconut coir mat) that provides some pre-treatment through cation exchange capacity (CEC) and dissipates the energy of stormwater runoff that enters the sidewalk vault. Treated runoff infiltrates through a 3 inches of the choke stone layer (3/8-inch Pea Gravel) and discharges into an underdrain which routes runoff to a drywell or to a storm drain network.

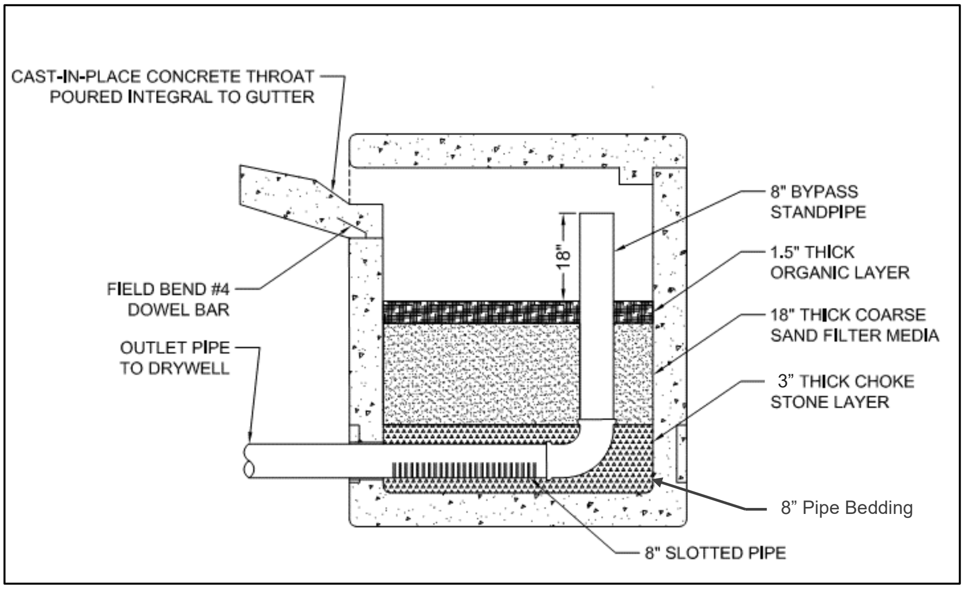

Figure 3.1 Cross Section of Sand Filter in Sidewalk Vault

The proposed sand filter sidewalk vault BMP design criteria is similar to the existing basic sand filter vault BMP defined in the Ecology Stormwater Manual (Ecology, 2004). Specifically, the proposed BMP is designed to treat 90% of the annual runoff volume (6-month 24-hour depth), while the volume of runoff from larger storms will overflow into a bypass pipe located 18-inches above the sand media. Differences between the proposed and existing sand filter vault BMP are summarized in Table 3.1. A primary difference is that the proposed BMP does not have a pretreatment cell to collect and remove gross solids prior to discharging into the BMP. As such the maintenance cycle of the proposed BMP is expected to be shorter (less time between cycles) when compared to the existing BMP.

Table 3.1 Comparison of Existing Basic Sand Filter Vault and Proposed Sand Filter Sidewalk Vault

<table>
<tr><th></th><th colspan="2">Existing
Sand Filter Vault BMP (Ecology, 2004)</th><th colspan="2">Proposed
Sand Filter Sidewalk Vault BMP</th></tr>
<tr><td>Pretreatment</td><td colspan="2">This BMP is contained in a vault which consists of two cells: a pretreatment cell and a sand filtration cell. Stormwater runoff enters the pretreatment cell where the runoff velocity is reduced and gross solids and oils are removed. Runoff then overflows into the sand filtration cell where TSS is reduced as runoff infiltrates through the sand media.</td><td colspan="2">This BMP consists of a single cell with no pretreatment. Stormwater runoff along with gross solids and oils from the contributing basin area enter the sand filtration cell where the runoff velocity is reduced by the coconut coir mat. Gross solids settle on top of the BMP and TSS is reduced as runoff infiltrates through the sand media.</td></tr>
<tr><td rowspan="10">Sand Media Gradation</td><td colspan="2">Medium Sand</td><td colspan="2">Coarse Sand</td></tr>
<tr><td>Particle Diameter (mm)</td><td>Gradation Range</td><td>Particle Diameter (mm)</td><td>Gradation Range</td></tr>
<tr><td>9.50</td><td>100</td><td>9.50</td><td>100</td></tr>
<tr><td>4.75</td><td>95-100</td><td>4.75</td><td>90-100</td></tr>
<tr><td>2.36</td><td>70-100</td><td>2.36</td><td>45-85</td></tr>
<tr><td>1.19</td><td>40-90</td><td>1.19</td><td>9-45</td></tr>
<tr><td>0.60</td><td>25-75</td><td>0.60</td><td>0-18</td></tr>
<tr><td>0.30</td><td>2-25</td><td>0.30</td><td>0-10</td></tr>
<tr><td>0.15</td><td>0-4</td><td>0.15</td><td>0-7</td></tr>
<tr><td>0.07</td><td>0-2</td><td>0.07</td><td>0-2</td></tr>
<tr><td>Design Infiltration Rate</td><td colspan="2">1 in/hr</td><td colspan="2">124 in/hr</td></tr>
<tr><td>BMP Size</td><td colspan="2">Varies depending on the size of contributing basin area</td><td colspan="2">Fixed at 4-feet by 5-feet
(20-sqft footprint)</td></tr>
</table>

This study will evaluate the effectiveness of a sand filter sidewalk vault BMP. Specifically, the runoff treatment performance, for reducing total suspended solids (TSS), dissolved Copper (Cu) and Zinc (Zn), and oils, and infiltration performance overtime. The primary treatment mechanism provided by this BMP include gravity separation, filtration, and sorption. Gravity separation relies on variations in material density for pollutant removal: pollutants denser than water (i.e., TSS and gross solids) will descend and settle on top of the BMP. While pollutants lighter than water (i.e. oils and grease) ascend to the top of ponded water, oils are known to sorb to sediment and are expected to reduce the concentration of oils (rather than discharge through the bypass pipe during events that exceed the water quality event). Filtration removes TSS as stormwater infiltrates through the sand filter becoming physically trapped in the media pore spaces (Minton, 2011). Sorption, due to the reportedly high cation exchange capacity (CEC) of coconut coir, is expected to provide some removal of dissolved metals. CEC values reported range from 21 to 186 meq/100g (Abad, 2002; Evans, 1996; Jeyaseeli 2010; Meerow, 1994).

3.2 Problem Description

Constructing BMPs at sites with space constraints creates a challenge for jurisdictions, particularly for retrofit or redevelopment projects that are located in built urban areas. A viable solution is to develop BMPs that can fit into these built areas, such as the proposed sand filter sidewalk vault.

Since the BMP is contained and provides treatment within the vault which can be installed under the sidewalk, it can be connected to existing (or new) storm drain networks. This BMP could eliminate (or reduce) the need for constructing a treatment BMP downstream and subsequently reduce the overall cost of stormwater management on future projects.

The primary reason for conducting this study is to meet Spokane County's permit requirements for evaluating the effectiveness of permit required stormwater management practices (see Section 3.4 for more details). This study is also being conducted to determine whether the proposed BMP meets the Ecology treatment criteria (Table 14.1) for basic (TSS), dissolved metals (Cu and Zn), and oils treatment as defined in the Technology Assessment Protocol Ecology (TAPE). In particular, TAPE requires that the treatment performance be evaluated in a field study. If the treatment performance goals are achieved, the results from this study will be used to justify the development of a new BMP that is approved for 'general use' on future projects. Results from this study will also be used to optimize the BMP design and maintenance guidance.

3.3 Results of Column Testing Sand Media

Flow through column testing was conducted on the proposed sand media for the purpose of: defining the BMP design and maintenance guidance; assessing the BMP treatment performance, and identifying the BMP design infiltration rate. The media selected consists of an 18-inch layer of coarse sand which is overlaid by a coconut coir mat (Appendix L). The column testing included two parts: 1) evaluate the treatment performance of the BMP for reducing TSS, dissolved Cu and dissolved Zn as well as assessing total phosphorus leaching potential; and 2) evaluate the change in infiltration rate over the duration of the testing period. This section provides an overview of the testing methods and a summary of the results.

3.3.1 Water Quality Treatment Performance

The column testing included simulating rainfall events using a synthetic stormwater solution. Two 2-inch schedule 40 clear plastic columns were packed with 18-inches of coarse sand in 6-inch layers (Figure 3.2). Each layer was compacted using a water settling method, which is consistent with the method Spokane County will use in the field for installing the sand in the sidewalk vaults. A synthetic stormwater solution composed of tap water and chemical standards for TSS, dissolved Cu and dissolved Zn (SIL-CO-SIL®, Copper Sulfate, and Zinc Chloride, respectively) was continuously mixed in a 70-liter tank using a mixer. The mixer ran continually during the testing to prevent the SIL-CO-SIL® from settling to the bottom of the tank. The synthetic stormwater was distributed to the columns using a peristaltic pump which ran continuously at a flow rate of 150 mL/min (the equivalent peak flow rate at the test site during the water quality event from the Type 1A rainfall distribution). The column testing system was designed to be representative of the sand filter sidewalk BMP constructed in the field. Specifically, the surface area of the column (0.022 sqft) was assumed equivalent to the surface area from the same diameter section in the sand filter sidewalk vault BMP in the field. In addition, the pollutant loading distributed to the columns (TSS, Cu, and Zn) was equivalent to the loading expected in the field annually, assuming a contributing basin area of 18,000 sqft and a mean annual precipitation rate of 16-inches over 2-years for a total of 32-inches. The annual pollutant loading was calculated using equivalent runoff from the contributing basin area (19.6 sqft) to the columns times the TAPE influent concentration range

(Ecology, 2011): the upper limit for Cu (0.02 mg/L) and Zn (0.30 mg/L) and the average of the range for TSS (150 mg/L).

Figure 3.2 Column Testing Setup (left), Expected TSS Accumulation in Sand Filter Media (middle), and TSS Accumulation in the Sand Filter Sidewalk Vault Media (right)

Samples were collected at the beginning of the simulated rainfall event. This included collecting the influent sample from the combined discharge of the pump distribution tubing. Then effluent samples was collected approximately 30-minutes after the influent sample to allow time for the stormwater solution to completely pass through the sand media. The samples were tested for TSS (SM 2540D-97), dissolved Cu and Zn (EPA 200.8), and total phosphorus (EPA 365.4). The average influent concentration and pollutant reduction is summarized in Table 3.2 (results represent the average values measured from the two columns).

The pollutant reduction was calculated to assess the treatment performance of the sand media (Table 3.2). Specifically, to assess whether the proposed BMP can achieve the Ecology treatment performance criteria for TSS, dissolved Cu, dissolved Zn, as well as the potential for the sand media to leach phosphorus. Since the average influent concentrations for Cu and Zn exceeded the upper influent concentration limit defined by TAPE, the pollutant reduction was calculated using the upper concentration limit as well as the measured influent concentration. As shown in Table 3.2, both TSS and dissolved Cu achieved the treatment performance goal, however the average dissolved Zn reduction was slightly less than the treatment performance goal. Since dissolved metals are known to sorb to the sediment in roadway runoff (which was not included in this portion of the column testing), metals removal is expected to be higher in the field (Minton, 2011). The columns leached total phosphorus (TP) during the first rainfall simulation, however TP was not detected in the samples collected for the 1- and 2-year event (equivalent to 16- and 32-inches of rainfall). These results suggest that TP leaching may only be a concern during the initial period after the BMP is installed in the field.

Table 3.2 Summary of Water Quality Testing

Average Influent Concentration	TSS=180 mg/L	Cu=0.04 mg/L	Cu=0.02[a] mg/L	Zn=0.46 mg/L	Zn=0.30[a] mg/L	TP=0 mg/L
Equivalent Precipitation Depth (inches)	TSS Average Reduction	Dissolved Cu Average Reduction	Dissolved Cu Average Reduction (TAPE Limit)	Dissolved Zn Average Reduction	Dissolved Zn Average Reduction (TAPE Limit)	Total Phosphorus Average Reduction
<1	95%	96%	96%	98%	97%	-120%
4	92%	NT	NT	NT	NT	NT
8	83%	NT	NT	NT	NT	NT
16	78%	62%	57%	30%	0%	ND
24	90%	NT	NT	NT	NT	NT
32	50%	65%	60%	46%	24%	ND
Average Pollutant Reduction	81%	74%	71%	58%	40%	
TAPE Treatment Performance Goal	80%	30%	30%	60%	60%	
TAPE Goal Achieved	✓	✓	✓	✗	✗	

NT - not tested, ND – not detected

a. The influent concentration represents the upper limit for each parameter as defined in TAPE.

The pollutant reduction ratio is the effluent concentration divided by the influent concentration (C_e/C_i). This value was calculated and graphed for each sampling event to assess the trend in the treatment performance over the testing period. As shown in Figures 3.3, 3.4, and 3.5 the treatment performance declines (C_e/C_i increases) over the testing period for all parameters. In particular, the effluent reduction for TSS was less than 80% until break-through occurred after the equivalent loading from 26-inches of rainfall. These results are different than what has been observed at other sand filter BMPs installations (i.e., the existing basic sand filter vault BMP). Specifically, the sand media typically clogs from TSS accumulation on top of and within the top 6-inches of the sand media (Figure 3.1). Clogging is due to sedimentation, as particles settle on the surface of the BMP, and filtration, as stormwater infiltrates through the sand media and particulates become physically trapped in the media pore spaces (Hatt, 2008; Hunt & Lord, 2006; Li & Davis, 2008). The primary reason for the difference in these results is that coarse sand consists of a larger grain size sand compared to the existing basic sand filter BMP (Table 3.1). The larger grain size media is associated with a larger porosity. The pore spaces of the entire depth of media appear to be filling with TSS (Figure 3.2) and once full, the influent appears to be displacing TSS from the columns during rainfall simulations.

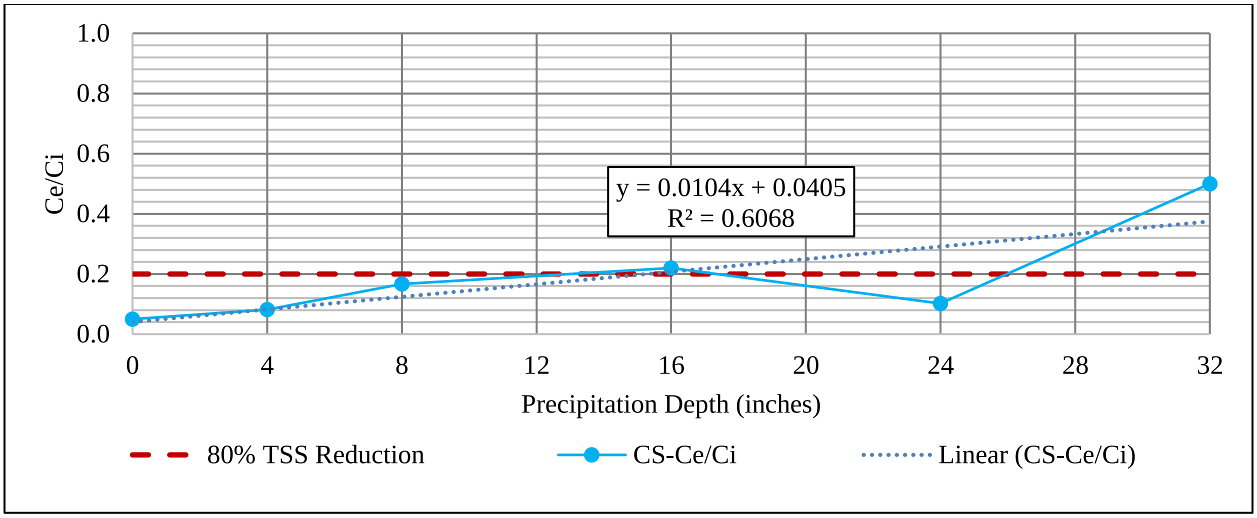

Figure 3.3 TSS Reduction Ratio (Ce/Ci) vs. Precipitation Depth (SIL-CO-SIL® 106 only)

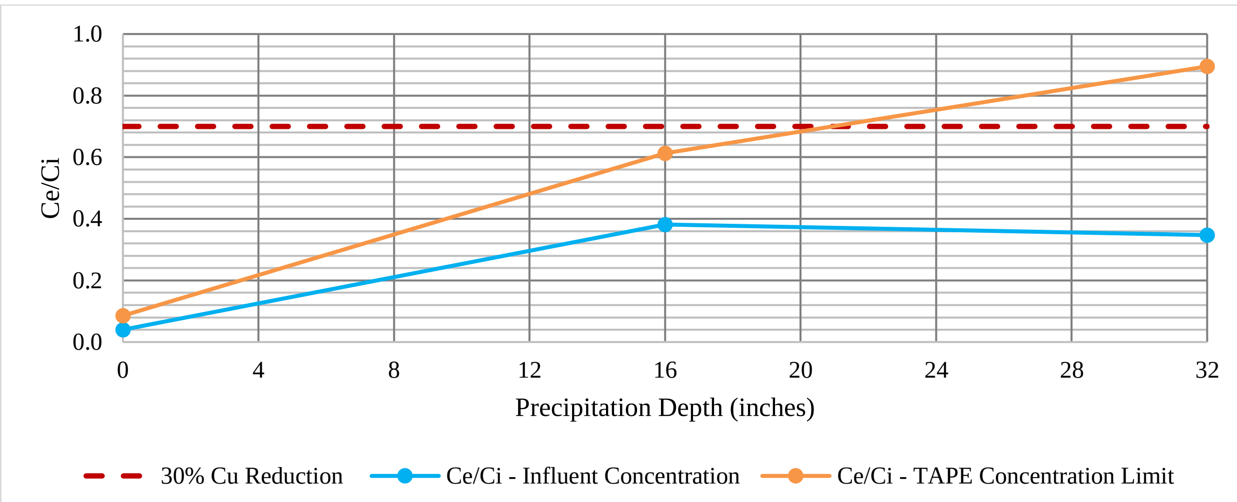

Figure 3.4 Dissolved Cu Reduction Ratio (Ce/Ci) vs. Precipitation Depth

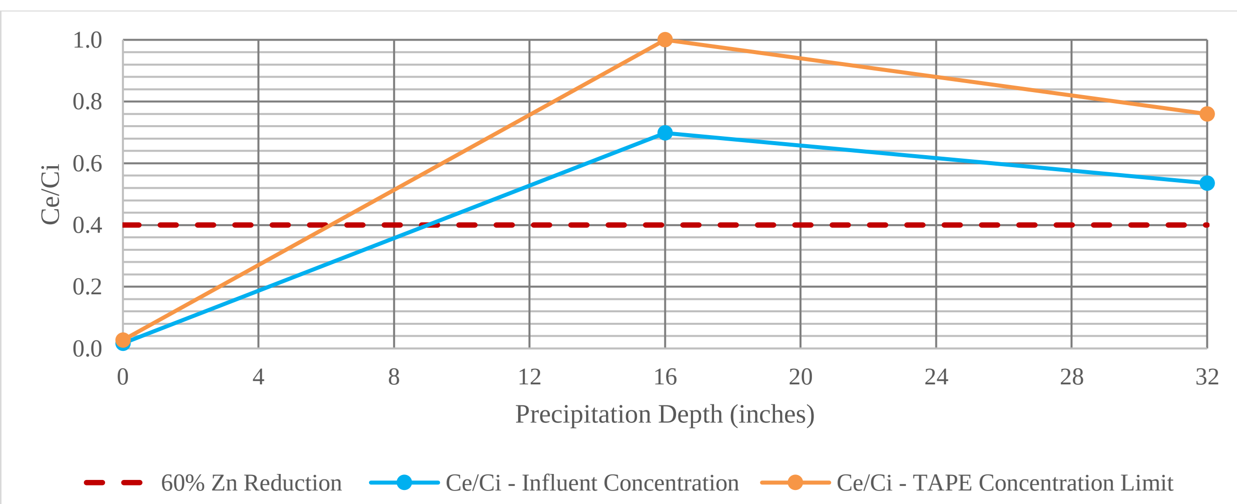

Figure 3.5 Dissolved Zn Reduction Ratio (Ce/Ci) vs. Precipitation Depth

3.3.2 Infiltration Rate Performance

The primary purpose of the infiltration rate performance testing was to predict the maintenance cycle of the sand filter sidewalk vault BMP. The following bullets provide a summary of the testing conducted. The subsequent sections provide the details of the testing conducted as well as the maintenance cycle predicted.

- <u>Singe Event Modeling</u> – the proposed BMP was modeled to determine the design infiltration rate. For this study, the design infiltration rate is the sand filter media infiltration rate just before runoff from the contributing basin area, during a 6-month 24-hour rainfall event, overflows into the bypass pipe. The bypass flow height is 18-inches above the sand filter media.

- <u>Falling Head Testing Post Water Quality Testing using SIL-CO-SIL®</u> – This testing occurred during and after the water quality treatment performance testing. The purpose of the testing was to determine the change in infiltration rate from *only* TSS loading.

- <u>Falling Head Testing Post Water Quality Testing using SIL-CO-SIL® and Roadway Sediment</u> - This testing occurred during and after the water quality treatment performance testing. The purpose of this testing was to determine the change in infiltration rate *from TSS loading and gross solids* from the contributing basin area.

Single Event Modeling
A single event model was used to determine the design flow rate and infiltration rate of the sand filter media. The design flow rate is the peak flow rate during the water quality event (6-month 24-hour event) and the design infiltration rate is the minimum infiltration rate needed to infiltrate the volume of runoff during the water quality event without overflowing into the bypass pipe. The design flow rate and infiltration rate were determined by modeling the sand filter BMP as a vault using StormShed 3G, a single event modeling software. The discharge for the vault was modeled as infiltration starting at a rate of 0-in/hr which was increased in 15-in/hr intervals up to 200-in/hr for a contributing basin area of 18,000 sqft. This contributing basin areas was selected because it is the area of the test-site where the sand filter media will be tested in the field which consists of 14,000 sqft, from impervious roads and sidewalks, and 4,000 sqft, from pervious lawns (See Section 4.3). Modeling was conducted assuming all 18,000 sqft was impervious (CN=98) to account for frozen ground conditions during the winter. The design infiltration rate was determined by modeling the BMP with 18-inches of stormwater ponded on top of the sand filter media. This is the maximum depth stormwater can pond without overflow into the bypass during the water quality event. Modeling consisted of using level pool routing, the Type 1A rainfall distribution, the Santa Barbara Urban Hydrograph (SBUH) method, and the precipitation depth from the 6-month 24-hour event for Spokane (approximately 1-inch of rainfall). The results indicate the peak flow rate is 0.08 cfs and the design infiltration rate is 124 in/hr (Figure 3.6). A copy of model output is located in Appendix F.

See Section 3.3.3 for discussion regarding methods for sizing this BMP. More specific details regarding the BMP sizing are located in Section 7.3.

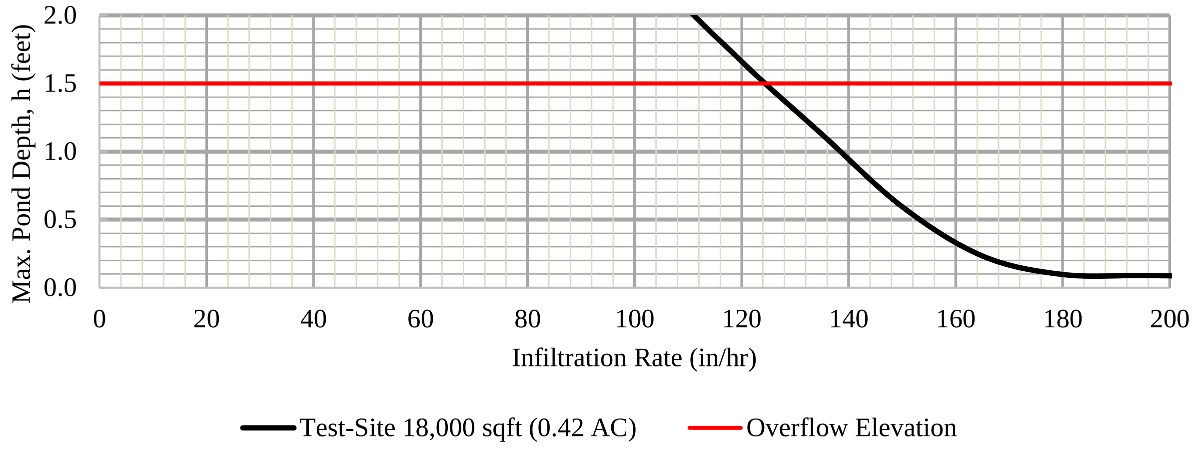

Figure 3.6 Design Infiltration Rate Based on Results from Single Event Modeling

3.3.2.1 Falling Head Testing After Treatment Performance Testing

The purpose of the falling head testing after the treatment performance testing (SIL-CO-SIL®) was to determine the change in infiltration rate from TSS loading. Falling head testing was conducted after the equivalent of every 4-inches of precipitation. This consisted of filling the column up to 6-inches higher (24-inches) than the maximum ponding depth (18-inches). Then the rate of fall was recorded from the maximum ponding depth of 18-inches to the top of the sand media. The results from this testing is summarized in Figure 3.7 (results represent the average values measured from the two columns). As shown, the infiltration rate declines as the TSS loading increases, and after the equivalent of 2-years of TSS loading, the measured infiltration rate (300-in/hr) is still greater than the design infiltration rate (124-in/hr). Comparing these results to the water quality results (Table 3.2 and Figure 3.3), breakthrough of TSS will occur before the infiltration rate is reduced below the design infiltration rate.

3.3.2.2 Falling Head Testing using SIL-CO-SIL® 106 and Roadway Sediment

The results from the falling head testing described in section 3.3.2.1 are different than what has been observed in the field. The test-site was constructed in 2016 and contains the sand media and coconut coir mat described in this section. Based on field observations it appears that the roadway sediment is clogging the top layers of the media, and as a result the sediment has to be removed from the top of the media at least once a year to restore the infiltration rate. Because of the observed differences, the column testing was modified and repeated in an effort to create conditions that are more representative of those expected in the field. The Spokane County Project Manager has visually observed approximately 3-inches of sediment and gross solids (i.e. debris, trash, large particulate matter, and TSS) accumulates on top of the sand media each year for a 36,000 sqft contributing basin area. Since the test-site will be configured to only receive runoff from an 18,000 sqft basin area, 1.5-inches of sediment accumulation is anticipated annually.

Rainfall simulations were run using the same methods as described in the Water Quality Treatment Performance section except the synthetic stormwater solution was only composed of TSS (SIL-CO-SIL®) and tap water (no metals were added to the solution). During the rainfall events, the equivalent amount of roadway sediment as visually observed in the field (1.5-inches annually; 0.10-inches for each 1-inch rainfall event) was added to the top of the column periodically during the event. After each rainfall event, falling head testing was conducted using the same methods as described in the previous section. Testing was conducted until the infiltration rate decreased to 4-in/hr. The results from the falling head test are shown in Figure 3.7 (results represent the average values measured from the two columns).

As shown in Figure 3.7, the rate of decline of the infiltration rate is faster using both TSS (SIL-CO-SIL®) and roadway sediment (compared to just SIL-CO-SIL®). The results from this testing predict that the infiltration rate of the sand media at the test site will drop below the design infiltration rate after the equivalent pollutant loading from 8-inches of rainfall. This is more frequent than has been observed at the test site. The differences are likely due to the differences in the gradation of the actual roadway sediment compared to what was used in the columns. Specifically, roadway sediment was collected from the top of the sand filter media and the sediment contained material larger than could not fit in the columns (i.e., leaves, vegetative material, etc.). As a result, only material less than 3/8-inch was added to the columns. Since the material has a smaller gradation than what is present in the field, the porosity of the sediment used during column testing is smaller, as such the infiltration rate is expected to be lower. Therefore, it is expected that the rate of decline of the sand media infiltration rate in the columns is faster than is expected in the field. These results indicate that clogging of the sand media due to roadway sediment loading will occur before the TSS break through described in the Water Quality Treatment Performance section (after 26-inches of rainfall). Additionally, it is expected that the TSS treatment performance goal (≥80% TSS reduction) will be achieved using the proposed BMP as long as maintenance is provided at the test site before the field infiltration rate drops below the design infiltration rate (124 in/hr).

A comparison of the sand media gradation (the existing sand filter BMP medium sand and the proposed BMP coarse sand) as well as the roadway sediment gradation (CB Sediment Geo) is shown Figure 3.8. Appendix M contains a copy of the results from the roadway sediment gradation testing.

3.3.2.3 Predicted Maintenance Cycle

Based on the results from the second falling head testing (SIL-CO-SIL® and roadway sediment) the required maintenance cycle is predicted after every 8-inches of rainfall. As noted in the last section, this is more frequent than has been observed in the field. Therefore, field data will be collected and analyzed to confirm the maintenance cycle. Specifically, the sediment accumulation will be measured (on top of the sand filter media) and compared to the change in infiltration rate (see Section 14.1.5 and 14.16). The required maintenance will consist of removing the coconut coir mat (with the sediment on top) and cleaning the mat (rinsing mat using tap water). Then the top 6-inches of the sand media will be removed and replaced with another 6-inches of sand and the coconut coir mat will be placed back on top of the sand media.

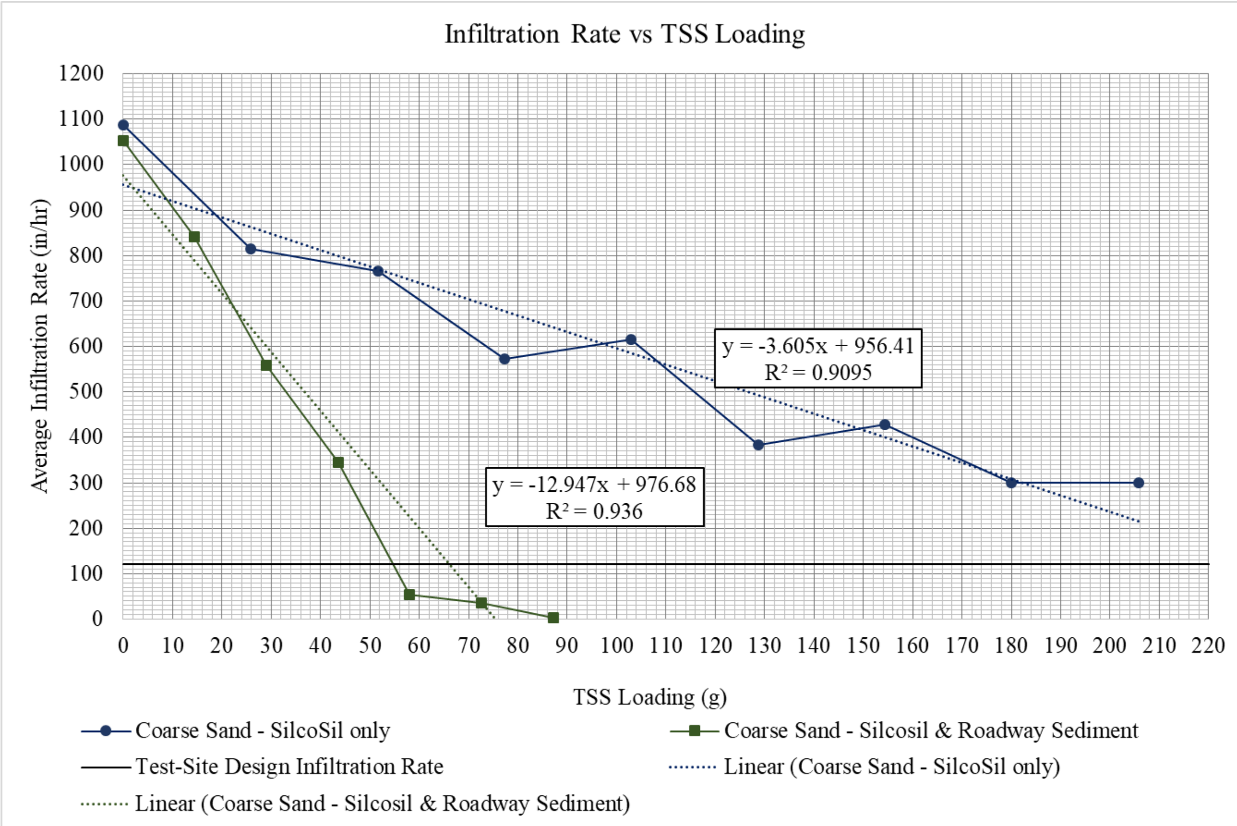

Figure 3.7 Results from Falling Head Testing

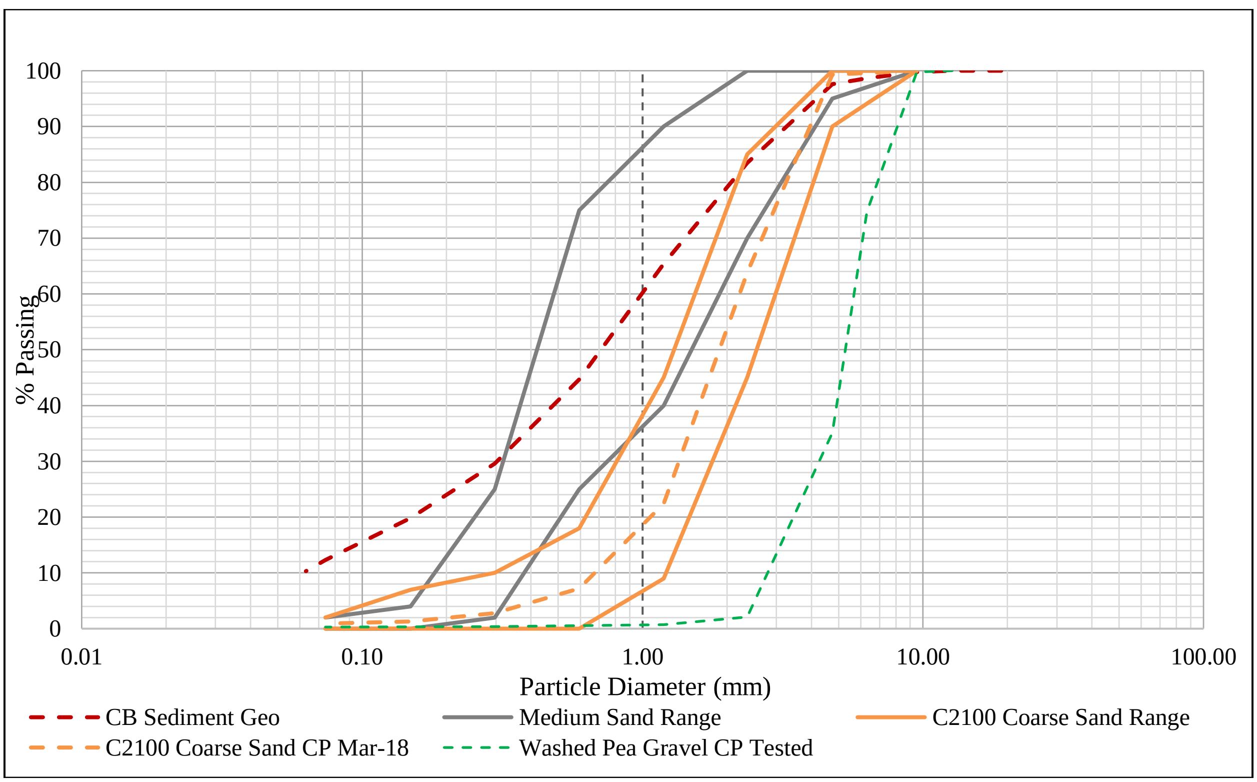

Figure 3.8 Comparison of Gradations: Medium Sand, Coarse Sand, and Roadway (CB) Sediment

3.3.3 BMP Sizing Discussion

The Type 1A rainfall distribution was selected for the column testing because it most closely reflects historical precipitation patterns in eastern Washington compared to the other methods (WSDOT, 2006). Methods identified in the EWA Ecology Stormwater Manual for Eastern Washington (SWMMEW) as acceptable for designing volume based BMPs include the Type 1A and Type II 24 hour rainfall distributions as well as the Rational Method. However, the TAPE Guidance Manual limits the BMP sizing methods for the BMP evaluation to either the Soil Conservation Service (SCS) Type II 24 hour rainfall distribution (6 month return frequency) or the Rational Method (6 month Mean Recurrence Interval).

The test-site was modeled using the Type II and the Rational Method to compare the differences in the sand filter sizing. The modeling for the Type II method was the same as described in Sections 3.3.1 and 3.3.2 for the Type 1A modeling except the SCS method was used instead of the SBUH. For the Rational Method, the Bowstring Method was used which is a Modified version of the Rational Method. The methods for this approach are defined in the SRSM (Spokane County, City of Spokane, and Spokane Valley, 2008). A copy of the modeling output is located in Appendix F. As shown in Table 3.3, the largest flow rate (0.41 cfs) was produced from the Type II event whereas the Type 1A rainfall event produced the smallest flow rate (0.08 cfs). Based on these results, 1 sand filter is required using the Type 1A event whereas 4.3 are required using the Type II event and 3.22 using the Bowstring Method. For this study, the Bowstring Method will be used for sizing the BMP system (Section 7.3).

Table 3.3 Comparison of Sand Filter Sizing using the Type 1A, Type II, and Rational Methods

	Q_{6m24h} Type IA	Q_{6m24h} Type II	Q_{6m} Rational	Units
Peak Flow Rate	0.08	0.41	0.38	cfs
Sand Filter Media Infiltration Rate		124		in/hr
Sand Filter Surface Area		20		sqft
Contributing Basin Area (Test Site)		18,000		sqft
Surface Area Required	20	84	65	sqft
# of Sand Filter BMPs Needed for 18,000 sqft area (test site)	1	4.30	3.22	
Contributing Basin Area: Sand Filter Surface Area	900	209	277	
Contributing Basin Area Size for One Sand Filter	18,000	4,270	5,538	sqft

3.4 Regulatory Requirements

The Eastern Washington Phase II Municipal Stormwater Permit issued to Spokane County by Ecology requires the Stormwater Management Program Effectiveness Studies as defined in Section 8 (S8), Monitoring and Assessment. Specifically, "*each city and county permittee listed in the permit shall collaborate with other permittees to select, propose, develop, and conduct Ecology-approved studies to assess, on a regional or sub-regional basis, effectiveness of permit-*

required stormwater management program activities and best management practices" (Ecology 2014b). This document addresses S8.B.6: *"Lead entities shall submit a Quality Assurance Project Plan (QAPP) for each study within six months of Ecology's written approval of each detailed proposal"*.

Spokane County is the lead entity for the effectiveness study defined in this QAPP. The permit requirement that the study addresses is defined in S5.B.5, Post-Construction Stormwater Management for New Development and Redevelopment: "*all Permittees shall implement and enforce a program to address post-construction stormwater runoff to the MS4 from new development and redevelopment projects that disturb one acre or more, and from projects of less than one acre that are part of a larger common plan of development or sale"* (Ecology 2014b).

4.0 Project Overview

4.1 Study Goal

The goal of this study is to evaluate the effectiveness of a sand filter BMP that can be installed within a sand filter sidewalk vault. Effectiveness will be based upon:

- The infiltration performance, specifically infiltrating the water quality volume (6-month 24-hour event) without overflowing into the bypass pipe (set 18-inches above the sand media) within the maintenance cycle (based on design infiltration rate)
- The treatment performance of the BMP will be evaluated for reducing the following stormwater runoff pollutants: total suspended solids (TSS), dissolved Cu and Zn, and oils

If the infiltration performance can be achieved as well as the Ecology treatment goals for basic (TSS), dissolved metals (enhanced), and oils, the results from this study will be used to justify the development of a new BMP that is approved for '*general use*' on future projects.

4.2 Study Description and Objectives

The goal for this study will be achieved by meeting the following objectives:

- Define the BMP design and maintenance guidance
- Determine the pollutant removal efficiency of the BMP by measuring and comparing the pollutant concentrations in the influent and effluent
- Verify the maintenance cycle defined in Section 7.3 using the results from infiltration testing. Specifically determine the time required between maintenance cycles based upon when infiltration rate declines to the design infiltration rate.
- Establish a design flow in gallons per minute per square foot of the sand filter surface area
- Determine whether the treatment performance goals were achieved by comparing study results to TAPE goals and requirements

Prior to the start of the field study, the BMP design and maintenance guidance was defined (Section 7.3) for the new BMP. The guidance was developed based on the results of the column testing (Section 3.3). This included conducting a literature search to develop a specification that defines the physiochemical properties and quantities of materials in the sand filter media. Flow through column testing was conducted to assess the treatment and infiltration performance of the sand filter media and define the BMP design guidance.

The focus of this QAPP, is the field testing. This will include installing new sand filter media, choke stone, and coir mat in the sidewalk vault prior to testing and evaluating the treatment and infiltration performance. Composite samples will be collected from qualifying rainfall events following the TAPE guidelines (Ecology 2011). Samples will be collected from a minimum of 12 storm events and tested for the required and screening parameters as defined in TAPE for basic, dissolved metals, and oil treatment (Table 4.2). The infiltration performance of the sand filter media will also be evaluated using data collected from falling head tests and the effluent flow rate measured by the autosamplers. The study duration is expected to extend through two wet seasons. The data will be evaluated to determine which pollutants meet Ecology's treatment performance criteria as defined in TAPE (Table 14.1). Affirmative results will result in a recommendation for the application of BMP design and maintenance guidance for providing runoff treatment. Specifically, if some or all the treatment performance goals are achieved, the final report will recommend approval of the new BMP and be submitted following the TAPE process for review This study also includes submitting a TAPE application that enters the new BMP into the evaluation program, and submitting a technical evaluation report (TER) to Ecology and the TAPE Board of External Reviewers (BER) for review and approval.

4.3 Study Location

This study will be conducted near the intersection of Hawthorne Road and U.S. 2 in Spokane, Washington (Figure 4.1). At this location, the land use is a mix of residential and commercial. The contributing basin area (Basin 19 in Figure 4.2) is approximately 18,000 sqft of which 14,000 sqft is impervious surfaces (roadway and sidewalks) and 4,000 sqft is pervious surfaces (lawns). The contributing roadway is primarily an urban arterial with some runoff from a residential road. Per the Web Soil Survey, the pervious area is defined as urban land-marble, disturbed complex with 0 to 3 percent slopes. No Hydrologic Soil Group (HSG) is provided for the contributing basin area however soils in the area are listed as class A HSG (Soil Survey Staff, 2018).

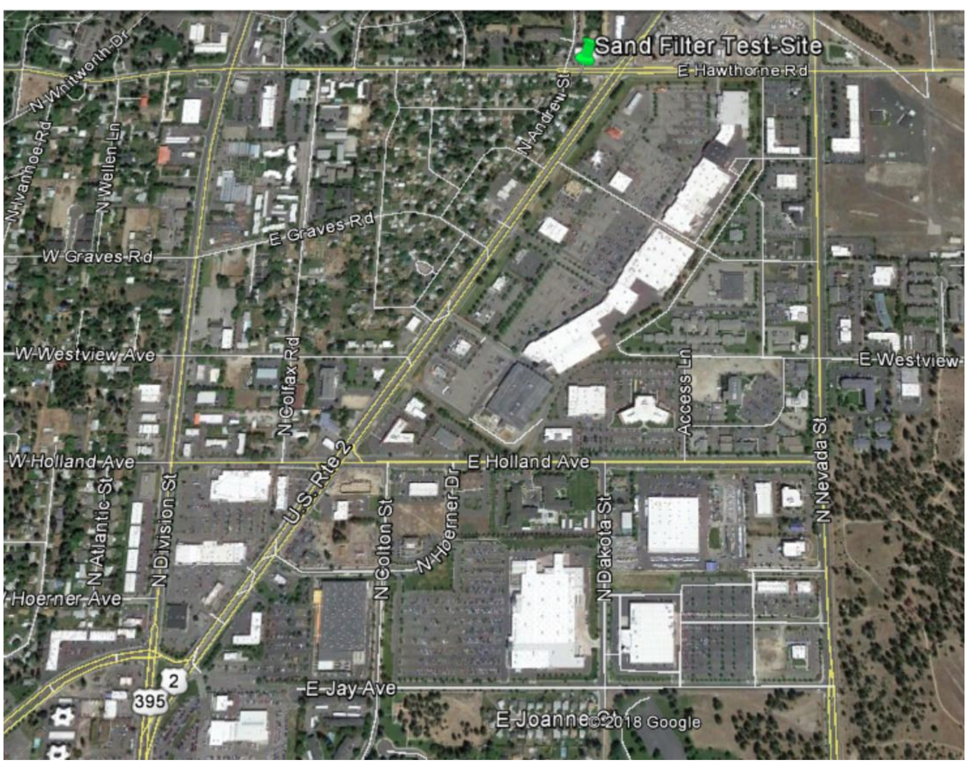

Figure 4.1 Test-Site Area Map

Figure 4.2 Test-Site Location and Contributing Basin Area

4.4 Data Needed to Meet Objectives

The data needed to conduct this study is summarized in Table 4.1. The water quality parameters that will be tested to demonstrate that the BMP meets the Ecology treatment performance goals are summarized in Table 4.2

Table 4.1 Data Needed to Meet Objectives

Data Type	How Data Will Be Collected	Purpose
Sand Filter media physiochemical properties	Samples of sand filter media will be collected prior to installing the media in the vault (see Section 8.0 SOPs) and sent to lab for analysis	Verify properties meet the media requirements defined in the design guidance (Section 7.3) and identify media properties which may influence the media treatment performance
Precipitation	A rain gauge connected (via cable) to the data logger at the test-site; data transmitted via cellular network	Determine whether rainfall event meets TAPE guidelines for a qualifying storm
Flow Depth, Temperature (influent, effluent, bypass)	Measured continuously using a pressure transducer located upstream of a control weir; Depth is converted to flow rate using a weir equation	Calculate flow rates and measure temperature (influent, effluent, bypass); determines when sampling should begin (if storm meets qualifying)
Composite Water Quality Samples; Table 4.2 parameters except oils	Autosamplers collect composite samples when triggered by the data logger when qualifying rainfall conditions occur	Quantify the influent and effluent concentrations of parameters; assess effectiveness of the structural BMP; PSD influent, quantify size range of TSS
Oils[1], Grab Samples	Collect grab samples during storm events from influent and effluent	Quantify removal of Northwest Total Petroleum Hydrocarbons, motor oil and diesel fractions (NWTPH-Dx)
Instantaneous pH Measurement, Oil Sheen Observations	Collect pH measurements from small amount of composite sample; observe oil sheen in effluent, sand filter, and composite sample	Quantify pH of influent and effluent; determine whether oils have entered the sand filter sidewalk vault
Sediment PSD from influent	Collect composite flow weighted samples from influent	Characterize the size of the sediment that enters the BMP
Sediment Depth on BMP, Sediment grain size (on top of & in top, middle, bottom layer of sand media	Measure depth on top of coir mat using decimal measuring tape; collect grab samples from influent	Verify maintenance cycle: calculate sediment accumulation rate on sand filter (with infiltration rate change); determine change in particle size in sand media layers (compared to pre-test gradation)
Infiltration rate	Modified falling head test (See Section 8.1.8 for SOP); autosampler effluent flow rate	Calculate change in infiltration rate of media and identify when the rate will decline to the design infiltration rate

1. References to oils throughout this document refers to the required screening parameter, NWTPH-Dx, which includes total petroleum hydrocarbons (TPH), motor oil and diesel fuel.

Table 4.2 Summary of Water Quality Testing Data

Performance Goal	Required Parameters	Required Screening Parameters
Basic	TSS	Particle size distribution (PSD), pH, total phosphorus (TP), orthophosphate, hardness, total and dissolved Cu and Zn
Dissolved metals	TSS, hardness, total and dissolved Cu and Zn	PSD, pH, TP, orthophosphate
Oils	NWTPH-Dx, visible sheen	pH, TP, orthophosphate, hardness, total and dissolved Cu and Zn

4.5 Tasks Required to Conduct Study

Tasks required to conduct the study include:

- **Grant Funding**
  - Centennial Grant Application - Applied for grant to fund study
- **Experiment Design**
  - Developed Detailed Study Design Proposal
    - Ecology Proposal Review; Respond to comments
  - Monitoring System Design
  - Sand Media Column Testing – developed BMP design and maintenance guidance
- **Monitoring Equipment**
  - Selected, ordered, and install equipment at test-site
  - Develop and provide monitoring equipment training for sampling staff
  - Developed standard operating procedures (SOPs) for operating, maintaining, and calibrating equipment
- **Quality Assurance Project Plan (QAPP)**
  - Develop TAPE application; Submit TAPE application to Ecology and board of external (BER) for review; Respond to comments
  - Developed QAPP; Submit QAPP to Ecology and BER for review; Respond to comments
- **Technical Advisory Group (TAG) Meetings**
  - Schedule 7 meetings with TAG for the purpose of discussing the project status, upcoming tasks, and soliciting input from the TAG on the study documents
- **Data Collection and Analysis:**
  - Test sand filter media (prior to installation)
  - Track and select storms (daily)
  - Maintain storm monitoring equipment (monthly)
  - Prepare stormwater monitoring equipment for storm sampling and calibrate equipment (immediately prior to sampling event)
  - Collect stormwater influent and effluent samples from a minimum of 12 rainfall events; submit samples to lab and test for required and screening parameters (immediately following qualifying rainfall events)
  - Following each monitoring event: download data (i.e., precipitation, influent, effluent, and bypass flow rate), analyze data
  - Measure sediment accumulation (following each qualifying rainfall event)
  - Conduct falling head testing (quarterly)
  - Develop and manage a database that contains all the collected data
  - Conduct audits; verify data and assess usability of data
  - Collect samples from on top of and in the top, middle, and bottom layers for grain size analysis (once post testing)
- **Develop Technical Report:**
  - Develop annual reports
  - Develop technical evaluation report (TER)
  - Develop study fact sheet
  - Submit TER to Ecology and BER for Review and Comment; Respond to comments

4.6 Potential Constraints

Potential constraints are conditions that may impact the project schedule, budget, or scope. The potential constraints identified in this section, along with the steps that will be taken to reduce the impact of these conditions (mitigation approach), are based on the information that was available at the time the QAPP was written.

Table 4.3 Summary of Potential Constraints and Mitigation Approaches

Potential Constraint	Mitigation Approach
Insufficient qualifying rainfall events	Extend monitoring period or collect data from lower depth (<0.15-inches) rainfall events
Spills: oil or other chemicals	Large spills could impact the treatment performance of the BMP. Visually inspect the sand filter media following each rainfall event; if a spill occurs, the appropriate maintenance will be conducted and the incident will be noted in the data collection log
Monitoring equipment malfunctions	Frequent inspection of equipment and review system output variables after each storm for any anomalies. If problems are encountered, equipment will be fixed promptly.

5.0 Organization and Schedule

The purpose of this section to describes who is responsible for completing the tasks, when the tasks will be completed, and how the study will be funded.

5.1 Key Project Team Members: Roles and Responsibilities

Table 5.1 Key Project Team Members: Roles and Responsibilities

Name Organization	Role	Contact Information
Matt Zarecor Spokane County	Lead Entity[1]	509.477.7255 mzarecor@spokanecounty.org
Jake Saxon Spokane County	Lead Entity[1] Project Manager[1] TAG Member[6]	509.477.7245 jsaxon@spokanecounty.org
Bill Galle Spokane County	Lead Entity[1] TAG Member[6]	509.477.7261 bgalle@spokanecounty.org
Ethan Murnin Spokane County	Lead Entity[1] TAG Member[6]	509.477.7261 emurnin@spokanecounty.org
Danielle Mullins City of West Richland	Participating Entity TAG Member[6]	509.967.5434 dmullins@westrichland.org
Bill Aukett City of Moses Lake	Participating Entity TAG Member[6]	509.764.3792 baukett@cityofml.com
Rob Buchert City of Pullman	Participating Entity TAG Member[6]	509.338.3314 rob.buchert@pullman-wa.gov
Nigel Pickering WSU	TAG Member[6]	509.335.8624 nigel.pickering@wsu.edu
Doug Howie Ecology	Ecology Reviewer[11]	360.407.6444 doho461@ecy.wa.gov
Adriane Borgias Ecology	Ecology Reviewer[11]	509.329.3515 abor461@ecy.wa.gov
Brandi Lubliner Ecology	Ecology Reviewer[11]	360.407.7140 brwa461@ecy.wa.gov
Kathy Sattler, Laboratory Anatek Laboratories	Laboratory Manager[5]	509-838-3999 technical@anateklabs.com
Stephen Burchett Budinger & Associates	Environmental Engineer Principal[5]	509-535-8841 tballard@budingerinc.com
Aimee Navickis-Brasch HDR, Inc.	Principal Investigator[2]	509.343.8515 aimee.navickis-brasch@hdrinc.com
Taylor Hoffman-Ballard HDR, Inc.	Researcher[3] Sampling Staff[4,8]	509.343.8477 taylor.hoffman-ballard@hdrinc.com
Jeff Price HDR, Inc.	Sampling Staff[4,8]	509.343.8475 jeff.price@hdrinc.com

1. Lead Entity or Project Manager – Responsible for ensuring the study is conducted as described in this QAPP. The Project Manager is the primary point of contact for the lead entity.
2. Principal Investigator – Responsible for developing an Ecology approved Proposal and QAPP. Serves as the primary point of contact for the laboratory manager, the project manager, sampling staff, the auditor, the TAG Members, and the Advisory Review Panel. Responsible for conducting the study

as defined in the Ecology approved QAPP. Responsible for submitting the study documents to Ecology including the Proposal, QAPP, and Final Technical Report. Responsible for management of all study documents, scheduling audits, verifying and assessing the usability of data, and executing corrective actions. Responsible for developing the final report including data analysis, interpretation of results, and summarizing the study findings. Responsible for ensuring that staff working on this project are trained and have adequate experience to complete their assigned tasks. Responsible for maintaining and operating the monitoring equipment.

3. Researcher - Responsible for assisting the Principal Investigator.
4. Sampling Staff – Responsible for monitoring storms, assisting the Principal Investigator with maintaining and operating the equipment, collecting and processing samples (water quality or sediment) following the standard operating procedures in this QAPP (Section 8.0) including delivering the samples to the lab, assisting with the falling head test, assisting with transferring data from the lab and field forms to spreadsheets, and assisting with the data analysis.
5. Laboratory Manager – Responsible for supervision of laboratory personnel involved in conducting analytical testing for this study and ensuring that laboratory personnel are properly trained in conducting the testing methods defined for this study. Also responsible for: providing sample containers and other sampling supplies (i.e. labels); analyzing samples using the standard methods selected for this study; carrying out lab quality control (QC) procedures to confirm that the related MPCs have been met (section 6.0); reporting results for samples and QC procedures; and reviewing data and verifying results before the results are sent to the principal investigator and the lead entity.
6. Technical Advisory Group (TAG) Member - The goal of the TAG is to provide insight, suggestions, and professional opinions to the Principal Investigator and Lead Entity throughout the study. The primary responsibilities of TAG members include: attending project meetings (by webinar or in person) and participating in the meeting discussion; review/comment on research materials (i.e. QAPP, data collected, data analyzed, final report, etc.) prior to submitting the documents to Ecology.
7. Technical Advisory Group (TAG) Lead – Responsible for organizing/scheduling meetings with the TAG members and distributing the project/meeting documents prior to the meeting. During meetings the TAG lead is responsible for ensuring that the TAG member’s comments are heard and addressed as well as developing/distributing meeting notes of any actions items from the meeting.
8. Data Verifiers - Data verifiers will review the analyzed data and verify the analysis is correct and that the data being analyzed matches the data collected. *See Section 11.0 of this document.*
9. Financial Support – Responsible for providing the lead entity with some level of financial support toward the cost of the study.
10. Auditor - Responsible for conducting audits to verify the study conforms to the plan and procedures as defined in *Section 12.0* of this document. This may include: verifying staff collecting the data are trained and follow SOPs for data collection; verifying data management procedures are followed including reviewing data records to ensure they are consistent, correct and complete, with no errors or omissions; and traveling where the data is stored to review the data records compared to the QAPP Data Management Plan. Auditors will report their findings directly to the lead entity Principal Investigator and Lead Entity.
11. Ecology Reviewer – Responsible for reviewing and approving the study documents: the Proposal, QAPP, and Final Report.

5.2 Project Schedule

A task timeline based on monthly activities is shown in Table 5.2.

Table 5.2 Proposed Study Timeline

Task Name	2017			2018				2019				2020			
	Q2: Apr-Jun	Q3: Jul-Sept	Q4: Oct-Dec	Q1: Jan-Mar	Q2: Apr-Jun	Q3: Jul-Sept	Q4: Oct-Dec	Q1: Jan-Mar	Q2: Apr-Jun	Q3: Jul-Sept	Q4: Oct-Dec	Q1: Jan-Mar	Q2: Apr-Jun	Q3: Jul-Sept	Q4: Oct-Dec
Experimental Design															
Proposal Development															
Ecology Proposal Review															
Monitoring System Design															
Column Testing															
Monitoring Equipment															
Select & Order Equipment															
Equipment Installation															
Equipment Training															
Develop Equipment SOPs															
QAPP															
QAPP Development															
Ecology QAPP Review															
TAPE Application															
BER TAPE & QAPP Review															
TAG Meetings					1/2				3		4		5		6
Data Collection & Analysis															
Technical Reports															
Annual Reports															
Technical Evaluation Report (TER)															
Study Fact Sheet															
Ecology & BER TER Review															

5.3 Budget and Funding Sources

This study is funded by Spokane County with supporting funds from an Ecology Centennial Grant.

Table 5.3 Estimate Study Budget

Task Name	Total
Project Management	$31,000
Monitoring Equipment and Maintenance	$86,000
QAPP Development[1,2]	$62,000
Data Collection and Analysis[2,3]	$77,000
Technical Evaluation Report (TER)	$38,000
Total	$294,000

1. The cost for QAPP Development includes the cost to develop the detailed study design proposal and the QAPP.
2. The work associated with developing the BMP design and maintenance guidance (column testing) is split between QAPP development and Data Collection and Analysis
3. Includes the cost for sand filter media material testing as well as water quality testing

6.0 Quality Objectives

This section of the QAPP provides a roadmap of the QA/QC plan that will be implemented in the experimental design and employed throughout the study.

The purpose of a QAPP is to ensure that the data collected during the study is scientifically and legally defensible (Ecology, 2011). The QAPP documents how quality assurance (QA) and quality control (QC) will be applied to a research project to assure that the results obtained are of the type and quality needed and expected. The QA/QC plan for this study is embedded throughout the QAPP and emphasizes how the data quality indicators (DQIs) and respective measurement performance criteria (MPCs) are addressed during the study.

DQIs are qualitative and quantitative measures that characterize the aspects of quality data (EPA, 2006). DQIs are goals for data quality that are specific to each study. DQIs are intended to minimize error and improve the accuracy of the data. DQIs guide the development of the experimental design as well as the process of creating and analyzing data. The six principle DQIs for Operational BMP studies are (Ecology, 2004):

- Precision
- Bias
- Representativeness
- Completeness
- Comparability
- Sensitivity

Once established, the DQIs provide the basis for the MPCs which are the acceptance criteria for the DQIs that specifies how good the data must be to meet the project objectives. Table 6.1 first defines each DQI, then the approach for addressing DQIs and the respective MPCs for this study are described.

Reference Section 13.0 for details regarding the process that will be employed to evaluate the quality and usability of the data for meeting the project objectives which is based primarily on whether the MPCs were met for the applicable DQIs.

Table 6.1 Summary of the Data Quality Indicators (DQIs) and Measurement Performance Criteria (MPC) for Structural BMP Studies

Precision DQIs for This Study	Precision MPCs for This Study
Precision – A measure of agreement among repeated measurements of the same property taken under identical or substantially similar conditions (EPA, 2006; Erickson, 2013; EPA, 2002). Data is considered precise when the measured values are consistently the same and imprecise when the measured values are consistently different (Erickson, 2013). Random error is a common cause of imprecise data and is always present because of normal variability in the many factors that affect measurement results. For example variability in sampling or data collection procedures and/or variations of the actual concentrations in the media being sampled (Ecology, 2011).	
Developing and consistently following SOPs for collecting samples and measuring data will reduce the potential of collecting imprecise data.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs. Data will be considered acceptable if the sampling staff are consistently following the SOPs.
Duplicate analytical testing will be performed for the water quality parameters shown in Table 6.2.	If the results of the duplicate sampling meet the respective relative percent difference (RPD) for the parameters listed in Table 6.2, the results of the analytical testing will be considered acceptable. Reference Section 6.1.
Rain gauge and flow measurements will also be assessed.	If the flow measurements and rain gauge data meet the RPD defined in section 6.1, that data will be considered acceptable. Reference Section 6.1.
Bias DQIs for this Study	**Bias MPCs for This Study**
Bias – A systematic error that results in sample values that are consistently distorted in one particular direction from the “true” or known value (EPA, 2006; Erickson, 2013). Bias can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques (Ecology, 2011).	
Calibration of instruments, including the pH meter, pressure transducers and ISCO, will occur according to manufacturer’s specifications. Buffer solutions will be used to calibrate the pH meter to reduce the potential for bias.	To reduce the potential for biased measurements, the instruments requiring calibration will be calibrated according to the procedures and frequency outlined in Section 8.0, per in manufacturer’s specifications. An audit (Section 12.0) will be conducted to verify that sampling staff are following the calibration procedures.
Lack of maintenance at the site can be a source of bias in sample values or measurements. For example, if ISCO tubing is not cleaned regularly, sediment, oils, etc. can accumulate in the tubing and affect sample results. For that reason, manufacturer’s recommendations for maintenance frequency and procedures will be followed to reduce the potential for bias.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0 (written to match manufacturer’s specifications).
SOPs defined in Section 8.0 will be followed when collecting samples and measuring data to limit bias.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0.
Method blanks, rinsate blanks, matrix spikes, and field duplicates will be analyzed to check for bias.	Sample results will be accepted if results of the method blanks, rinsate blanks, matrix spikes, and/or field duplicates are below the limits shown in Table 6.2. Please note that percent recovery for matrix spikes is defined in section 6.2.

Representativeness DQIs for This Study	**Representativeness MPCs for This Study**
Representativeness – A qualitative term that expresses the degree to which the data accurately and precisely represents the conditions being evaluated (EPA, 2002). Common variables considered when determining the degree of representativeness include the selected sampling locations, sampling frequency and duration, and sampling methods (Ecology, 2011).	
The location selected for this study is on an urban arterial, within commercial and residential zones. The space constraints at the site would preclude the use of a basic sand filter BMP.	These conditions reflect the characteristics of a location where a sand filter sidewalk vault would be installed: a developed, urban area with space constraints and the presence of a sidewalk.
Hydrologic conditions at the site should be representative of a range of weather patterns and conditions seen throughout the wet season.	Local stormwater hydrologic conditions are represented by conducting the study over two wet seasons and collecting data from a minimum of 12 qualifying storm events (described in Section 7.5).
Rainfall data, flow data, and water quality samples should be representative of the site.	Equipment will be set up to achieve representative rainfall, flow, and water quality data as follows: • The rain gauge will be installed within the drainage basin of the sand filter sidewalk vault and in a location where no buildings, trees, or other objects obstruct or divert rainfall from entering the rain gage • Pressure transducers will be installed upstream of weirs in influent, effluent, and bypass pipes, which will mimic typical sand filter sidewalk vault construction • Water quality samples (except oils grab samples, due to NWTPH-Dx method requirements) will be collected as composite samples. pH measurements will also be taken from the composite samples. The composite samples will capture at least 10 aliquots and 75% of the qualifying rainfall event hydrograph to be representative of water quality during the storm
Equipment at the site will be installed per manufacturer specifications.	
Completeness DQIs for This Study	**Completeness MPCs for This Study**
Completeness - The amount of valid data needed to be obtained during the study to meet the project objectives (Ecology, 2004).	
A minimum of 12 qualifying rainfall events (Section 7.5) are required to be sampled for the duration of the study, per TAPE. Additionally, at least 10	The number of rainfall events sampled will be compared to the minimum amount at the end of the project, and additional rainfall events will be sampled as needed. Samples which represent less than 75% of the hydrograph will not be accepted. If

aliquots and 75% of the hydrograph must be sampled during the qualifying rainfall event.	samples only consist of 7-9 aliquots, the samples may be accepted if rationale is provided in the TER as to why the sample was used (per TAPE).
A minimum of 95% of the samples analyzed by the lab must be considered valid prior to the end of the study.	95% of the samples must be accompanied by method blanks, rinsate blanks, matrix spikes, lab control spikes, and field duplicate results which are valid. Additionally, the samples must be received and analyzed within the appropriate temperatures and holding times. Temperature will be verified from the results reported by the lab.
Define procedures for handling missing data, use appropriate coding for missing data, and report missing data with the results	Procedures for handling missing data and coding missing data are defined in section 11.0. The Final Technical Report for this study will include consideration for how missing data could limit the comparability of the data set.
Conduct routine maintenance for equipment at the site, in accordance with SOPs outlined in Section 8.0, to limit the possibility of missing or invalid data.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0 (written to match manufacturer's specifications).
An equipment checklist and Chain of Custody forms will be used to prevent loss of data resulting from missing containers, inoperable delivery and collection apparatus or sample delivery.	
Comparability DQIs for This Study	**Comparability MPQs for This Study**
Comparability - A qualitative term that expresses the measure of confidence that one dataset can be compared to another and can be combined or contrasted for the decision(s) to be made. Data is comparable if sample collection techniques, measurement procedures, analytical methods, and reporting are equivalent for samples within a sample set, and meet acceptance criteria between sample sets.	
The test site is located on an arterial in a developed urban area with commercial and residential land use surrounding the site.	The process for selecting the study area is defined in section 7.2: the process focused on having a test site that is representative of locations where the sand filter sidewalk vault will be installed.
Define and consistently follow SOPs for sample collection and field measurements	SOPs were developed and will be consistently followed during this study
All data and sample collection will be conducted in accordance with the SOPs outlined in Section 8.0.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0.
Standard testing methods will be used to analyze samples submitted to the lab.	Anatek, the laboratory proposed for water quality testing in this study, is certified by Ecology and will follow standard methods approved by the US Environmental Protection Agency (EPA) (APHA et al. 1992, 1998; US EPA 1983, 1984). The methods to be used are listed in Table 9.1. Deviations from methods will be noted on analytical reports.

Sensitivity DQIs for This Study	Sensitivity MPQs for This Study
Sensitivity - The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest (EPA, 2002).	
Analytical results for water quality samples will be reported if they are above the reporting limit.	Reporting limits for water quality parameters are listed in Table 6.2. Data reported as below the detection limit will be calculated using the reporting limit shown in Table 9.1
All water quality testing methods selected have detection limits above the expected range of results.	The expected range of results and respective reporting limit were compared in Table 9.1.
Instruments capable of accurately measuring variables at the site will be used during the study.	The sensitivity of instruments at the site is included with the monitoring equipment specifications in Appendix G.

6.1 *Precision*

Water quality sample and measurement precision will be assessed using laboratory and field duplicates. Precision for laboratory duplicates will be ± 40 percent relative percent difference (RPD) for oils (NWTPH-Dx), ± 25 percent for TSS, and 20 percent for all other water quality parameters (Table 6.1). Precision for field duplicates will be ± 40 percent RPD for oils (NWTPH-Dx) and ± 20 percent for all other water quality parameters. In all cases, the RPD of duplicate samples will be calculated using the following equation:

$$\text{RPD} = \frac{|C_1 - C_2|}{\bar{x}} \times 100\%$$

Where: RPD = relative percent difference
C_1 = concentration (or value) of original sample
C_2 = concentration (or value) of duplicate
$\bar{x}$ = mean of samples

Rain gauge and flow measurement precision will be assessed at the beginning and end of the study. The rain gage precision will be assessed by pouring a known quantity of water into the tipping bucket two times. Precision for the rain gage measurements will be ± 20 percent RPD. Precision for flow will be assessed by comparing repeated pressure measurements with a known depth of water over each of the respective pressure transducers. Precision for pressure transducer measurements will be ± 20 percent RPD.

6.2 *Bias*

Bias will be assessed based on analyses of method blanks, rinsate blanks matrix spikes, and control standards (Table 6.1). Method blank values will not exceed the reporting limit. Rinsate blank values will not exceed two times the reporting limit. The percent recovery of matrix spikes will be ± 25 percent for total phosphorus, ortho-phosphorus, hardness, total and dissolved metals, and oils (NWTPH-Dx). Duplicate matrix spikes will also be run on a portion of the samples. The laboratory control sample recovery will be ± 20 percent for TSS, total phosphorus, and ortho-phosphorus, and ± 30 percent for hardness, total and dissolved metals and oils (NWTPH-Dx). Percent recovery (%R) for matrix spikes will be calculated using the following equation:

$$\%R_m = \frac{(X_s - X_o)}{C_s} \times 100\%$$

Where: $\%R$ = percent recovery
X_s = spike sample result
X_o = original sample amount
C_s = concentration of spike

If the analyte is not detected in the un-spiked sample, then a value of zero will be used in the equation. Percent recovery (%R) for control standards will be calculated using the following equation:

$$\%R_c = \frac{M}{T} \times 100\%$$

Where: %R = percent recovery
M = measured value
T = true value

6.3 Representativeness

Representativeness is the degree that the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency, and sampling methods. The BMP location selected for the Study is representative of an urban area with space constraints that would preclude the use of a basic sand filter BMP (see Section 3.2, Problem Description). Local stormwater hydrologic conditions are represented by conducting the study over two wet seasons and collecting data from a minimum of 12 storm sampling events. Qualifying storm events are described in Section 7.5. The rainfall tipping bucket gage will have a measurement resolution of 0.01 inches, which will be adequate to evaluate these qualifying storm criteria. Rainfall measurements will be made every 15 minutes and every 5 minutes during storm events, which will be an adequate resolution to characterize the storm hydrograph. The tipping bucket rain gage will be located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. The rain gage will be installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage.

Field and laboratory methods will have measurement ranges and reporting limits adequate to evaluate achievement of TAPE treatment performance goals (Ecology 2011). Grab samples will be collected during the rising limb of the storm hydrograph, per TAPE guidance. Composite samples will be collected by in-situ flow-weighted composite sampling. These methods will provide samples representative of the storm water quality.

Table 6.2 Measurement Performance Criteria (MPC) for Water Quality, Sediment, and Sand Filter Media Data.

Matrix	Parameter	Units	Method	RL	Method Blank	Rinsate Blank	LCS Recovery (Percent)	MS Recovery (Percent)	MSD (RPD)	Field Duplicate (RPD)[a]
Water Quality	Total Suspended Solids (TSS)	mg/L	SM 2540D	1	<RL	<2X RL	80 - 120	N/A	NA	≤25%
	Particle Size Distribution (PSD)	%	ASTM D3977-97[b]	NA	NA	NA	NA	NA	NA	≤10%
	pH	std. units	EPA 150.1	NA	NA	NA	NA	NA	NA	≤10%
	Water Temperature	Celsius	EPA 170.1[c]	NA	NA	NA	NA	NA	NA	≤10%
	Dissolved Copper (Cu)	µg/L	EPA 200.8 (ICP/MS)	0.1	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%
	Dissolved Zinc (Zn)	µg/L	EPA 200.8 (ICP/MS)	5	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%
	Total Copper (Cu)	µg/L	EPA 200.8 (ICP/MS)	0.1	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%
	Total Zinc (Zn)	µg/L	EPA 200.8 (ICP/MS)	5	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%
	Hardness as CaCO3	mg/L	SM 2340B (ICP)	1	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%
	Ortho-phosphate (OP)	mg/L	SM 4500-P G	0.01	<RL	<2X RL	80 - 120	75-125	≤20% or ± 2 x RL	≤20%
	Total Phosphorus (TP)	mg/L	SM 4500-P F	0.01	<RL	<2X RL	80 - 120	75-125	≤20% or ± 2 x RL	≤20%
	NWTPH-Dx	mg/L	Ecology NWTPH Dx	0.25	<RL	NA	70 - 130	70 - 130	≤40% or ± 2 x RL	≤40%
Sediment	Sediment PSD	percent	ASTM D422 and Modified SSC method (based on ASTM Method D3977-97)	NA	NA	NA	NA	NA	NA	≤25%

a. The relative percent difference will be less than or equal to the indicated percentage for values greater than 5 times the reporting limit, and ± 2 times the reporting limit for values less than or equal to 5 times the reporting limit.

b. Modified Suspended Sediment Concentration (SSC) Method according to ASTM Method D3977-97 (ASTM 2002) using wet sieve filtration (Method C) and glass fiber filtration (Method B)

c. Continuous temperature data is field metered (EPA, 2014).

mg/L = milligrams per liter, µg/L = micrograms per liter, std. units = standard units
RL = Reporting Limit, LCS = Laboratory Control Sample, MS= Matrix Spike
MSD = Matrix Spike Duplicate, RPD = Relative Percent Difference, NA = Not Applicable, PSD = Particle Size Distribution

7.0 Experimental Design

7.1 Study Design Overview

The BMP design and maintenance guidance was developed using the results from flow through column testing conducted prior to the development of this QAPP (Section 3.3). The BMP will be sized such that the maximum ponding in the vault will not overflow into the bypass pipe (18-inches above the sand media) during a water quality event. The water quality event is defined as the 6-month 24-hour storm. Maintenance will occur before the field measured infiltration rate drops below the design infiltration rate. Maintenance includes removing and cleaning the coconut coir mat, replacing the top six inches of the sand media, and placing the coconut coir mat back on top of the sand media.

The test-site was constructed in 2016 and includes a non-sumped inlet box with a grate inlet, concrete monitoring vault and the sand filter sidewalk vault (Figure 7.1). A tipping bucket rain gauge will also be installed at the test-site to monitor rainfall depth overtime. This data will be used to confirm that rainfall events meet Ecology's requirements for qualifying events for sample collection. The sidewalk vault will contain the sand filter media, an underdrain, and a bypass pipe.

Major components of the monitoring system are shown in Figure 7.1 and defined below:

- A non-sumped inlet box with a concrete inlet type 1 that captures runoff from the contributing basin area which is conveyed to a treatment cell (i.e., the sand filter sidewalk vault).
- The sand filter sidewalk vault contains the sand filter media mix (an organic blanket overlaying an 18-inch medium sand layer), gravel drain rock, underdrain pipe, and an bypass pipe (for overflow)
- A concrete monitoring vault will house the monitoring equipment including two automated samplers, a data logger, flow and temperature (pressure transducers)
- Two monitoring vault pipe networks, which consist of 6-inch polyvinylchloride (PVC) pipe and tees, located in the monitoring vault where influent, bypass and effluent flow rates and water quality samples will be collected

Runoff, primarily from impervious surfaces, is intercepted by a non-sumped inlet box with a grate inlet and conveyed to the sand filter via a 6" pipe. After infiltrating through the sand filter, the treated stormwater (effluent) will discharge to an underdrain. The underdrain will convey the treated runoff back to the monitoring vault through the effluent monitoring and sampling tees. Then runoff will be discharged to an adjacent drywell. Stage and temperature data will be collected using a pressure transducer that is located upstream of a control weir. The data logger is programmed to calculate the flow rate at the weir using the stage measured by the pressure transducer. Auto samplers will collect stormwater samples from another tee located just downstream of the control weir. The bypass flow rate will also be measured using a control weir and a pressure transducer. Figure 7.2 is a process drawing of the monitoring system and Table 7.1 provides a summary of all the monitoring equipment.

The duration of this study is expected to occur over two wet seasons and samples from the influent and effluent will be collected from a minimum of 12 rainfall events. The samples will be submitted to an Ecology certified lab for analytical testing. The samples will be tested for the required and screening parameters identified in Table 4.1 for basic, dissolved metals, and oil treatment.

The data will be evaluated to determine which pollutants meet Ecology treatment performance requirements defined in TAPE. For those pollutants that meet Ecology treatment goals, the final technical evaluation report will include recommendation for approving the BMP for a '*general use*' designation. This study also includes submitting a TAPE application that enters the new BMP into the evaluation program, submitting annual reports, developing the QAPP and technical evaluation report for Ecology and the TAPE Board of External Reviewers (BER) to review and approve.

The final report will also be submitted to Ecology at the end of the study to meet the requirements for an effectiveness study. Annual reports will be developed and included in the city's annual stormwater report.

Note: The photos were taken prior to installation of monitoring equipment in the monitoring vault.

1. Concrete Type 1 non-sumped inlet box with a grate inlet
2. 6-inch PVC inlet pipe in monitoring vault (upper right) and in sand filter sidewalk vault (lower right)
3. Concrete monitoring vault
4. Sand filter sidewalk vault
5. 6-inch PVC overflow pipe in sand filter sidewalk vault
6. 6-inch PVC effluent pipe in monitoring vault

Figure 7.1 Monitoring system and sand filter BMP located at the Test-Site

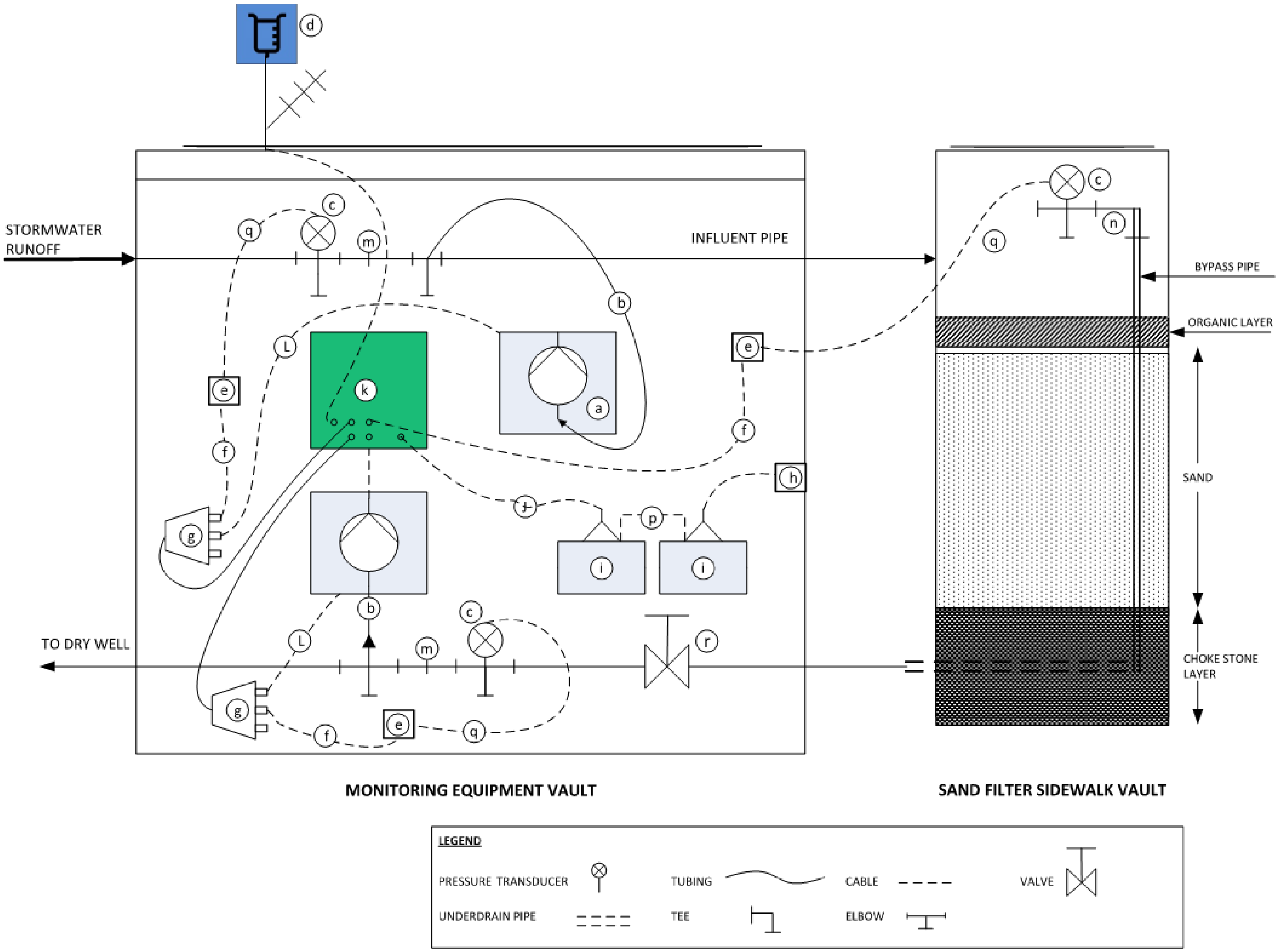

Figure 7.2 Water Quality Monitoring System Process Drawing: Cross-Section View

Table 7.1 Summary of Monitoring Equipment and Instrumentation

Symbol	Equipment Name	Equipment Function	Quantity
a	ISCO Avalanche Refrigerated Autosampler	Collects and stores influent and effluent samples	2
	Avalanche 2.5 Gallon Nalgene Bottle Configuration		2
b	3/8 inch ID x 25 ft. Vinyl Suction Line, with Standard Weighted Polypropylene Strainer and Tubing Coupler	Suction tubing conveys influent and effluent to the samplers	2
c	OTT Pressure Level Sensor (PLS), 0-4 meter Range, SDI-12 Communication	Measures depth of water in pipes which is used with the Thel-Mar weirs to determine the influent, effluent, and bypass flow rates	3
d	Rain Gauge, Tri-leg Mount and 20 ft Armored Cable	Records rainfall data	1
e	FAD 5 Humidity Absorber Connection Box	Controls humidity within the monitoring equipment vault	3
	Replacement Desiccant Cartridge	Humidity indicator within the monitoring equipment vault	3
f	Cable, Terminal Strip to SDI Port, 1.5 ft	Connects SDI port to the humidity box and samplers	3
g	Cable, SDI Connectors to SDI Port, 2 ft	Connects SDI port to the trickle battery charger	2
h	Trickle Battery Charger (AC to DC Charger)	Continually charges batteries	1
i	Battery, GNB Sunlyte, 100AH, Starved Electrolyte	Battery powers samplers and data logger	2
j	Battery Cable, Dual 10A Fuse, F6 & H2, 8.5ft	Connects data logger and samplers to battery	1
k	Axiom H2 Data logger	Records data over time via connected external instruments and sensors	1
l	SDI-ISCO Interface, 4.5ft Cable	Connects pressure transducer to humidity box and samplers	2
m	Thel-Mar Volumetric Weir 6”	Measures influent and effluent flow rates	1
n	Thel-Mar Volumetric Weir 8”	Measures overflow flow rate	1
o	Plastic Pressure Transducer/Sample Tubing Supports	Supports pressure transducer and sample tubing	5
p	Cable, Two Batteries in Parallel	Connects batteries to operate in parallel	1
q	PLS Probe Cable	Connects pressure transducer to SDI port and data logger	3
r	Valve	Allows effluent pipe to be closed and allows falling head test to be performed	1
s	Spears Mfg. Pressure Transducer Molded Flange	Supports pressure transducer and secures in an upright position	3

7.2 Test-Site(s) Selection Process

The proposed test-site is located near the intersection of Hawthorne Road and U.S. 2 in Spokane, Washington (see section 4.3 for aerial photos of the site). This site was selected because the average daily traffic (ADT) count on both roads exceeds 15,000 and the site is adjacent to a signaled intersection where high traffic turn-over is expected. As defined in the EWA Phase II NPDES MS4 permit and the Underground Injection Control (UIC) guidance manual, this type of land use triggers runoff treatment requirements for dissolved metals and spill containment of oils and hydrocarbons. As such, it is anticipated that sufficient quantities of pollutants will be present to meet Ecology's influent pollutant range goals defined in TAPE (Table 14.1).

7.3 The Structural BMP System Sizing

The new BMP is sized to provide runoff treatment for the water quality event (6-month 24-hour event) with larger flows managed with the bypass pipe which is located 18-inches above the sand filter media. The methods and assumptions for sizing the BMP include:

- The BMP will be sized using the Bowstring Method as defined in the SRSM (Spokane County, City of Spokane, and Spokane Valley, 2008).
- The sand filter sidewalk vault footprint is 20 sqft (internal base area of the vault)
- The sand filter media design infiltration rate is 124 in/hr (K_{sat} = 248 in/hr)
- The maximum ponding depth in the sand filter is 18-inches (height of overflow pipe) during the water quality event.

7.3.1 Recommended Design Guidance and Sand Media Specification

This section provides a summary of the recommended design guidance for the sand filter sidewalk vault and sand media specification. Performance objectives, applications, limitations, siting, design criteria, sand filter media criteria, construction criteria, and maintenance criteria are outlined in the following paragraphs. The guidance presented in based on the results of the column testing (Section 3.3) combined with the design guidance defined in the Eastern Washington Stormwater Management Manual for the basic sand filter BMP (Ecology, 2004).

Performance Objectives
The sand filter sidewalk vault is designed to meet the following performance objectives:

- Basic Treatment Goal: 80% reduction of TSS (at influent event mean concentrations of 100-200 mg/L)
- Dissolved Metals Treatment Goals: greater than 30% reduction of dissolved copper; greater than 60% dissolved zinc
- Oil Performance Treatment Goal: oil and grease in effluent is below 10 mg/L daily average and below 15 mg/L at any time; no visible sheen in discharge

Applications and Limitations
The applications of the sand filter sidewalk vault include the areas listed below where basic, dissolved metals, and/or oils treatment are required:

- Residential and commercial roadways
- Locations with space constraints
- Retrofit or re-development projects

The limitations of the sand filter sidewalk vault include:

- Design infiltration rate = 124 in/hr
- Sized to treat only the 6-month, 24-hour storm event (72% of the intensity calculated using the 2 year 24 hour Rational Method)
- Not designed to handle pollutant loads higher than those expected from residential or commercial roadways

Site Suitability Criteria
The characteristics to consider when assessing a potential sand filter sidewalk vault site include:

- Space availability (5 feet long, 4 feet wide) in sidewalk
- Access to a dry well or storm drain network for effluent discharge
- Adequate access for operation and maintenance of the sand filter sidewalk vault
- Contributing basin is residential or commercial roadway

Design Criteria
The sand filter sidewalk vault is sized according to the criteria in the bulleted list below.

- Size to infiltrate the water quality event, 6-month 24-hour storm (72% of the intensity calculated using the 2 year 24 hour Rational Method)
- Up to 18-inch ponding depth allowed above media during the water quality event
- Bypass pipe set at 18 inches above media
- Design using the Bowstring Method
- Design infiltration rate is 124 in/hr

Sand Filter Media Criteria
The sand filter media placed within the sand filter sidewalk vault will be 18 inches minimum in depth and must consist of a coarse sand meeting the size gradation provided in Table 7.2.

Table 7.2 Sand Filter Media (C2100 Coarse Sand) Gradation

U.S. Sieve Number	Particle Diameter (mm)	Percent Passing Range (%)
3/8	9.50	100
4	4.75	90-100
8	2.36	45-85
16	1.19	9-45
30	0.60	0-18
50	0.30	0-10
100	0.15	0-7
200	0.07	0-2

The sand filter media is placed on top of a 3 inch thick layer of choke stone which overlays a 8 inch layer of pipe bedding. Pea Gravel is used for both the choke stone and pipe bedding. The gradation of Pea Gravel is summarized in Table 7.3.

Table 7.3 Choke Stone and Pipe Bedding (Washed Pea Gravel) Gradation

U.S. Sieve Number	Particle Diameter (mm)	Percent Passing Range (%)
1/2	12.7	100
3/8	9.50	99.8
1/4	6.30	74.7
4	4.75	35.1
8	2.36	2.10
16	1.19	0.70
50	0.30	0.40
200	0.07	0.29

Within the pea gravel layer is an underdrain which collects flow and conveys the effluent to a collector pipe and then drywell or storm drain network. The underdrain pipe should meet the specifications listed below.

- 3-inches of the choke stone should be placed above the underdrain and underneath the sand filter media
- Size to handle the two-year return frequency flow, assuming at least one foot of hydraulic head above the invert of the collector pipe leaving the sand filter sidewalk vault
- Use an underdrain pipe with an internal diameter of 8 inches, with two rows of ½-inch holes spaced six inches apart longitudinally, and holes 120° apart (pipe laid with holes downward)
- Slope underdrain at a minimum of 0.5 percent
- Cleanout wyes should extend to the surface and provide access to clean all underdrain piping in the sand filter sidewalk vault.

Coconut coir is laid on top of the sand filter media in the sand filter sidewalk vault to dissipate energy of influent stormwater, assist with distributing runoff over the sand filter media surface, and provide some treatment through the CEC of the material. The coconut coir to be used is approximately 1.5 inches thick. A specification sheet for the coconut coir used in the study is included in Appendix L.

Construction Criteria

No runoff should enter the sand filter sidewalk vault prior to completion of construction and approval of site stabilization by the responsible inspector. Level placement of sand filter media during installation is important to avoid formation of voids within the sand that could lead to short-circuiting. Sand filter media will be placed into the vault in 6-inch lifts above the choke stone layer. After each 6-inch lift, water will be used to compact and settle the sand filter media. Once all of the 6-inch lifts have been settled, the coconut coir mat can be placed on top of the sand filter media.

Maintenance Criteria
Maintenance frequency of the sand filter sidewalk vault will be confirmed during the study. Prior to measured infiltration dropping below the design infiltration rate, the coconut coir mat will be removed, and the top 6 inches of sand filter media will be removed by a vactor truck. A new 6-inch lift will be placed and settled using the procedures outlined in the previous section (Construction Criteria). The coconut coir mat will also be cleaned by either sweeping or rinsing accumulated debris from the top of the mat. The mat will be shaken to remove remaining debris, and replaced on the sand filter media.

7.4 Type of Data Being Collected

Sampling process design has been developed based on monitoring requirements identified in the Eastern Washington NPDES Phase II Permit (Ecology, 2014) and in TAPE (Ecology, 2011). This section addresses the steps and processes taken to develop these monitoring sites and sampling strategies and to ensure the data collection and monitoring methods satisfy the requirements of TAPE and the permit. Table 7.4 provides a summary of the type of data that will be collected along with the frequency of data collection, sampling method, and the sampling location.

Table 7.4 Summary of Data to be Collected

Parameters	Frequency	Sampling Method and Sampling Location
Precipitation	Continuous, year-round	Rain Gage, on-site
Stage (Discharge)	Continuous[1], year-round	PT: influent, effluent, and by-pass
Time	Continuous[1], year-round	PT, influent, effluent, and by-pass
Temperature	Continuous[1], year-round	PT, influent, effluent, and by-pass
TSS, Metals, Hardness, pH	Storm events (min. of 12 events)	Composite with Autosampler, Influent and effluent
OP, TP	Storm events (min. of 3 events)	Composite with Autosampler, Influent and effluent
NWTPH-Dx, visible sheen observation	Storm events (min. of 12 events)	Grab sample, influent and effluent
PSD influent	Storm events (min. of 3 events)	Composite with Autosampler, Influent
Infiltration Rate	Quarterly (falling head test); after each qualifying event (effluent flow rate)	Falling head test; close effluent valve, fill vault using water (from water truck or fire hydrant), measure rate of fall with yard sticks; Composite with Autosampler, effluent flow rate
Sediment Accumulation	After each qualifying rainfall event; once after testing is completed	Measure sediment accumulation depth on top of sand filter media using a measuring tape and calculate average of 5 measurements; post testing, three samples of the sand filter media will be collected from on top of the sand filter media as well as the top, middle, and bottom layers of the media, PSD will be graphed and compared to PSD measured prior to testing
Sand filter media	Once	Grab sample, BMP media prior to installing media in vault

1. Measured in 5-minute intervals when storms are monitored and 15-minute intervals during all other times.
PT = Pressure transducer data logger; Metals = Total and Dissolved Copper and Zinc; PSD = Particle Size Distribution; OP = Ortho-phosphate; TP = Total Phosphorus

The study is expected to last two wet seasons. Water quality samples will be collected during a minimum of 12 qualifying rainfall events (see Table 7.5 for definition of qualifying rainfall events). This will include collecting flow weighted composite and grab samples from the influent and the effluent. Composite samples collected will represent at least 75% of the storm event hydrograph (by volume). Additionally, sampled storm events will target a minimum of 10 aliquots per storm event. Samples will be tested for the required parameters (12 minimum samples) and screening parameters (three minimum samples) as defined in TAPE in order to demonstrate treatment performance goals for basic, dissolved metals, and oils.

The discharge flow rate for the influent, effluent, and bypass are calculated by the data logger using stage values measured by the pressure transducers (PTs) combined with weir equations specific to the pipe diameter. Weirs are located upstream of the PT in the influent, effluent, and bypass pipes. Weirs were selected for this test site because they are preferred over flumes in lower-flow "flashy" systems in order to more accurately characterize small-scale hydrological features (Rantz at al, 1982; USEPA, 2002c). However, weirs tend to be more influenced by debris than flumes (Church et al., 2003) and need to be carefully monitored and maintained. Equations for the weirs are derived specifically for each size of weir (based on the pipe diameter) and are provided by the manufacturer below. These equations are programmed into the data logger logic and calculate the discharge flow rate at each time interval using the stage (feet) measured by the PTs based on the flow over the weirs at the site (see Figure 7.2) for the 8-inch weir (in the overflow pipe) and the 6-inch weirs (in the influent and effluent pipes):

8-inch Weir – Bypass Flow

$$Q = 7807.1 \times (d_{PT})^{2.6316}$$

6-inch Weir – Influent and Effluent Flow

$$Q = 6085.1 \times (d_{PT})^{2.5756}$$

Where:

Q=flow rate (liters per minute)
d_{PT}=depth measured at pressure transducer (feet)

7.5 Precipitation Monitoring

Precipitation monitoring consists of two parts: storm event prediction and rainfall measurements. This section describes the methods for both.

7.5.1 Storm Event Prediction

Sampling will be attempted for storms that are predicted to meet the storm event guidelines defined in TAPE (Ecology, 2011). These events are referred to as 'qualifying rainfall events' in this document which have the characteristics included in Table 7.5.

Table 7.5 Storm Event Guidelines for TAPE Monitoring

Parameter	Definition	Guideline [a]
Minimum storm depth	Total rainfall amount during storm event	0.15 inches
Storm start (antecedent dry period)	Defines the storm event's beginning as designated by the minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Storm end (post storm dry period)	Defines the storm event's end as designated by minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Minimum storm duration	Shortest acceptable rainfall duration	1 hour
Average storm intensity	Total rainfall amount divided by total rainfall duration (e.g. inches per hour)	Range of rainfall intensities [b]

[a] Will provide justification in the Technical Evaluation Report (TER) for storm event data that does not meet the storm event guidelines, but is included in the data analysis. . Currently the data logger is programed to only collect samples during qualifying events.

[b] To assess performance on an annual average basis and performance at the system's peak design rate, samples will be collected over a range of rainfall intensities.

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, Spokane forecast office website will be monitored daily for storm forecasts. (http://graphical.weather.gov/sectors/otx.php). These observations will determine if a predicted storm will meet the qualifying event criteria and whether sample collection will occur.

7.5.2 Rainfall Measurements

Precipitation monitoring will be conducted to quantify rainfall during storm events and to measure the duration, intensity and distribution of rainfall throughout a discrete storm event. Precipitation will be monitored in 15 minute increments during typical operating conditions and every 5 minutes during rainfall events. The information is downloaded from the data logger at the test site. The precipitation monitoring device used for this study is a jeweled bearing tipping bucket rain gage. The tipping bucket rain gage has a data resolution of 0.01 inches.

The tipping bucket rain gage will be located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. The rain gage will be installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage. Rain gage placement will follow the National Weather Service (NWS) specifications (http://www.weather.gov/om/coop/standard.htm) as closely as practical for the site. Minor deviations from NWS specifications may be needed due to site specific constraints.

Rain gages will be mounted to the antenna mast approximately 6 to 8 feet from the ground unless otherwise specified. The rain gage will be calibrated prior to installation and maintained in accordance with the manufacturers' specifications. If a deviation from NWS or manufacturer's specification is needed, notation will be made regarding the alteration and included in the Technical Evaluation Report (TER).

Actual precipitation data at the site will be available remotely through a cellular connection with the data logger. The data will be used to identify on-site weather characteristics and estimate when sampling crew need to deploy for sample collection. During each station visit, the rain gage will be inspected, cleared of debris, and maintained in accordance with the manufacturers' specifications. All rain gage data collected will be downloaded from the data logger following each time samples are collected or during the maintenance schedule.

7.6 Water Quality Sampling

This section describes the two types of water quality sampling methods that will be used during this study: grab sampling and composite sampling.

7.6.1 Grab Sampling

TAPE states that grab samples should be collected on the rising limb of the hydrograph. Sampling staff are to collect grab samples as early in the runoff event as practical to ensure representativeness of the sample. A minimum of twelve samples will be collected for statistical comparison following TAPE guidelines.

If grab samples are not collected or are missed during qualifying storm events, allowable non-qualifying sized storm events may be sampled to ensure statistical requirements are met. An allowable non-qualifying storm means that only the stormwater rainfall depth can be the reason the storm is non-qualifying. Samples collected from non-qualifying storms will be noted and flagged in the dataset.

Grab samples are collected manually in jars or measured in situ with a probe. For this study, the oils samples will be collected manually in jars. The oils grab sample will be collected by placing a bottle beneath the opening of the influent pipe in the sand filter sidewalk vault and by dipping a bottle into an opening on the top of a tee in-line with the effluent pipe. pH and temperature will be measured in situ using a probe in a small amount of composite sample placed into a clean container. Visible sheen will be noted by observation of effluent in the pipes and composite sample. Additional details regarding the grab sample collection and probe measurement procedures are defined in the SOPs which are located in Section 8.1.4.

7.6.2 Composite Sampling

TAPE specifies that stormwater runoff must be collected by in-situ flow-weighted composite sampling. Each monitoring station will be equipped with an autosampler and a 2.5-gallon glass bottle for sample containment. Autosamplers such as an ISCO or a similar product will be used at each of the monitoring stations to collect stormwater samples during a qualifying storm event. Autosamplers will be programmed to begin sampling when initiated by the data logger. Autosamplers are programmed to begin sampling at the predetermined rates required for the collection of at least 75 percent of the event hydrograph. Sample collection into autosampler bottles will be triggered by the characteristics of a 'qualifying rainfall event' as described in Section 7.5. Specifically, the data logger is programmed to only collect samples when qualifying conditions occur. If conditions fall outside the limits of a qualifying event, the data logger is programmed to stop sampling. The characteristics (i.e., water temperature, rainfall, discharge, and time) are necessary to determine whether the antecedent criteria and rainfall criteria required by TAPE were met, stormwater runoff is occurring and the water is not frozen. Water temperature, rainfall, and discharge will be measured using external probes connected to the data logger. Time will be measured by the data logger itself. If these characteristics are not met during the storm, samples will not be collected.

7.7 Infiltration Testing

The infiltration rate of the sand filter media will be evaluated following each qualifying storm event using the effluent flow rates. Flow rates will be based on PT depth data and the associated equation for the 6-inch weir defined in Section 7.4. If a reduction in infiltration rates are observed below the design infiltration rate, the BMP will be inspected and maintenance cycle will be assessed.

Collecting a representative infiltration rate measurement using the influent and effluent flow data recorded by the data logger requires that the media is saturated. This condition is expected to occur when the influent flow rate exceeds the effluent discharge rate for a sufficient period of time. However, the initial infiltration rate of the sand filter media is expected to be approximately 1000 in/hr which will most likely be higher than the influent flow rate (from rainfall runoff) for the initial rainfall events. During these events it will not be possible to measure a representative infiltration rate using the flow data until the infiltration has declined and saturated (ponding) conditions occur in the sand filter vault. As such, a modified version of the falling head tests will also be (see Section 8.1.8) performed a minimum of four times per year.

7.8 Sediment Sampling

After testing is complete (post testing) the sediment that accumulates on top of the BMP and within the top, middle, and bottom layer of the sand filter will be collected and sent to the laboratory to determine the particle size distribution (PSD). Composition of sediments on top of the BMP will be noted on field forms (based on visual observation) as well to assist with characterization and corroborate the laboratory findings.

7.9 Sand Filter Media Material Testing

The sand filter media will be tested once prior to installation at the test site. The purpose of this testing is to define the media physiochemical properties. This information will be used to define the media properties for the BMP design specification. The physiochemical properties selected for testing include those that are known to influence treatment and flow control performance. The testing anticipated for this study is summarized in Table 7.6.

Table 7.6 Summary of Sand Filter Media Material Testing Parameters and Methods

Parameter	Standard Methods
pH	S-2.20
Moisture Content	ASTM D2216
Cation Exchange Capacity (CEC)	S10.10
Maximum Dry Density	ASTM D1557
Saturated Hydraulic Conductivity (K_{sat}) @ 85% compaction rate	ASTM D2434
Particle Size Distribution for the following sieve sizes: 4, 8, 16, 30, 50, 60, 100, 200, 230, retained on 1.5µm glass fiber filter	ASTM D422 and Modified SSC method
Total Elements: Zn, Cu, Pb, TP, Mg, Ca	EPA 3050A/6010B
Total Organic Carbon	EPA 415.3
Carbon to Nitrogen ratio	EPA 415.3/351.2

8.0 Sampling Procedures

This section defines the field procedures for collecting samples, measuring data, as well as operating, maintaining, and calibrating the equipment.

8.1 Procedures for Collecting Field Measurements

Water quality samples will be collected in the field, following standard operating procedures (SOPs). The SOPs developed for this study define how to conduct storm selection, sample collection, site measurements and equipment maintenance and calibration in detail, including the frequency of the activity. All visits to the site should be conducted with a partner or multiple personnel. SOPs included in this section are:

- Storm Selection and Tracking
- Storm Monitoring Equipment Maintenance
- Preparing Stormwater Monitoring Equipment for Storm Sampling
- Stormwater Grab Sampling
- Stormwater Sample Collection and Processing
- Monitoring Equipment Data Download
- Sediment Accumulation Rate
- Falling Head Test

8.1.1 Storm Selection and Tracking

The purpose of this SOP is to define the procedures for selecting and tracking storm events prior to and during stormwater monitoring activities.

Equipment Needed:

- A computer or mobile device with the ability to access weather forecasting websites or applications
- A cellular phone to allow communication between sampling staff and staff tracking the storm event
- A Storm Decision Log (Appendix H) to record the decision process, weather activity, and outcome of the event

A summary of the procedures for storm tracking prior to a monitoring event and storm selection are as follows. Note: throughout this section and document, the term sampling event and monitoring event are used interchangeably. Both terms refer to a predicted qualifying storm event in which the data logger and autosamplers are set to the *sample mode* to collect storm data and water quality samples.

- Step 1: Review weather forecast daily to determine whether upcoming storm events meet the storm event guidelines defined in TAPE (qualifying rainfall event) and described in Section 7.5 of this document. Storm event probability will be tracked via the NOAA National Weather Service Spokane forecast office website at the following link:

https://forecast.weather.gov/MapClick.php?lat=47.75&lon=-117.41&unit=0&lg=english&FcstType=graphical

- Step 2: The probability of a qualifying rainfall event will be determined based on the weather forecast and the following qualitative classification system:
  - Unlikely: a storm event that is classified as unlikely will produce less than the minimum depth (0.15-inches) for a qualifying rain event and has less than a 50% chance of occurring.
  - Marginal: a storm event that is classified as marginal will produce less than the minimum depth for a qualifying rain event and has a 50% to 75% chance of occurring.
  - Likely: a storm event that is classified as likely will produce greater than the minimum depth for a qualifying rain event and has a greater than 75% probability.
- Step 3: Based on the classification of the predicted rainfall event, the sampling staff will determine whether to prepare to monitor the rainfall event. Specifically:
  - If the storm is deemed unlikely, sampling staff will not plan to collect samples during the event
  - If the storm is deemed marginal, the principal investigator or project manager will determine whether the conditions of the storm look favorable or not using their professional judgment. The judgment will take storm characteristics and sampling success to date into account. For storm events with a marginal chance of being a qualifying rainfall event, sampling staff may be informed several days in advance of a possible upcoming event.
  - If the storm is deemed likely, the principal investigator or project manager will inform sampling staff as soon as possible in advance (preferably 24 to 48 hours in advance) of the anticipated monitoring event.
- Step 4: If a storm event is selected for monitoring, sample bottles will be obtained from the lab as necessary and equipment will be prepared in accordance with the procedures outlined in Section 8.1.3.
- Step 5: Prior to and during a storm event that is selected for sampling, actual rain gauge data at the test-site will be monitored remotely through a cellular connection to the data logger. The data will be used to determine when sampling personnel will go to the site to collect grab samples or composite samples.

8.1.2 Storm Monitoring Equipment Maintenance

The purpose of this SOP is to outline the steps required for maintaining stormwater monitoring equipment at the test site. Maintenance of storm monitoring equipment should occur at minimum once per month, unless otherwise specified.

Equipment needed:

- Traffic cones
- Personal Protective Equipment (PPE) including: eye protection, gloves, high visibility vest, work boots, etc.
- Tools necessary to access vaults
- Periodic Maintenance Checklist Field Form (Appendix H)

- Wet-dry vacuum
- Soft brush
- Volt meter
- USB drive
- Screwdriver
- Replacement suction, head, and pump tubing
- Volumetric plastic beaker
- Adjustable wrench
- Telescopic mirror
- Torpedo level
- Flashlight
- Replacement battery
- Spare desiccant bags (for ISCO and PT)
- Electronic water level indicator (tapedown tool)
- Nitrile gloves
- Cellular phone

Summary of procedures for initial inspection of site conditions and monitoring equipment at the test-site:

- Step 1: Place traffic cones as needed to call attention to the presence of staff along the roadway. Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the Periodic Maintenance Checklist Field Form (Field Form) in Appendix H.
- Step 2: Open the monitoring equipment vault and sand filter vault and remove the inlet grate. Visually inspect pipes, cables, wiring, tubing, and monitoring equipment. Note any frayed wires or damaged equipment on the Periodic Maintenance Checklist Field Form. Contact principal investigator or project manager on how to proceed if damage is significant. *Note: When accessing the equipment in the vaults, do not disturb pipes or pipe tees*.
- Step 3: Inspect pipes, tees and weirs for debris or obstructions. Note and describe any debris on the field form.
    - If debris or sediment are observed in pipes, tees, or weirs, clean pipes according to Steps 3 – 5 in Section 8.1.3. Then immediately replace the grate inlet.
- Step 4: Disconnect power supply to battery. Check voltage of battery using a voltage meter. Battery voltage reading should be above 10.3 volts. Record the voltage reading on the Periodic Maintenance Checklist and reconnect power to the battery.
    - If battery voltage is not within the specified range, replace battery with the spare, fully charged battery.
- Step 5: Connect the USB flash drive to the data logger, tap the screen to wake up the data logger, and start a visit report. *Note: when the visit report is ended in Step 14, the current conditions data is automatically downloaded to the USB.*

    - To start a visit report, press service on the main menu. Tap the visit report icon on the next page, and fill in the information as applicable for the visit report. Tap the start visit icon and follow the prompts to start the visit report.
- Step 6: Once every three months, unplug the rain gage from the data logger. Remove cover from rain gage and check instrument for levelness and cleanliness of internal parts. Clear any debris carefully. Note any discrepancies and reset level of rain gage platform if needed. Replace cover on rain gage and plug rain gage back in to the data logger.
- Step 7: Inspect ISCO suction tubing, head tubing and pump tubing for wear. Note and describe condition on the Periodic Maintenance Checklist. If kinks or bellies are observed in the tubing, replace tubing. Document whether replacement of tubing occurred during the site visit on the Periodic Maintenance Checklist.
- Step 8: Check the Internal Humidity Indicator to the right of the keypad on the ISCO.
    - If all of the indicator is blue, no additional action is needed. Record the indicator color on Periodic Maintenance Checklist.
    - If the area of the indicator next to 20% is white or pink, no additional action is needed, though action may be required in the near future. The color change near the 20% indicates that the level of humidity inside the ISCO controls compartment is 20%. Record indicator color on Periodic Maintenance Checklist.
    - If the area of the indicator next to 30% or any of the other areas above 30% are white or pink, the desiccant inside the ISCO controls compartment needs to be replaced. Record indicator color and whether the desiccant was replaced on Periodic Maintenance Checklist.
        - Pull discharge and pump tube away from bulkhead fitting. Remove the distributor arm by unscrewing the nut that attaches the arm to the distributor shaft. Unscrew the 11 screws securing the cover for the ISCO controls compartment.
        - Remove the desiccant bag from the box inside the controls compartment and replace with a new desiccant bag.
        - Replace the cover for the controls compartment and replace the 11 screws needed to secure the cover. Reattach the distributor arm and discharge and pump tubing.
- Step 9: Check the colored indicator on each of the PT humidity absorbing systems. Record the observed color on the Periodic Maintenance Checklist.
    - If the indicator is orange/brown, the desiccant cartridge is dry and does not need to be replaced.
    - If the indicator is white, the desiccant cartridge must be replaced per the manufacturer's instructions. Note that either the desiccant cartridge needs to be replaced, or has been replaced in the field on the Periodic Maintenance Checklist.
- Step 10: If the ISCO controller keypad is inflated, carefully reach behind the head unit and unscrew one of the bulkhead caps to relieve pressure. Retighten cap after pressure has been relieved to maximize desiccant lifespan.
- Step 11: Check the ISCOs pump capabilities by manually initiating a grab sample to test purging and pumping capabilities. Do this with the suction tubing disconnected to avoid falsely pumping a sample into clean sampling equipment.
    - Obtain the volumetric plastic beaker.

  - To manually initiate a grab sample, press the return arrow button on the control pad, navigate to “grab sample” and hit the return arrow button again. Follow the prompts to begin the grab sample.
  - Hold the beaker below the pump tubing. Once the sample has been pumped into the beaker, verify that the volume pumped matches what volume was reportedly pumped by the ISCO. If the volumes do not match, perform volumetric verification test as detailed in Step 12.
- Step 12: Once every three months (quarterly), conduct a volumetric verification test to ensure accuracy of ISCO calibration. Do this with the suction tubing disconnected to avoid falsely pumping a sample into clean sampling equipment. Repeat test as necessary until volumes are accurate.
  - Press the return arrow button, and navigate to “calibrate volume”. Enter the sample volume desired.
  - Hold a volumetric plastic beaker (large enough to hold sample volume) under the pump tubing, and hit the return arrow button when ready.
  - After the sample volume has been delivered, measure the actual volume delivered to the beaker and enter the amount on the ISCO screen as prompted. Press the return arrow button and follow the prompts.
  - The calibration is complete when the display on the ISCO screen returns to the list of manual functions.
- Step 13: Reconnect suction tubing to pump tubing.
- Step 14: Once all maintenance, cleaning, and calibration has been completed, end the visit report on the data logger, close the monitoring vault and sand filter vault, and secure as needed before leaving the site. Collect any traffic cones used.
  - To end the visit report, press service on the main menu. Tap the visit report icon on the next page, and tap the end visit icon near the bottom of the page. Follow the prompts as necessary, and remove the USB drive.

8.1.3 Preparing Stormwater Monitoring Equipment for Storm Sampling

The purpose of this SOP is to outline the steps required for cleaning and calibrating stormwater sampling equipment and the pH probe prior to monitor and sample storms, and preferably within 24-hours of the start of the monitoring event. Additional, general steps to prepare for stormwater sampling and processing are also covered in this SOP. *Note: prior to performing the steps outlined in this SOP, the lab will be notified that sampling is expected to occur, and that rinsate blanks, grab samples, and composite samples will be transported to the lab. An estimate of when each set of samples will be delivered will be provided to the lab.*

Equipment:

- Tools necessary to access vaults
- Telescopic mirror
- Adjustable wrench
- Torpedo level
- Volt meter
- Flashlight

- Wet-dry vacuum
- Soft brush
- Water source or 5 gallon bucket (with lid) filled with tap water
- Cleaning solutions for tubing (10% HNO3 acid solution, liquinox soap solution) in 5-gallon buckets (one for each solution) with lids
- Carboy(s) filled with DI water
- Sample bottles for rinsate blanks
- Cooler for sample bottles
- Hard ice packs for cooler
- Trash bag (for any large debris)
- pH meter
- pH probe storage solution
- pH probe cleaning solution
- Buffer solutions for pH meter
- Two small plastic beakers
- Traffic cones
- Clean, powder-free nitrile gloves
- Personal Protective Equipment (PPE) including: eye protection, gloves, high visibility vest, work boots, etc.
- Electronic water level indicator (tape down tool)
- Cellular phone
- Pre-Storm Event Maintenance Checklist, Chain of Custody Form

Summary of procedures to prepare monitoring equipment for storm sampling:

- Step 1: Place traffic cones as needed to call attention to the presence of staff along the roadway. Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering, or unsafe conditions. Note any findings on the Pre-Storm Event Maintenance Checklist.
- Step 2: Open the monitoring equipment vault and sand filter vault and remove the inlet grate. Start a visit report on the data logger according to Step 5 in Section 8.1.2. *Note: In accordance with "clean hands/dirty hands" procedures, one staff member will be designated to install new ISCO composite bottles, if necessary, in Step 16. This staff member may not handle other equipment during the site visit. Additionally, the staff member will wear two pairs of gloves during sample handling: after obtaining samples from cooler and opening the bag containing the sample bottles, the outer set of gloves will be removed to handle the clean sample bottles inside the bag.*
- Step 3: Inspect pipes, tees, weirs, and pipe connections. If debris or sediment are observed, put on gloves and eye protection, as needed. Check for sharp or potentially hazardous materials before beginning to clean. *Note: When accessing the equipment in the equipment vault and catch basin, do not disturb pipes or pipe tees*.
- Step 4: Before starting to clean, collect a water surface elevation measurement from the reference point on the control tee. Record the measurement and reference elevation on the

Pre-Storm Event Maintenance Checklist in the assigned space. Assign a + or – value to your reading if there is any uncertainty due to debris, blockage, etc. Subtract the measurement from the reference elevation to determine water surface elevation and record the value on the form. Compare this value to the measurement collected by the data logger to identify any prior instrument drift.

- Step 5: Use the vacuum to remove sediment or debris from pipe, pipe tees, pipe connections, and weirs. Drain or vacuum any remaining liquid or sediment within the sampling and control tees. Then immediately replace the grate inlet.
- Step 6: Inspect the pump, suction, and head tubing for the ISCO. If kinks or bellies are observed in the tubing, replace the tubing. Clean any ISCO tubing that was not replaced as follows:
    - Triple rinse the tubing with 10% HNO3 acid solution, then wash the tubing with liquinox soap solution, and finally triple rinse the tubing with DI water.
- Step 7: Put on a new pair of clean nitrile gloves and obtain the sample bottles provided for the rinsate blank.
- Step 8: Access the influent autosampler. Place the end of the clean suction tubing for that autosampler in a carboy containing DI water, and place the end of the clean pump tubing over one bottle provided by the laboratory for the rinsate blank. Set the ISCO to "Pump Forward" and fill the bottle so that no airspace is remaining when the cap is replaced.
- Step 9: Replace the cap on the sample bottle, taking care to not touch the inside of the cap.
- Step 10: Repeat Steps 8-9 for the effluent autosampler and associated rinsate blank bottle.
- Step 11: Once both rinsate bottles have been filled, place bottles in the cooler and fill out the Chain of Custody form for the rinsate samples.
- Step 12: Use a level to check position of weirs and pipe tees. Adjust to a level position as needed, and note if weirs or tees were not level on the Pre-Storm Event Maintenance Checklist.
- Step 13: Inspect pressure transducers (PT) and mounts. If PTs and/or mounts are dirty, remove PT and gently scrub to remove material with a soft brush. Once PTs and mounts are clean, reinstall PTs in original position within the mounts.
- Step 14: Fill the control tee with clean water until water runs over the v-notch of the weir (This may take a few gallons of water to achieve). Once the water stops flowing over the weir (point of zero flow), use the data logger to get a current PT reading. The PT reading may take a few minutes to update.
- Step 15: Once the PT reading updates, verify using the data logger that the PT reading value is zero. Take another water surface elevation reading using the electronic water level indicator to verify the PT and data logger reading.
    - If the values do not match zero or the elevation of water at zero flow, record the observed value on the field form and reset the stage reading for the pressure transducer to zero in the data logger. Notify the principal investigator or project manager of the drift as soon as possible.
- Step 16: Access the sample bottle inside the ISCO and check bottle configuration. If a new bottle is needed before a storm, install using clean hands/dirty hands procedures, as defined in Step 2 of this Section.
- Step 17: Make sure all tubing is connected properly, bulkhead caps are secured and that cables are properly attached.

- Step 18: Before leaving the site, set the data logger and ISCO autosampler mode to sample if the criteria for qualifying rainfall event (see Section 7.5) are met at the site during the forecasted storm.
    - On the ISCO, navigate to the main menu and set the ISCO to sample. The display should read, “Bottle 1 After 1 Pulses”.
    - On the data logger display, tap the processes icon on the screen, then the set sampl_enabl icon. Set the data logger to zero. This will set the data logger to sample if the criteria are met.
- Step 19: Additionally, set the threshold on the data logger to tell the system when to trigger influent and effluent sampling.
    - The threshold is determined through the spreadsheet calculator described in Appendix N.
    - The threshold values are set in the data logger by tapping the processes icon on the home screen, and then by tapping either of the threshold icons on the next page. The threshold value determined from the spreadsheet calculator in Appendix N is entered for both the influent and effluent thresholds.
- Step 20: Once all maintenance, cleaning, and calibration has been completed, end the visit report on the data logger (according to Step 14 in Section 8.1.2), close the monitoring vault and sand filter vault, and secure as needed before leaving the site. Collect any traffic cones used. Return rinsate samples and associated Chain of Custody to Anatek Laboratory in Spokane.
- Step 21: Upon returning to the HDR lab, obtain the pH meter and turn on the meter. Put on nitrile gloves and eye protection.
- Step 22: Inspect the electrode for cracks in the electrode stem or bulb. If scratches or cracks are present, the electrode must be replaced.
- Step 23: Inspect the cable connecting the electrode to the meter. The cable must be intact with no points of broken insulation on the cable. If breaks are observed, the cable and probe may need to be sent in to the manufacturer. End maintenance of pH meter and refer to the manual for the pH meter for further instructions.
- Step 24: Inspect the electrode for oil, calcium, or sediment build-up on the electrode stem or bulb. If present, remove the protective cap and clean the probe using DI water. Replace the protective cap once cleaning is complete.
- Step 25: Inspect connectors and ensure they are clean and dry. Rinse off any deposits with deionized water.
- Step 26: Inspect the protective cap and replace or refill the storage solution as needed to keep the glass bulb and junction of the pH meter submerged.
- Step 27: Clean the probe by soaking the probe in cleaning solution for at least one half hour. Once the probe has been cleaned, replace the protective cap with storage solution and discard the cleaning solution.
- Step 28: Pour a small amount of each buffer solution into a clean beaker, so the probe will be immersed at least 1 ½ inches. Begin a new calibration on the pH meter.
- Step 29: Remove the protective cap on the probe and rinse the electrode with some of the buffer solution to be used for the first calibration point. Place the probe in the first buffer and stir gently.
- Step 30: The screen should show the first expected buffer value; change the expected buffer to a different value if needed. Wait for the measured pH value to stabilize.

- Step 31: Once the pH value is stable, confirm the reading and record on the Pre-Storm Event Maintenance Checklist.
- Step 32: Remove the probe from the buffer solution, rinse the probe with the second buffer solution, and place the probe in the beaker with the second buffer solution. Adjust the expected buffer value on the meter screen as needed.
- Step 33: Stir the probe gently in the buffer solution and wait for the reading to stabilize. Once the reading is stable, confirm the reading and record on the Pre-Storm Event Maintenance Checklist.
- Step 34: Navigate back to the measurement mode and turn off the pH meter; the meter will save the calibration data. Replace the protective cap on the probe and refill with storage solution as needed. Discard the used buffer solutions.

8.1.4 Stormwater Grab Sampling

The purpose of this SOP is to outline the steps required to collect grab samples for oils grab samples. Grab samples will be collected during monitoring events, specifically during the rising limb of the event hydrograph. The rising limb is expected to occur within the first hour or two of the monitoring event.

Equipment:

- Traffic Cones
- Tools necessary to access vaults
- Electronic water level indicator (tape down tool)
- Cellular phone to enable communication between field staff and the principal investigator or project manager
- Flashlight
- Personal Protective Equipment (PPE) including: eye protection, high visibility vest, work boots, etc.
- Clean nitrile gloves
- Sample bottles
- Cooler for sample bottles
- Hard ice pack for cooler
- pH probe
- Sample Collection Field Form (Appendix H)
- Falling Head Test Form from most recent infiltration test
- Chain of custody form (Appendix I) and sample tag

Summary of procedures to obtain grab samples:

- Step 1: At least one hour prior to departing for the site, place sample bottles in the refrigerator to keep the bottles cool.
- Step 2: Place traffic cones as needed to call attention to the presence of staff along the roadway. Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the field form.

- Step 3: Open the monitoring vault (containing the monitoring equipment) and sand filter vault. If any visible sheen is observed in the sand filter vault, note that in the Sample Collection Field Form. Start a visit report on the data logger according to Step 5 in Section 8.1.2. *Note: In accordance with "clean hands/dirty hands" procedures, one staff member will be designated to handle sample bottles, collect samples, and package samples for the lab during a sampling event. This staff member may not handle other equipment during the sampling event. Additionally, the staff member will wear two pairs of gloves during sample handling: after obtaining samples from cooler and opening the bag containing the sample bottles, the outer set of gloves will be removed to handle the clean sample bottles inside the bag and return the bottles to the bag after collection of samples.*
- Step 4: Put on clean nitrile gloves and obtain the bottles for the influent oils samples.
- Step 5: Carefully remove the lid of the oils bottle without touching the inside of the lid. Place the bottle below the opening of the influent pipe in the sand filter vault. Fill the bottle.
- Step 6: Once the bottle is full, place the cap on the bottle and transfer bottle to the plastic bag in the cooler.
- Step 7: Step not used.
- Step 8: Put on new, clean nitrile gloves and obtain the bottles for the effluent oils sample.
    - The collection of the effluent sample will be delayed a certain amount of time after the influent sample to ensure effluent conditions reflect the conditions in the influent sample. The delay time will be equivalent to the estimated infiltration rate through the sand media that was calculated and recorded on the Falling Head Test Form during the previous sample event.
- Step 9: Carefully remove the lid of the first oils sample bottle without touching the inside of the lid. Dip the bottle for the oils effluent sample into the opening in the top of the tee so the surface of the water is captured in the bottle. Pull the bottle forward to fill.
- Step 10: Once the bottle is full, place the cap on the bottle and transfer the bottle to the plastic bag in the cooler.
- Step 11: Repeat steps 9 and 10 for the remaining oils sample bottles.
- Step 12: Fill out the Chain of Custody for the grab samples according to the procedures outlined in Section 8.5. Measure the temperature in the cooler using the pH meter and record the temperature on the Chain of Custody form.
- Step 13: When ready to leave the site, end the visit report on the data logger (according to Step 14 in Section 8.1.2), close the monitoring vault and sand filter vault. Collect any traffic cones used.
- Step 14: Transport samples to Anatek Laboratory in Spokane.
    - If samples have been collected after laboratory hours, keep samples below 6°C in a cooler or refrigerator until the laboratory reopens.

8.1.5 Stormwater Sample Collection and Processing

The purpose of this SOP is to outline the steps required for pH measurement and sample collection and processing at the test site.

Equipment:

- Traffic Cones
- Tools necessary to access vaults
- USB flash drive
- Electronic water level indicator (tape down tool)
- Cellular phone to enable communication between staff and project manager or principal investigator
- Flashlight
- Volt meter
- Torpedo level
- pH meter
- Small, clean plastic beaker
- Personal Protective Equipment (PPE) including: eye protection, gloves high visibility vest, work boots, etc.
- Clean, powder-free, nitrile gloves
- Sample bottles
- Gallon plastic bags
- Cooler for sample bottles
- Hard ice pack for cooler
- Syringe
- 0.45 µm filter
- Chain of custody form (Appendix I), sample tag, Sample Collection Field Form (Appendix H)

Summary of procedures for preparation of stormwater sampling equipment prior to monitoring and sampling.

- Step 1: At least one hour prior to departing for the site, place sample bottles in the plastic bag in the refrigerator to keep the bottles cool.
- Step 2: Place traffic cones as needed to call attention to the presence of staff along the roadway. Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the field form.
- Step 3: Open the monitoring equipment vault and sand filter vault. Start a visit report on the data logger according to Step 5 in Section 8.1.2. *Note: "clean hands/dirty hands" procedures as defined in Step 3 of Section 8.1.4 will be followed during sample collection.*
- Step 4: Measure the water surface elevation using the electronic water level indicator. Note the current water surface elevation measurement on the field form.

- Step 5: Check the ISCO and data logger to verify that the ISCO has completed its sampling and/or that the data logger has disabled sampling. If neither scenario has happened, wait until sampling is complete before collecting the sample.
    - The ISCO will show that sampling is complete on the display if it says “sample X after 1 pulses”.
    - The data logger will show that sampling is complete if the data logger sampl_enabl value (tap processes, then sampl_enabl icon) is set to 1.
- Step 6: Open the ISCO and put on clean, nitrile gloves. Visually check that the amount of water in the composite jar roughly correlates to the number of aliquots reported to have been collected by the ISCO (i.e., if the number of aliquots reported is 20, and very little to no water is present, there has been a malfunction).
- Step 7: Pour some of the sample into a small beaker to a depth of at least 1 ½ inches (100 mL) and place the pH probe in the beaker. Stir the liquid with the probe and proceed with Steps 8-9 while waiting for the reading to stabilize.
- Step 8: Replace the lid on the composite jar with a lab-cleaned, solid lid.
- Step 9: Remove jar from the ISCO and place the composite sample into a plastic bag within the cooler for transport to the HDR lab.
- Step 10: Check the pH reading to see if it has stabilized. If it has, record the pH and temperature reading on the field form. If not, wait for the reading to stabilize before recording pH and temperature on the form. Remove the pH probe from the beaker, add the pH storage solution to the protective cap, replace the protective cap on the probe, and discard the small amount of sample.
- Step 11: End the visit report (according to Step 14 in Section 8.1.2) after all samples have been collected and the ISCO indicates that the program has been reset.
- Step 12: When ready to leave the site, close the monitoring vault and sand filter vault, and secure as needed before leaving the site. Collect any traffic cones used.
- Step 13: Return to the HDR lab. Composite samples are transported to the HDR lab prior to Anatek to transfer composite samples in ISCO bottles to the laboratory-specified bottles listed in Table 8.1 and to filter samples for dissolved metals and ortho-phosphate analysis.
    - To filter the samples for dissolved metals and ortho-phosphate analysis, obtain the syringe and place a 0.45 µm filter on the end of the syringe. Fill the syringe with 50 mL of sample, and use the plunger on the syringe to filter the sample into a 125 mL bottle that has been preserved with trace metals grade nitric acid. Repeat the process to get 100 mL of filtered sample in the bottle.
- Step 14: Place the filled laboratory bottles in the plastic bags provided by the lab, and place the plastic bag(s) in the cooler.
- Step 15: Fill out the Chain of Custody for the samples according to the procedures outlined in Section 8.5. Measure the temperature in the cooler using the thermometer and record the temperature on the Chain of Custody form.
- Step 16: Transport the samples to Anatek.
    - If samples have been collected after laboratory hours, keep samples below 6°C in a cooler or refrigerator until the laboratory reopens.

8.1.6 Monitoring Equipment Data Download

The purpose of this SOP is to outline the steps required to collect data from the data logger following the sampling event.

Equipment:

- Traffic Cones
- Tools necessary to access vaults
- USB flash drive
- Cellular phone to enable communication between staff and principal investigator or project manager
- Flashlight
- Personal Protective Equipment (PPE) including but not limited to: high visibility vest, gloves, work boots, etc.
- Monitoring Equipment Data Download Field Form

Summary of procedures for download of data from test site:

- Step 1: Place traffic cones as needed to call attention to the presence of staff along the roadway. Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the field form.
- Step 2: Open the monitoring equipment vault.
- Step 3: Insert USB flash drive and download the data. Remove the USB flash drive when the download is complete.
  - To download the data, tap data on the main screen, then tap the download (downward arrow) icon on the bottom of the screen. Select the desired range of data and press the checkmark.
- Step 4: Close the monitoring vault and collect the cones.

8.1.7 Sediment Accumulation Rate

This section describes the procedures for measuring the sediment depth on top of the sand filter media and collecting samples of the sand media from the top, middle, and bottom layers of the sand filter media.

Equipment needed:

- Traffic Cones
- Tools necessary to access vaults
- Personal Protective Equipment (PPE) including but not limited to: high visibility vest, gloves, work boots, etc.
- Decimal measuring tape
- Clean stainless steel scoop
- Clean stainless steel bowl
- Sample containers

- Gallon plastic bags
- Cooler for sample bottles
- Hard ice pack for cooler
- Chain of Custody form (Appendix I) and Field Data Collection Form: Sand Filter Media Sediment Depth Measurements (Appendix H)

Summary of procedures for taking measurements prior to the start of the study:

- Step 1: At the start of the study, immediately after the sand filter media and coconut coir mat have been installed, the depth from the top of the mat to the top of the sidewalk will be measured in order to compare later sediment accumulation measurements
- Step 2: Randomly select a location in the sidewalk vault
- Step 3: Place the measuring tape on top of the coir mat without compressing the mat
- Step 4: Verify the tape is perpendicular to the bottom of the sidewalk, record the depth on the measuring tape taken at the top of the sidewalk on the field data collection form
- Step 5: Repeat steps 2-4 at four more locations in the sidewalk vault
- Step 6: Calculate the average depth of the five measurements and record the value on the data collection form

Summary of procedures for taking measurements following the start of the study. These measurement will be taken after each qualifying rainfall event and immediately prior to the falling head test.

- Step 7: This process will be followed after sample collection (SOP 8.1.5).
- Step 8: Open the sidewalk vault that contains the sand filter media.
- Step 9: Randomly select a location on top of the sand filter media
- Step 10: Lower the measuring tape onto the top of the accumulated sediment
- Step 11: Once the measuring tape is on top of the sediment, verify the rod is perpendicular to the sidewalk and record the depth reading on the measuring tape taken at the top of the sidewalk on the data collection form
- Step 12: Repeat steps 9-11 at four more locations in the sidewalk vault
- Step 13: Calculate the average depth of the five measurements and record the value on the data collection form.
- Step 14: Calculate the average depth of sediment on top of the sand filter media: subtract the average depth measured in the clean sidewalk vault (Step 6) from the Step 13 average depth calculated.
    - If samples have been collected after laboratory hours, keep samples below 6°C in a cooler or refrigerator until the laboratory reopens.

Samples of the sediment on top of the sand filter media and within the top, middle, and bottom layer of the sand filter media will be collected. Samples will only be collected once after all testing is completed.

- Step 15: Randomly select three locations on the accumulated sediment on top of the sand filter sidewalk vault. Create a 3 inch by 4 inch transect in those locations. Scoop sediment accumulated on the coconut coir for the full transect are into the sample containers provided by the laboratory (3 samples total).

- Step 16: Collect samples from the top layer of the sand filter media (3 inch horizon). A push probe will be used to collect samples from each of the four quadrants and one from the center of the sand filter.
- Step 17: Samples will be homogenized in a stainless-steel bowl and transferred to the laboratory bottles in the plastic bags provided by the lab, and place the plastic bag(s) in the cooler.
- Step 18: Repeat steps 16 and 17 for the middle layer of the sand filter media (9 inch horizon).
- Step 19: Repeat steps 16 and 17 for the middle layer of the sand filter media (15 inch horizon).
- Step 20: Fill out the Chain of Custody for the samples according to the procedures outlined in Section 8.5.
- Step 21: Transport the samples to Budinger for analysis.

8.1.8 Falling Head Test

The purpose of this SOP is to outline the steps required to perform a modified version of the falling head test on the sand filter media in the vault and measure the infiltration rate.

Equipment needed:

- Traffic Cones
- Tools necessary to access vaults
- Personal Protective Equipment (PPE) including but not limited to: high visibility vest, gloves, work boots, etc.
- A water source sufficient to saturate the sand filter media and fill the vault to the top of the overflow pipe
- Timer
- Yard stick
- Falling Head Test Field Form (Appendix H)

Summary of procedures for the falling head test:

- Step 1: Once the monitoring vault and sand filter sidewalk vault have been accessed, turn the valve in the monitoring vault on the effluent pipe to the closed position to prevent water from discharging through the pipe.
- Step 2: measure the height from the top of sediment to the top of the bypass pipe in five different locations in the vault. Calculate the average height of the bypass pipe above the sediment.
- Step 3: Fill the sand filter sidewalk vault with water until the water surface is even with the top of the overflow pipe. Wait an hour to allow time for the media to become saturated. Add water until the water surface elevation is again even with the overflow pipe.
- Step 4: Open the valve on the effluent pipe and start the timer.

- Step 5: Stop the timer once all of the water has infiltrated below the sand media surface. Record the time on the Falling Head Test Field Form. *Note: the infiltration rate is calculated by dividing the average height of the water (step 2) by the time it takes water to infiltrate below the media surface.*
- Step 6: Close and secure the vaults before leaving the site.

8.2 Containers, Preservation Methods, Holding Times

Clean sample bottles and associated preservatives will be provided by Anatek Laboratory and Budinger (PSD only) in Spokane, WA, according to Table 8.1. Sample containers and preparation will follow Code of Federal Regulations [40 CFR 136] guidelines. Spare sample bottles will be carried by the sampling staff conducting the testing in case of breakage or possible contamination.

Table 8.1 Sample containers, preservative, and holding times

Matrix	Parameter	Method	Sample Container & Volume	Preservative	Pre-Filtration Holding Time	Total Holding Time
Water Quality	pH	EPA 150.1	100 mL	NA	15 min.	15 min.
	PSD, influent	Modified SSC	Plastic; 1L	NA	NA	NA
	Total Suspended Solids (TSS)	SM 2540D	Plastic; 125 mL	Cool, ≤6°C	NA	7 days
	Dissolved Metals (Cu, Zn)	EPA 200.8 (ICP/MS)	Plastic; 125 mL	Cool, ≤6°C; filtration, 0.45 µm; HNO3 to pH<2	12 hours	180 days
	Total Metals (Cu, Zn)	EPA 200.8 (ICP/MS)	Plastic; 125 mL	Cool, ≤6°C; HNO3 to pH<2	NA	180 days
	Hardness as CaCO3	SM 2340B (ICP)	Plastic; 500 mL	HNO3 ph<2	NA	180 days
	Ortho-phosphate (OP)	SM 4500-P G	Plastic; 1 L	Cool, ≤6°C; filtration, 0.45 µm	12 hours	2 days
	Total Phosphorus (TP)	SM 4500-P F	Glass; 1 L	Cool, ≤6°C; H2SO4 to pH < 2	NA	28 days
	NWTPH-Dx	Ecology NWTPH Dx	Glass; 1L	Cool, ≤6°C; HCL to pH < 2	NA	14 Days
Sediment	Sediment PSD	ASTM D422 and Modified SSC	Plastic; 1L	NA	NA	NA
Sand Filter Media	pH	S-2.20	Plastic; 0.5 grams	Cool, ≤6°C	NA	NA
	Moisture Content	ASTM D2216	4 oz. Clear Glass Wide Jar; 10 grams	Cool, < 6°C	NA	NA
	Cation Exchange Capacity	S-10.10	Plastic; 2 grams	Cool, ≤6°C	NA	NA
	Maximum Dry Density	ASTM D1557	Plastic; 200 grams	Cool, ≤6°C	NA	NA
	Saturated Hydraulic Conductivity	ASTM D2434	Plastic; 500 grams	Cool, ≤6°C	NA	NA
	Particle Size Distribution	ASTM D422	Plastic; 500 grams	Cool, ≤6°C	NA	NA
	Total Elements (Zn, Cu, Pb, TP, Mg, Ca)	EPA 3050A/6010B	Plastic; 20 grams	Cool, ≤6°C	NA	NA
	Total Organic Carbon	EPA 415.3	Plastic; 0.5 grams	Cool, ≤6°C	NA	NA
	C:N Ratio	EPA 415.3/351.2	Plastic; 50 grams	Cool, ≤6°C	NA	NA

8.3 Equipment Decontamination

Equipment decontamination will follow procedures in SOP "Preparing Stormwater Monitoring Equipment for Storm Sampling". The following equipment will be decontaminated between sampling events:

- pH Meter
- ISCO Sample Bottles (laboratory)
- ISCO Sample Tubing
- Grab sample bottles (laboratory)
- Pressure transducers

8.4 Sample Identification

All sample containers will be labeled with the following information, using waterproof labels and indelible ink and placed on dry sample container lids:

- Sample Identification
- Date of sample collection (month/day/year)
- Time of sample collection (military format)
- Sampler initials
- Parameters (pre-printed and provided by laboratory)

8.5 Chain of Custody

After samples have been obtained and the collection procedures properly documented, a written record of the chain-of-custody of each sample will be completed by field personnel to ensure that samples have not been tampered with or compromised in any way and to track the requested analysis for the analytical laboratory. Information that will be provided on the chain-of-custody form includes:

- Name(s) of field personnel
- Date and time of sample collection
- Location of sample collection
- Printed names, signatures and contact information of field personnel and laboratory personnel handling the samples
- Laboratory analysis requested and control information (e.g., duplicate or spiked samples) and any special instructions (e.g., time sensitive analyses)

After collection, samples will be immediately delivered to Anatek and/or Budinger in Spokane, WA. Sample custody will be tracked in the field and laboratory through the entire sample collection process, and the signed chain-of-custody forms and analytical results returned to the HDR principal investigator or project manager. The sampling staff will record the date and time of sample deliveries for the project file. The chain of custody form is in Appendix I.

8.6 Field Log Requirements

Field observations and measurements associated with a monitoring event will be recorded on the field forms (Appendix H). The field form will document all activities completed, measurements taken, and samples collected during the field event. The field form documents the following information:

- Date and time
- Field staff names
- Climate conditions
- Sampling equipment condition
- Samples collected (checklist)
- QC samples collected (checklist)
- Water temperature, pH, and oil sheen measurements/ observations
- Instrument calibration results
- Comments on activities or issues that may influence the quality of the data

9.0 Measurement Procedures

This section of the QAPP focuses on identifying the methods required to measure the data collected during the study including the equipment and instruments that will be used.

9.1 Procedures for Collecting Field Measurements

Field measurements will be made for precipitation, discharge (influent, effluent, and bypass flow rate), water quality (stormwater influent and effluent), pH, stormwater temperature, and the accumulated sediment volume. Precipitation and discharge measurements will be collected during data download (from the data logger) at the test-site as described in Section 8.1.6. Grab and composite samples will be collected according to the procedures in Section 8.1.4 and 8.1.5, respectively. The pH and water temperature measurements will be instantaneous measurements collected with a calibrated pH meter, as described in Section 8.1.5. Sediment accumulation measurements will be made as described in Section 8.1.7.

Field measurement quality will be evaluated in terms of bias and precision (See Section 6.2 and 6.1). Measurement bias will be measured and corrected by calibrating the rain gauge at the beginning and end of the study, checking the depth measurements of the PTs during each maintenance cycle, calibrating the pH meter prior to sampling events, and calibrating the ISCO quarterly. Detailed calibration procedures are in the Sections 8.1.2 and 8.1.3. Measurement precision will be evaluated for pH and water temperature by collecting duplicate measurements for at least 10% of all measurements.

9.2 Laboratory Procedures

Laboratory analytical procedures will follow methods approved by the US Environmental Protection Agency (EPA) (APHA et al. 1992, 1998; US EPA 1983, 1984). These methods provide reporting limits that are below the TAPE criteria or guidelines and will allow direct comparison of the analytical results with these criteria. Preservation methods, analytical methods, reporting limits, and sample holding times are presented in Table 9.1. HDR will filter for parameters requiring filtration (i.e., ortho-phosphorus, dissolved copper, and dissolved zinc) and preserve the samples within four hours of their collection. The samples will be stored at the temperature noted in Table 8.1 and delivered to the laboratory during their business hours (Monday-Friday, 8:00am to 5:00pm). Anatek, the laboratory identified for the water quality samples for this project, is certified by Ecology. SoilTest Farm Consultants, Inc. Laboratory (SoilTest) is the lab identified for soil analytical samples. PSD sample analysis will be performed by Budinger & Associates, Inc. (Budinger). These performance and system audits have verified the adequacy of the laboratory's standard operating procedures, which include preventive maintenance and data reduction procedures.

The laboratories will report the analytical results within 30 days of receipt of the samples. The laboratories will provide sample and quality control data in standardized reports suitable for evaluating the project data. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Table 9.1. Laboratory measurement methods.

Matrix	Parameter	Units	Method	Reporting Limits	Expected Range of Results	Minimum Number of Sample Events	Samples Per Event
Water Quality Stormwater	pH	units	EPA 150.2	0.2	6.5-8.0	12	2
	PSD, influent	%	Modified SSC method	NA		3	2
	Total Suspended Solids (TSS)	mg/L	SM 2540D	1.0	20 - 500	12	2
	Dissolved Copper (Cu)	µg/L	EPA 200.8 (ICP/MS) or SM 3125 (ICP/MS)	0.1	0.1 - 20	12	2
	Dissolved Zinc (Zn)	µg/L		1.0	5 - 300	12	2
	Total Copper (Cu)	µg/L		0.1	0.1 - 40	12	2
	Total Zinc (Zn)	µg/L		5.0	5 - 600	12	2
	Hardness as CaCO3	mg/L	SM 2340B (ICP)	1.0	1 - 100	12	2
	Ortho-phosphate (OP)	mg/L	SM 4500-P G	0.01	0.01 - 0.5	3	2
	Total Phosphorus (TP)	mg/L	SM 4500-P F	0.01	0.01 - 0.5	3	2
	NWTPH-Dx	mg/L	Ecology NWTPH Dx	0.25-0.50		12	2
Sediment	Sediment PSD	percent	ASTM D422 and Modified SSC method	NA	< 3/8 sieve to > 1.5µ	3	3
Sand Filter Media	pH	std. units	S-2.20	NA	6-9	1	1
	Moisture Content	%	ASTM D2216	NA	< 2%	1	1
	Cation Exchange Capacity	meq/100g	S-10.10	NA	< 5meq/100g	1	1
	Maximum Dry Density	lb/ft^3	ASTM D1557	NA		1	1
	Saturated Hydraulic Conductivity	ft/day	ASTM D2434	NA	2-4	1	1
	Particle Size Distribution	percent	ASTM D422 and Modified SSC method	NA	< 3/8 sieve	1	1
	Total Elements (Zn, Cu, Pb, TP, Mg, Ca)	mg/kg	EPA 3050A/6010B	5.0 (Zn); 0.01 (P) 0.1 (others)		1	1
	Total Organic Carbon	mg/kg	EPA 415.3			1	1
	C:N Ratio	Ratio	EPA 415.3/351.2	NA		1	1

9.3 Sample Preparation Methods

Ortho-phosphorus, dissolved, copper, and dissolved zinc require filtration and preservation prior to delivery to Anatek. HDR personnel will filter and preserve the samples which will be analyzed for those parameters according to the methods outlined in Section 8.1.5.

9.4 Special Method Requirements

Anatek, SoilTest, and Budinger do not require any special methods for the parameters to be analyzed during the study.

9.5 Lab(s) Accredited for Methods

Anatek laboratory is accredited by Ecology for the stormwater parameters collected for this study (Table 9.1) and participates in audits and inter-laboratory studies by Ecology and EPA. SoilTest will analyze the sediment and sand filter media parameters collected for this study and is also accredited by Ecology. Budinger is USACE accredited for materials testing in accordance with ASTM and WSDOT methods.

10.0 Quality Control

This section includes information on field quality assurance/quality control (QA/QC) and laboratory quality control.

10.1 Field QC Required

Field quality control will be maintained by personnel training, SOP development, equipment maintenance and calibration, and quality control samples.

At least two field staff will be trained in all field activities. Field staff will be trained to consistently follow field sampling procedures (see Section 8.1.4 and 8.1.5) and measurement procedures, (see section 9.0). Field staff must become familiar with all associated SOPs (Section 8.0) which cover all field activities. Training will include conducting all procedures in the field at least one time under the supervision of the principal investigator or project manager. Completion of each element of training will be verified and documented by the principal investigator or project manager in a training completion log (Appendix H).

Equipment maintenance and calibration will ensure that the BMP, the sampling equipment, and the water quality meters are working properly. Equipment maintenance will occur once in early fall, prior to the first monitoring event of the wet season, and monthly between monitoring events. Calibration of the ISCO pumps will likely occur during equipment maintenance, according to the frequency specified by the manufacturer. Calibration of the remaining storm monitoring equipment, including the pH meter will occur prior to field measurements, preferably on the day of a monitoring event. Details of equipment maintenance and calibration are provided in Sections 8.1.2 and 8.1.3 and will consist of the following activities:

- Inspection of all equipment for damage.
- Cleaning and/or repair of all equipment, connections, tubing, and influent/effluent pipes.
- Calibration of the pH meter, pressure transducer, rain gage, and ISCO pump.

Maintenance and calibration will be documented with either the Periodic Maintenance Checklist Field Form or the Pre-Storm Checklist Field Form (Appendix H). Recordkeeping procedures will be developed and consistently followed (see Section 11.0).

Field quality control samples will consist of rinsate blank and field duplicate samples. Rinsate blanks are samples of analyte free water poured over or through decontaminated field sampling equipment prior to the collection of environmental samples. The purpose of collecting rinsate blanks is to assess the adequacy of the decontamination process. Rinsate blanks will be collected for all water quality parameters collected by flow-weighted composite sampling (i.e. the collected in the autosamplers). They will be collected immediately after decontamination of each respective autosampler. After decontamination, the autosamplers will be filled with distilled deionized water and then dispensed through the autosampler to fill sample containers. Rinsate blanks will not be collected for grab samples, since those samples are collected directly into the sample containers or measured in situ. Rinsate blanks will be collected three times throughout the study for TSS, total phosphorus, orthophosphate, hardness, oils (NWTPH-Dx), and total and dissolved copper and zinc. The parameter concentrations in the rinsate blanks are expected to be less than two times the reporting limit concentrations (see Table 6.2, Table 9.1 for reporting limits).

A field duplicate is a second independent sample collected at the same time and location as the original sample. Field duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. Field duplicates will be collected for all water quality and sediment parameters (Table 10.1) and must meet the associated relative percent difference MPCs in Table 6.2. Field duplicates will also be collected for sediment PSD and filter media variables.

10.2 Laboratory QC Required

Laboratory quality control will be maintained for the water quality samples by running method blanks and laboratory control standards, matrix spikes, and matrix spike duplicates, and laboratory duplicates (Table 10.1). MPCs associated with the quality control samples are in Table 6.1. Method blanks and laboratory control standards will evaluate bias, in terms of overall method accuracy. Matrix spike and matrix spike duplicates will evaluate bias in terms of method interferences. Laboratory duplicates will evaluate the precision of laboratory measurements. Each of these quality control samples will be run in the laboratory one time for each respective laboratory batch.

10.3 Corrective Action

The auditor will notify the lead entity and principal investigator in writing (via email) within 2 business days if corrective actions is needed based on the audit findings. The lead entity and principal investigator are responsible for developing and implementing a written corrective action plan within 30 days of being notified by the auditor. A record of the corrective action plan will be kept throughout the study (see example in Appendix K) and included in the final report.

Table 10.1. Quality control samples.

Matrix	Parameter	Sample Type	Field		Laboratory				
			Equipment Rinsate Blanks	Field Duplicates	Laboratory Control Standards	Method Blanks	Laboratory Duplicates	Matrix Spike	Matrix Spike Duplicates
Stormwater	Total Suspended Solids (TSS)	Composite	3	10% of samples	1/batch	1/batch	1/batch	NA	NA
	PSD, influent	Composite	NA	10% of samples	NA	NA	NA	NA	NA
	Dissolved Copper (Cu)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Dissolved Zinc (Zn)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Total Copper (Cu)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Total Zinc (Zn)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Hardness as CaCO3	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Ortho-phosphate (OP)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	Total Phosphorus (TP)	Composite	3	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
	NWTPH-Dx	Grab	NA	10% of samples	1/batch	1/batch	1/batch	1/batch	1/batch
Sediment	Sediment PSD	Grab	NA	10% of samples	NA	NA	NA	NA	NA

11.0 Data Management Plan Procedures

This section defines the data management plans. It specifically describes how the data and other important project documents will be managed, stored, and archived during the study. These plans are developed to reduce the potential for errors during the data collection and analysis phases of the project.

11.1 Data Recording & Reporting Requirements

Field data will be recorded on standard field forms (Appendix H). The field form includes the date and time, data collectors name(s), sample identification, field measurements, field observations, a checklist of samples collected for laboratory analysis, and comment field. All field measurements will be entered manually into the project database (Microsoft Access) within 24 hours of sample collection. HDR's quality assurance lead for the project will perform an independent review to ensure that the data were entered without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and crosschecking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found in the data. HDR's quality assurance lead will qualify or reject field measurements based on field DQIs and associated MPCs (Section 6.0). All files will be archived for the duration of the study on an HDR server and transferred to Spokane County after completion of the study.

Laboratory results from Anatek, SoilTest, and Budinger will report the analytical results within 30 days of receipt of the samples. The laboratories will provide sample and quality control data in standardized Electronic Data Deliverable (EDD) spreadsheets and reports that are suitable for evaluating the project data. These EDDs and reports will include all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. HDR's quality assurance lead for the project will perform an independent data verification to ensure laboratory consistency with this QAPP, add additional qualifiers, or reject data based on field DQIs and associated MPCs (Section 6.0). A new qualifier column will be created in each EDD that represents HDRs independent data verification and will include both field and laboratory qualifiers. HDR's quality assurance lead for the project will perform an independent review to ensure that the data were uploaded without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and crosschecking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found in the data. The information contained in the EDD and independent data verification will be stored (archived) in a database such as Microsoft Access on HDRs server for 1-year after the technical evaluation report has been approved.

11.2 Electronic Transfer Requirements

All field and calibration forms will be scanned and electronically filed on the HDR server. The laboratory reports, original laboratory EDDs and verified laboratory EDDs will be electronically filed in HDRs server. Verified EDDs will be uploaded into the project database for all subsequent data management and archiving tasks.

11.3 Laboratory Data Package Requirements

Anatek and SoilTest will provide Level II data packages, corresponding to Stage 2A verification and validation checks (USEPA 2009). These data packages will provide the following documentation:

- Sample submittal and receipt
- Analytical methods, sampling dates and times, data and time of laboratory receipt, sample conditions upon receipt at the laboratory, and sample analysis dates and times
- Evaluation of sample holding times
- Analyte results, units, detection limits, reporting limits, and laboratory data qualifiers
- Sample-related QC data and QC acceptance criteria (Tables 6.1 and 6.2)
- Frequency of QC samples
- Sample results are evaluated and qualified based on meeting holding times and sample-related QC results (Table 6.2)

11.4 Procedures for Missing Data

Missing data will be qualified as missing, and will have a qualifier code (M) that is unique from a rejected value. In addition a note will be added to the spreadsheet explaining the reasons why the data is missing (if known). Missing data will also be reported with the results and discussed in the "Data Summaries and Analysis" section of the TER along with a description of how the data set was analyzed without the missing data. All missing data contributes to the completeness DQI and MPC of 95% valid data collection.

11.5 Acceptance Criteria for Existing Data

No existing data will be used for this study.

11.6 Data Upload Procedures

At the end of the study, the data collected will be uploaded to the International BMP database. Additionally, a spreadsheet of all applicable data collected, including rejected or un-useable data, will be sent to the municipal stormwater permit manager with the final report.

12.0 Audits

12.1 Technical System Audits

Technical system audits performed for field data collection will occur during the first monitoring event, and at one additional event, at the discretion of the project manager or principal investigator. The technical system audits will be performed by a third party. The field audit will verify that field staff are following the SOPs for sample collection, all field data are being recorded, and equipment and instruments are being maintained and calibrated per manufacturer's requirements. Results from these audits will be documented in field audit worksheets (Appendix H) that will be prepared for each batch of samples.

Technical system audits performed for laboratory data will occur within seven business days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Specific quality control elements for the data (6.1) and raw data will also be examined to determine if the DQIs for the project have been met. Results from these audits will be documented in QA worksheets (Appendix H) that will be prepared for each batch of samples.

In the event that a potential QA issue is identified through these audits, HDR's data quality assurance lead will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples, reanalysis of existing samples if not yet past holding time, or advising the laboratory that methodologies or QA/QC procedures need to be improved.

12.2 Proficiency Testing

Proficiency testing is a quantitative determination of an analyte in a blind standard to evaluate the proficiency of the analyst or laboratory. No proficiency testing will be conducted as part of this study.

13.0 Data Verification and Usability Assessment

The section will define the process that the project will employ to evaluate the quality of the data and the usability of the data for meeting the project objectives. The following includes a list of the data that will be verified:

- Water quality data
- Flow measurements
- Rainfall data

13.1 Data Verification

Water quality results will first be reviewed at the laboratory for errors or omissions. Laboratory quality control results will be reviewed by the laboratory to verify compliance with acceptance criteria. The laboratory will also validate the results by examining the completeness of the data package to determine whether method procedures and laboratory quality assurance procedures were followed. The review, verification, and validation by the laboratory will be documented in a case narrative that accompanies the analytical results. Data will be reviewed and validated within 7 days of receiving the results from the laboratory. This review will be performed to ensure that all data are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data include the following:

- Reviewing all the data records to ensure they are consistent, correct and complete, with no errors or omissions
- Review data records to verify the entries are consistent, correct, and complete
- Review the results from the QC section

Results from these data validation reviews will be summarized in quality assurance worksheets (Appendix C) that are prepared for each sample batch. The HDR quality assurance officer will be responsible for identifying and initiating corrective action. Values associated with minor quality control problems will be considered estimates and assigned “J” qualifiers. Values associated with major quality control problems will be rejected and qualified with an “R”. Estimated values may be used for evaluation purposes, but rejected values will not be used.

13.2 Data Usability Assessment

The HDR quality assurance officer will provide an independent review of the water quality QC data from each sampling event by determining whether or not MPCs for each DQI identified in this QAPP have been met. The data usability assessment will be presented along with the data verification results in an appendix to the TER. The data usability assessment will summarize quality control results, identify when data quality objectives were not met, and discuss any resulting limitations on the use or interpretation of the data. Specific quality assurance information that will be noted in the data quality assessment report includes the following:

- Changes in and deviations from the QAPP

- Results of field and laboratory data verification
- Results of technical system audits
- Identification of significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data

14.0 Data Analysis Methods

14.1 Data Analysis Methods

14.1.1 Storm, Hydrologic, and Pollutant Information

Storm, hydrologic, and pollutant data will be compiled for each sampling event that occurred during the data collection and summarized into tables. This will include:

- Storm date
- Total storm precipitation depth
- Storm duration
- Storm average and peak precipitation intensity
- Storm antecedent dry period
- Total influent, effluent, and bypass runoff volume
- Influent and effluent peak flow rates
- Influent, effluent, and bypass average flow rates
- Influent and effluent flow duration
- Number of influent and effluent aliquots
- Percentage of influent and effluent storm volume sampled
- Parameters monitored
- Pollutant removal efficiency
- Lab detection limits
- Data flags for identified QA issues

This information will be used to develop individual storm reports for each sampling event. The information will also be used to demonstrate that the data collected meets the requirements defined in TAPE (i.e., qualifying storm events, treatment performance goals, etc.) and define flow characteristics through the sand filter media over a range of influent flow rates. In addition, the individual storm reports may also provide justification for why data has been included that does not meet TAPE requirements. Details regarding data that will be graphed is summarized in Section 14.2.

14.1.2 Statistical Comparisons of Pollutant Concentrations

A statistical comparison will be conducted to assess whether there was a statistically significant difference in the analytical results between the influent and effluent pollutant concentrations. This is expected to include evaluating whether the data was normally distributed using the Ryan-Joiner test (similar to Shapiro-Wilk test) (Helsel & Hirsch, 2002). Normality will be assumed if the tests produced a p-value greater than 0.05 (Ecology, 2008). If the data is normally distributed, a two-sample t-test was used to determine if there was a significant difference between the influent and effluent concentrations. If the data was non-normally distributed, a Wilcoxon rank sum test (a nonparametric analogue to the paired t-test) was used instead. The specific null hypothesis (H_o) and alternative hypothesis (H_a) evaluated are:

- H_o: Effluent pollutant concentration is equal to the influent concentration

- H_a: Effluent concentrations are less or greater than influent concentrations

The statistical comparison was based on a confidence level of 95% (α=0.05).

14.1.3 Calculation and Evaluation of Pollutant Reduction Efficiencies

The effectiveness of the BMP will be evaluated based on the average removal efficiency and mean concentration for each parameter over 12 qualifying rainfall events. This will include calculating the removal efficiency for each pollutant from each individual rainfall events using the equation below. The bootstrapping method will be used to compute the 95% confidence interval for the average removal efficiency from all rainfall events for each pollutant. The boot strapping method is the Ecology recommended method which assumes the dataset is non-normally distributed (Ecology, 2011). If analytical results provided by the laboratory included values that are non-detectable, the reporting limit for the respective pollutant will be used as defined by the standard testing method.

$$\Delta C = 100 \times \frac{C_{in} - C_{eff}}{C_{in}}$$

Where:
C_{in} = influent concentration (mg/L)
C_{eff} = effluent concentration (mg/L)

14.1.4 Water Quality Treatment Performance

The water quality data will be evaluated for meeting the Ecology performance goals for basic, dissolved metals, and oils treatment. The evaluation will include comparing the average removal efficiency at the 95% confidence interval and influent concentration from all rainfall events to the Ecology information noted in Table 14.1. The bootstrapping method will be used to compute the 95% confidence interval for the average removal efficiency from all rainfall events for each pollutant. If the removal efficiency is equal to or greater than the treatment performance criteria and if the average influent concentration falls within the range specified by Ecology, it will be concluded that the treatment performance criteria was met for pollutant of concern.

Table 14.1 Ecology Treatment Performance Goals

Performance Goal	Pollutant	Influent Concentration Range	Treatment Performance Criteria
Basic Treatment	Total Suspended Solids (TSS)	100-200 mg/L	80% Reduction
Dissolved Metals Treatment	Dissolved Copper (Cu)	5.0-20.0 μg/L	30% Reduction
	Dissolved Zinc (Zn)	20-300 μg/L	60% Reduction
Oil Treatment	NWTPH-Dx, visible sheen	Total petroleum hydrocarbons (TPH) > 10 mg/L	1) No ongoing/recurring visible sheen in effluent 2) Daily average effluent TPH concentration < 10 mg/L 3) Max. effluent TPH concentration of 15mg/L for a discrete sample

14.1.5 Infiltration Evaluation

The change in infiltration will be evaluated using the results from the modified falling head testing and using the influent and effluent flow rate measured by the data logger during storm events.

The SOP for the modified falling head test is described in section 8.1.8. The infiltration will be determined using the following equation.

$$f = \frac{depth\ of\ water\ at\ start\ of\ test\ (inches)}{time\ it\ takes\ water\ to\ \ completely\ infiltrate\ into\ media\ (hours)}$$

For rainfall events when the media is saturated, the infiltration rate may also be calculated as follows. The analysis should be repeated at each time interval data is recorded (5 minutes intervals) until the difference is less than 10% between three time intervals.

$$Q_{out} = fA$$

Where:

Q_{out} = effluent flow rate (cft/hr)
A = surface areas of sand filter sidewalk vault (20 sqft)
f = infiltration rate (in/hr)

The data collected will be graphed and a regression analysis will be used to establish a trend line of the rate of decline in the infiltration rate. Specifically, this data will be used (along with the sediment accumulation rate in Section 14.1.6) to identify when the field design infiltration rate (124 in/hr) may occur and subsequently identify when maintenance will need to occur to remove sediment and restore the infiltration rate.

The saturated hydraulic conductivity can be calculated from infiltration rate measurements when the depth of ponding above the sand filter media is known. For example, when the ponding depth is 18-inch (height of bypass) the gradient (i) equals the depth of ponded water (36 inches) divided by the sand filter media depth (18 inches). Using Darcy's law ($f=Q/A=iK_{sat}$), the saturated hydraulic conductivity (for this example) is twice the measured infiltration rate.

14.1.6 Sediment Accumulation Rate

Sediment accumulation will be evaluated to determine the maintenance cycle for this BMP using sediment depth measurements, dry weight of samples collected, and results from the particle size distribution testing. The approach is outlined in this section.

Particle Size Distribution

The sediment accumulated in the sand filter vault over the testing period will also be evaluated. PSD measurements from samples collected post testing (from on top of and in the top, middle, and bottom layers of the sand filter media) will be graphed along with pre-testing PSD measurements. The graph will be similar to Figure 3.8 and used to compare changes in the PSD from the start to end of testing.

Sediment Mass

The mass of sediment loading on top of and within the sand filter media will be estimated using the dry weights determined as part of the PSD testing. The mass of sediment on top of the BMP will be estimated by multiplying the average of the three dry weights from each of the transects (12 sqin = 1 sqft) by 20 (surface area of the sand filter). The mass of sediment within the sand filter media will be estimated by determining the change in the mass retained particularly from the smaller sieves from the PSD testing pre and post testing and then calculating the change in the total mass in the BMP (from on top and within the BMP).

Sediment Accumulation Rate

The sediment accumulation rate will be calculated to predict when the infiltration rate will decline to the design infiltration rate based on the sediment accumulated on top of the sand media. This will be done two ways first using the depth measurements (to compare with lab testing described in Section 3) and then using mass loading.

1. The sediment accumulation rate will be calculated using the total sediment depth measured on top of the BMP (equation below). Then sediment accumulation (S_{AR}) vs the respective infiltration rate measured (when the sediment depth was measured) will be graphed. A regression analysis will be used to establish a trend line. The sediment accumulation rate will also be normalized to predict when maintenance will be required at locations where the contributing basin area is different than the test-site. This will include dividing the value below by the total contributing basin area at the test site.

$$S_{AR-Depth} = \frac{sediment\ depth\ (inches)}{total\ depth\ of\ precipitation\ since\ start\ of\ study\ (inches)}$$

2. The sediment accumulation rate will be calculated using the total mass of sediment accumulation within the BMP (equation below). Then sediment accumulation (S_{AR}) vs the respective infiltration rate measured (when the sediment depth was measured) will be graphed. The sediment accumulation rate will also be normalized to predict when maintenance will be required at locations where the contributing basin area is different than the test-site. This will include dividing the value below by the total contributing basin area at the test site.

$$S_{AR-Mass} = \frac{sediment\ mass\ (pounds)}{total\ depth\ of\ precipitation\ since\ start\ of\ study\ (inches)}$$

14.2 Data Presentation

The data will be presented (i.e., tables, charts, and/or graphs) in the final reports to illustrate trends, relationships, and anomalies. Examples of how the data may be presented is shown in Figures 14.1, 14.2, and Table 14.1 and briefly described below:

- Figure 14.1 - Box and Whisker Plots display the distribution of data collected during the study. This will include the average and range of influent and effluent concentrations and any outliers. When applicable, the concentration representing the Ecology treatment performance goal will be graphed (red dashed line) to illustrate the relationship to the influent and effluent average concentrations.

- Figure 14.2 - Log-Normal Graphs are line graphs of the removal efficiency (C_{eff}/C_{in}) for each sampling event. These graphs illustrate the trend in the treatment performance over the duration of the study.
- Table 14.2 – A summary of the water quality results will be included in a table. This will include the average influent and effluent concentrations, sample size, results from the hypothesis testing, and the removal efficiency corresponding to the 95% confidence interval.
- The results from infiltration testing will be graphed to illustrating any changes over time.
- A table summarizing all the values/parameters measured for each testing event (i.e., pollutant information, storm data, hydrologic data, infiltration rate, etc.)
- A hydrograph for each storm during a sampling event that includes time and precipitation depth as well as the influent and effluent flow rates and aliquots

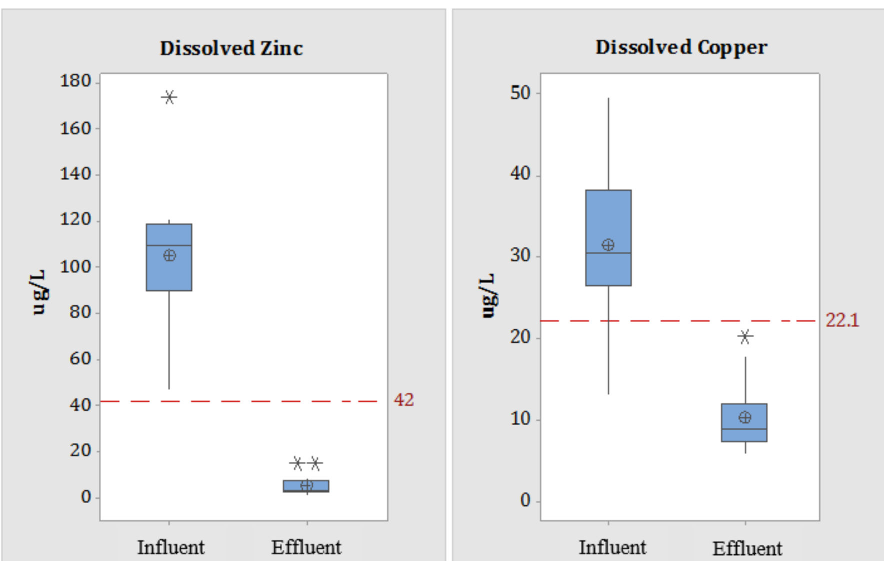

Figure 14.1 Example of Box Plots

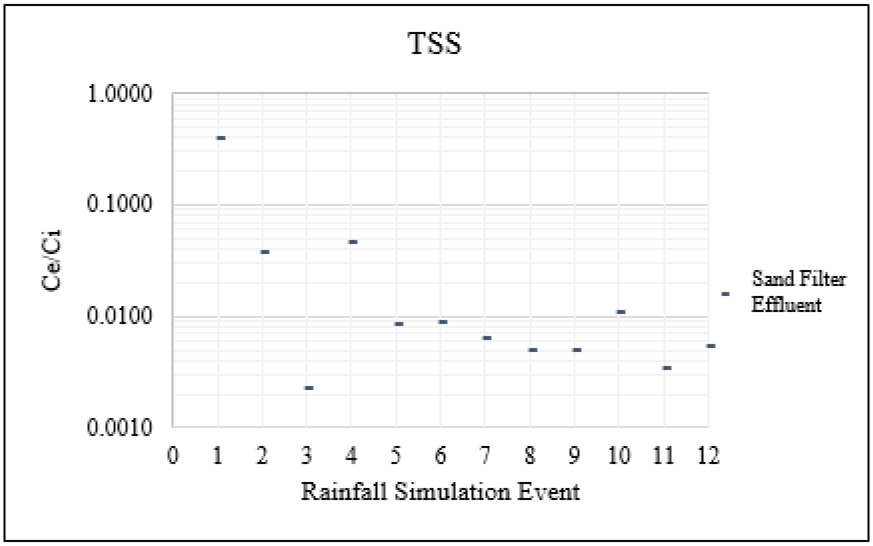

Figure 14.2 Example of Log-Normal Plot

Table 14.2 Example of Water Quality Results Summary

Column ID	Average Influent Concentration	Average Effluent Concentration	Sample Size (n)	Statistically Significant (Y/N)	95% CI Removal Efficiency	Performance Criteria	Pass or Fail
TSS	171	2.64	12	Y	92%	80%	Pass
Cu	31.57	10.42	12	Y	62%	30%	Pass
Zn	105.15	5.67	12	Y	94%	60%	Pass
TPH	7.4	8	12	N		10 mg/L; no visible sheen	Pass

**A summary of all required and screening parameters will be included in the final table*

15.0 Reporting

The purpose of this section is to describe how the study findings will be reported and disseminated.

15.1 Final Reporting

The following provides a summary of the reports that will be produced for this study as well as the party responsible for preparing the reports.

- Annual Reports (Permit Section S8.B8) – the lead entity will develop the annual reports which will describe the interim results and status of the study
- Final Technical Report (Permit Section S8.B10) – the principal investigator will produce the final technical report which will summarize the results of the study and recommends future actions based on the study findings. Table 15.1 provides an outline of the final technical report. Since this study includes the goal of developing a new BMP, the final report will also be developed to meet the requirements specified in the Ecology TAPE Guidance Document section *Preparing a Technical Evaluation Report (TER)*, (Ecology, 2011).
- A Fact Sheet – a fact sheet (2-4 page) will develop that summarizes the key points of the study along with the study findings

Table 15.1 Proposed Effectiveness Study Report Content

Final Report Sections		Effectiveness Studies
0.0	Cover Letter	✓
1.0	Executive Summary	✓
2.0	Introduction	See Note 1
3.0	Technology Description	See Note 1
4.0	Sampling Procedures	See Note 1
5.0	Data Summaries and Analysis	✓
6.0	Operation and Maintenance (O&M) Information	✓
7.0	Discussion	✓
8.0	Conclusions	✓
9.0	Future Action Recommendations	✓
10.0	Appendices	✓
11.0	Third-Party Review[2]	✓

1. The Final Report will reference the noted sections in the approved QAPP (in lieu of rewriting the sections in the report). Any changes made in those sections of the study since the QAPP was approved will also be documented.
2. The principal investigator will convene a Board of External Reviewers (BER): three to five individuals (two of whom should be from Ecology) with technical skills necessary to provide a peer review of the TER. This is only required for studies with the goal of developing a new BMP.

15.2 Dissemination of Project Documents

The Final Technical Report will be shared with the participating agencies and will be posted to the Spokane County webpage (https://www.spokanecounty.org) along with a fact sheet about the study and study findings. The data collected over the duration of the study will be uploaded to the International BMP database. Additionally, a spreadsheet of all data collected, including rejected or un-useable data, will be sent to the municipal stormwater permit manager with the final report.

16.0 References

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17.0 Appendices

Appendix A. Ecology Proposal Approval Letter and Comments

DEPARTMENT OF
ECOLOGY
State of Washington

To: Karen Dinicola, Department of Ecology

From: Douglas C. Howie, P.E., Department of Ecology

Cc: Abbey Stockwell, Department of Ecology

Date: July 20, 2017

Subject: Comments on Eastern Washington Effectiveness Study Proposals

Here are my comments on the eight Eastern Washington Effectiveness Studies submitted to Ecology on July 11 and following days. The proposals follow a common format with significant portions of the documents left for later completion. There is still adequate information in each proposal to identify what the author intends to complete.

Documents Reviewed:

1. *Detailed Study Design Proposal: Elementary School Stormwater Education*, by HDR, Inc. June 30, 2017
2. *Detailed Study Design Proposal: BMP Inspection and Maintenance Responsibilities,* by HDR, Inc. and Drummond Carpenter, PLLC, June 30, 2017
3. *Detailed Study Design Proposal: Bioretention Soil Media Study*, by HDR, Inc. and D&H Technology Solutions, LLC, June 30, 2017
4. *Detailed Study Design Proposal: Sharp Avenue Porous Pavement*, by City of Spokane, June 2017
5. *Detailed Study Design Proposal: Garland Stormwater Gardens with Biochar Amended Soil*, by City of Spokane, June 2017
6. *Detailed Study Design Proposal: Mobile Contractor Illicit Discharge Education & Outreach Effectiveness Study*, by City of Wenatchee, June 28, 2017
7. *Detailed Study Design Proposal: Sand Filter Sidewalk Vault BMP*, by Spokane County, June 30, 2017
8. *Detailed Study Design Proposal: Street Sweeping and Catch Basin Cleaning Comparison*, by City of Ellensburg, June 30, 2017

General Comments on Proposals

1. There are still a number of significant issues left to fill in when producing the QAPP for these studies. I will probably have more comments when they submit the QAPP.

Comments on Elementary School Stormwater Education

1. It's a small thing, but they sometimes italicize *Drain Rangers* and sometimes not.

2. How will they adapt the WWA program to EWA students? There are no specifics identified, particularly when they include “engineering design processes” in the curriculum. In Section 4.1, they describe the study goals. These are universal issues, not a WWA or EWA specific issue.
3. Will the report on the WWA Drain Rangers project contain before and after information that they could use to help in the development of the before and after evaluations?
4. There is a reference to “See Section 4.5 for more information about IRB’s”. This reference is in Section 4.5 and there is no further information about IRB’s in the document. There is a detailed discussion of IRBs in the BMP Inspection and Maintenance Responsibilities Proposal.
5. In Section 13, they discuss using the Likert Scale. What is the Likert Scale and how do they apply it to data from this study?
6. The information shown in Table 13.3 is quite limited. I think they should include gender in the data as well as age.
7. It would be good to include some thinking about following-up with the student in another 2 or 3 years to see what they retained and if they applied any of the lessons learned to their life.

Comments on BMP Inspection and Maintenance Responsibilities

1. I’m not seeing a lot in the way of evaluating the information they collect for effectiveness. As I read the Project Overview section, my final thought was that I still didn’t know exactly what they plan to evaluate and compare.
2. Early in the text, they refer to “similar semi-arid jurisdictions”, but in Section 7.0, the scope is limited to “Washington and Columbia River Basin”. What happened to using information from eastern Oregon and southern Idaho?
3. Add two additional questions for the survey: What benefits do they derive from the inspections and what do they use to determine the need for maintenance?
4. I think the survey will take more than 10 minutes if they include all the bulleted items listed. There are some questions, which will take research on the part of the responder, such as funds spend, number of privately owned BMPs, and number inspected each year.
5. The proposed report information does not include information on the effectiveness of the inspections, it just reports on the information gathered.

Comments on Bioretention Soil Media Study

1. Please do not call bioretention facilities “ponds”. They are “Swales” or “cells”, but not ponds. While water does collect in the facility before passing through the media, they are not a pond.
2. In Section 4.2, they refer to the “TAPE Board of External Reviewers” as someone who will review the QAPP and TER. They also mention this elsewhere in the proposal. This is not necessary for this study. They need to create an advisory/review panel that will independently review the results of the monitoring, but it doesn’t have to be the TAPE BER. This is a modification to an existing BMP that has already received a lot of study.

This work doesn't need to go through the full TAPE process. The study should still follow the TAPE protocol, but not to the extent of bringing in members of the BER for review.

3. In Section 5.0, they list Brad Daly multiple times. There may be a conflict between his tasks if he is both an Advisory Board lead/member and a reviewer. They also list Art Jenkins twice in the table.
4. I would expect to see the Bioretention sizing calculations in the QAPP.
5. There are several sections left to be completed, which have a bearing on the success of this study.
6. What happens if the grass proposed for the vegetated swale doesn't grow, or show sparse growth? When do they determine that they have adequate vegetation to compare the two cells accurately? Will they perform any analysis on the amount of vegetation in the cell?

Comments on Sharp Avenue Porous Pavement

1. They need to follow much of the protocol described in the TAPE Guidance Manual if they want to have permeable pavement approved for treatment. They don't need to use the TAPE Board of External Reviewers (BER), but they do need to develop a technical review panel that will independently review the results of the monitoring. They also need to collect water quality samples from a suite of pollutants, as described in the TAPE guidance. They haven't identified what pollutants they want to monitor in the document yet.
2. They need to evaluate the removal percentages for the various pollutants. They need to follow the statistical analysis described in the TAPE guidance manual for this analysis.
3. They should probably add Ray Latham, CRO Municipal Stormwater Permit Manager (rlat461@ecy.wa.gov) to the distribution list.
4. They will need to describe the basins that receive rainfall and direct runoff to the sampling stations better. Will there be run-on to the permeable pavement? Will runoff occur from lands other than the street?
5. The minimum rainfall for a qualifying event in TAPE is 0.15 inches, not 0.2 inches.
6. The statement at the start of Section 5.3 is confusing. Are they collecting only one sample per quarter, or will they attempt to collect samples from all potentially qualifying rainfall events throughout the year.
7. Will they want to collect grab samples during the monitoring? If so, they need to describe the process for collecting.

Comments on Garland Stormwater Gardens with Biochar Amended Soil

1. They should probably add Ray Latham, CRO Municipal Stormwater Permit Manager (rlat461@ecy.wa.gov) to the distribution list.
2. I'm confused about just what a Storm Garden is. I thought it is an Eastern Washington version of a Bioretention facility. In this proposal, they speak of it as a bio-infiltration swale. Bio-infiltration swales don't include engineered soil, so the BMP discussed this proposal is not a bio-infiltration swale. If they want to test a Bioretention Soil Mix that

uses biochar instead of compost, they need to remove references to bio-infiltration swales, and say that Storm Gardens are equivalent to Bioretention.

3. The previous laboratory study that found biochar could remove pollutants is important and they should include summary data from the study as an appendix to the QAPP.
4. Based on the text in Section 3.5 they will use grab samples to get their data. The effluent grab sampler does produce a pseudo-composite sample, but the influent sampler does not. The number of samples is very small and probably the calculations won't produce statistically significant data unless the level of treatment is very high. It is also very difficult to accept data as paired when one is a single grab and the other is a composite over time.
5. Section 5.3 appears to say that there will be only one sample per quarter. They should collect samples from all potentially qualifying rainfall events throughout the year, particularly if they have a limited volume of sample to work with and a large number of pollutants to sample. They could select some pollutants for testing and some to skip, knowing that they can reverse the pollutants tested after the next storm.
6. What pollutants to they propose to test for in this project. They list pollutants tested in the lab study on biochar, but they don't list anything for this study.
7. The minimum rainfall for a qualifying event in TAPE is 0.15 inches, not 0.2 inches.

Comments on Mobile Contractor Illicit Discharge Education & Outreach

1. They need to develop a distribution list by name along with specifying particular people for signatures.
2. In the first paragraph, they say there were two programs in eastern Washington and then mention Snohomish County as one of the programs. They explain this later, but it is confusing at the start. Maybe leave out the "eastern" at the first mention.
3. The text for the pledge in the third bullet should stand out as italics or in quote marks.
4. In Section 4.5, they have language that implies they will go for consultant selection twice, once for data collection preparation and once for data collection. Couldn't they combine the two pieces into a single project and save some time, money and effort?
5. In Table 4.1, they could include as a constraint the thought that the mobile business owner may fear some sort of penalty if they admit they discharge incorrectly. This may limit the number of responses you get from those who are not obeying the Dump Smart Program.

Comments on Sand Filter Sidewalk Vault BMP

1. Page 4: They identify an initial mix that meets Ecology's requirements for treatment of dissolved Cu and Zn and total phosphorus, but not TSS. All BMPs must meet the minimum level of TSS treatment before they perform any evaluation for other pollutants.
2. For TAPE approval, there is no maximum number of samples to collect. You need to collect a minimum of 12 samples and you need to meet the statistical requirements for confidence. If that takes more than 36 samples, you need to collect more than 36 samples. Typically, if someone needs to collect more than 25 samples to show treatment, they

realize the existing device doesn't work and they stop sampling. They might change the treatment technology and start the process again, or they move out of the TAPE program.

3. You need to add a goal of establishing a design flow rate in gallons per minute per square foot of the sand filter surface.
4. Highlight the location of the vault on Figure 4.1.
5. Section 4.4, you need to collect continuous flow measurements and water quality samples must include event mean concentrations, not just grab samples.
6. Section 4.5, Ecology must review and approve the QAPP.
7. Section 7.2, do you have values for the current influent concentrations? You might want to collect samples to get a feel for the influent pollutants.
8. Table 7.2, you should include an analysis of the organic content of the soils and possibly other parameters, such as carbon: nitrogen ratio.

Comments on Street Sweeping and Catch Basin Cleaning Comparison

1. There are a several places where sentences suddenly end, there are missing words, or text doesn't make sense. The proposal is still understandable and I assume the next edit will correct these issues.
2. Section 3.3, add a bullet that discusses the potential that sediment in the catch basin could resuspend and flow out of the catch basin during a large storm. A catch basin could catch some sediment, at least for a short time, and then discharge to the swale. The sediment bags should catch this sediment.
3. You are vacuuming the street with a hand held vacuum to collect samples. How will this work with the street sweeper volumes of sediment removed?

If you have any further questions, please contact me by email at douglas.howie@ecy.wa.gov or by phone at (360) 407-6444.

Appendix B. Proposal: Responses to Ecology's Comments

Comment #	Ecology's Comment	HDR's Response
1	Page 4: They identify an initial mix that meets Ecology's requirements for treatment of dissolved Cu and Zn and total phosphorus, but not TSS. All BMPs must meet the min. level of TSS treatment before they perform any evaluation for other pollutants.	The section in the proposal was deleted and has been completely revised in the QAPP.
2	For TAPE approval, there is no maximum number of samples to collect. You need to collect a minimum of 12 samples and you need to meet the statistical requirements for confidence. If that takes more than 36 samples, you need to collect more than 36 samples. Typically, if someone needs to collect more than 25 samples to show treatment, they realize the existing device doesn't work and they stop sampling. They might change the treatment technology and start the process again, or they move out of the TAPE program.	Reference to a maximum of 36 samples has been deleted.
3	You need to add a goal of establishing a design flow rate in gallons per minute per square foot of the sand filter surface.	Text has been revised to clarify this goal.
4	Highlight the location of the vault on Figure 4.1.	Vault will be highlighted in the QAPP submittal
5	Section 4.4, you need to collect continuous flow measurements and water quality samples must include event mean concentrations, not just grab samples.	Text was revised to clarify flow measurements will be collected continuously and water quality samples will be composite. This section focuses on the data that will be collected, since event mean concentration (EMC) is part of the analysis and defined in Section 14, it was not added to this section. Note: there is no mention of grab samples in section 4.4. Grab samples were mentioned in Table 7.~~6~~ 5 and this table was revised to clarify that composite samples will be collected.

6	Section 4.5, Ecology must review and approve the QAPP	Please note that the following task was in the proposal submitted to Ecology. **Develop Quality Assurance Project Plan (QAPP)** • Submit QAPP to Ecology and BER for review Under the primary task 'Develop Technical Report', the following was added: o Submit TER to Ecology and the BER for Review and Comment
7	Section 7.2, do you have values for the current influent concentrations? You might want to collect samples to get a feel for the influent pollutants.	Influent and effluent samples have not been collected at the test-site.
8	Table 7.65, you should include an analysis of the organic content of the soils and possibly other parameters, such as carbon: nitrogen ratio.	Organic content and carbon to nitrogen ration tests were added to the table.

Appendix C. QAPP: TAG Comments and Responses to Comments

#	Commenter Initials	Section	Page	Comment	Suggested Revision	HDR Response to Comment
1	RWB	2.0	9	Last sentence - typo	add, "…will occur over..."	Will update.
2	RWB	3.1	10	2nd paragraph, 4th sentence - typo	change collects to collect	Will update.
3	RWB	3.1	10	2nd paragraph, 5th sentence - typo	add, "…to be shorter..."	Will update.
4	RWB	3.2	11	Last sentence - typo	delete extra "a"?	Will update.
5	RWB	3.3	12	2nd paragraph, last sentence - typo	add, "…equivalent to the loading…"	Will update.
6	RWB	3.3	15	*Single Event Modeling, second sentence* - typo	change infiltrate to infiltration	Will update.
7		3.3	17	1st paragraph, last sentence - typo	add space - "at least"	Will update.
8	RWB	8.3	58	*Equipment Decontamination* - Section 8.1.2 calls out an SOP for Storm Monitoring Equipment Maintenance. Does not appear to address "Cleaning and Calibration" or Decontamination procedures.	Conform 8.1.2 and 8.3.	Cleaning, calibration, and decontamination procedures are included in the SOPs
9	RWB	16.0	77	3rd reference - check spelling	Change to *Evaluating*	Will update.
10	BR	3.1	10	Dimensions of the vault seem odd. Typically a sidewalk is much longer than 4 feet.	revise for clarity	Revised to "The sidewalk vault is 5-feet long and the same width as the sidewalk (typically 4-feet)".
11	BR	3.1	11	Wording in the last paragraph is confusing.	revise for clarity	revised
12	BR	3.3	12	Plexiglas is a brand name		Changed to clear plastic
13	BR	3.3	13	Firt value in table 3.2 "0 inches percipitation"	This rads as though most removal of pollutants occurred when there was no precip. I suggest < 1 rather than 0	Changed to < 1
14	BR	3.3	13	table 3.2 please indicate somewhere what ND and NT are.		done
15	BR	3.3		all figures	please include descriptions for letters and abbreviations.	done
16	BR	3.3	13	paragrapgh preceeding fig 3.2	Please revise for flow and clarity.	revised

17	BR	3.3	16		put a date in place fo " a few years ago" for when the vault was constructed	Changed to 2016
18	BR	4.2	23	Composite and grab samples will be collected for each storm event? Why grab sample for TPH and composite samples for other pollutants?		According to the Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies, certain samples are required to be composite samples/grab samples. Grab samples for TPH are the required sampling method.
19	BR	4.4	24	table 4,1	define NWTPH-Dx	Defined in Table 4.1
20	BR	All		Please be sure that all acronyms are defined.		done
21	BR	All		Generally edit for grammar and readability		done
22	JS	3.1	11	Not a flow control BMP (sand filter sidewalk vault). Is this in reference to infiltration rate during treatment?		Reference to flow control was deleted. Changed to permeability
23	JS	3.3		Lines in background of graphs are hard to see		Graphs were reformatted
24	JS	7.1	36	Confusing (first sentence)	revise for clarity	revised
25	nbp	-	-	Why is there no phosphorus measurement at all? If sediment and metals are expected to be removed, then some P will be removed too. This is relevant because of the Spokane River DO TMDL.	Add P monitoring to project.	There is phosphorus testing, see Table 4.2. However TP is not expected to be reduced the to level required in the permit.
26	nbp	-	-	If phosphorus is not monitored, then references to it are unnecessary.	Remove all references to P in the document and appendix.	See response to last comment
27	nbp	-	-	If phosphrus monitoring is required for the TARP protocaol but not for BMP performance, then an explantion would help.	Add additional text and/or footnotes to table.	Monitoring for Phosphorus is a required screen parameter for TAPE, please reference the TAPE guidance document

28	nbp	-	-	Why is there no pre-treatment to catch large sediments, trash, and oil & grease?	The forebay could be part of the sidewalk vault and have an inverted outlet to the sand filter.	That is not what Spokane County wanted to design
29	nbp	-	-	Why is the study only two years? The sand media adsorption sites could easily be saturated after two years.	It would be good to analyze the CEC of the sand media at the end of two years or plan to completely replace the sand media.	Please reference the TAPE guidance document. Monitoring for 2 wet seasons is required.
30	nbp	-	-	The ratio of impervious area to practice area is about 700 (14,000/20). Most WQ BMPs use a ratio of 10-20 except maybe for tree pits. Can we realistically expect this sand filter to function well?	The size of sand filter need to be made bigger to better match the drainage area.	noted
31	nbp	Preface	i, ii	Phone numbers	Need a space	Noted.
32	nbp	Preface	v	Nigel Pickering's title	Change to "Research Associate Professor"	done
33	nbp	2	9	"infiltrate"	Change to "treat".	noted
34	nbp	2	9	"24- hour"	Delete space.	Noted.
35	nbp	3	11	Table 3.1. Why different infiltration rates?	Single max design infiltration rate. For TAPE, you need to establish a design flow rate in gpm/min/sf of sand filter surface (see Appendix pg 5).	A design infiltration rate is also needed for the BMP design guidance. An objective was added to the study to determine the design flow rate using data collected during the field study
36	nbp	3.3	13	Undefined BSM abbreviation.	Add definition.	Changed to sand media
37	nbp	3.3	15	Last para on infiltration.	Single max design infiltration rate.	Section has been revised
38	nbp	3.3	17	"atleast"	Add space	Will update.
39	nbp	3.3	17	Design rate of 124 in/hr. Confusing relative to Table 3.1.	Single max design infiltration rate.	Section has been revised
40	nbp	4.2	23	"basic dissolved metals"	Change to "basic treatment for dissolved metals".	Basic treatment applies to TSS removal not dissolved metals.
41	nbp	4.4	24	TSS in two parts of Table 4.1	Remove from second line.	This table is straight from the TAPE guidance manual. TSS is a required

						parameter for both basic and dissolved metals performance goals.
42	nbp	4.5	25	"screening parameter"	Change to "screening parameters"	Will update.
43	nbp	4.5	25	Unnecessary capitalization	Change to lower case	noted
44	nbp	4.5	25	Undefined BER and TER abbreviations.	Add definitions	BER and TER are now defined in Section 4.2.
45	nbp	4.6	25	Table 4.2 "output variable" and "are encounter"	Change to "output variables" and "are encountered"	Will update.
46	nbp	6	30	"Precision for flow". There is no precision check on flow without an external measurement.	Change to ""Precision for depth".	
47	nbp	6.3	31	"Tape"	Change to "TAPE"	
48	nbp	6.5	33	Table 6.1. "???"	Finalize table.	Table will be finalized once comments are received from the laboratories. The question marks have been removed.
49	nbp	7.1	35	"The BMP design and maintenance guidance was developed..."	Change to "The BMP design and maintenance guidance developed..."	If you're referring to the first sentence, that will make it an incomplete sentence "The BMP design and maintenance guidance developed through laboratory testing conducted prior to QAPP development". Will leave as is.
50	nbp	7.1	38	Table 7.1. Undefined PT and SDE abbreviations.	Add definitions.	PT has been spelled out in the table. By SDE do you mean SDI?
51	nbp	7.5	41	NOAA versus Weather Underground. Confusing.	Clarify when each is used.	NOAA will be used to predict the potential for a qualifying storm event (per TAPE guidelines). Weather Underground was going to be used to monitor actual precipitation near the site (has stations closer than the nearest NOAA station). However, actual rain data at the site will now be monitored via a cellular connection to the data logger. Will make sure it is

						clear that NOAA is being used for prediction of storm events, and actual data is being used to determine whether TAPE requirements for storm events are being met.
52	nbp	7.5	41	"wire mesh will be placed over the pipe leading from the inlet box to the monitoring and sand filter sidewalk vault." Will this just be for the experiment or for general use? Seems like it would clog up really fast in some situations. That's why sediment forebays are generally used.	Clarify general use protocol for trach capture.	Trash capture will occur in the sand filter vault. Spokane County requested that the vault not contain a forebay due to space constraints
53	nbp	7.9	43	Table 7.2. End-of-project (2 years) testing would be useful for some parameters.	Add some parameters (CEC, total elements) to post-project testing.	Not required per TAPE. In addition the permittees are paying for these studies and they do not have funds to conduct testing that does not answer their research questions.
54	nbp	8	44	SOPs are long and hard to read. Some repetition too.	Suggest breaking into sections. A common section might decrease repetition.	commented
55	nbp	8.1	45	"The judgment will take storm physiology and sampling success to date into account."	Change "physiology" to "characteristics".	Comment noted
56	nbp	8.1.2	47	Undefined DCP abbreviation.	Add definition.	DCP references have been removed.
57	nbp	8.1.7	55	Steps are out of time sequence?	Place steps 9-14 first, then 1-8, and renumber.	Will update.
58	nbp	9.1	60	Paragraphs are hard to read.	Bullet items?	noted
59	nbp	11	67	"electronically filed in HDRs server."	Change "in" to "on"	Will update.
60	nbp	11.3	68	Level II Data Package. What's this?	Explain.	Part of information provided by the lab

61	nbp	14.1	74	"Infiltration will be evaluated by comparing the influent and effluent flow rate measurements during each qualifying event." Does not seem right. Outflow = infiltration. Inflow affects volume stored and stage above sand media only.	Check statement.	While effluent flow represents the infiltration rate, unless the sand media is saturated then the value measured is not a steady state parameter. Section has been updated for clarity.
62	nbp	14.2	75	Figure 14.2. Why use log scale?	Change to linear scale?	Noted. Trend in data is more easily observed at log scale.
63	nbp	14.2	75	Table 14.2. TPH Performance Criteria = N/A.	Change to <10 mg/L.	noted
64	nbp	App	pdf 34	Long-term accuracy is 0.15 in.	Add SOP check for accuracy.	noted
65	nbp	App	pdf 34	Raingage accuracy versus rainfall intensity.	Add SOP check for rainfall intensity to evaluate tipping bucket spillage. A correction curve can be developed, if necessary.	SOPs follow manufactures recommendations
66	nbp	App	pdf 36	Leakage around weir.	Add SOP check for leakage for all 3 weirs.	noted
67	nbp	App	pdf 56	Inlet filter. Is this used in the project?	Delete in appendix or add text to narrative.	These are the specifications for the coconut coir mat which is placed on top of the sand filter. The mat is also commonly used as an inlet filter, hence the title of the spec sheet. Will add a note to the appendix to clarify.

Appendix D. Ecology QAPP Approval Letter, Comments, and Responses to Comments

DEPARTMENT OF
ECOLOGY
State of Washington

To: Karen Dinicola, Department of Ecology

Via: Brandi Lubliner, Department of Ecology

From: Douglas C. Howie, P.E., Department of Ecology

Cc: Abbey Stockwell, Department of Ecology

Date: June 5, 2018

Subject: Comments on *Detailed Study Design Proposal Sand Filter Sidewalk Vault BMP Study*

Here are my comments on the package provided by Spokane County for our review.

Documents Reviewed:

1. *Eastern Washington Stormwater Effectiveness Studies Sand Filter Sidewalk Vault BMP Study*, by HDR, Inc., May 8, 2018

General Comments:

1. I did not review the entire document. I limited my review to Sections 1 – 5, 7, 8, 14, and Appendices A – F.
2. I am also a member of the Technical Advisory Group (TAG). Can I be a member of the TAG as well as an Ecology Reviewer?
3. This is a new BMP and must go through the TAPE review and approval process before it can go into general use. TAPE requires an approved QAPP before the beginning of field monitoring. They must submit the final version of this document for TAPE review and approval prior to starting field monitoring if they want TAPE to accept their data for a GULD review.
4. Section 3.1 and Figure 3.1: They identify a choke stone layer of 3-inches in the text and show 10-inches in the figure.
5. Section 3.3.1: They refer to SIL-CO-SIL® and SilcoSil in the same paragraph. Please be consistent in naming conventions.
6. Table 3.2: TAPE uses a Bootstrap evaluation method that calculates the lower 95% confidence value, which is typically lower than the average value. As such, an average pollutant reduction of 81% is unlikely to meet the TAPE pollutant reduction goal.
7. Section 3.3.1: In the last paragraph they refer to “TSS loading from 26-inches of rainfall.” I believe they mean 16-inches of rainfall, based on earlier text and Figure 3.3.
8. Section 3.3.2.2: In the third paragraph they state “sediment contained material larger than could not fit in the columns.” I don’t understand what they are trying to say here.

9. Section 4.2: The TAPE BER will need to approve the field monitoring QAPP prior to starting field monitoring if they want to use the data collected for TAPE approval.
10. Section 4.5: They do not "convene the board of external reviewers (BER) from the TAPE program." If this is a group they form, they need to use another name than BER. They could use the name "Advisory Review Panel" from the BSM study.
11. Section 7.1: Can they adequately spread the flow across the full 20 square feet of the sand filter when it enters from the catch basin through a single 6-inch diameter pipe. They depend on use of the full surface area for their flow rate and treatment.
12. Section 7.3.1:
    a. I am having difficulty accepting the calculations that a single 4-foot by 5-foot sand filter can handle the runoff from 18,000 sq ft of impervious surface (ratio of 900:1, drainage basin:filter). Based on my calculations if they want to filter runoff from 18,000 sq ft through 20 sq ft of filter, they need to have an infiltration rate of 670 inches/hour. If they hold the infiltration rate to 124 in/hr they can infiltrate from an area of 3,305 sq ft. See the attached spreadsheet for calculations.

       Use of the Rational Formula here is appropriate since Spokane County and the City of Spokane use the Bowstring calculation frequently when developing BMP sizing. The Bowstring technique uses the Rational Formula to calculate runoff from rainfall. If my calculations are correct, they need to re-look at the scaling of the lab testing and revise the design criteria in this section.
    b. In the text above Table 7.4 they say there is a 10-inch layer of choke stone and in the text immediately below the table they say 12-inches. They also list 3-inches of choke stone in the first bullet.
13. Section 7.4: They might want to modify their equations to get the flow in gallons per minute instead of gallons per minute since they need to report flows using gallons per minute.
14. Section 7.5.2: TAPE requires continuous rainfall monitoring, not just during the monitoring periods. This allows us to have an idea of how much runoff passes through the device overall, not just during monitoring events.
15. Section 7.7: If they have a ponding depth of 18-inches they will have a gradient of 36-inches (water depth) / 18-inches (filter depth) and the infiltration rate will be double the saturated hydraulic conductivity.
16. Section 7.9: How do they separate the sediment that enters the filter via runoff from the media already in the filter?
17. Table 7.6: Confirm that the sieve sizes they propose to measure agree with those required by TAPE.
18. Section 14.2.4: Include a discussion of the TAPE required bootstrap statistical method in this section.

If you have any further questions, please contact me by email at douglas.howie@ecy.wa.gov or by phone at (360) 407-6444.

DEPARTMENT OF
ECOLOGY
State of Washington

To: David Duncan, Department of Ecology, Municipal Stormwater Permit Manager

From: Brandi Lubliner, P.E., Department of Ecology, QA Coordinator

Cc: Douglas C. Howie, P.E., Department of Ecology

Date: June 27, 2018

Subject: Eastern Washington Stormwater Effectiveness Study QAPP Review Comments

This *Eastern Washington Stormwater Effectiveness Studies Quality Assurance Project Plan: Sand Filter Sidewalk Vault Study*, draft dated May 8, 2018, is well developed. I reviewed the entire document. The following revisions are necessary for approval, and other comment is for your consideration.

Necessary edits:

1. Section 4.2: Is the sand in the vault going to be built with completely new sand material?
2. Section 4.5: This section verb tenses need some updating. Many of these steps are already accomplished. One bullet for the QAPP approval is missing.
3. Looks like the revision (unknown date) took care of much of the disagreement between terms for the PSD and SSC methods. There is still some edits for the following:
    a. Table 4.1 and 4.2; the footnote on NWTPH-Dx should probably be the same. Not sure a second one is needed if defined in the earlier table or maybe do in text. All the rest of the text and tables just use the abbrev.
    b. Why is there a method for temperature in 6.2? It should be "field meter" right? If you want to put the correct reference for 170 then cite this document. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=280013&simpleSearch=0&showCriteria=2&searchAll=best+practices+for+continuous+monitoring&TIMSType=&dateBeginPublishedPresented=06%2F27%2F2008
    c. Strike pH from Table 8.1
    d. Table 10.1 the field duplicates of 10% doesn't make sense for the sand filter media. Probably should just delete these 8 rows from this table since it's a one-time analysis.
4. I understand why sediment buildup at the top of the BMP surface was added as a parameter in Table 4.1. However, these depth measurements may be somewhat subjective. How will the measurement be conducted without accidentally measuring into the sand? Because of the larger pore sizes it seems like based on the pilot column work,

the stormwater solids will be all through the BMP. I wonder if the sediment PSD or grainsize analysis at the end from a cored sample of the entire sand filter may provide a better sense of before/after size distribution from stormwater solids captured by the BMP. Like Figure 3.7

5. Section 8.3: the single SOP named “Storm Monitoring Equipment Maintenance, Cleaning and Calibration” is not included in this QAPP
6. Section 11.1 or 15.2: The data generated by this study will be loaded to the International BMP database. In additional I recommend you ask that a spreadsheet of all the study data be sent to you the municipal stormwater permit manager with the final report. This spreadsheet should contain all the data from the study. This means all the useable quality assured data used for the analysis, and the rejected or un-useable data gathered as part of the study. The rejected data can be included in a separate file or a different tab and the reasons for its failure described.

General Comments:

1. Clarify which grants are supporting the project. Section 5.3 says Centennial, but Section 4.5 says GRSS grant.
2. Solids buildup behind a weir happens and frequent inspection and clean out will be needed, each storm event to not bias your flow results.
3. Generally I like to refer to in-system material as stormwater “solids” and not stormwater “sediments”. I think this helps to reduce confusion. Stormwater solids are generally the particulate matter in-system. Sediments are sometimes confused with the bed layer of a lake/stream under water. I’m not requiring this change in this QAPP.

My role as QA Coordinator for municipal stormwater monitoring is relatively new, and was not yet established in the earlier drafts of this QAPP. Please send the final PDF for signature when ready. If you have any further questions, please contact me by email at brandi.lubliner@ecy.wa.gov or by phone at (360) 407-7140.

Comment #	Reviewer	Ecology's Comment	HDR's Response
1	DH	I am also a member of the Technical Advisory Group (TAG). Can I be a member of the TAG as well as an Ecology Reviewer?	Comment Noted
2	DH	This is a new BMP and must go through the TAPE review and approval process before it can go into general use. TAPE requires an approved QAPP before the beginning of field monitoring. They must submit the final version of this document for TAPE review and approval prior to starting field monitoring if they want TAPE to accept their data for a GULD review.	Comment noted
3	DH	Section 3.1 and Figure 3.1: They identify a choke stone layer of 3-inches in the text and show 10-inches in the figure.	The 3-inch layer refers to the depth of choke stone that is between the bottom of the sand media and top of the underdrain, and does not refer to the full depth of choke stone. Figure was updated to clarify.
4	DH	Section 3.3.1: They refer to SIL-CO-SIL® and SilcoSil in the same paragraph. Please be consistent in naming conventions.	Updated to SIL-CO-SIL®
5	DH	Table 3.2: TAPE uses a Bootstrap evaluation method that calculates the lower 95% confidence value, which is typically lower than the average value. As such, an average pollutant reduction of 81% is unlikely to meet the TAPE pollutant reduction goal.	The 81% reduction was calculated from the equivalent of 32 inches of rainfall for the equivalent of an 18,000 sqft contributing basin area to the columns. As shown in Figure 3.3, breakthrough of TSS occurs around the equivalent of 26 inches of rainfall as such it is anticipated that the maintenance cycle would occur prior to the 26 inches. Considering this and that 87% reduction occurred at the equivalent rainfall of 24 inches (average TSS reduction for <1 to 24 inches from Table 3.2) it is anticipated that the treatment performance goal would be achieved when the bootstrap evaluation is conducted.
6	DH	Section 3.3.1: In the last paragraph they refer to "TSS loading from 26-inches of rainfall." I believe they mean 16-inches of rainfall, based on earlier text and Figure 3.3.	The 26 inches is correct. 26 inches is the equivalent amount of rainfall that went through the column before breakthrough occurred.

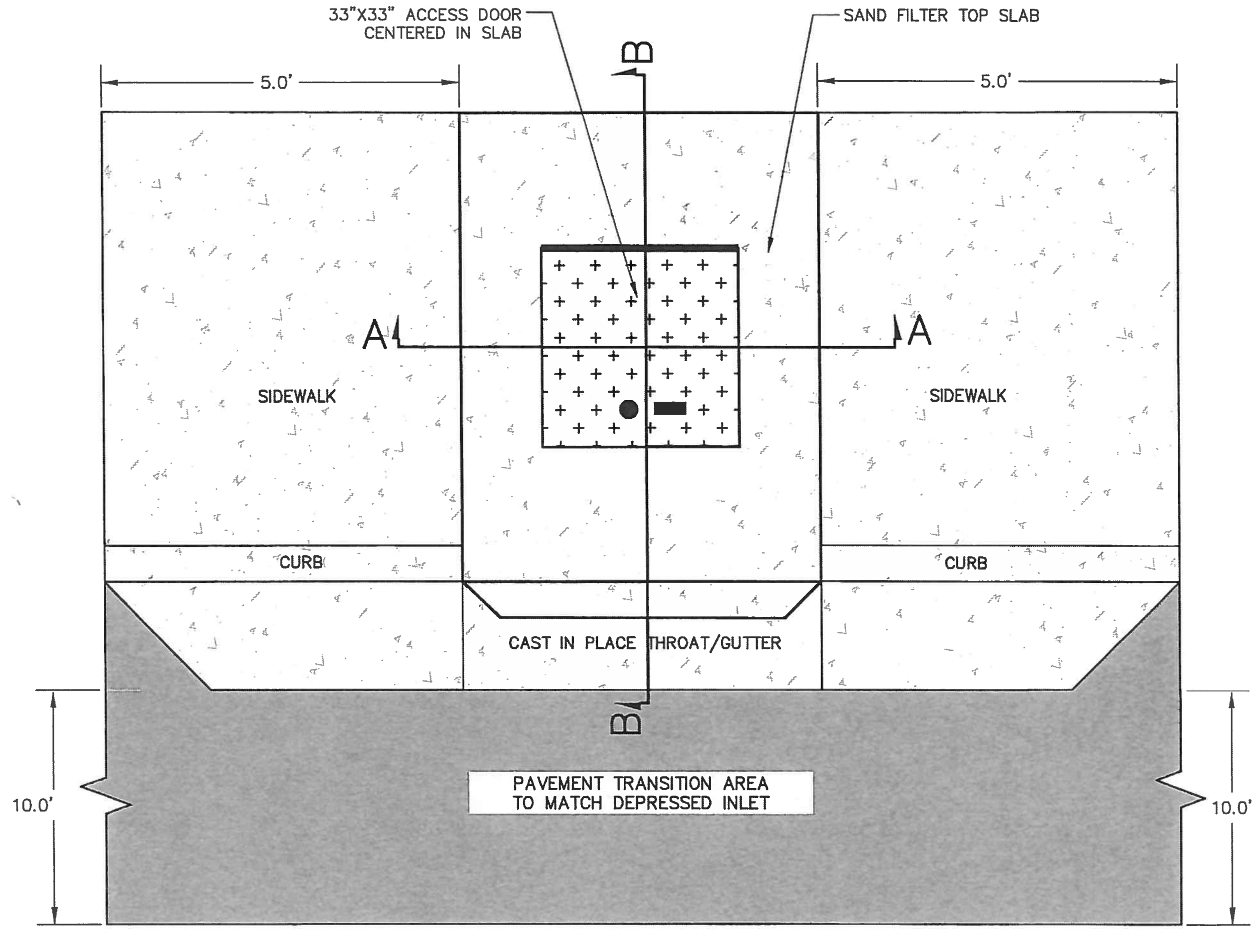
7	DH	Section 3.3.2.2: In the third paragraph they state "sediment contained material larger than could not fit in the columns." I don't understand what they are trying to say here.	Material observed in the sand filter vaults in the field included a significant amount of gross solids such as leaves, sticks, clothing, cigarettes, garbage, etc. These materials were too large (or unsuitable) to fit into the 3-inch diameter columns. Language was added to the paragraph to clarify.
8	DH	Section 4.2: The TAPE BER will need to approve the field monitoring QAPP prior to starting field monitoring if they want to use the data collected for TAPE approval.	Comment noted
9	DH	Section 4.5: They do not "convene the board of external reviewers (BER) from the TAPE program." If this is a group they form, they need to use another name than BER. They could use the name "Advisory Review Panel" from the BSM study.	Reference to convening BER was deleted.
10	DH	Section 7.1: Can they adequately spread the flow across the full 20 square feet of the sand filter when it enters from the catch basin through a single 6-inch diameter pipe. They depend on use of the full surface area for their flow rate and treatment.	The coconut coir matt provides energy distribution when runoff enters the sand filter. Based on visual observation, runoff appears to distribute over the sand filter area during rainfall events.
11	DH	1. Section 7.3.1: a. I am having difficulty accepting the calculations that a single 4-foot by 5-foot sand filter can handle the runoff from 18,000 sq ft of impervious surface (ratio of 900:1, drainage basin:filter). Based on my calculations if they want to filter runoff from 18,000 sq ft through 20 sq ft of filter, they need to have an infiltration rate of 670 inches/hour. If they hold the infiltration rate to 124 in/hr they can infiltrate from an area of 3,305 sq ft. See the attached spreadsheet for calculations. Use of the Rational Formula here is appropriate since Spokane County and the City of Spokane use the Bowstring calculation frequently when developing BMP sizing. The Bowstring technique uses the Rational Formula to calculate runoff from rainfall. If my calculations are correct, they need to re-look at	a. The calculations for the column testing were run using the Type 1A rainfall distribution. This method was selected because research indicates it most closely represents historical rainfall records in EWA. A new section 3.3.4 was added to the QAPP which compares the sand filter sizing using the Rational Method and the Type 1A rainfall distribution to the Type 1A rainfall distribution. As requested, I have changed the BMP design method to the Bowstring Method (Modified Rational Method) following the Spokane Regional Stormwater Manual guidance. The QAPP text has been updated accordingly.

		the scaling of the lab testing and revise the design criteria in this section. b. In the text above Table 7.4 they say there is a 10-inch layer of choke stone and in the text immediately below the table they say 12-inches. They also list 3-inches of choke stone in the first bullet.	b. Will update to match depths. The 3-inch layer of choke stone refers to the depth of choke stone that should be present *between* the top of the underdrain and the bottom of the sand media, not the total depth of the choke stone.
12	DH	Section 7.4: They might want to modify their equations to get the flow in gallons per minute instead of gallons per minute since they need to report flows using gallons per minute.	All the units in the data loggers are in liters and for consistency the weir equations have been left in liters.
13	DH	Section 7.5.2: TAPE requires continuous rainfall monitoring, not just during the monitoring periods. This allows us to have an idea of how much runoff passes through the device overall, not just during monitoring events.	Rainfall will be monitored continuously and stored on the data logger. Each time data is downloaded, rainfall data from all periods (monitoring or not) will be downloaded with the rest of the data. Language was add to Section 7.5.2 for clarification.
14	DH	Section 7.7: If they have a ponding depth of 18-inches they will have a gradient of 36-inches (water depth) / 18-inches (filter depth) and the infiltration rate will be double the saturated hydraulic conductivity.	Note regarding Ksat was deleted from Section 7.1 and discussion regarding Ksat calculations (including calculating the hydraulic gradient) was added to Section 14.1.5.
15	DH	Section 7.9: How do they separate the sediment that enters the filter via runoff from the media already in the filter?	The samples from the top of the BMP will be used solely to estimate the frequency with which maintenance should occur. The sediment will not be separated from the media, and the amount of sediment will be estimated based on estimated loading to the sand filter. Grain size analysis was added post testing to characterize the size sediment in the top, middle, and bottom layers of the sand filter media. Changes in the grain size will be determined by comparing the grain size of the sand filter post testing to the size pretesting. Information about this testing was added to the QAPP.

16	DH	Table 7.6: Confirm that the sieve sizes they propose to measure agree with those required by TAPE.	Updated table to include sieve sizes for both ASTM D422 and Modified SSC method
17	DH	Section 14.2.4: Include a discussion of the TAPE required bootstrap statistical method in this section.	Added
18	BL	Section 4.2: Is the sand in the vault going to be built with completely new sand material?	The sand media, choke stone, and coir mat were completely replaced in October 2018. This was clarified in Section 4.2.
19	BL	Section 4.5: This section verb tenses need some updating. Many of these steps are already accomplished. One bullet for the QAPP approval is missing.	Verb tenses were updated.
20	BL	1. Looks like the revision (unknown date) took care of much of the disagreement between terms for the PSD and SSC methods. There is still some edits for the following: a. Table 4.1 and 4.2; the footnote on NWTPH-Dx should probably be the same. Not sure a second one is needed if defined in the earlier table or maybe do in text. All the rest of the text and tables just use the abbrev. b. Why is there a method for temperature in 6.2? It should be "field meter" right? If you want to put the correct reference for 170 then cite this document. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=280013&simpleSearch=0&showCriteria=2&searchAll=best+practices+for+continuous+monitoring&TIMSType=&dateBeginPublishedPresented=06%2F27%2F2008 c. Strike pH from Table 8.1 d. Table 10.1 the field duplicates of 10% doesn't make sense for the sand filter media. Probably should just delete these 8 rows from this table since it's a one-time analysis.	a. Footnotes were re-worded to be consistent. b. Reference to document was added to Table 6.2 for temperature. c. pH was left in the table because this test is conducted within 15 minutes of collecting samples d. Field duplicates for sand filter media will not be collected. References to duplicates were removed from the table for the sand filter media.
21	BL	I understand why sediment buildup at the top of the BMP surface was added as a parameter in Table 4.1. However, these depth measurements may be somewhat subjective. How will the measurement be conducted without accidentally measuring into the sand? Because of the larger pore sizes it seems like based on the pilot column work, the stormwater solids will be all through the BMP. I	Sediment grain size analysis for sediment on top of and within the top, middle, and bottom layers of the sand filter media was added to the QAPP.

		wonder if the sediment PSD or grain size analysis at the end from a cored sample of the entire sand filter may provide a better sense of before/after size distribution from stormwater solids captured by the BMP. Like Figure 3.7	
22	BL	Section 8.3: the single SOP named “Storm Monitoring Equipment Maintenance, Cleaning and Calibration” is not included in this QAPP	Updated to match name for SOP included in Section 8.1.3.
23	BL	Section 11.1 or 15.2: The data generated by this study will be loaded to the International BMP database. In addition I recommend you ask that a spreadsheet of all the study data be sent to you the municipal stormwater permit manager with the final report. This spreadsheet should contain all the data from the study. This means all the useable quality assured data used for the analysis, and the rejected or un-useable data gathered as part of the study. The rejected data can be included in a separate file or a different tab and the reasons for its failure described.	Comment added to Section 15.2.
24	BL	Clarify which grants are supporting the project. Section 5.3 says Centennial, but Section 4.5 says GRSS grant.	Revised to Centennial Grant Application
25	BL	Solids buildup behind a weir happens and frequent inspection and clean out will be needed, each storm event to not bias your flow results.	Cleaning of pipes, weirs, tees, and monitoring equipment/meters will be cleaned prior to each storm event (see Section 8.1.3).
26	BL	Generally I like to refer to in-system material as stormwater “solids” and not stormwater “sediments”. I think this helps to reduce confusion. Stormwater solids are generally the particulate matter in-system. Sediments are sometimes confused with the bed layer of a lake/stream under water. I’m not requiring this change in this QAPP.	Comment noted

Appendix E. Test-Site Construction Plans

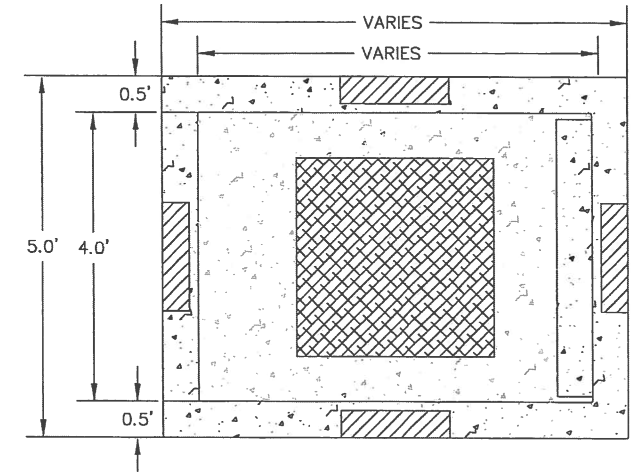


SAND FILTER PLACEMENT IN SIDEWALK

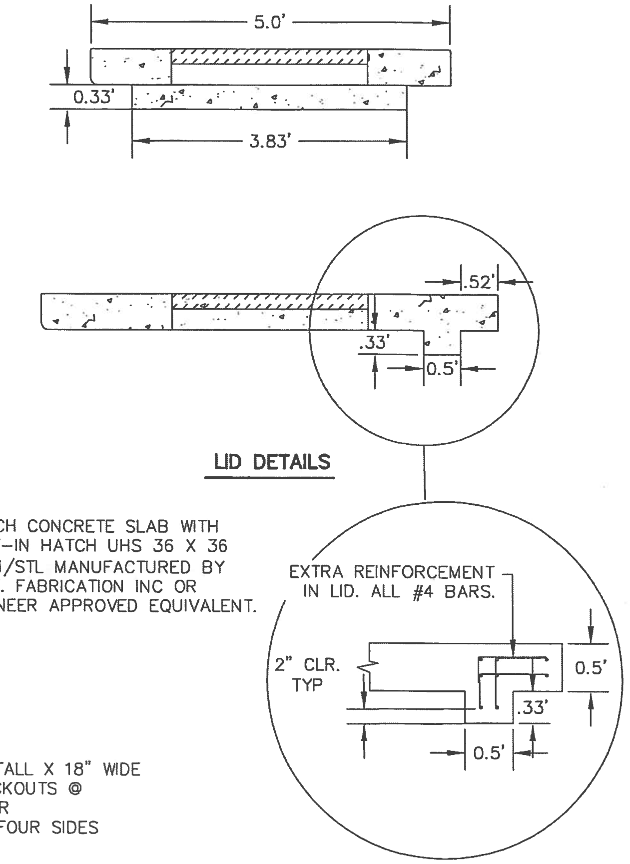
NTS

NOTES:

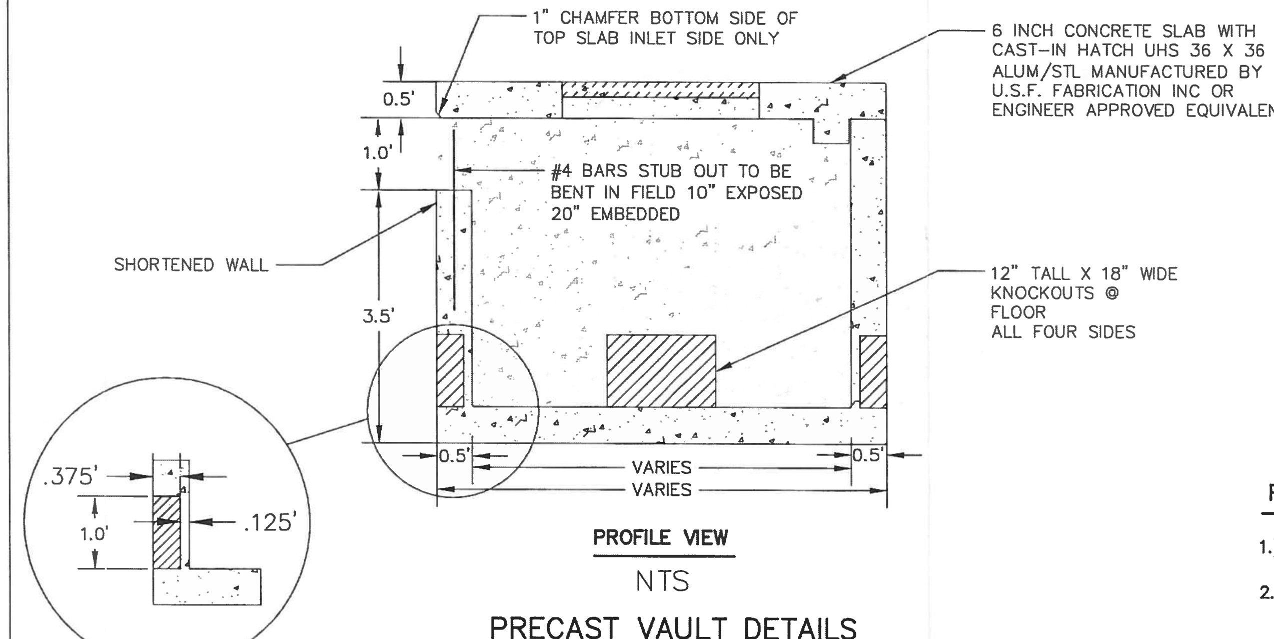
1) ALL PIPES SHALL BE PLACED AT 0.50% GRADE MINIMUM.
2) SAND FILTER LOCATIONS ARE APPROXIMATE AND MAY BE MOVED WITH THE ENGINEER'S APPROVAL TO AVOID UTILITY, DRIVEWAY, AND OTHER CONFLICT.
3) REFER TO SPECIAL PROVISIONS SECTION 7 FOR SAND FILTER SPECIFICATIONS.
4) SAND FILTER VAULT DIMENSIONS INDICATED AS "VARIES" ARE DEPENDENT ON SPECIFIC LOCATIONS SIDEWALK WIDTH INCLUDING CURB. CONTRACTOR SHALL MEASURE TO VERIFY NECESSARY DIMENSION.
5) WHERE INDICATED ON PLAN SHEETS, CONTRACTOR SHALL VERIFY EXISTING UTILITY LOCATIONS TO DETERMINE IF SAND FILTER VAULT CAN BE INSTALLED.



PLAN VIEW



LID DETAILS



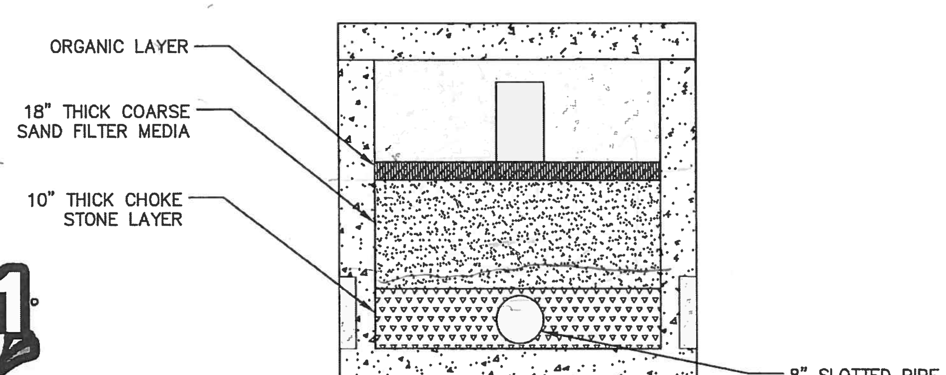
PROFILE VIEW

NTS

PRECAST VAULT DETAILS

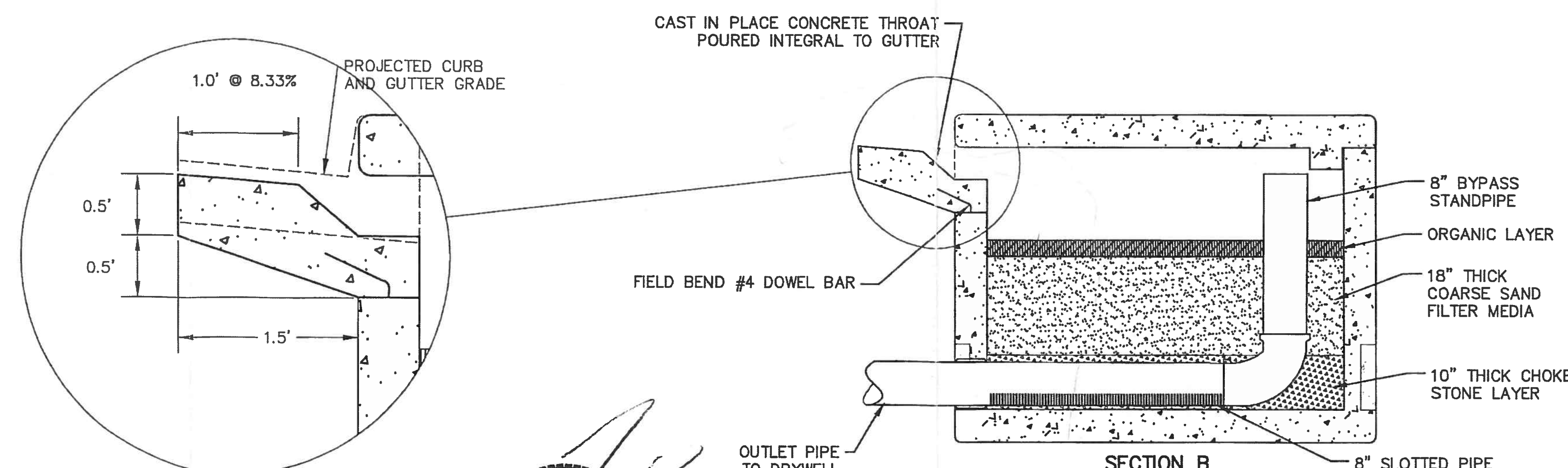
PRECAST VAULT NOTES:

1.) #4 BAR 12" O.C.E.W. THROUGHOUT, 6" O.C.E.W. IN TOP.
2.) ¼" RADIUS ON ALL EDGES OF TOP SLAB.



SECTION A

NTS



SECTION B

NTS

811
Know what's **below.**
Call before you dig.
ONE CALL NUMBER
48 HR. NOTICE REQUIRED

NO	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

REGION NO.	STATE	FED. AID PROJECT NO.
10	WASH.	STPUL-3974 (002)
DRAWN BY:	J.R.	1-19-16
DESIGNED BY:	J.S.	1-19-116
CHECKED BY:	M.Z.	1-19-16

SPOKANE COUNTY

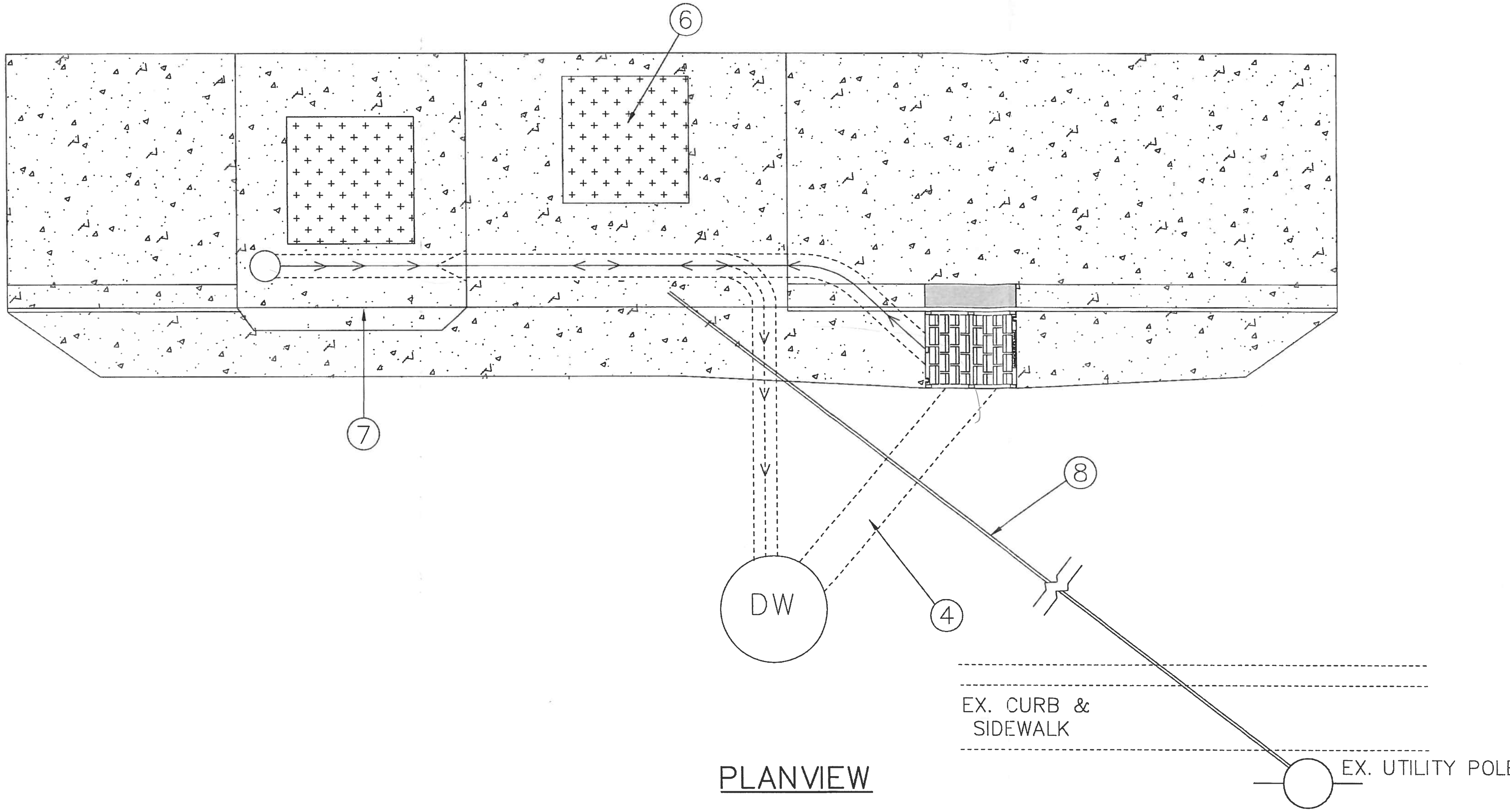
Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED:
STORMWATER ENGINEER
Date: 4/19/16

MATTHEW B. ZARECOR
STATE OF WASHINGTON
38216
REGISTERED PROFESSIONAL ENGINEER

COUNTY ROAD PROJECT No.3166 / SWN 223
HAWTHORNE ROAD
STATE ROUTE 395 TO HIGHWAY 2
SAND FILTER VAULT DETAILS

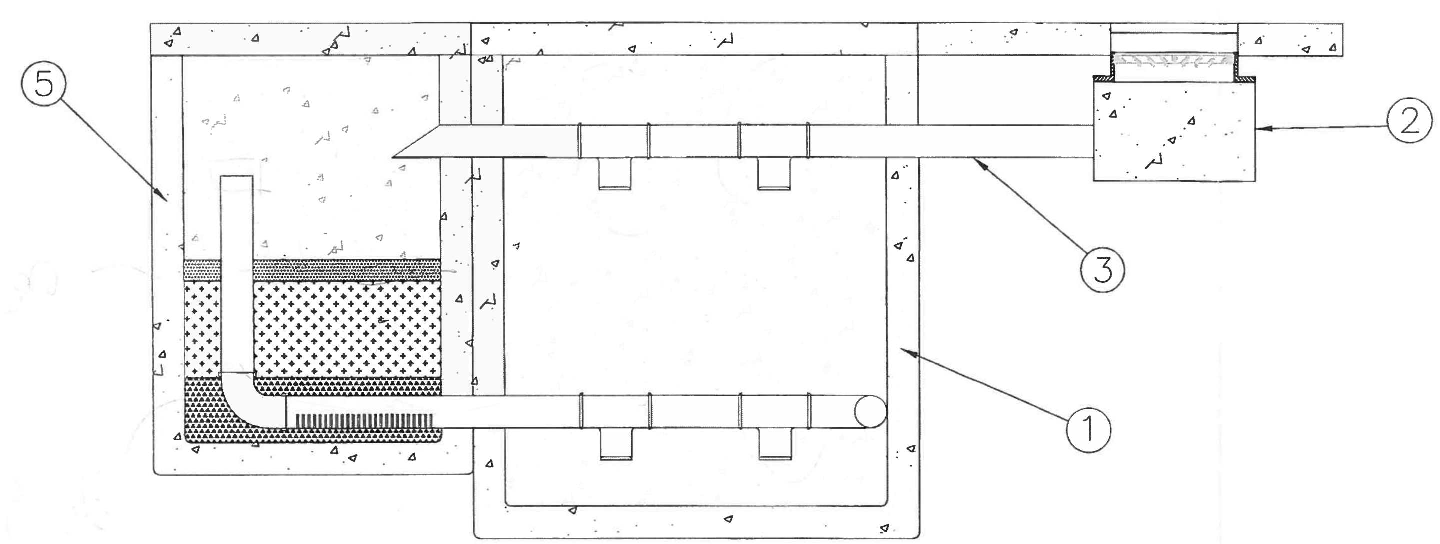
SHEET 13 of 20



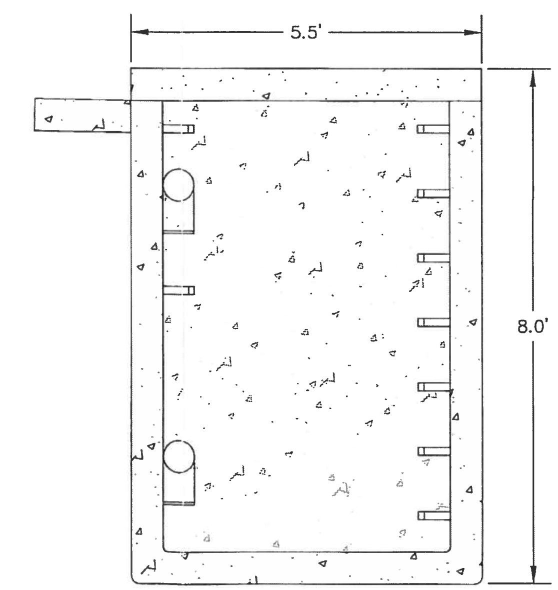
PLANVIEW

NOTES:

1. CONCRETE MONITORING VAULT 5.5'X7.0'X8.0' EXTERIOR DIMENSIONS.
2. CONCRETE INLET TYPE 1. PIPE SHALL BE INSTALLED AS SHALLOW AS ALLOWED BY KNOCKOUT LOCATION.
3. MONITORING VAULT PIPES SHALL BE 6" PVC.
4. 10" PIPE SHALL PROJECT INTO INLET FAR ENOUGH TO ALLOW A TEMPORARY CAP TO BE PLACED ON PIPE.
5. EXTRA-DEPTH SAND FILTER VAULT. OVERALL HEIGHT INCLUDING TOP SLAB SHALL BE 7 FEET. FOR ALL OTHER DETAILS REFER TO SAND FILTER VAULT DETAILS SHEET.
6. MONITORING VAULT SHALL HAVE SAME ACCESS DOOR/HATCH AS SAND FILTER VAULTS. ACCESS HATCH SHALL BE OFFSET TO BACK OF TOP SLAB.
7. TEMPORARILY PLUG SAND FILTER VAULT THROAT BY MEANS ACCEPTABLE TO THE ENGINEER. PLUG SHALL BE WATER-TIGHT AND STURDY ENOUGH TO LAST UP TO FIVE YEARS. PLUG SHALL BE ABLE TO BE REMOVED WITH BASIC HAND TOOLS. SAND FILTER IMMEDIATELY UP-STATION SHALL BE PLUGGED BY THE SAME MEANS.
8. INSTALL ELECTRICAL CONDUIT FROM EXISTING UTILITY POLE TO MONITORING VAULT.



PROFILE VIEW



SECTION VIEW

811
Know what's **below.**
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ONE CALL NUMBER
48 HR. NOTICE REQUIRED

NO	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

DRAWN BY:	J.R.	1-19-16
DESIGNED BY:	J.S.	1-19-16
CHECKED BY:	M.Z.	4-19-16

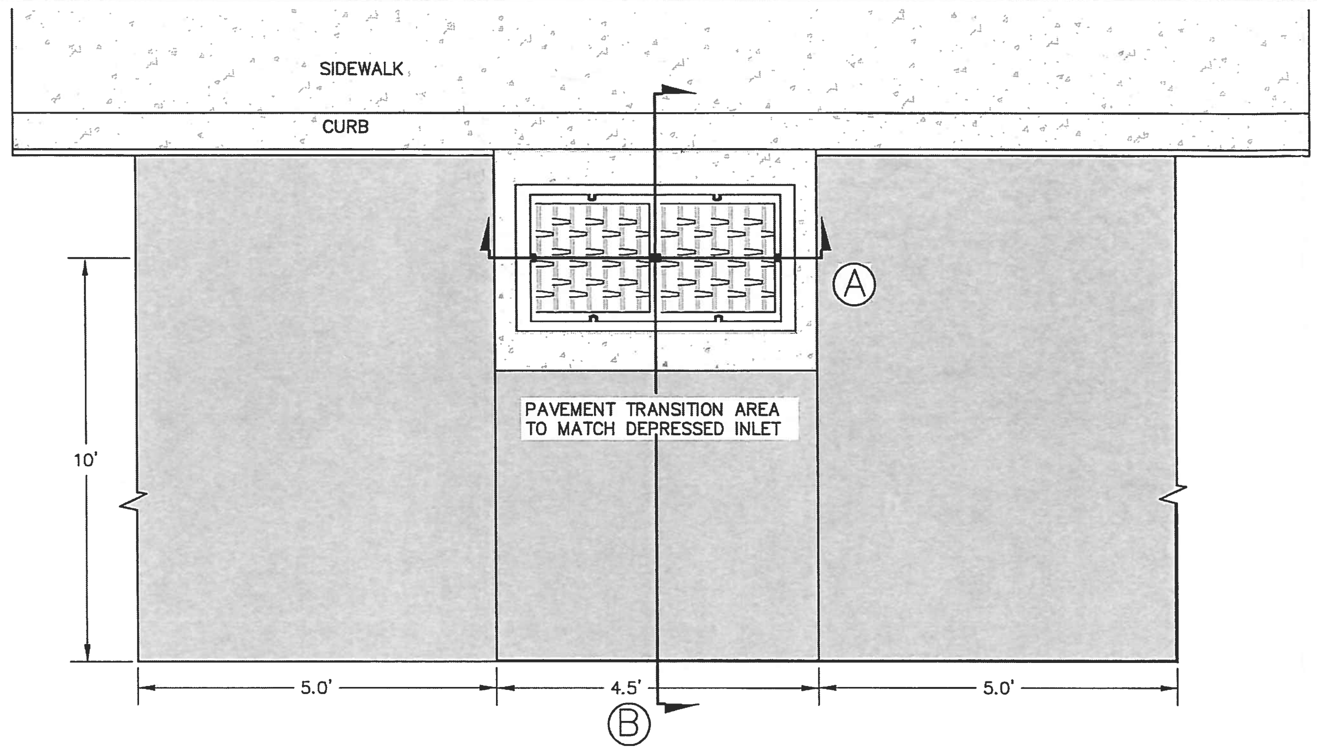
SPOKANE COUNTY
Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED:
STORMWATER ENGINEER
Date: 4/19/16

MATHEW B. ZARECOR
STATE OF WASHINGTON
36216
REGISTERED
PROFESSIONAL ENGINEER

COUNTY ROAD PROJECT No.3166 / SWN 223
HAWTHORNE ROAD
STATE ROUTE 395 TO HIGHWAY 2
MONITORING VAULT DETAILS

SHEET
15 of 20

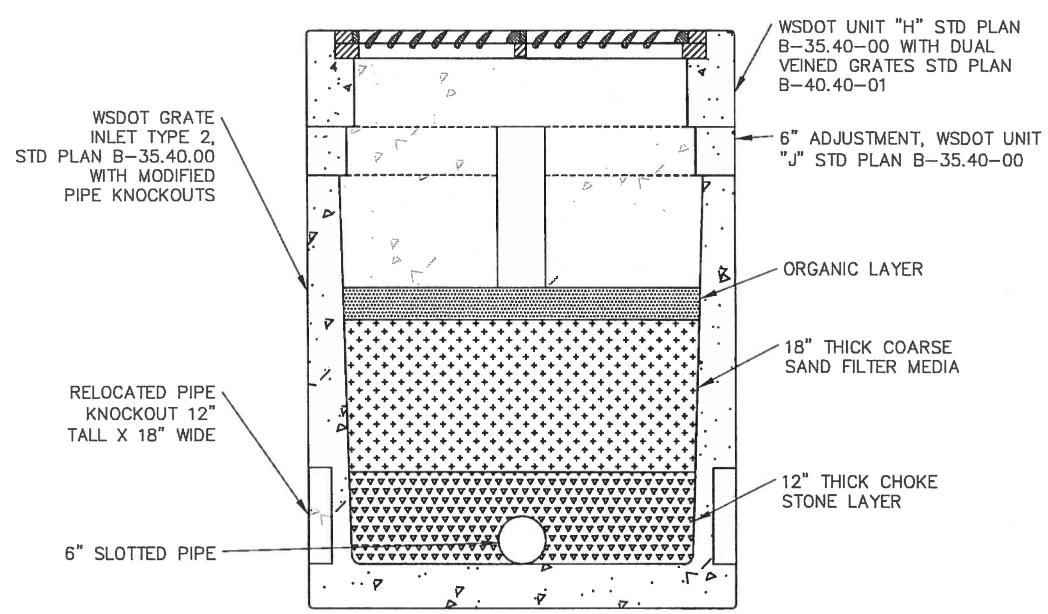


SAND FILTER CATCH BASIN AND INLET DEPRESSION DETAIL

NTS

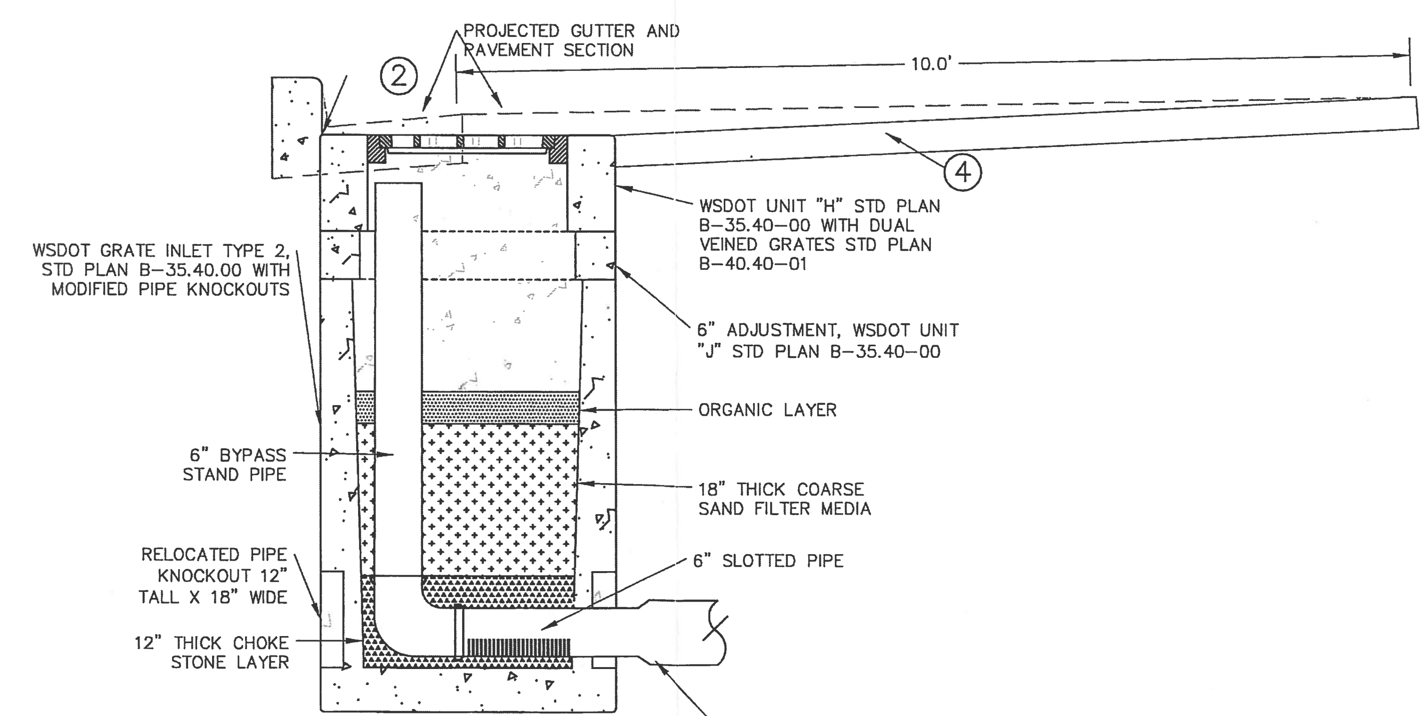
NOTES:

1. REFER TO CONTRACT SPECIAL PROVISIONS FOR MATERIAL SPECIFICATIONS.
2. UNIT H SHALL BE SET LEVEL WITH A RIM ELEVATION .05' BELOW PROJECTED FLOWLINE AT MIDDLE OF INLET.
3. 5 FOOT GUTTER FLARE SECTIONS SHALL TRANSITION GUTTER TO SMOOTHLY TIE IN TO TOP SLAB.
4. PAVEMENT CROSS SLOPE SHALL BE INCREASED TO ALLOW PAVING FLUSH WITH TOP OF INLET SLAB.



SECTION A

NTS



SECTION B

NTS

811. Know what's **below.** **Call** before you dig. ONE CALL NUMBER 48 HR. NOTICE REQUIRED

NO	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

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10	WASH.	STPUL-3974 (002)
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SPOKANE COUNTY

Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED: STORMWATER ENGINEER
Date: 4/19/16

COUNTY ROAD PROJECT No.3166 / SWN 223

HAWTHORNE ROAD

STATE ROUTE 395 TO HIGHWAY 2

CATCH BASIN SAND FILTER DETAILS

SHEET 14 of 20

Appendix F. Sand Filter Sidewalk Vault BMP Sizing Calculations

LPOOLCOMPUTE [Level Pool] SUMMARY using Puls, 24 hr Storm Event

Type 1A Rainfall Distribution

Start of live storage:0 ft

Event	Match Q (cfs)	Peak Q (cfs)	Max El (ft)	Vol (cf)	Vol (acft)	Time to Empty (hr)
6m24h	0.0805	0.0574	1.491	29.82	0.0007	0.1667

Summary Report of all Detention Pond Data

Project Precips

Event	Precip (in)
6m24h	0.97
2 yr 24 hr	1.40

BASLIST2
[041 Acre] Using [TYPE1a.rac] As [6m24h] [24.0]
LSTEND

BasinID	Event	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-cf)	Area (ac)	Method/Loss	Raintype
041 Acre	6m24h	0.0805	8.00	0.0265	0.418	SBUH	TYPE1a.rac
041 Acre	6m24h	0.0805	8.00	0.0265	0.418	SBUH	TYPE1a.rac

BASLIST
[041 Acre]
LSTEND
Record Id: 041 Acre

Design Method	SBUH	**Rainfall type**	TYPE1a.rac
Hyd Intv	10.00 min	**Peaking Factor**	484.00
Storm Duration	24.00 hrs	**Abstraction Coeff**	0.20
Pervious Area	0.00 ac	**DCIA**	0.418 ac
Pervious CN	0.00	**DC CN**	98.00
Pervious TC	0.00 min	**DC TC**	5.00 min

DCI - CN Calc

Description	SubArea	Sub cn
Impervious surfaces (pavements, roofs, etc)	0.418 ac	98.00
DC Composited CN (AMC 2)		98.00

DCI - TC Calc

Type	Description	Length	Slope	Coeff	Misc	TT
Sheet		0.00 ft	0.0%	5.0	0.00 in	5.00 min
Pervious TC						5.00 min

HYDLIST SUMMARY
[6m24h out]
LSTEND

HydID	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-ft)	Cont Area (ac)
6m24h out	0.0574	7.83	0.0265	0.418

STORLIST
[Sand Filter]
LSTEND
Record Id: Sand Filter

Descrip:		Increment	0.10 ft
Start El.	0.00 ft	Max El.	20.00 ft
Void Ratio	100.00		
Length	4.00 ft	Width	5.00 ft
		Consider Bottom Only	
Vault Type Node			

DISCHLIST
[Infiltration Discharge]
LSTEND
Record Id: Infiltration Discharge

Infiltration			
Descrip:	Infiltration Discharge	**Increment**	0.10 ft
Start El.	0.00 ft	**Max El.**	20.00 ft
Infiltration rate	124.00 in/hr	**WP Multiplier**	1.00

LPOOLCOMPUTE [Level Pool] SUMMARY using Puls, 24 hr Storm Event

Type II Rainfall Distribution

Start of live storage:0 ft

Event	Match Q (cfs)	Peak Q (cfs)	Max El (ft)	Vol (cf)	Vol (acft)	Time to Empty (hr)
6m24h	0.4172	0.2469	1.4721	126.5973	0.0029	0.0059

Summary Report of all Detention Pond Data

Project Precips

Event	Precip (in)
6m24h	0.97
2 yr 24 hr	1.40

BASLIST2
[041 Acre] Using [TYPE2.rac] As [6m24h] [24.0]
LSTEND

BasinID	Event	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-cf)	Area (ac)	Method/Loss	Raintype
041 Acre	6m24h	0.4172	12.01	0.0266	0.418	SCS	TYPE2.rac
041 Acre	6m24h	0.4172	12.01	0.0266	0.418	SCS	TYPE2.rac

BASLIST
[041 Acre]
LSTEND
Record Id: 041 Acre

Design Method	SCS	**Rainfall type**	TYPE2.rac
Hyd Intv	10.00 min	**Peaking Factor**	484.00
Storm Duration	24.00 hrs	**Abstraction Coeff**	0.20
Pervious Area	0.00 ac	**DCIA**	0.418 ac
Pervious CN	0.00	**DC CN**	98.00
Pervious TC	0.00 min	**DC TC**	5.00 min

DCI - CN Calc		
Description	**SubArea**	**Sub cn**
Impervious surfaces (pavements, roofs, etc)	0.418 ac	98.00
DC Composited CN (AMC 2)		98.00

DCI - TC Calc						
Type	**Description**	**Length**	**Slope**	**Coeff**	**Misc**	**TT**
Sheet		0.00 ft	0.0%	5.0	0.00 in	5.00 min
Pervious TC						5.00 min

HYDLIST SUMMARY
[6m24h out]
LSTEND

HydID	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-ft)	Cont Area (ac)
6m24h out	0.2469	11.82	0.0266	0.418

STORLIST
[Sand Filter]
LSTEND
Record Id: Sand Filter

Descrip:		Increment	0.10 ft
Start El.	0.00 ft	Max El.	20.00 ft
Void Ratio	100.00		
Length	8.60 ft	Width	10.00 ft
		Consider Bottom Only	
Vault Type Node			

DISCHLIST
[Infiltration Discharge]
LSTEND
Record Id: Infiltration Discharge

Infiltration			
Descrip:	Infiltration Discharge	**Increment**	0.10 ft
Start El.	0.00 ft	**Max El.**	20.00 ft
Infiltration rate	124.00 in/hr	**WP Multiplier**	1.00

Bowstring Method

Bowstring Method (Spokane Regional Stormwater Manual)

Contributing Basin Area =	18,000	sqft
C=	0.9	impervious area
T_c =	5	minutes
m =	3.47	Spokane, WA
n =	0.556	
i_{2yr} =	1.42	in/hr
i_{6m} =	72%*I_{24hr}	in/hr
i_{6m} =	1.02	in/hr
Sand Filter Infiltration Rate =	124	in/hour
A_{SF} =	65	sqft
Qout =	0.19	cfs

Time (min)	Time (sec)	Intensity (in/hr)	Q (cfs)	V_{in} (cft)	Vout (cft)	Storage (cft)
0	0	0.00	0	0	0	0
5	300	1.02	0.38	152.65	55.97	96.67
10	600	0.69	0.26	207.66	111.94	95.71
15	900	0.55	0.21	248.62	167.92	80.70
20	1200	0.47	0.18	282.49	223.89	58.60
25	1500	0.42	0.16	311.91	279.86	32.05

Storage Required = 96.67 cft
Max Ponding Depth = 18 in
Sand Filter Surface Area Needed = 96.67 cft/1.5 ft = 64.44 sqft
# of Sand Filter Vaults Needed = 64.44 sqft/20 sqft = **3.22**

Appendix G. Monitoring Equipment Specifications

Isco Product Data

Isco Avalanche® Multi-bottle, Refrigerated Portable Sampler

Multi-function sampling and data logging with dual-power cooling

Avalanche® is based on Isco's industry-leading 6712 controller. You get all the advanced control, data logging, and communication features of the 6712, with cooling from either AC or battery power.

Bottle options include 5- and 2.5 gallon composites as well as 4 x 1-gallon and 14 x 950 ml sequentials.

A 12V deep-cycle battery delivers 48 hours - or more- of refrigeration. The power-saving cooling system remains on standby until the first sample is drawn, and only then switches on to preserve the collected samples for pickup.

Available routines include: pause-and-resume for intermittent-discharge flow monitoring; sampler pacing by time, non-uniform time, flow or external event; and random interval sample collection.

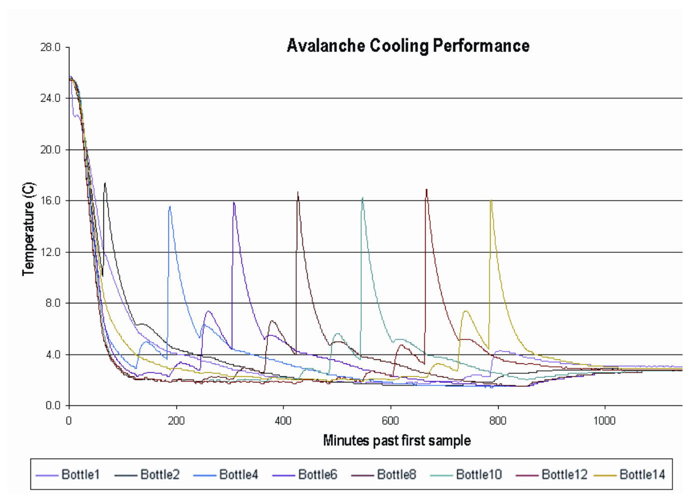
Standard Features

- Standard and extended programming keeps setup simple when you don't need advanced features.
- NEMA 4x, 6 (IP67) controller enclosure.
- SDI-12 interface provides "plug and play" connection with multi-parameter water-quality sondes and other compatible devices.
- 512kB memory gives you great flexibility for logging environmental data.
- Sample delivery at the EPA-recommended velocity of 2 ft/sec. at head heights up to 26 feet.
- Patented pump revolution counter ensures accurate sample volumes - and tells you when tubing should be replaced.

Optional mobility kit includes pneumatic tires for ease of transport over rough terrain, and a convenient battery platform.

Applications

- Stormwater runoff compliance
- TMDL and watershed monitoring
- Enforcement monitoring
- Advanced sampling combined with data logging and communications for flow, rainfall, and water quality parameters.



Isco temperature control technology accurately preserves samples at 3°C – even under difficult conditions shown above (40°C ambient, 20°C sample temperature).

Specifications

Isco Avalanche Sampler	
Size (H x W x D):	30.5 x 14 x 24 inches (78 x 36 x 60 cm)
Weight:	Dry, less battery - 76 lbs (35 kg)
Bottle configurations:	5-gallon poly bottle 2.5-gallon glass bottle configuration 2.5-gallon poly bottle configuration 1-gallon poly bottle configuration (4 bottles 950 ml poly bottle configuration (14 bottles)
Power Requirements:	12V DC (Supplied by battery or AC power converter.)
Pump	
Intake suction tubing: Length Material Inside dimension	 3 to 99 feet (1 to 30 m) Vinyl or Teflon 3/8 inch (1 cm)
Pump tubing life:	Typically 1,000,000 pump counts
Maximum lift:	28 feet (8.5 m)
Typical Repeatability	±5 ml or ±5% of the average volume in a set
Typical line velocity at Head height: of 3 ft. (0.9 m) 10 ft. (3.1 m) 15 ft. (4.6 m)	 3.0 ft./s (0.91 m/s) 2.9 ft./s (0.87 m/s) 2.7 ft./s (0.83 m/s)
Liquid presence detector:	Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.

Controller	
Weight:	13 lbs. (5.9 kg)
Size (HxWxD)	10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)
Operational temperature:	32° to 120°F (0° to 49°C)
Enclosure rating:	NEMA 4X, 6 (IP67)
Program memory:	Non-volatile ROM
Flow meter signal input:	5 to 15 volt DC pulse or 25 millisecond isolated contact closure.
No. of composite samples:	Programmable from 1 to 999 samples.
Clock Accuracy:	1 minute per month, typical, for real time clock
Software	
Sample frequency:	1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses
Sampling modes:	Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)
Programmable sample volumes:	10 to 9,990 ml in 1 ml increments
Sample retries:	If no sample is detected, up to 3 attempts; user selectable
Rinse cycles:	Automatic rinsing of suction line up to 3 rinses for each sample collection
Program storage:	5 sampling programs
Sampling Stop/Resume:	Up to 24 real time/date sample stop/resume commands
Controller diagnostics:	Tests for RAM, ROM, pump, display, and distributor

Ordering Information

Note: *Bottle configuration, suction line, and strainer must be ordered separately. 12 VDC operation requires external battery. Contact Isco or your Isco Representative for complete information.*

Description	Part Number
Isco Avalanche Sampler (115-230 VAC/12V DC) Includes controller, distributor arm, instruction manual, pocket guide. Standard power cord.*	**68-2970-003**
5-gallon poly bottle	**68-2970-008**
2.5-gallon glass bottle configuration	**68-2970-006**
2.5-gallon poly bottle configuration	**68-2970-009**
1-gallon poly bottle configuration (4 bottles	**68-2970-002**
950 ml poly bottle configuration (14 bottles)	**68-2970-001**
Mobility Kit	**68-2960-004**

TELEDYNE ISCO
Everywhereyoulook™

4700 Superior Street
Lincoln NE 68504 USA
Tel: (402) 464-0231
USA and Canada: (800) 228-4373
Fax: (402) 465-3022
E-Mail: iscoinfo@teledyne.com
Internet: www.teledyneisco.com

FTS

RAIN GAUGE (RG-T)

The rugged, all-metal RG-T rain gauge is FTS' take on a simple, proven, mature technology. It has earned tremendous loyalty over several years for its extreme accuracy, excellent calibration retention and super simple deployment that ensures success—customers especially appreciate the fact that unlike many tipping buckets available, it doesn't rust.

Extremely simple

- Screens in the funnel and over the base plate water outlets seal the tipping mechanism completely from insects and wind-borne material
- Built-in bubble levels and full 2-axis leveling mechanism, make it quick and easy to mount the tipping bucket perfectly level on any surface (even a vertical pole)
- Employs a tool-less design that utilizes "bicycle-style" quick-release clamps

CANADA 1065 Henry Eng Place | Victoria, BC | V9B 6B2
USA 1124 Fir Avenue, Suite C | Blaine, WA | 98230
ftsinc.com | 1.800.548.4264

Unmatched durability

- Metal construction provides rugged durability
- Cable sheathed in braided stainless steel, to protect it from animal damage
- Cable terminates in a waterproof, military-style bayonet connector for use with Axiom dataloggers (optionally available without military connector for use with other dataloggers)

Long-term accuracy and calibration retention

- The tipping mechanism is injection moulded engineered resin, resulting in extreme accuracy
- Inner surface of tipper is super-smooth with no corners so it sheds water better than metal tippers and doesn't allow dust or small debris to collect
- Jeweled (ruby) bearings mean no friction, no resistance to tipping resulting in high sensitivity to accurately capture even very small rain events and long-term calibration retention
- The base and support posts are precision cast as a single structure, providing maximum vibration resistance. False measurements from wind are eliminated, ensuring long-term repeatable accuracy
- Stainless steel quick-release clamps eliminate retaining screws that can rust and affect accuracy

Technical Specifications

Type:	Tipping bucket
Resolution:	0.01" per tip (0.254 mm) (optional calibration to 0.2 mm)
Accuracy:	±2% at 2" per hour (50 mm)
Cylinder dimensions:	10.5" x 8" diameter (257 mm x 203 mm)
Materials:	Aluminum and stainless steel, engineered resin tipping mechanism
Operating temperature range:	0°C to +60°C
Operating humidity range:	5% to 100%
Cable:	20 ft. (6 m) metal-clad armoured
Weight:	5.3lbs (2.4kg)
Options:	Available with Tri-leg tower mount and portable RAWS mounting (base plate) options. Optional calibration of resolution to 0.2mm available.

EXTREME ENVIRONMENTS
EXTREMELY RELIABLE

AXIOM H1 / H2
DATALOGGER / DCP

**Tough on the outside.
Clever on the inside.**

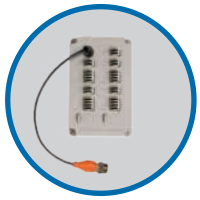
The Axiom Datalogger / DCP offers uncompromising reliability (borne out of our experience meeting the strict reliability demands of the North American fire weather market for over 35 years), extreme rugged construction and integrated waterproof touchscreen. These unique innovations result in lower post-purchase costs through reduced replacement from damage, higher data reliability and elimination of damage to (and even purchase of) laptops.

The Axiom Datalogger

Flexibility and expandability.

- Install new programs, firmware and operating system updates easily via any standard USB flash memory stick.
- Large internal memory capacity can store upwards of 10 years of data (assuming 8 sensors sampling once per hour).
- A virtually unlimited library of configurations can be stored, uploaded, downloaded and selected via the touchscreen, ideal for large network operators maintaining an inventory of spare equipment.
- Allows virtually unlimited expandability—up to 62 digital sensors. Calibration coefficients are not required.
- Can also be expanded with multiple analog sensors via optional SDI-AM analog interface module.

Transfer data or firmware updates via standard USB memory sticks



The SDI analog module provides analog sensor expansion

Integrated, preconfigured GOES, and optional 2-way cellular/Iridium.

The industry-leading G6 GOES transmitter—the same equipment that's a standard for all North American fire weather stations—is available as an integrated option in the Axiom. Extremely low power consumption and accurate time keeping enables reliable hourly data for up to 28 days even without a GPS fix.

For added reliability and 2-way remote management of the station, Iridium satellite telemetry can be easily added with Ubicom.

Ubicom
2-way remote management

Reliable connections.

We pioneered the use of military-style bayonet connectors for attaching external devices to our dataloggers. Why?

- The watertight, corrosion-resistant, positive-locking connection becomes incredibly reliable, eliminating the most probable point of failure.
- The color-coded, single-port design makes connecting sensors and other features during installation and maintenance dead simple and fast.
- All FTS sensors include bayonet connectors, and they can be added to any of your current SDI-12 sensors, power sources and rain gauges.

Leave the laptop at the office.

Integrated waterproof, daylight-readable touchscreen.

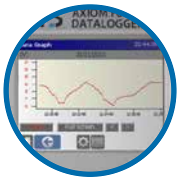
Built like a tank.

Fully watertight. 3 levels of lightning protection. Waterproof military bayonet connectors. IP67 aluminum case.

No laptop required.

The Axiom integrates a waterproof, industrial-grade, daylight-readable, color touch screen. By embedding the software right into the datalogger, we eliminate the need for field laptops and cables.

Create graphs of any parameter from any range of dates, to spot data anomalies.



View and export data in tabular format.

Simple diagnosis.

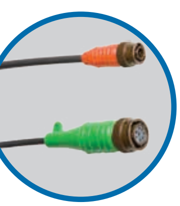
Axiom integrates a power manager and a solar charge regulator (H2 only) which is sealed inside the waterproof case. This reduces the chance of a problem with the power system—a common source of problems—and minimizes your time spent troubleshooting.

- The Axiom is constantly aware of parameters like solar voltage and current, battery voltage and current, battery and internal ambient temperature, and can transmit this information via any telemetry method. This allows the datalogger to provide a complete picture of power conditions for diagnosing power issues remotely, eliminating unnecessary site visits.
- At the site, this information is readily available as a graph on the integrated touchscreen with one click. Find out quickly when the problem occurred by viewing the log of data graphically.
- The integrated power manager adds an additional layer of intelligence to the Axiom by allowing the datalogger to directly talk to and manage the solar panel and battery.

Extreme ruggedness.

Because reliability is paramount and any downtime means lost data and increased liability, the Axiom is engineered for long-term durability in the harshest environments (minimizing site visits is nice too).

- Three levels of lightning protection. We have over 33 years of experience building equipment for the most extreme lightning strike locations, and it's in here.
- The entire unit—the cast aluminum, O-ring sealed case and all ports—is completely impervious to the elements. Even the touchscreen. And not just splashproof: fully watertight.
- Positive-locking, waterproof, color-coded, cadmium-plated, corrosion resistant, military-style bayonet connectors.



Extremely simple.

Clever graphical interface makes configuration and troubleshooting easy. Reduces the chance for things to go wrong.

Embracing SDI-12

The Axiom's waterproof SDI-12 ports are each on a **separate, electrically isolated SDI bus,** and each can supply **up to 500mA to sensors.**

Reduced risk of failure:

If one port becomes disabled because of one of the sensors that's attached to it, the other sensors on the other ports will continue to function. More independent SDI-12 ports means you can reduce the risk of failure by spreading out the sensors among more ports.

More responsive data throughput:

Because each SDI port is independent of the other, the datalogger can drive multiple sets of sensors without having to wait for the first to respond before polling the second, and so on.

Increased reliability for complex systems:

The DCP can issue simultaneous M commands to each port to manage long read-time, high power draw sensors such as side lookers. This allows sensors to collect data concurrently so all the data from the station is from the same time window.

Modular analog expansion:

The SDI-AM analog module permits analog sensor expansion on any of the SDI ports.

H1-R: Rain counter,
2 SDI-12 ports

H1-RS: Rain counter, 2 SDI-12 ports,
Integrated solar charge regulator

Axiom H1

Simple hydrology applications where reliability, data integrity and a competitive price are important.

Axiom H2

Simple to complex hydrology or meteorology applications where reliability is paramount and/or the station is very remote.

DCP Comparison Table

ATTRIBUTE	Axiom H1	Axiom H2	Sutron 8310-N w/Satlink2	Sutron Satlink2-V2	Design Analysis H-522+
DISPLAY	Waterproof, daylight-readable, 3.5" color graphical display	Waterproof, daylight-readable, 3.5" color graphical display	40 character (2-line) monochrome LCD	No (optional 40 character monochrome LCD)	20 character monochrome LCD
USER INTERFACE	Graphical touchscreen or PC Software	Graphical touchscreen or PC Software	Basic configuration via 6-button membrane-type key panel; connected laptop for diagnosis, programming and more advanced configuration	None (connected laptop required); optional 6-button key panel	Basic configuration via 7-button key panel; connected laptop for diagnosis, programming, more advanced configuration
FILE TRANSFER (configuration/firmware update, data download)	USB memory stick or PC Software	USB memory stick or PC Software	SD card	Connected laptop	Connected laptop
PROGRAMMING	GUI on integrated touchscreen or GUI on PC	GUI on integrated touchscreen or GUI on PC	BASIC, C++ programming languages	GUI running on connected laptop	GUI running on connected laptop
POWER CONSUMPTION					
STANDBY	7mA	7mA	12mA	8.2mA	10mA
OPERATING - DISPLAY ON	60mA	60mA	73mA	n/a	250mA
OPERATING - DISPLAY OFF	12mA	12mA	up to 33mA	n/a	80mA
TRANSMITTING - 300 BPS	2.6A	2.6A	3.5A	3.1A	2.75A
SENSOR PORT TYPE	Waterproof, military-style bayonet connector	Waterproof, military-style bayonet connector	Unprotected terminal strip	Unprotected terminal strip	Unprotected terminal strip
SDI-12 PORTS					
HOW MANY?	2	4	2	1	1
NUMBER OF SDI-12 BUSES	2	4	1	1	1
ELECTRICALLY ISOLATED?	Yes	Yes	No	No	No
MAX. CURRENT OUTPUT PER PORT	500mA	500mA	100mA max output across all ports	No digital output	1A
ANALOG PORTS	Up to 62 available via modular expansion	1 rain counter, up to 62 available via modular expansion	8	4	6
ENVIRONMENTAL SEALING	NEMA Type 6P (IP67): completely protected against dust and dirt, protected against immersion in water up to 1m.	NEMA Type 6P (IP67): completely protected against dust and dirt, protected against immersion in water up to 1m.	NEMA Type 4 (IP65): Weatherproof (not submersible), must exclude at least 65 GPM of water from 1" nozzle delivered from a distance greater than 10' for 5 min.	None	None
LIGHTNING PROTECTION	3 levels	3 levels	Multistage input protection including spark gaps (analog ports only)	No	No
INTEGRATED SOLAR CHARGE REGULATOR	No (H1-R), Yes (H1-RS)	Yes, sealed in watertight enclosure	Yes	No	No
PC CONNECTION	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**

CANADA 1065 Henry Eng Place | Victoria, BC | V9B 6B2
USA 1124 Fir Avenue, Suite C | Blaine, WA | 98230
ftsinc.com | 1.800.548.4264

**EXTREME ENVIRONMENTS
EXTREMELY RELIABLE**

Management System registered to ISO 9001 QMI-SAI Global
Rev. 2016_10_12_01

Robust ceramic pressure transducer for water level measurement

- Application
  Surface water, Groundwater
- Measurement technology
  Vented pressure cell
- Parameters measured
  Water level, Pressure, Temperature
- Product Highlights
  Water level and temperature measurement - for use with external data logger
- Measurement range
  0 ... 4, 10, 20, 40, and 100 m
- Accuracy
  ± 0.05% FS
- Internal data logger
  No
- Interface
  SDI-12, RS-485 (using SDI-12), or 4 ... 20 mA

The OTT PLS measures water level, depth to water, or pressure by means of an integrated controller and ceramic pressure-measuring cell. Design features such as multiple communication outputs (SDI-12 or 4 ... 20 mA), stainless steel housing, and a rugged cable make this sensor ideal for monitoring water level in a variety of applications.

Water level measurement	
Measurement range	0 ... 4 m, 10 m, 20 m, 40 m, 100 m

Accuracy	
SDI-12	±0.05 % FS (linearity and hysteresis)
4 ... 20 mA	±0.1 % FS (linearity and hysteresis) 10 ppm/°C at 20 °C
Resolution (SDI-12)	0.001 m; 0.1 cm; 0.01 ft; 0.1 mbar; 0.001 psi
Temperature compensated working range	-5 °C ... +45 °C (ice-free)

Temperature measurement	-25 °C ... +70 °C (ice-free)
Resolution	0.1 °C / 0.1 °F
Accuracy	±0.5 °C / ±0.9 °F

Electrical data	
Available interfaces (use as required)	4 ... 20 mA, SDI-12, RS485 (via SDI-12 protocol)
Supply voltage	+9.6 ... +28 V DC, typically 12/24 V DC

Power consumption (SDI-12)	
Sleep	<600 µA
Active	<3.6 mA

Pressure sensor	(capacitive pressure sensor) ceramic, temperature compensated, overload safe for up to 5 times the measuring range without permanent mechanical damage

Temperature sensor	NTC

Dimensions	195 mm x 22 mm
Weight	approx. 0.3 kg

Environmental conditions	
Operating temperature	-25 ... +70 °C
Storage temperature	-40 ... +85 °C

Materials	
Housing	stainless steel 1.4539 (904L) resistant to sea water
Seals	Viton
Cable jacket	PUR
Protection type	IP68
Mechanical Strength	meets the mechanical shock tests of IEC 68-2-32

EMC limits	CE conformity; EN 61000-4-2/3/4/5/6 and EN 61000-6-3 Class B are adhered to

ubicom

Take control of your network.

For customers who require extreme reliability of data access from extremely remote environmental monitoring stations, Ubicom is bidirectional communications, and ensures critical information is available anywhere, anytime. Unlike other remote communication products, Ubicom provides detailed insight into the health of the station and the connection, a complete toolset to diagnose any conditions which inhibit data access, and ultimate control over remote hardware which minimizes the need to visit the site.

- 2-way satellite and/or cellular in a single device
- Low power and customizable duty cycle
- Remote station management
- Completely provisioned, ready-to-go out of the box
- Data pooling across your network
- No monthly bill

Key Features

Reliability with dual telemetry in a single device

No monthly fees and shared data pool across your network

Remote station management including power cycling of up to 4 devices

Technical Specifications

COMMON

MECHANICAL	Height	189 mm (7.45")
	Diameter at widest point	90 mm (3.55")
	Weight	2-way satellite version: 376 g (0.83 lbs) Cellular version: 374 g (0.82 lbs) Hybrid version: 403 g (0.89 lbs)
	Case material	Lexan™ polycarbonate
	Cable length	5 m (16.4'), 50' max
	Cable jacket	Polyurethane
	Mounting	Surface mount, or 1" NPT with supplied flange
	Connector interface	Waterproof, military-style bayonet connector or spring-clip terminal strip connectors
	Status LEDs	4 coloured LEDs, visible from up to 9m (30ft), indicates up to 14 different operational conditions
	Mechanical vibration rating	MIL-STD-167-1 Type 1
	Power relays	4 in total for power cycling up to 4 12V devices. Military-style connection module uses all relays for Axiom datalogger.
ENVIRONMENTAL	Operating temperature range	-40°C to +60°C (2-way satellite version) -30°C to +60°C (Cellular and hybrid versions)
	Operating humidity range	0% to 100% RH
	Storage temperature range	-40°C to +85°C
	Storage humidity range	0% to 100% RH
	Dust and water ingress	IP66
POWER	Input voltage	9 - 16VDC
DATA I/O	Message size	6-250 bytes typically, no maximum
	Serial protocols	AT commands, PPP, SLIP, UDP/IP, TCP/IP
	Serial interface	RS-232
	RS-232 data rate	1,200 bps to 115.2 kbps
GPS	Acquisition time	Hot 1 sec; cold < 35 sec
	Accuracy	2.5 m (Horizontal CEP)
	Sensitivity	Acquisition: -147 dBm Tracking: -159 dBm
MISCELLANEOUS	EMC Certification	FCC, CE Mark
	No. of antennas	1 (2-way satellite), 2 (hybrid and cellular versions)
ORDERING CODES	2-way satellite only	UC-TXCVR-IR
	Cellular only	UC-TXCVR-CELL
	Hybrid 2-way satellite + Cell	UC-TXCVR-IR-CELL

2-WAY SATELLITE

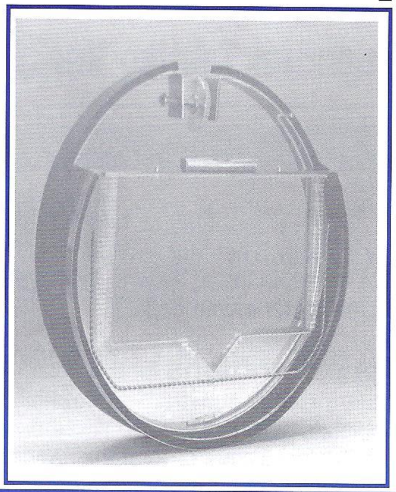
GENERAL	Coverage	Global
	Satellite service provider	Iridium
	Typical latency	<15 sec
RF PARAMETERS	Frequency range	1616 MHz to 1626.5 MHz
	Input/output impedance	50 ohms
	Duplexing method	TDD
	Multiplexing method	TDMA/FDMA
	Oscillator stability	±1.5 ppm
	Maximum transmit power	1.6 W
	FCC ID	Q639602
POWER CONSUMPTION	Avg. current consumption - send	250 mA
	Avg. current consumption - receive	28 mA
	Sleep mode (cannot send/receive)	< 5 mA
ANTENNA	Radiation pattern	Hemispherical
	Polarization	Right hand circular
	VSWR	Less than 1.5:1
	Gain (dB)	3 dBi
	Impedence	50 ohms

CELLULAR

GENERAL	Technology	HSPA penta-band
	Bands	GSM quad-band: 850/900/1800/1900 MHz UMTS/HSPA penta-band: 850/900/1700/2100 MHz
RF PARAMETERS	Transmit power	Class 4 (2W, 33dBm) @ GSM 850/900 Class 1 (1W, 30dBm) @ GSM 1800/1900 Class 3 (0.25W, 24 dBm) @ UMTS Class E2 (0.5W, 27 dBm) @ EDGE 850/900 Class E2 (0.4W, 26 dBm) @ EDGE
	Input/output impedance	50 ohms
	FCC ID	RI7HE910
POWER CONSUMPTION	Avg. current consumption - send	250 mA
	Avg. current consumption - receive	20 mA
	Sleep mode (cannot send/receive)	< 5 mA
ANTENNA	Radiation pattern	Linear vertical
	Efficiency	> 50% across all bands
	Return loss	> 8 dB across all bands
OTHER	SIM interface	Standard 3V SIM receptacle
	Throughput	HSPA: 21 Mbps download, 5.7 Mbps upload

Specifications are subject to change without notice.

Volumetric Weir for Measuring Flows in Manholes and Open End Pipe

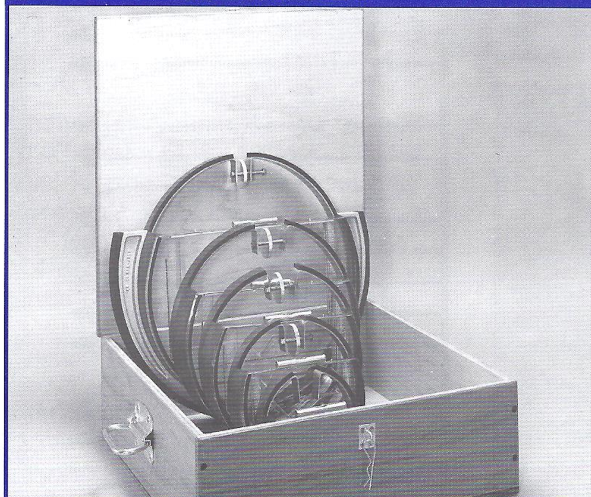


The Most Accurate Portable Flow Measuring Device Available

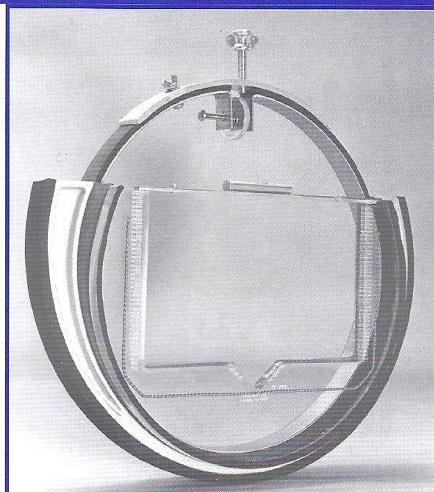
THEL-MAR COMPANY

Post Office Box 1529 • Brevard, North Carolina 28712
(828) 883-8908 • Fax: (828) 883-8908
TOLL FREE 1- 800-322-WEIR (9347)

WEIR SET



15" WEIR WITH 18" ADAPTOR



The Most Practical, Economical Instrument for Testing New Sewer Lines

A volumetric calibrated weir is a portable flow measuring device that is used to determine infiltration in newly installed sewer lines, or measure substantial flows in existing lines.

The Thel-Mar volumetric weir is basically a compound weir that incorporates the advantage of a 90° v-notch for measuring small infiltration flow where accuracy is of prime importance. The v-notch section measures from 57 gallons to 3700 gallons per 24 hours, which is the range of normal acceptance test requirements. The rectangular section of the weir is capable of measuring in gallons per day up to 35% of pipe capacity.

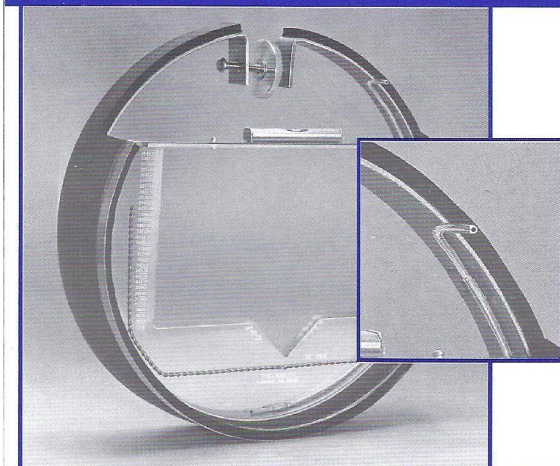
A bubble level is mounted at the top of the weir's face plate for easy visibility. Thel-Mar weirs are calibrated in U.S. gallons per 24 hours in large, easy to read type. Calibration lines are in 2 millimeter increments.

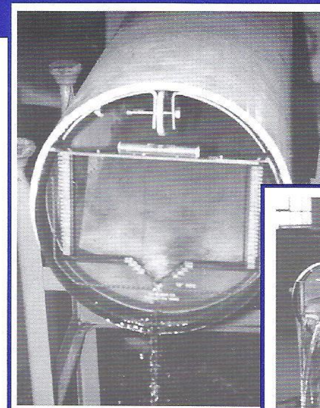
Discharge calibrations for the Volumetric Weir were accurately determined in a hydraulic laboratory where manhole conditions were duplicated. Therefore, there are no induced errors by insufficient drop of the nappe or by contractions, velocity of approach, submergency, or drawdown.

Rugged Construction and noncorroding materials make the Thel-Mar weir extremely reliable. There are no loose parts that require assembly. Installation is quick and positive and the weir requires a minimum of care.

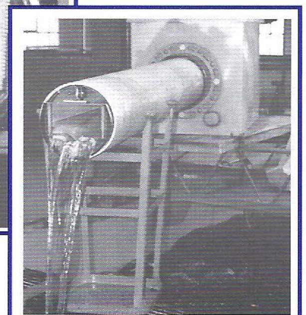
Easy to read flow rate
Simply check water level at the face plate. The figure above the line matching the water level gives you the rate of flow in gallons per 24 hours.

WEIR WITH BUBBLER TUBE





University Tested



Lehigh University Lab Photos

- Night Flow Studies of Existing Lines - Free Flow From Open Pipe.

A compound Weir offers minimum restriction to flow and is relatively free from becoming clogged by debris from sewage. **Thel-Mar Weirs** can be installed for extended periods of time without accumulation of sediment.

Errors in excess of 100% exist in other calibrated V-notch weirs.

Unlike the Thel-Mar weir these were calibrated by the Cone formula.

Bubbler Flow Meters

Especially designed for use with Bubbler Flow meters, all Volumetric Weirs are now available with an attached "Bubbler Tube". These weirs are manufactured with a ⅛-inch O.D. stainless steel tube attached to the right side of the adjustable ring. The bubbler tube protrudes forward approximately two inches from near the top of the ring for easy connection to a line. It runs for there down the inside of the ring to the center bottom approximately 1⅜-inch behind and below the V-notch. This bubbler tube does not in any way affect the function of the Volumetric Weir.

Installation Instructions

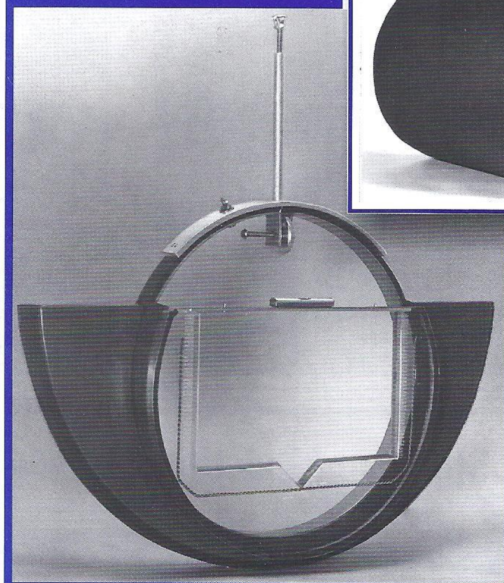
Prior to installation, the interior edge of the incoming pipe should be cleaned of sediment and foreign matter to assure seal of the gasket.

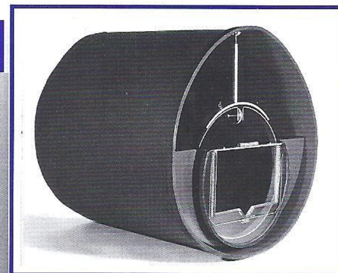
Turn thumb-wheel to extreme right. Place hand through weir opening, with thumb and index finger compress spring. Insert weir into incoming pipe about 1", adjust for leveling, press down and release tension from spring. Secure by turning thumb-wheel to left and finger tighten.

Allow sufficient time for water to back up behind the weir and establish a uniform flow; five to ten minutes for existing flow to an hour for accurate infiltration readings.

15" Weir with adaptor installed in 24" pipe

Individual Volumetric Weirs are available for 6", 8", 10", 12", 14", 15" and 16" pipe. The 14" weir uses a 12" face plate, while the 16" weir uses a 15" face plate. Adaptors for 18", 21", 24", 27", 30", 36", 42" and 48" pipe are used in conjunction with the 15" weir.





Volumetric Weirs are also available in sets.
Set A consists of 6", 8", 10", 12" and 15" weirs with an 18" adaptor **without a storage case.**

Set B is the same as set A, but has Bubbler Tubes Attached to the weirs.

Set C consists of 21" through 48" adaptors **without a storage case.**

Adaptors are available individually or in sets.

WEIR CAPACITIES AND HEAD

Capacities*			Head**
6"	57 to 3700 GPD within V-notch,	rectangular to 46,000 GPD	2.8437
8"	57 to 3700 GPD within V-notch,	rectangular to 124,000 GPD	4.0000
10"	57 to 3700 GPD within V-notch,	rectangular to 234,000 GPD	5.1250
12"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
14"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
15"	57 to 3700 GPD within V-notch,	rectangular to 620,000 GPD	7.3125
16"	57 to 3700 GPD within V-notch,	rectangular to 620,000 GPD	7.3125

*Calibration lines are in 2 millimeter increments
**In inches from top of rectangular opening to bottom of V-notch

Metric Flow Conversion Charts Available

Appendix H. Field Data Collection Forms

Sample Collection Field Form

Field staff name:				Date:
Test-Site Name:				Time:
Sample Number:	Weather Observation:			
Qualifying storm event Yes No				
Temperature Calibration:		pH Calibration:		
Sampling Equipment Condition:				
Oil Sheen Measurements/Observations:				
Sediment Composition:				
Water Temperature:			pH:	
Accumulated Sediment Volume:				
Pressure Transducer Staff Gauge Measurement (inches):				
Stormwater Samples Collected				
☐	Total Suspended Solids (TSS)			
☐	Metals (Zn, Cu)			
☐	Hardness as CaCO3			
☐	Ortho-phosphate (OP)			
☐	Total Phosphorus (TP)			
☐	NWTPH-Dx			
☐	Particle Size Distribution (PSD)			
QC Samples Collected				
☐	Rinsate Blank			
☐	Field Duplicate			
Comments:				

Storm Decision Log

<table>
<tr><th colspan="4">Pre-Storm</th></tr>
<tr><td colspan="3">Field staff name:</td><td>Date:</td></tr>
<tr><td colspan="3">Test Site Name:</td><td>Time:</td></tr>
<tr><td colspan="4">Source of Forecast:</td></tr>
<tr><td colspan="4">Location of Forecasted Storm (region):</td></tr>
<tr><td colspan="2">Predicted Rainfall:</td><td colspan="2">Predicted Rainfall is ≥ 0.15-inches? Y / N</td></tr>
<tr><td colspan="2">Predicted Storm Duration:</td><td colspan="2">Predicted Storm Duration is ≥ 1-hour? Y / N</td></tr>
<tr><td colspan="2">Predicted Antecedent Dry Period
Since the Last Storm:</td><td colspan="2">Predicted Antecedent Dry Period is ≥ 6-hours? Y / N</td></tr>
<tr><td colspan="4">Classification of Predicted Rainfall Event Meeting for Meeting Qualifying Rainfall Conditions:
Unlikely Marginal Likely</td></tr>
<tr><td>☐</td><td colspan="3">Attach a copy of the forecast to this sheet.</td></tr>
<tr><td>☐</td><td colspan="3">If deployment is OK'd, contact field staff and inform them of the storm characteristics and duration.</td></tr>
<tr><td>☐</td><td colspan="3">Monitor the precipitation data (available remotely) files. Notify field staff of storm status and if rain begins to fall on-site.</td></tr>
<tr><th colspan="4">Post-Storm</th></tr>
<tr><td colspan="2">Time of first rainfall on-site:</td><td colspan="2">Time of last rainfall on-site:</td></tr>
<tr><td colspan="4">Verify Storm event met qualifying rainfall event criteria (Section 7.5 of QAPP) Y / N
Note: If storm did not meeting qualifying conditions, water quality samples will not be submitted to the lab for analysis.</td></tr>
<tr><td colspan="4">Grab/composite samples collected? Y / N</td></tr>
<tr><td colspan="4">Samples processed and sent to lab? Y / N</td></tr>
</table>

Periodic Maintenance Checklist Field Form

Field staff names:				Date:
				Time:
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):				
Maintenance Activities	**Activity Complete?**	**Notes (circle text as appropriate):**		
Debris/Obstruction Removal from piping		Debris removed? Y N		
Check voltage of battery		Measured voltage:	Voltage should be above 10.3V. If not, replace battery.	
Rain gage internal part cleanliness and level (quarterly)		Debris removed? Y N	Reset level of gage? Y N	
ISCO head tubing check		Tubing replaced? Y N		
ISCO pump tubing check		Tubing replaced? Y N		
ISCO suction tubing check		Tubing replaced? Y N		
ISCO Internal Humidity Indicator check		Indicator Color and Percent:		Desiccant replaced? Y N
PT #1 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
PT #2 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
PT #3 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
Deflate ISCO controller pad (as needed)				
ISCO pump capabilities				
ISCO volumetric verification (performed quarterly)		Service needed? Y N		

Pre-Storm Event Maintenance Checklist Field Form

<table>
<tr><td rowspan="2" colspan="3">Field staff names:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Time:</td></tr>
<tr><td colspan="5">Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):</td></tr>
<tr><th>Maintenance Activities</th><th>Activity Complete?</th><th colspan="3">Notes (circle text as appropriate):</th></tr>
<tr><td rowspan="2">Check datalogger water surface elevation (WSE) against measured WSE</td><td rowspan="2"></td><td>Reference elevation:</td><td colspan="2">Uncertainty value (±) and reason:</td></tr>
<tr><td>Electronic water level indicator reading:</td><td>Measured WSE:</td><td>Datalogger WSE:</td></tr>
<tr><td>Debris/Obstruction Removal from piping</td><td></td><td>Debris removed? Y N</td><td colspan="2"></td></tr>
<tr><td>ISCO head tubing check</td><td></td><td>Tubing replaced? Y N</td><td>Tubing cleaned? Y N</td><td></td></tr>
<tr><td>ISCO pump tubing check</td><td></td><td>Tubing replaced? Y N</td><td>Tubing cleaned? Y N</td><td></td></tr>
<tr><td>ISCO suction tubing check</td><td></td><td>Tubing replaced? Y N</td><td>Tubing cleaned? Y N</td><td></td></tr>
<tr><td>Check level of weirs, pipe tees</td><td></td><td colspan="3"></td></tr>
<tr><td>Pressure transducers (PT) and mounts cleaning</td><td></td><td>PTs cleaned? Y N</td><td>Mounts cleaned? Y N</td><td></td></tr>
<tr><td>Pressure transducers (PT) reading check</td><td></td><td>PT reading zero flow? Y N</td><td>If no, PT reading:</td><td>Any drift observed? Y N Value:</td></tr>
<tr><td>Check tubing, bulkhead caps, and cable attachments</td><td></td><td colspan="3"></td></tr>
<tr><td>Data logger and ISCO set to sample</td><td></td><td>DL set? Y N</td><td>ISCO set? Y N</td><td></td></tr>
<tr><td>Threshold values set</td><td></td><td>Threshold value:</td><td colspan="2"></td></tr>
<tr><td>pH meter inspection and cleaning</td><td></td><td>Service needed? Y N</td><td colspan="2"></td></tr>
<tr><td>pH meter calibration</td><td></td><td>1st Calibration Point:</td><td>2nd Calibration Point:</td><td></td></tr>
</table>

Monitoring Equipment Data Download Field Form

Field staff names:	Date:	
	Time:	
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):		
Monitoring data covering the entire qualifying storm event and antecedent and post storm periods was downloaded:		☐

Sand Filter Media Sediment Depth Field Form

Field staff names:	Date:
	Time:
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):	

Depth Measurement Location in Sand Filter:			**1**	**2**	**3**	**4**	**5**	**Avg**	**Units**
Depth of Sand Filter Empty:	Measure from the top of coconut coir to rim of vault in 5 different locations	$\mathbf{D_i}$							**decimal feet**
Depth to Top of Sediment in Sand Filter:	Measure from top of sediment in vault to vault rim in 5 different locations	$\mathbf{D_S}$							**decimal feet**

Falling Head Test Field Form

Field staff names:		Date:
		Time:
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):		
Time for water surface to fall from top of overflow pipe to top of sand media (18 inches):		min:s

Field Audit Form

Note: items listed under each SOP are in order listed in the SOP. Reference the SOP to verify whether steps have been completed successfully.

Standard Operating Procedure (SOP)	**Actions Compliant with SOPs?**	**Comments:**
Storm Selection and Tracking	**Overall SOP audit notes:**	
All qualifying storm event criteria met		
Field staff contacted (as applicable)		
Laboratory contacted (as applicable)		
Precipitation data downloaded		
Storm Monitoring Equipment Maintenance	**Overall SOP audit notes:**	
Appropriate PPE		
General inspection of monitoring vault and sand filter vault		
Inspection and/or cleaning of pipes, tees, weirs		
Battery voltage check		
Visit report started		
Rain gauge check (as applicable)		
ISCO tubing inspection and/or replacement		
ISCO internal humidity indicator check		
Pressure transducer humidity absorbing system check		
ISCO internal pressure check (indicated by keypad inflation)		
ISCO pump capabilities check		
ISCO volumetric verification test		
Visit report ended		
Equipment secured prior to leaving site		

Preparing Stormwater Monitoring Equipment for Storm Sampling	**Overall SOP audit notes:**	
Appropriate PPE		
General inspection of monitoring vault and sand filter vault		
Start visit report		
Water surface elevation measurement check		
Inspection and/or cleaning of pipes, tees, weirs		
ISCO tubing inspection and cleaning (replace if needed)		
Obtain rinsate blank (using clean hands/dirty hands procedures)		
Rinsate blank sample bottles labeled		
COC filled out		
Check whether weirs, pipe tees are level		
Inspection and/or cleaning of pressure transducers, mounts		
Check and/or adjustment of pressure transducer reading		
Install sample bottle (using clean hands/dirty hands procedures)		
Check and/or secure ISCO tubing, caps, and cable connections		
Data logger and ISCO set to sample		
Visit report ended		
Equipment secured prior to leaving site		
pH meter maintenance		
pH meter calibration		

Stormwater Grab Sampling	**Overall SOP audit notes:**	
Bottles cooled prior to site visit		
Appropriate PPE		
General inspection of monitoring vault and sand filter vault		
Start visit report		
Collect influent and effluent oils grab samples		
Collect influent particle size distribution grab sample		
Clean hands dirty hands procedures followed		
Sample bottles labeled		
COC filled out		
Stormwater Sample Collection and Processing	**Overall SOP audit notes:**	
Appropriate PPE		
Start visit report		
Water surface elevation measurement check		
Check whether sampling has been disabled		
Visual verification of aliquots collected		
pH measurement		
Stormwater composite sample collection		
Sample bottles labeled		
COC filled out		
Clean hands dirty hands procedures followed		
End visit report		
Filtration for composite samples performed		
Monitoring Equipment Download	**Overall SOP audit notes:**	
Appropriate PPE		
Data downloaded covers entire event?		

Sediment Accumulation Rate	**Overall SOP audit notes:**	
Appropriate PPE		
Initial depth measured and recorded (initial site visit only)		
Depth of sediment measured and recorded		
Sediment samples collected		
Sample bottles labeled		
COC filled out		
Falling Head Test	**Overall SOP audit notes:**	
Appropriate PPE		
Falling head test performed		

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Matrix	Parameter	Method	Chain-of-Custody Issues?	Completeness/ Methodology	Holding Times (days)		Cooler Temperature	Blanks/ Reporting Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
					Reported	Goal			Reported	Goal	Reported	Goal	Reported	Goal	Reported	Goal	OK	
Stormwater	Total Suspended Solids (TSS)	SM 2540D																
	Dissolved Copper (Cu) and Zinc (Zn)	EPA 200.8 (ICP/MS)																
	Total Copper (Cu) and Zinc (Zn)	EPA 200.8 (ICP/MS)																
	Hardness as CaCO3	SM 2340B (ICP)																
	Ortho-phosphate (OP)	SM 4500-P G																
	Total Phosphorus (TP)	SM 4500-P F																
	NWTPH-Dx	Ecology NWTPH Dx																
Sediment	Sediment PSD	ASTM D422																
Sand Filter Media	pH	S-2.20																
	Moisture Content	ASTM D2216																
	Cation Exchange Capacity	S-10.10																
	Maximum Dry Density	ASTM D1557																
	Saturated Hydraulic Conductivity	ASTM D2434																
	Particle Size Distribution	ASTM D422																
	Total Elements (Zn, Cu, Pb, Fe, Al, P, Mg, Ca)	EPA 3050A/6010B																
	Total Organic Carbon	EPA 415.3																
	C:N Ratio	EPA 415.3/351.2																

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Training Completion Log

Employee Name	Date	Storm Selection and Storm Tracking	Equipment Cleaning and Calibration	Storm Monitoring Equipment and Setup	Water Quality Sampling

Appendix I. Chain of Custody Forms

Anatek Labs, Inc.

Chain of Custody Record

1282 Alturas Drive, Moscow ID 83843 (208) 883-2839 FAX 882-9246
504 E Sprague Ste D, Spokane WA 99202 (509) 838-3999 FAX 838-4433

Anatek Log-In #

Company Name:	Project Manager:	**Turn Around Time & Reporting**
Address:	Project Name & #:	Please refer to our normal turn around times at: http://www.anateklabs.com/services/guidelines/reporting.asp
City: State: Zip:	Email Address:	__Normal __Next Day* __2nd Day* __Other*______
Phone:	Purchase Order #:	*All rush order requests must be prior approved.
Fax:	Sampler Name & phone:	__Phone __Mail __Fax x Email

Provide Sample Description				List Analyses Requested											Note Special Instructions/Comments
synthetic stormwater influent and effluent				Preservative:											
Lab ID	Sample Identification	Sampling Date/Time	Matrix	# of Containers	Sample Volume										

Inspection Checklist

Received Intact?	Y	N
Labels & Chains Agree?	Y	N
Containers Sealed?	Y	N
VOC Head Space?	Y	N

Temperature (°C):____________

Preservative:____________

____

Date & Time:____________

Inspected By:____________

	Printed Name	Signature	Company	Date	Time
Relinquished by					
Received by					
Relinquished by					
Received by					
Relinquished by					
Received by					

Form COC01.00 - Eff 1 Mar 2015

Page 1 of 1

Samples submitted to Anatek Labs may be subcontracted to other accredited labs if necessary. This message serves as notice of this possibility. Sub-contracted analyses will be clearly noted on the analytical report.

soiltest
farm consultants, inc.
2925 Driggs Dr., Moses Lake, Wa 98837 - www.soiltestlab.com
Office: (509)765-1622 - Fax:(509)765-0314 - (800)764-1622

Laboratory Chain of Custody

Client: Please fill out:	**Copy of report sent to:**
Company:	Company:
Contact:	Contact:
Address:	Address:
City, ST, Zip.:	City, ST, Zip.:
Telephone:	Telephone:
Fax:	Fax:
e mail:	e mail:

Date: ____________

Page ______ of ______

Job #/ Name: ____________

Payment Method: Credit Card____ Est. Acct.___

Write sample information in horizontal rows. Write test name(s) or code(s) in verticle boxes at left. Mark an "X" at the intersection(s) where appropriate.

				Analyses Requested					Lab Use Only	
Sample Identification	Date Sampled	No. of Containers	Sample Matrix						Sample Condition	LAB ID

Releasing	Date/Time	**Receiving**	Date	Time
Releasing signature 1		Receiving Signature 1		
Releasing signature 2		Receiving Signature 2		
Releasing signature 3		Receiving Signature 3		

Submission of samples to Laboratory with a Chain of Custody constitutes a contract for services requested. Provide payment detail with each COC. If no payment information is provided, you will be contacted by the laboratory. We will make every effort to provide an accurate analysis of this sample. For reasonable cause, we will repeat the tests, but because of factors beyond our control, in sampling procedures and inherent sample variability in compost, soils, plants and water our liability is limited to the price of the tests.

Appendix J. Summary of QAPP Revisions Table

Revision #	Revised By	Section and Page	Status of Revision (Draft/Approved)	Summary of Revision

Appendix K. Corrective Action Plan Table

#	Date Need for Corrective Action Was Identified	Issue Identified	Summary of Corrective Action	Implementation Date of Corrective Action

Appendix L. Sand Filter Media Material Information

Gradation Test With Sieve Chart Report

Plant 120_01136-Sullivan Road
Product 2100-Coarse Sand
Specification 2100-Coarse Sand

1980119992

Sample Information

Sample No 1980119992
Date Sampled 01/26/2018 07:14
Sampled By Clay Allen
Type Stockpile
Method Stockpile

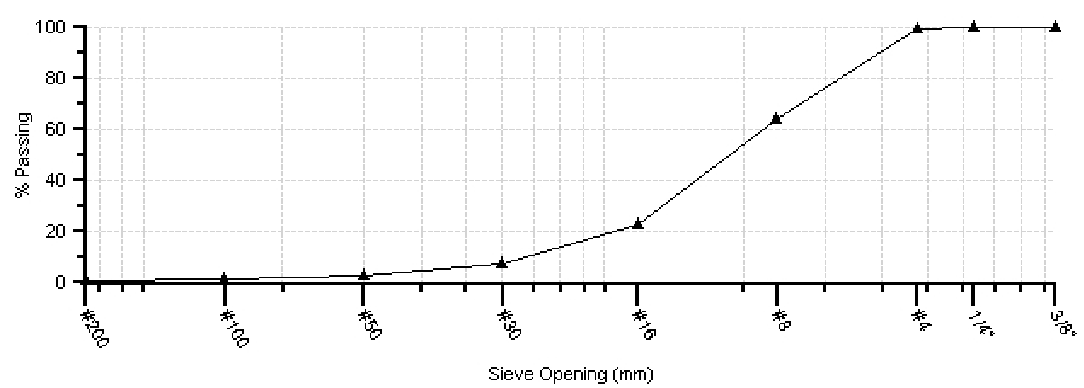
Split Sample ☐
Resample ☐

Gradation Results

Date Completed 01/26/2018 07:14
Tested By Clay Allen

Unit	Moist Mass	Dry Mass	Wash Mass	Moisture %	Wash Loss %	Procedure
g		949.20	941.20		0.8	

Sieve	Mass Retained	Cum Mass Retained	Ind % Retained	% Retained	% Passing	Target	Specification	Comment
3/8" (9.5mm)	0.00	0.00	0.0	0.0	100.0	100-100\100		
1/4" (6.3mm)	0.70	0.70	0.1	0.1	99.9	99.9-100\100		
#4 (4.75mm)	6.10	6.80	0.6	0.7	99.3	98.3-99.5\98.9		
#8 (2.36mm)	336.90	343.70	35.5	36.2	63.8	50.3-71\59.4		
#16 (1.18mm)	392.70	736.40	41.4	77.6	22.4	14.2-30.3\22.2		
#30 (0.6mm)	144.50	880.90	15.2	92.8	7.2	3-13.5\8.8		
#50 (0.3mm)	42.10	923.00	4.4	97.2	2.8	0.8-5.9\3.6		
#100 (0.15mm)	13.40	936.40	1.4	98.7	1.3	0.3-2.6\1.4		
#200 (75µm)	4.20	940.60	0.44	99.09	0.91	0.11-1.64\0.88		
Pan	0.80	941.40	0.91	100.00	0.00			



Tests: 1 D10(ES): 0.680 D15: 0.849 D30: 1.340 D50: 1.873 D60: 2.215 D85: 3.584 D90: 3.955 Cu: 3.259 Cc: 1.193

Please note: the following pages include specifications for the coconut coir mat which is placed on top of the sand filter. The material is also commonly used as an inlet filter.

Inlet Filter Specifications:

Item #	Dimensions	Pieces per Carton	Pieces Per Pallet
IF1527X30C	1.5” x 27” x 30”	10 pads	120 pads
IF1527X21FTB	1.5” x 27” x 21’	1 roll	12 rolls
IF1527X75FTB	1.5” x 27” x 75’	N/A	3 rolls

Other pad and roll sizes are available upon request.
Cartons sized to ship by UPS.

Inlet Filter Installation Instructions:

1. Remove sediment, debris, ice and snow from the inlet grate surface and surrounding area.

2. Verify fit by placing filter over inlet grate to ensure that Inlet Filter extends at least one inch beyond the front and both curb ends. The overlap slows water flow and starts filtering sediment and debris before water drops into the inlet.

3. Position the mat. Place Inlet Filter on grate with the net side down, flush to the back edge and extending beyond the grate opening on the front and both sides. The zip ties attach Inlet Filter to the inlet grate cover WITHOUT LIFTING THE GRATE COVER.

4. Insert zip ties. Lift Inlet Filter slightly to enable you to see the first grate bar from the edge of the grate cover.

Push the zip tie down through the Inlet Filter and loop under the grate bar. Insert the pointed end of the zip tie about 2” away from the first zip tie penetration and push back up through the filter.

Push the pointed end of the zip tie into the receiving end just enough to hold ends loosely. LEAVE ZIP TIES LOOSE UNTIL ALL TIES ARE LOOPED THROUGH THE MATS AROUND THE GRATES. Repeat Step 4 until all zip ties are installed loosely.

5. Tighten zip ties.
After attaching all of the zip ties, re-position Inlet Filter to completely cover and overlap the grate. Pull free end of zip-ties hand tight to anchor Inlet Filter to the grate. Cut off free end of zip ties to leave a 1” tail.

Inlet Filter Maintenance Instructions:

Inlet Filter will collect a lot of sediment. Clean Inlet Filter while mounted on the grate, even if ponded water surrounds the inlet. This unique feature ensures all water entering the grate is filtered. Sweep sides and top of Inlet Filter to remove sediment and debris after each rain event.

1. Remove sediment from the sides of the filter by sweeping away from Inlet Filter.

2. Remove sediment from the top of the filter by sweeping off of Inlet Filter.

Inlet Filter is prepared for the next rain event.

Blocksom & Co.
P.O. Box 2007 Michigan City, IN 46361-8007
Toll free: (800) 745-1408 Fax: (219) 874-3752

TRI Environmental, Inc. provided the following test results:

UV Resistance (ASTM D 4355 – 500 hour exposure)
Tensile Properties (ASTM D 5035/ECTC)
(4 inch wide strip specimen)

Baseline Properties	
MD – Maximum Load (ppi)	14.6
TD – Maximum Load (ppi)	18.7
MD – Elongation @ Max Load (%)	19.3
TD – Elongation @ Max Load (%)	27.7

500 Hour Exposed Properties	
MD – Maximum Load (ppi)	10.2
TD – Maximum Load (ppi)	13.8
MD – Elongation @ Max Load (%)	16.9
TD – Elongation @ Max Load (%)	16.6

Light Penetration (ECTC Guidelines)	
Baseline Reading	125
Reading with sample	10
% Light Penetration	<8

Resiliency (ASTM D 6524)	
Pre-loading thickness (mils)	1943
Post-loading thickness (mils)	326
% change	-83

Swell (ECTC)	
Dry thickness (mils)	1984
Thickness after soak (mils)	2098
% change	6

Mass/Unit Area (ASTM D 6565)	
Mass/unit area (oz/sq. yd)	50.89
Mass/unit area (g/sq. meter)	1725

Water Absorption (ASTM D 1117/ECTC)	
Pre-soak Weight (grams)	69
Post-Soak (grams)	152
Weight change (grams)	82
% Weight Change	119

Smolder Resistance (ECTC)	
Maximum Burn Distance (in)	.29

Sediment Control (ASTM D 5141)	
Test material:	Sand sieved thru No. 10 sieve
Filtering Efficiency (%)	59.1
Flow Rate (liter/minute)	150

Blocksom & Co.
P.O. Box 2007 Michigan City, IN 46361-8007
Toll free: (800) 745-1408   Fax: (219) 874-3752

Appendix M. Roadway Sediment Gradation Testing Results

GeoEngineers
523 East Second Avenue
Spokane, Washington 99202
509.363.3125

February 14, 2018

HDR Engineering, Inc.
1401 East Trent Avenue, Suite 101
Spokane, Washington 99202-2902

Attention: Aimee Navickis-Brasch, P.E.

Subject: Laboratory Test Results
Spokane County Sand Filter
File No. 0188-169-00

This letter presents our laboratory testing results of a material sample of material that was delivered by you to our laboratory for testing on January 16, 2018. The sample was identified as Road Sediment and consisted of moist to wet sand with silt and organic matter, such as leaves and small wood fragments. We understand that the sample had been minimally processed prior to delivery to us, to remove the larger portions of the organic material. You requested that the mineral portion of the sample be tested by ASTM D 422 for particle size analysis, with estimation of the percent passing a 62.5-micron (No. 230) sieve.

We attempted to separate the organics from the sediment both by manual sorting and by flotation. These attempts were not satisfactory due to organic content being present at all particle size ranges. We then elected to perform a loss-on-ignition test to better characterize the amount of organics present. The test results are summarized below and presented in full on the attached data sheets.

Test	Result
Moisture content of sample as delivered, ASTM D 2216	29.0%
Organic content by AASHTO T267	10.0%
Organic content, Total Volatile Solids by SM2540E	9.1%
Sediment percent passing 0.75”	100.0
Sediment percent passing 0.375”	99.8
Sediment percent passing 0.25”	98.7
Sediment percent passing No. 4	97.6
Sediment percent passing No. 10	83.5
Sediment percent passing No. 20	65.4
Sediment percent passing No. 40	44.7
Sediment percent passing No. 60	29.6

Test	Result
Sediment percent passing No. 100	19.8
Sediment percent passing No. 200	12.3
Sediment percent passing No. 230 (by estimate)	10.8

We hope this information is sufficient for your needs at this time. Please call if you have any questions regarding the test methods or results. Thank you for assigning this work to GeoEngineers.

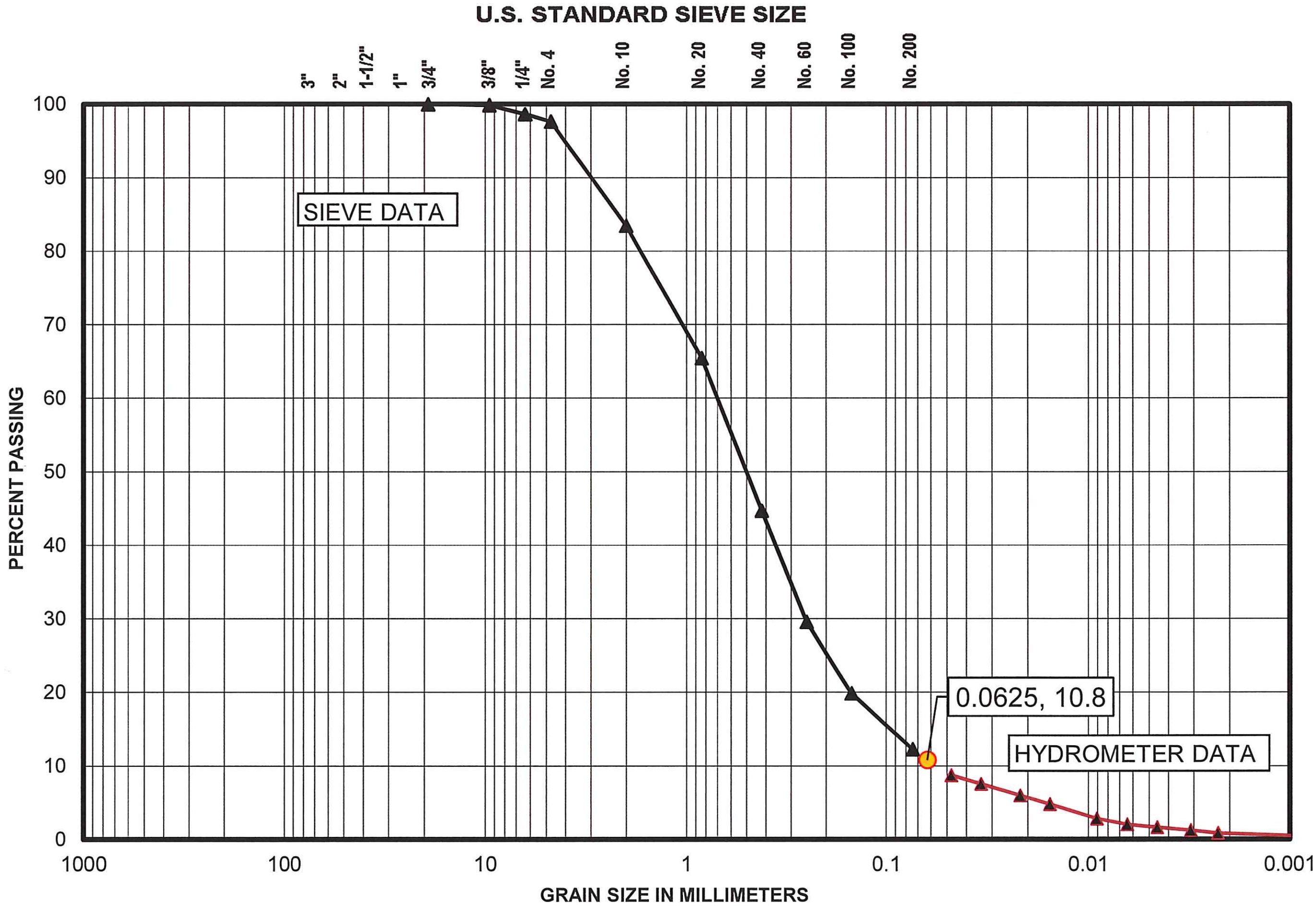
Sincerely,
GeoEngineers, Inc.

Timothy D. Barber

Timothy D. Barber
Laboratory Manager

TDB:TAD:mce:tjh

Attachments:
ASTM D 422 Soil Particle Size Analysis
ASTM D 2974 Data Reduction Sheet
Analytical Results Report, Anatek Labs



COBBLES	GRAVEL		SAND			FINES	
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT	CLAY

Coarse Gravel %	0.0	Medium Sand %		38.8	
Fine Gravel %	2.4	Fine Sand %		32.4	
Coarse Sand %	14.2	Fines (Silt & Clay) %		12.3	
USC Symbol	SM	C_U	n/a	C_C	n/a
Description (D 2487)	Silty fine to coarse sand (SM)				

Individual Sieve Data - % Passing			
3"	100.0	No. 4	97.6
2"	100.0	No. 10	83.5
1 1/2"	100.0	No. 20	65.4
1"	100.0	No. 40	44.7
3/4"	100.0	No. 60	29.6
3/8"	99.8	No. 100	19.8
1/4"	98.7	No. 200	12.3
Estimated percent passing No. 230 sieve:		10.8	

Specific Gravity*	2.70
Dispersion Device	Type A
Dispersion Time	1 min.
Dispersing Agent	$(NaPO_3)_6$
Sieve set(s):	A
Hydrometer Type	152H
Hydrometer ID:	1387
Hydrometer Jar ID:	1387

*assumed unless noted

Project	Spokane County Sand Filter	Date Tested	1/18/2018
Project No.	00188-169-00	Tested By	GT
Sample ID.	M18-001	Checked By	TDB
Source/Depth	Client	Project Manager	TAD

NOTE: Test was performed in general accordance with the referenced test method. Test results are applicable only to the specific sample on which they were performed, and should not be interpreted as representative of any other samples obtained at other times, depths or locations or generated by separate operations or processes. This report may not be reproduced, except in full, without written approval of GeoEngineers, Inc.

GEOENGINEERS

523 East Second Avenue, Spokane, Washington 99202

ASTM D 422 SOIL PARTICLE SIZE ANALYSIS

Version date 4/3/2012

Data Reduction Sheet
Organic Content Tests
ASTM D 2974 / AASHTO T 267

Project Name:	Spokane County Sand Filter			**Project Number:**	0188-169-00	
Tested by:	MLC			**Date:**	2/12/18	
Checked by:	SAS			**Date:**	2/12/18	
Exploration No.	Road Sediment					
Sample No.	1					
Depth	Grab					
Dish + Moist Soil (g)	527.86					
Dish + Dry Soil (g)	453.78					
Moisture Loss (g)	74.08					
Dish Wt. (g)	197.02					
Dry Soil Wt. (g)	256.76					
Moisture Content (%)	**29**					
Dish + Soil After Burn (g)	428.17					
Ash Content (%)	90.0%					
Organic Content (%)	**10.0%**					
Entire Sample Used?	N					
Meets ASTM/AASHTO Minimum Weight Requirements?	Y					
Note Oven Temperature, if different than 110° C						
Furnace Temp. (° C)	440					
Visual Soil Description	Fine to medium sand with o.m. (SP)					

GEOENGINEERS

https://projects.geoengineers.com/sites/0018816900/Analytical Data/Organic Content 21218.xlsx

Anatek Labs, Inc.

1282 Alturas Drive • Moscow, ID 83843 • (208) 883-2839 • Fax (208) 882-9246 • email moscow@anateklabs.com
504 E Sprague Ste. D • Spokane WA 99202 • (509) 838-3999 • Fax (509) 838-4433 • email spokane@anateklabs.com

Client:	GEO ENGINEERS	**Batch #:**	180119018
Address:	523 E 2ND AVE SPOKANE, WA 99202	**Project Name:**	SPOKANE COUNTY SAND FILTER
Attn:	TERESA DUGGER		

Analytical Results Report

Sample Number	180119018-001	**Sampling Date**	1/16/2018	**Date/Time Received**	1/19/2018	10:58 AM
Client Sample ID	M18-001	**Sampling Time**		**Extraction Date**		
Matrix	Soil	**Sample Location**				
Comments						

Parameter	Result	Units	PQL	Analysis Date	Analyst	Method	Qualifier
TVS	9.1	%	0.01	1/30/2018 9:00:00 AM	HMD	SM2540E	
%moisture	0.5	Percent		1/30/2018 9:00:00 AM	HMD	%moisture	

Authorized Signature Kathleen A. Sattler

Kathleen A. Sattler, Lab Manager

MCL EPA's Maximum Contaminant Level
ND Not Detected
PQL Practical Quantitation Limit

The results reported relate only to the samples indicated.
Soil/solid results are reported on a dry-weight basis unless otherwise noted.

Certifications held by Anatek Labs ID: EPA:ID00013; AZ:0701; FL(NELAP):E87893; ID:ID00013; MT:CERT0028; NM: ID00013;NV:ID00013; OR:ID200001-002; WA:C595
Certifications held by Anatek Labs WA: EPA:WA00169; ID:WA00169; WA:C585; MT:Cert0095; FL(NELAP): E871099

Appendix N. Data Logger Threshold Spreadsheet Calculator

The threshold values entered into the data logger determine when the data logger and ISCOs initiate sampling: once a threshold is reached, the data logger sends the signal to the respective automated sampler to begin sampling. At the study location, the threshold values refer to the volume of water which is expected to enter the monitoring system and BMP. The values vary depending on the precipitation depth of the upcoming storm, and are calculated in Excel using a modified version of the Rational Method. An example of the spreadsheet is shown below and the analysis methods are described on the next page. *Note: the total volume sampled in the table below is for example purposes only and does not reflect the total volume to be sampled at the site.*

Table N.1 Example Threshold Calculation

Rainfall (in)	*Runoff (ft^3)*	*Runoff (L)*	*# of Samples*	*aliquot volume (L)*	*Threshold (L)*	*Total Volume Sampled (L)*
0.000	0.000	0	0	0.250	0	0
0.01	13.500	382	37	0.250	10	9.25
0.02	27.000	765	37	0.250	21	9.25
0.03	40.500	1147	37	0.250	31	9.25
0.04	54.000	1529	37	0.250	41	9.25
0.05	67.500	1911	37	0.250	52	9.25
0.06	81.000	2294	37	0.250	62	9.25
0.07	94.500	2676	37	0.250	72	9.25
0.08	108.000	3058	37	0.250	83	9.25
0.09	121.500	3440	37	0.250	93	9.25
0.1	135.000	3823	37	0.250	103	9.25
0.11	148.500	4205	37	0.250	114	9.25
0.12	162.000	4587	37	0.250	124	9.25
0.13	175.500	4970	37	0.250	134	9.25
0.14	189.000	5352	37	0.250	145	9.25
0.15	202.500	5734	37	0.250	155	9.25
0.16	216.000	6116	37	0.250	165	9.25
0.17	229.500	6499	37	0.250	176	9.25
0.18	243.000	6881	37	0.250	186	9.25
0.19	256.500	7263	37	0.250	196	9.25
0.2	270.000	7646	37	0.250	207	9.25
0.21	283.500	8028	37	0.250	217	9.25
0.22	297.000	8410	37	0.250	227	9.25
0.23	310.500	8792	37	0.250	238	9.25
0.24	324.000	9175	37	0.250	248	9.25
0.25	337.500	9557	37	0.250	258	9.25
0.26	351.000	9939	37	0.250	269	9.25

Note: these calculations do not account for evaporation.

The first column lists possible (predicted) precipitation depths. The second column is runoff calculated from the following equation:

$$V = CiA$$

Where:

$V = predicted\ volume\ of\ runoff, ft^3$
$C = rational\ method\ coefficient\ for\ impervious\ surfaces,$ 0.90
$i = precipitation\ depth, in.$
$A = contributing\ basin\ area, ft^2$

As mentioned previously, the precipitation depth is listed in the first column. The contributing basin area at the study location is approximately 18,000 square feet, as described in Section 4.3. The resulting volume of runoff is converted to liters in the third column.

The values in the fourth and fifth columns represent the number of aliquots and volume of each aliquot pulled by the ISCO, respectively. The targeted minimum number of aliquots that will be collected by the ISCO is 10, and the targeted maximum number of aliquots is 37. During the study, the ISCO will be set to sample 37 aliquots. The product of the fourth and fifth columns is equal to the total volume pulled by the automated samplers, in the seventh column. The total volume pulled by the automated samplers must be sufficient for the quantity and types of samples needed at the study location. The threshold value is equal to the total runoff in liters expected at the test site divided by the number of aliquots pulled by the ISCO. This volume represents the frequency of which aliquots will be collected. Specifically, after the pressure transducer measures this threshold volume the data logger triggers the ISCO sampler to collect a sample. This process continues until the storm event end and results in obtaining samples at equal volumes (aliquots) spaced evenly throughout the storm.

For example, Table N.1 displays the threshold value for a storm rainfall depth of 0.15 inches (highlighted in green). Given the amount of runoff that is expected for the rainfall depth, the ISCOs would need to start sampling once 155 liters had entered the influent and effluent pipes in order to obtain the aliquots and total sample volume needed during the storm.