Eastern Washington
Stormwater Effectiveness Studies

Detailed Study Design Proposal & Quality Assurance Project Plan (QAPP)

Non-Vegetated Filtration Swale Stormwater Effectiveness Study

Study Classification:

☑ Structural BMP ☐ Operational BMP ☐ Education & Outreach

Study Objective(s):

☑ Evaluate Effectiveness ☐ Compare Effectiveness
☑ Develop Modified BMP ☐ Develop New BMP

Prepared For:

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1.0 Table of Contents

2.0 Executive Summary

A non-vegetated filtration swale is a sloped, rock-lined swale that is similar to the biofiltration swale (BMP T5.40) defined in the Eastern Washington Ecology Stormwater Manual (SWMMEW, 2019), except treatment in the proposed BMP occurs as runoff flows through a layer of rock instead of grass. Constructing a non-vegetated filtration swale is highly desirable for locations with hot and dry summers such as Eastern Washington which has a semi-arid climate and requires irrigation to maintain the vegetation between storm events. Vegetation requires irrigation and the cost to construct and operate irrigation systems adds to the overall life-cycle expense of the BMP. In theory, the non-vegetated filtration swale could reduce maintenance costs in comparison to the biofiltration swale and limit water usage while meeting basic treatment performance goals. The goal for this study is to evaluate the effectiveness of a non-vegetated filtration swale BMP. Effectiveness will be based on whether the BMP is able to provide basic treatment (80% reduction of TSS) in accordance with Ecology treatment performance goals (Ecology, 2011). If the non-vegetated filtration swale meets the Ecology's basic treatment performance goal, the results from this study will be used to justify that a non-vegetated filtration swale is functionally equivalent to a biofiltration swale.

The goal of the study will be achieved by conducting controlled field experiments which use synthetic stormwater to simulate storm events at a test site installed at the West Richland municipal services building. Four non-vegetated filtration swale alternatives will be installed with impermeable liners to limit the influence of soils at the site and tested, and the best-performing alternative will be installed without a liner to further evaluate performance of the swale alternative. Six simulated storm events will be conducted for each swale alternative. During the simulated storm events, water quality samples will be collected to measure TSS pollutant removal efficiency at eight locations spaced at 25-foot intervals in the swale. Velocity in the rock layer will be calculated as well to define the flow rate and velocity for which the BMP provides treatment. After the water quality samples are collected, an approximate annual loading of TSS will be delivered to the swale to simulate one year between each simulated storm event. The water quality sample results will be used to determine whether the basic treatment performance goals were met for each alternative and what length of swale is needed to meet this goal, as well as estimate the maintenance frequency of the non-vegetated filtration swale based on performance changes over the six simulated storm events. The results of the controlled field experiments will be used to select the alternative with the best treatment performance and finalize the design and maintenance guidance for that alternative.

The controlled field experiments will be conducted in later summer and early fall of 2022 to limit the chance of precipitation occurring at the site during testing. The final technical evaluation report will be developed in Spring of 2023. This study is funded by a Washington State Department of Ecology GROSS Grant.

3.0 Introduction and Background

3.1 Introduction to the Structural BMP

The focus of this study is to evaluate the effectiveness of a non-vegetated filtration swale. A non-vegetated filtration swale is a sloped, rock-lined swale as can be seen in Figure 3.1. The proposed Best Management Practice (BMP) is similar to a biofiltration swale (BMP T5.40) defined in the Eastern Washington Ecology Stormwater Manual (SWMMEW, 2019), except treatment in the proposed BMP occurs as runoff flows through a layer of rock instead of grass. The proposed BMP is designed so that water will flow through the rock rather than over to maximize the contact time between rock and stormwater. During a precipitation event, stormwater is collected and enters the non-vegetated biofiltration swale either through an inlet structure or along the length of the swale. The stormwater flows through the layer of rock in the proposed BMP (treatment rock layer) and discharges into another stormwater BMP, drywell, or catch basin connected to the storm drain network. Depending on the size of the rock used in the treatment rock layer, a stabilization layer of rock may be included on top of the treatment rock layer (Section 3.3).

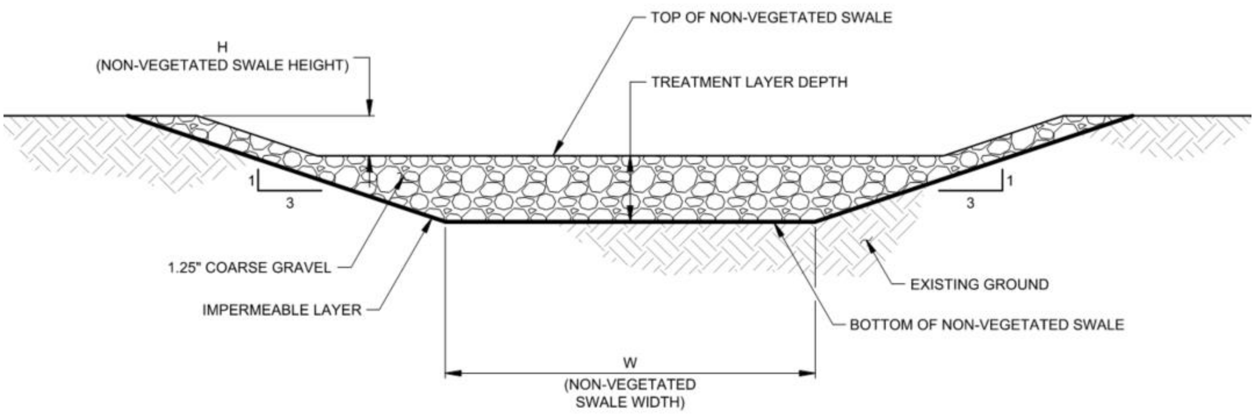


Figure 3.1 Non-Vegetated Filtration Swale Cross-Section

The design process for the non-vegetated filtration swale (Appendix A) is similar to the biofiltration swale defined in the Ecology Stormwater Manual. The non-vegetated filtration swale is a runoff treatment BMP and is sized for the water quality design flow rate according to Section 2.7.6 of the SWMMEW. The width of the proposed BMP should be sized using one of the approved water quality design storms in Section 2.7.6, which includes the Rational Method 2-year 24-hour storm event, the short duration (3-hour) 6-month storm, and the SCS Type II 6-month 24-hour storm event. The SWMMWW requires that the BMP should be sized to treat the water quality design flow rate, which is determined through continuous simulation models. The width (and treatment rock layer depth) are sized to contain the water quality design flow within the treatment rock layer (water flows through the pore spaces). Any storm events larger than the water quality design storm would flow above the treatment rock layer. As such, the non-vegetated filtration swales are sized to provide freeboard for conveyance to the outlet during design events up to the 25-year 24-hour event.

Differences between the proposed non-vegetated filtration swale and the existing biofiltration swale are summarized in Table 3.1. The primary difference between the existing and proposed swale is that the proposed BMP has a treatment rock layer and does not require the planting, seeding of vegetation, or irrigation and mowing. The stabilization rock layer found at the surface of the BMP was selected based upon the longitudinal slope of the BMP as well as to limit the movement of rock during a 25-year event, as discussed in Section 3.3 and Appendix A. The movement of rock was expected to occur if the critical shear stress was exceeded by the flow of stormwater through the swale.

Table 3.1 Comparison of SWMMEW Biofiltration Swale and Non-Vegetated Filtration Swale

Swale Parameters	**Existing Biofiltration Swale (SWMMEW, 2019)**	**Proposed Non-Vegetated Filtration Swale**
BMP Cover	Grass	Rock
Longitudinal Slope	>1% and <5%	>1% and <5%
Shape of Swale	Trapezoidal	Trapezoidal
Manning's n (2-year)	0.3	0.4[1]
Manning's n (25-year)	0.04	0.036[1]
Flow Depth (y)	≤ 4 inches	3 inches[2]
Bottom Width (B)	≤ 10 feet[3]	2-10 feet
Side Slopes	3:1 or flatter	3:1 or flatter
Length (L)	200 ft[4]	100 ft[1]
Hydraulic Residence Time	9 minutes	9 minutes[1]
Maximum Velocity During Water Quality Event	<1 ft/sec	<1 ft/sec

1. This parameter will be verified during field testing.
2. The effective depth is the flow depth if it were unobstructed by the treatment rock layer.
3. The SWMMEW specifies ≤ 10 feet however it should be 2-10 feet.
4. The SWMMEW specifies a minimum 200-foot length for swales however it should be a minimum of 100 feet. This change will be made in the next update of the manual.

This study will evaluate the effectiveness of four different configurations of non-vegetated filtration swale designs by assessing whether they meet the basic treatment performance goal (80% removal of TSS). The four proposed BMP designs can be found in Section 3.3 and Appendix A. The primary treatment mechanisms for a non-vegetated filtration swale includes gravity separation and filtration when runoff flows through the treatment rock layer. Gravity separation relies on variations in material density for pollutant removal: pollutants denser than water (i.e., TSS and gross solids) will descend within the treatment rock layer depth and settle on top of the BMP. Filtration is anticipated to remove TSS as stormwater flows through the treatment rock layer becoming physically trapped in the pore spaces (Hunt & Lord, 2006; Minton, 2012).

3.2 Problem Description

Constructing a non-vegetated filtration swale is highly desirable for locations with hot and dry summers such as Eastern Washington which has a semi-arid climate and requires irrigation to maintain the vegetation between storm events. A non-vegetated BMP will benefit multiple Washington State Permittees by providing a BMP option that does not require a supplemental water source. Vegetation requires irrigation and the cost to construct and operate irrigation systems adds to the overall life-cycle expense of the BMP and consumes water that could have a higher beneficial use. Additionally, the lack of vegetation reduces landscaping maintenance costs in comparison to the existing BMP.

This study supports the implementation of NPDES permit required municipal stormwater programs, specifically NPDES Municipal Separate Storm Sewer System (MS4) Phase II Permit as described in Section 3.4. If the results are successful, they will inform a modification to the Ecology approved biofiltration swale design guidance to include an option for non-vegetated filtration swales. The modified BMP will also support implementation of Permit Section S5.5 Post Construction Stormwater Water Management for the New Development and Redevelopment by providing water quality treatment for runoff on-site and conveying the 25-year storm event as required in the SWMMEW (based on BMP T5.40). If the modified BMP meets Ecology's basic treatment goal of 80% TSS removal, the results of the study will be used to demonstrate that the BMP is functionally equivalent to a grass lined biofiltration swale and establish the length of swale required to provide this treatment.

3.3 Results of Prior Studies

A literature review was performed to develop the non-vegetated filtration swale design and maintenance guidance that will be used during this study (the final guidance will be updated to reflect the study results). Specifically, the literature review consisted of identifying if any research had been conducted that provided information regarding non-vegetated or rock-lined swales: treatment performance, design criteria, design procedures, or maintenance of. The following paragraphs described the findings of the literature review.

Stormwater design manuals, in particular those for jurisdictions located in arid or semi-arid regions, were identified as potential sources of information. Out of the twelve manuals reviewed, eight contained design criteria and procedures for a rock-lined BMP. Of those manuals, four of the options provided design guidance on how to design a rock-lined swale as a modified vegetation BMP (County of San Diego Department of Public Works, 2014; City of Flagstaff Utilities Division, 2009),. The remaining four manuals provided design guidance specifically for a rock-lined swale (State of Nevada State Conservation Commission, 1994; Pima County and the City of Tucson, 2015; Tahoe Interagency Roadway Runoff Subcommittee, 2001; Ohio Environmental Protection Agency, 2006). The types of rock used for the twelve BMPs reviewed were based on the jurisdiction's specifications and what is available in the area. The literature search indicated that the primary purpose of rock-lined BMPs was for conveyance and erosion control or can be used as part of a treatment train to reduce runoff volume and flow rate. In other words, these BMPs were not developed to provide treatment of TSS to the level defined (80% reduction) in the Washington State MS4 Permits.

From the review, limited information was found regarding the treatment performance of rock-lined swales. Two of the manuals identified indicated that a rock-lined swale can provide some water quality treatment but did not specify which pollutants or the pollutant removal (Pima County and the City of Tucson, 2015; Tahoe Regional Planning Agency (TRPA), 2014). Three manuals suggested that a rock-lined swale can provide some treatment but that the treatment is based on the underlying soil conditions, preferably high-infiltrating sandy soils (County of San Diego Department of Public Works, 2014; City of Flagstaff Utilities Division, 2009).

Literature was identified during the review for similar applications to the non-vegetated filtration swale that suggest a rock-lined swale could be effective for reducing TSS. The Federal Highway Administration uses a combination of rock sizes for streambank stabilization to prevent fines from migrating into the stream (Richardson, Simons, & Lagasse, 2001). The same principle is used in many stormwater applications when a choke stone layer (3- to 4-inches of pea gravel) replaces filter fabric (Hunt & Lord, 2006; Minnesota Pollution Control Agency, 2017). For example, choke stone can prevent the migration of finer treatment soil particles into the underlaying gravel for bioretention cells with underdrains.

Information regarding operation and maintenance procedures for rock-lined BMPs was found during the literature review. Of the stormwater design manuals reviewed, one manual suggested that if sediment buildup is greater than three inches, or covers underlying rock at any location, sediment should be removed from the swale semi-annually (Tahoe Regional Planning Agency (TRPA), 2014). On the same frequency, the maintenance crew should remove trash, debris and large vegetation (California Stormwater Quality Association, 2003). If vegetation or ponding water are observed at any location, it is likely an indicator that sediment has built up in the BMP, and that sediment should be removed (Department of Environmental Protection, 2018). Literature also suggests that the BMP should be inspected for erosion, animal burrows, or dislodged and unstable rock (Tahoe Regional Planning Agency (TRPA), 2014).

The information collected during the literature review, along with the design guidance for the biofiltration swale BMP in the SWMMEW, was used as a basis for the development of design and maintenance guidance for the non-vegetated filtration swale. The following paragraphs describe non-vegetated filtration swale design alternatives that were developed.

3.3.1 Developed Non-Vegetated Filtration Swale Alternatives

Four swale design alternatives were developed to be tested during the study (Section 7.1). The swale design alternatives utilize a range of particle size gradations for the treatment rock layer, in order to increase the likelihood of meeting basic treatment goals and because of the findings of the literature search indicated potentially effective treatment rock layers include choke stone or riprap (Section 3.3). The gradations of the treatment rock layers were also selected wherever possible to align with specifications in WSDOT specifications or the SWMMEW to specify rock that would be readily available in Washington State. Each swale design alternative is underlain by an impermeable liner, to evaluate the treatment performance of the rock independent of the underlying soils. The swale design alternative with the best performance in terms of treatment performance and maintenance will be tested without an impermeable liner below the treatment rock layer, as future installations of the swale design, if approved for inclusion in the SWMMEW, would not require an impermeable liner. The following paragraphs describe the swale design alternatives and treatment rock layers used in each. Additional information regarding development of treatment rock layers and stabilization rock layers is included in Appendix A.

Swale Alternative 1

The first swale design alternative utilizes one rock gradation for the treatment rock layer. The treatment rock layer specified is the largest gradation selected for the treatment rock layers and consists of a 7.5-inch depth of 1.25-inch coarse gravel. The rock meets the gradation in WSDOT

Standard Specification 9-03.1(4)C, as shown in Table 3.2. Figure 3.2 below shows a cross-section of the swale design alternative.

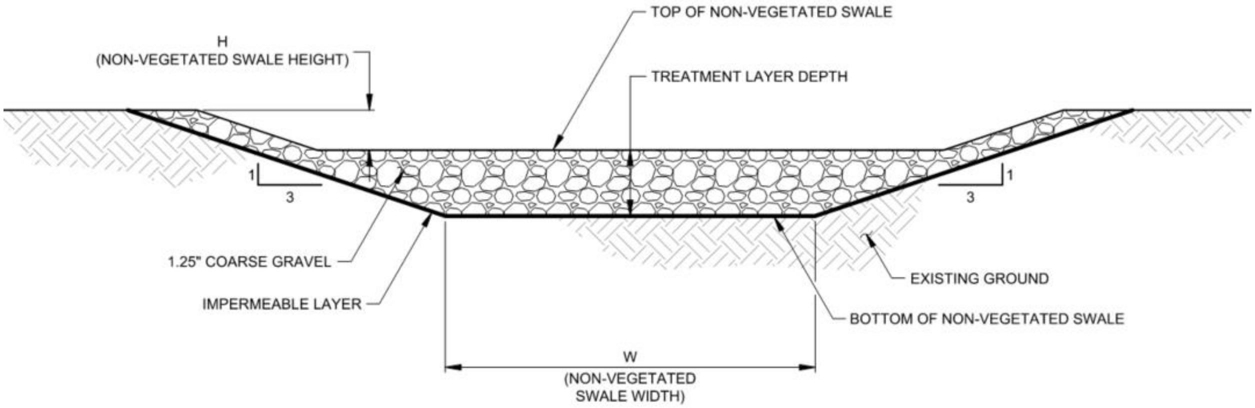


Figure 3.2 Swale Alternative 1 Cross Section

Swale Alternative 2

The second swale design alternative utilizes one rock gradation for the treatment rock layer, which consists of a 7.5-inch depth of pea gravel. The rock meets the gradation in WSDOT Standard Specification 9-03.1(4)C, as shown in Table 3.2. The treatment rock layer is overlain by a 2.5-inch depth stabilization layer of either 1.25-inch (for swales with longitudinal slopes of 1% to 2.5%) or 2.5-inch coarse gravel (for swales with longitudinal slopes of 2.5% to 5%). A stabilization layer is a layer of rock that is placed on top of the treatment rock layer to limit rock movement and erosion during high flow events, up to the 25-year event. Figure 3.3 below shows a cross-section of the swale design alternative.

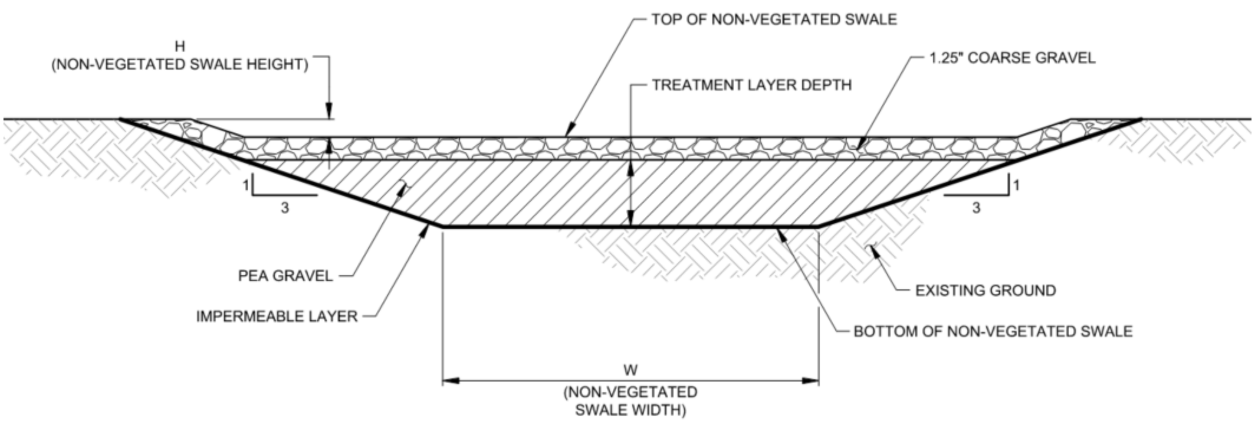


Figure 3.3 Swale Alternative 2 Cross Section

Swale Alternative 3

The third swale design alternative utilizes one rock gradation for the treatment rock layer, which consists of a 7.5-inch depth of gravel backfill for drywells. The rock meets the gradation in WSDOT Standard Specification 9-03.12(5), as shown in Table 3.2. The treatment rock layer is overlain by a 2.5-inch depth stabilization layer of either 1.25-inch (for swales with longitudinal slopes of 1% to 2.5%) or 2.5-inch coarse gravel (for swales with longitudinal slopes of 2.5% to 5%). Figure 3.4 below shows a cross-section of the swale design alternative.

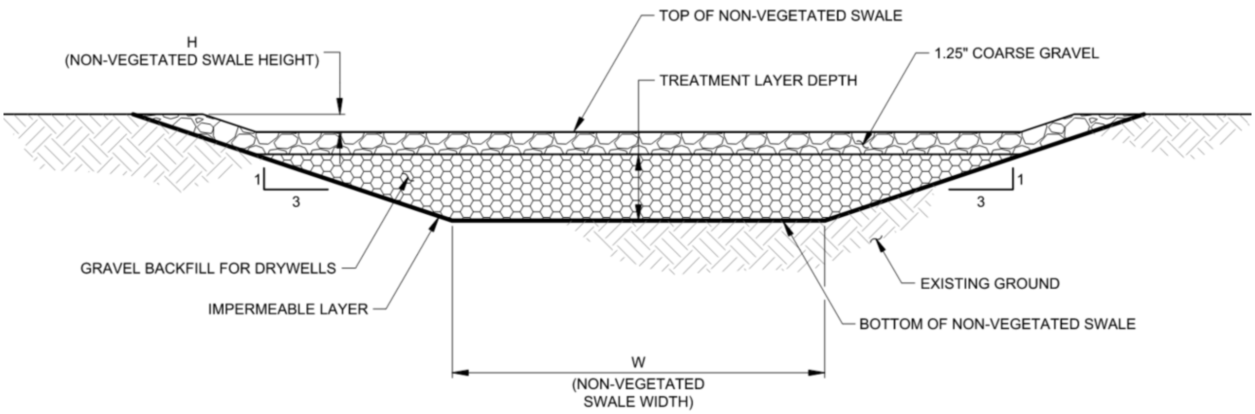


Figure 3.4 Swale Alternative 3 Cross Section

Swale Alternative 4

The fourth swale design alternative utilizes two rock gradations for the treatment rock layer, which consists of a 4.5-inch depth of sand media under a 3-inch layer of pea gravel. The sand media follows the gradation in the SWMMEW for medium sand and the pea gravel follows WSDOT Standard Specification 9-03.1(4)C, as shown in Table 3.2. The sand placed in the swale will be compacted according to ASTM 1557. The treatment rock layer (sand plus pea gravel) is overlain by a 2.5-inch depth stabilization layer of either 1.25-inch (for swales with longitudinal slopes of 1% to 2.5%) or 2.5-inch coarse gravel (for swales with longitudinal slopes of 2.5% to 5%). Figure 3.5 below shows a cross-section of the swale design alternative.

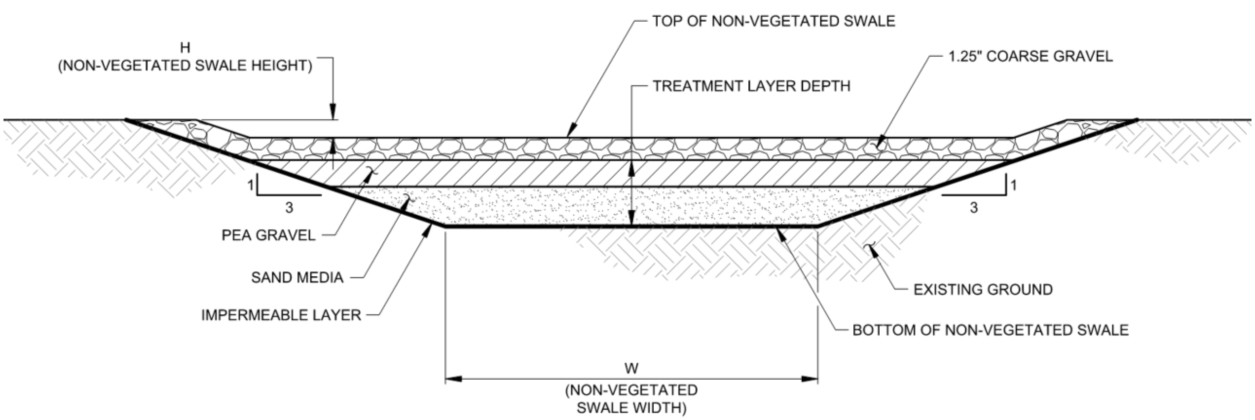


Figure 3.5 Swale Alternative 4 Cross Section

Table 3.2 Stabilization Rock Layer and Treatment Rock Layer Gradations

Sieve Size	2.5" Coarse Gravel[1]	1.25" Coarse Gravel	Gravel Backfill for Drywells	Pea Gravel	Sand Media
	AASHTO #2	WSDOT Standard Specification 9-03.1(4)C (AASHTO #4)	WSDOT Standard Specification 9-03.12(5)	WSDOT Standard Specification 9-03.1(4)C (AASHTO #8)	SWMMEW Sand Media Specification
3"	100				
2 ½"	90-100				
2	35-70	100			
1 ½"	0-15	99-100			
1"	-	20-55	100		
¾"	0-5	0-15	90-100	100	
½"		-	20-55	99-100	
3/8"		0-5	0-15	85-100	100
#4			0-5	10-30	95-100
#8				0-10	70-100
#16				0-5	40-90
#30					25-75
#50					2-25
#100					< 4
#200					< 2

[1] 2.5" coarse gravel is used in the stabilization layer when the longitudinal slope of the swale is between 2.5% to 5%. The 2.5" coarse gravel is placed at a depth of 2.5 inches above the treatment rock layer.

3.4 Regulatory Requirements

The Eastern Washington Phase II Municipal Stormwater Permit issued to the City of West Richland by Ecology requires the Stormwater Management Program Effectiveness Studies as defined in Section 8.B (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 is intended to fulfill both S8.A.2.c (*Submit a detailed study design proposal to Ecology on or before September 30, 2022*) and S8.A.2.d (*"Submit a completed QAPP on or before July 31, 2023").* As such, this QAPP will be submitted as the detailed study design proposal and QAPP needed for the study.

The City of West Richland 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, 2019).

4.0 Project Overview

4.1 Study Goal

The goal of this study is to evaluate the effectiveness of a non-vegetated filtration swale BMP. Effectiveness will be based upon whether the BMP is able to provide basic treatment (80% reduction of TSS) in accordance with Ecology treatment performance goals (Ecology, 2011). If the non-vegetated filtration swale meets the Ecology's basic treatment performance goal, the results from this study will be used to justify that a non-vegetated filtration swale is functionally equivalent to a biofiltration swale.

4.2 Study Description and Objectives:

The goal of this study will be achieved by meeting the objectives below. At the end of the study, one swale design alternative will be recommended based on the findings from the objectives.

- Define the draft BMP design and maintenance guidance (contained in Appendix A). Finalize the BMP design and maintenance guidance based on the results of the study
- Determine the TSS pollutant removal efficiency of the BMP by measuring and comparing pollutant concentrations in the synthetic influent and eight effluent locations in each test swale. The TSS pollutant removal efficiency will be associated with an allowable maximum flow rate.
- Determine the design flow rate and velocity for which the BMP provides treatment by measuring depth at the upstream and downstream end of each swale, and calculating velocity and flow rate
- Determine whether the treatment performance goals were achieved by comparing study results to TAPE goals and requirements

The non-vegetated filtration swale design and maintenance guidance was defined prior to developing this document and is included in Appendix A. The guidance was developed using the design and maintenance guidance for a biofiltration swale in the SWMMEW and Highway Runoff Manual (HRM) and then modified based on the findings of a literature review (Section 3.3). The literature search consisted of reviewing journal articles and stormwater design manuals. Four swale design alternatives were identified following the literature search for testing in the field.

Field testing of the swale design alternatives will include retrofit of the existing swale at the test site and installation of the four swale design alternatives prior to testing and evaluating the treatment of each alternative. Two 200-foot-long swales (each a different alternative) will be installed adjacent within the footprint of the existing 430-foot-long swale at a time for testing. Each swale design alternative will be installed with an impermeable liner. Once testing is complete for two of the swale design alternatives, the swale design alternatives will be removed, and the remaining two swale design alternatives will be installed for testing. Once the four swale design alternatives have been tested, the swale design alternative with the best treatment performance will be installed within the footprint of the existing swale without an impermeable liner. The final swale installation will be tested to verify performance and assess maintenance frequency. The site will be returned to its original condition (one, 430-foot long swale) following completion of testing.

Testing of the swale design alternatives will include sending separate batches of synthetic stormwater influent to each swale. Each swale design alternative will receive six batches of synthetic stormwater (simulated storm event, Section 7.5) that represent a water quality storm event and approximately one year of TSS loading. Grab samples will be collected during the simulated water quality storm event at the influent and at eight evenly spaced locations in each 200-foot-long swale design alternative (nine samples per event, per swale). Depth of flow will also be measured at the upstream and downstream ends of the swale to estimate the velocity of the flow through the treatment layer which will be used to inform the design guidance. Following the six simulated storm events, the flow rate from a 25-year storm event will be simulated to confirm that the rock does not move during this event as described in the design and maintenance guidance (Appendix A). Flow from each event will be collected at the downstream end of each swale by a vactor truck or submersible pump directed to a water truck and will not enter the adjacent swale. Samples collected during the simulated water quality event will be analyzed for TSS by an analytical laboratory and the data from the samples will be used to evaluate whether the swale design alternatives meet Ecology's basic treatment performance goals as defined in TAPE. Affirmative results will result in a recommendation that the BMP is included in the SWMMEW and SWMMWW as an alternative to the biofiltration BMP.

4.3 Study Location

The study will take place in the City of West Richland, which has a semi-arid climate. The test-site is located on the City of West Richland Public Works property, south of the Municipal Services Building and adjacent to a gravel parking lot. The parking lot serves as overflow parking for the building and does not have a high trip end count. There is an existing 430-foot long swale at the site with 6.5-foot bottom width and 3:1 slopes. The total depth of the existing swale is approximately 12-18 inches. The surrounding soils and soil in the swale are anticipated to have high infiltration rates, based on observations provided by the City of West Richland (no water has been observed in the swale). Figure 4.1 provides an aerial view of the test site location.

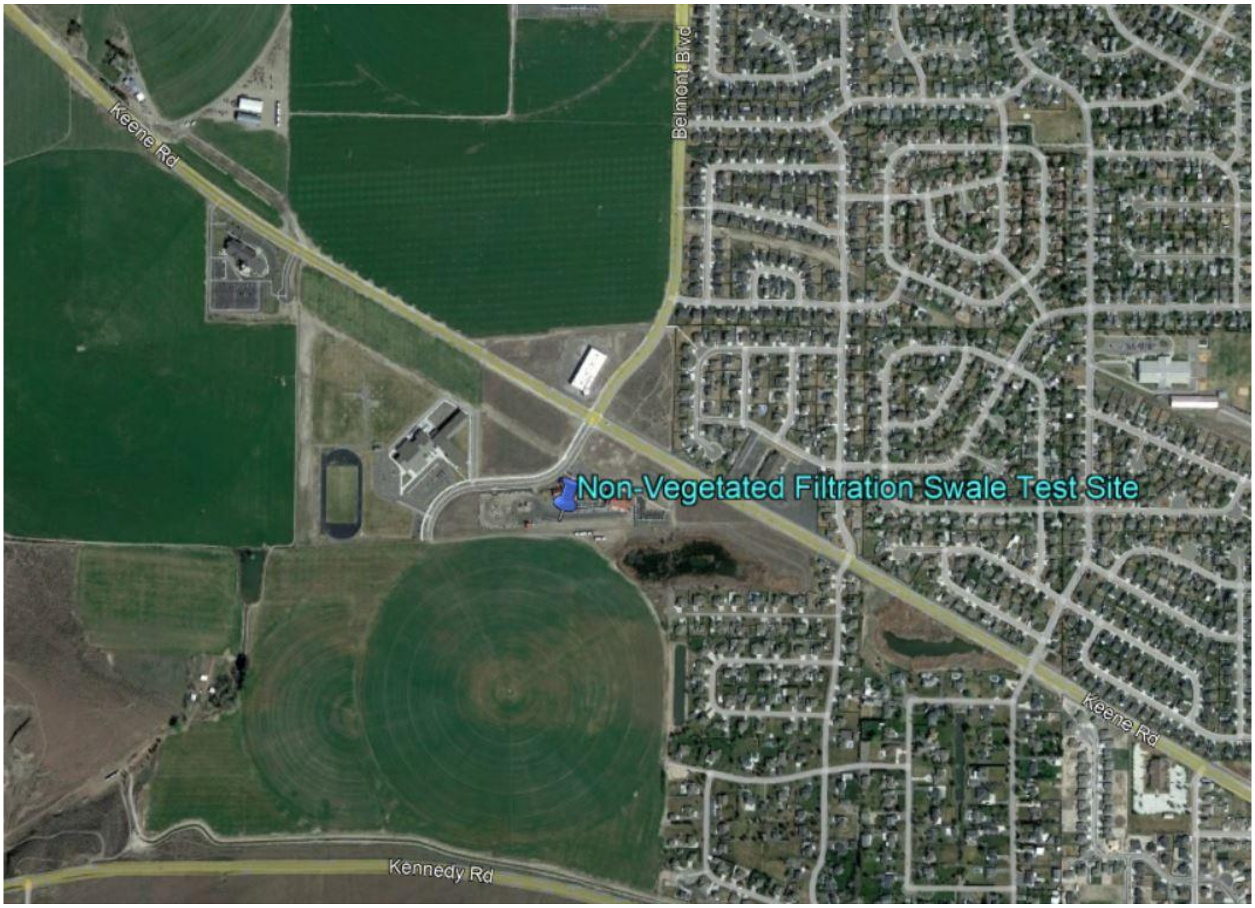


Figure 4.1 Test Site Aerial View

4.4 Data Needed to Meet Objectives

The data needed to conduct this study is summarized in Table 4.1.

Table 4.1 Data Needed to Meet Objectives

Data Type	How Data Will Be Collected	Purpose
Influent Flow Rate	Flow meter located between pump (upstream) and outlet of piping to swale (downstream).	Verify flow rate entering the swale matches the water quality design flow rate for the swale (Section 7.3).
Water Quality Grab Samples	Collect grab samples from sample ports at 25-foot intervals along the 200-foot-long swale during simulated storm events and analyze for TSS	Quantify removal of TSS at different locations in the swale; use to determine whether the basic treatment performance goal is met and that length of swale needed to achieve this
Effluent Velocity	Two piezometers, one located at the upstream end and one at the downstream end, will be used to measure depth and using Darcy's Law (Section 7.4) calculate velocity.	Estimate the velocity of water flowing through the swale; calculate the design flow rate in the swale; and verify Manning's n to include in the final design guidelines

4.5 Tasks Required to Conduct Study

Tasks required to conduct the study include:

- Technical Advisory Committee (TAC) Meetings
  - Schedule and facilitate 4 meetings with the TAC for the purpose of discussing the project status, upcoming tasks, and soliciting input from the TAC on study documents
- Develop Swale Design
  - Developed draft swale design & maintenance guidelines
    - Respond to Ecology comments on draft swale design & maintenance guidelines
- Develop QAPP
  - Develop combined draft detailed study design proposal and QAPP
    - Respond to Ecology and TAC Comments on combined draft detailed study design proposal and QAPP
  - Develop a draft construction package, including construction drawings and specifications for the study.
    - Respond to Ecology Comments on Draft construction package
- Construct Test Site
  - Provide construction oversight to confirm equipment and materials are installed as discussed in the specifications.
  - Develop a detailed construction quality assurance plan (CQAP) before the start of construction, including development of:
    - A Stormwater Pollution Prevention Plan (SWPPP)
    - A plan for construction staging and sequencing
    - A plan for restoration of the biofiltration swale to original design grades
  - Organize and facilitate one pre-Construction Conference Meeting; develop minutes from the meeting.
  - Develop a construction project schedule.
  - Develop eligible change orders (if needed) for items that deviate from Ecology-accepted plans and specifications.
  - Select and order construction materials and equipment necessary to retrofit the biofiltration swale, as well as equipment needed to construct the stormwater distribution system and sample ports. This includes development of an itemized list of construction materials and equipment needed.
  - Take photographs of the site prior to, during, and after construction to show the test setup.
  - Prepare record construction drawings, which will consist of redline corrections to the plan sheets submitted with the QAPP.
  - Following completion of the study, return the test site and swale to existing conditions.
- Data Collection & Analysis
  - Prepare a synthetic stormwater solution for each simulated event and distribute the solution to the swale.

    - Measure influent flow rate and flow depth in the swale (to calculate velocity and flow rate in the treatment rock layer).
    - Collect water quality samples at the influent (one sample) and at eight additional locations every 25-feet along the swale (9 samples total per event) and deliver to the Ecology-accredited lab for the study. Six events will be simulated at each swale.
    - Perform audits to confirm standard operating procedures for data collection are being followed.
    - Analyze water quality data for normality, pollutant removal efficiency, hypothesis testing, confidence interval testing using the bootstrapping method, a regression analysis, and maintenance frequency estimation.
    - Analyze flow rate data to determine allowable velocities in the swale and verify the Manning's n values included in the design guidelines.
    - Summarize results of the data analysis into tables and graphs.
- Reporting
    - Develop study fact sheet, technical evaluation report (TER), and study summary for annual reports
    - Upload Data to International BMP Database
    - Develop finalized swale design & maintenance guidelines
    - Submit TER to Ecology 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 Table 4.3, 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
Equipment malfunction	Inspections of equipment and verification that equipment is functioning properly will occur before each simulated storm event. If problems are encountered, equipment will be fixed or replaced promptly.
Uneven distribution of flow to the swale	Use a flow meter to measure influent flows; verify that the flow rate measurement is consistent according to procedures outlined in Section 8.1.
Influent TSS concentration is fairly consistent and meets the target values	Use a submergible pump to recirculate the solution in tank to prevent TSS from settling.
Vandalism of the test site	The test site is on the City of West Richland property which is not open to the public.
Inability to provide adequate water at upstream end of swale to meet the Water Quality Design Flow Rate for the swale	Change size of swale, or provide larger pump or water storage facility

5.0 Organization and Schedule

The purpose of this section is to describe 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

Key Team Members	Role	Contact Information
Drew Woodruff City of West Richland	Lead Entity PM[1] TAC Member[2]	509-967-5434 drew@westrichland.org
Martin Nelson City of Kennewick	Contributing Entity[3] TAC Member[2]	509-585-4306 martin.nelson@ci.kennewick.wa.us
Brian Pope City of Richland	Contributing Entity[3] TAC Member[2]	509-942-7508 bpope@ci.richland.wa.us
Michael Henao City of Pasco	Contributing Entity[3] TAC Member[2]	509-545-3454 henaom@pasco-wa.gov
Brian Morgenroth City of Walla Walla	Contributing Entity[3] TAC Member[2]	509-534-4559 bmorgenroth@wallawalla.gov
Doug Howie	Ecology Reviewer[4]	360-407-6444 douglas.howie@ecy.wa.gov
Brandi Lubliner	Ecology Reviewer[4]	360-407-7140 brandi.lubliner@ecy.wa.gov
Andrea Jedel	Ecology Reviewer[4]	509-961-0625 andrea.jedel@ecy.wa.gov
Chuck Geissel Walla Walla County	Contributing Entity[3] TAC Member[2]	509-524-2729 cgeissel@co.walla-walla.wa.us
Seth Walker Walla Walla County	Contributing Entity[3] TAC Member[2]	509-524-2710 swalker@co.walla-walla.wa.us
Joy Bader Walla Walla County	Contributing Entity[3] TAC Member[2]	509-524-2733 jbader@co.walla-walla.wa.us
Shilo Sprouse City of Pullman	TAC Member[2]	509-432-9052 shilo-sprouse@pullman-wa.gov
Kristin Lowell City of Coeur d'Alene	TAC Member[2]	208-769-1422 kristin.lowell@deq.idaho.gov
Jamie Brunner City of Coeur d'Alene	TAC Member[2]	208-666-4623 jamie.brunner@deq.idaho.gov
Aimee Navickis-Brasch, PhD, PE Evergreen StormH2O LLC	Principal Investigator[5]	509-995-0557 aimeen@evergreenstormh2o.com
Taylor Hoffman-Ballard Evergreen StormH2O LLC	Researcher[6]	952-836-7863 taylor@evergreenstormh2o.com
Mark Maurer Evergreen StormH2O LLC	QA/QC Lead[7]	360-790-6421 mark@evergreenstormh2o.com

[1]Lead Entity Project Manager: Responsible for ensuring the study is conducted as described in the QAPP. The Project Manager is the primary point of contact for the lead entity.

[2]Technical Advisory Committee (TAC) Member: the goal the TAC is to provide insight, suggestions, and professional opinions to the Principal Investigator throughout the study. The primary responsibilities of TAC members include attending up to six project meetings (by webinar

or in person) and participating in the meeting discussion; review and provide comment on research materials (i.e., QAPP, data collected, data analyzed, final report, etc.) prior to the lead entity submitting the documents to Ecology. Members of the TAC may also serve as an auditor to verify the study conforms to the plan and procedures as defined in the QAPP and/or a data verifier who reviews the analyzed data and verifies the analysis is correct and that the data being analyzed matches the data collected.

[3]Contributing Entity: Roles of the contributing entity include Financial Support, Reviewer, Advisory Board Lead/Member, QAPP Author, Data Collector, Data Verifier, Auditor, Final Report Author, TAC Member.

[4] Ecology Reviewer: Responsible for reviewing and approving the study documents: the design and maintenance guidelines, QAPP, and Final Report.

[5] Principal Investigator: Responsible for developing all project technical documents including the Ecology approved Detailed Study Design Proposal, Quality Assurance Project plan (QAPP), technical Evaluation Report (TER), and Fact Sheet; conducting the study; and uploading the data from the study to International BMP Database.

[6] Researcher: Responsible for assisting the Principal Investigator.

[7] QA/QC Lead: Responsible for performing quality assurance and quality control (QA/QC) reviews as noted in this QAPP.

5.2 Project Schedule

A task timeline based on monthly activities proposed in Table 5.2. Red boxes indicate where TAC and/or Ecology review periods. Dates may vary and are not compliance dates. Minor date changes, such as delays up to month timeframe will be communicated to Ecology via quarterly reports. Significant delays, 2 months or greater, will be communicated to Ecology directly and may result in a need for a QAPP addendum if field testing is impacted.

Table 5.2 Proposed Study Timeline

Calendar Year	2022												2023				
Task and Deliverables	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
1. Project Administration & Management																	
D1.1 Progress Reports (Consultant to City)[1]		2/15	3/15	4/15	5/15	6/15	7/15	8/15	9/15	10/15	11/15	12/15	1/15	2/15	3/15	4/15	5/15
D1.1 Progress Reports (City to Ecology)[1]				4/29			7/29			10/28			1/30				5/30
D1.2 Closeout Report																4/30	
D1.3 Outcome Summary Report																4/30	
2. Project Coordination																	
D2.1 Final Project Schedule		2/4															
D2.2 List of TAC Members; Roles & Responsibilities		2/4															
D2.3 Cultural Resource Review Form																	
D2.4 Inadvertent Discovery Plan		2/11															
D2.5 List of Permits Required			3/31														
D2.6 TAC Meeting #1: Agenda		2/17															
D2.6 TAC Meeting #1: TAC Meeting/Notes		3/3															
D2.6 TAC Meeting #1: Comment Responses		3/10															
D2.7 TAC Meeting #2: Agenda					5/10												
D2.7 TAC Meeting #2: TAC Meeting/Notes					5/24												
D2.7 TAC Meeting #2: Comment Responses					5/31												
D2.8 TAC Meeting #3: Agenda												11/30					
D2.8 TAC Meeting #3: TAC Meeting/Notes												12/14					
D2.8 TAC Meeting #3: Comment Responses												12/21					
D2.9 TAC Meeting #4: Agenda															3/10		
D2.9 TAC Meeting #4: TAC Meeting/Notes															3/24		
D2.9 TAC Meeting #4: Comment Responses															3/31		
3. Develop Study Design																	
D3.1 Draft Filtration Swale Design & Maintenance Guidelines		2/17															
D3.1 Ecology & TAC Review Period		2/17-3/19															
D3.2 Response to Ecology & TAC Comments			4/1														
D3.3 Ecology Filtration Swale Design & Acceptance Letter			4/15														
D3.4 Final Filtration Swale Design & Maintenance Guidelines			4/15														
4. Develop QAPP																	
D4.1 Draft QAPP				4/29													

Calendar Year	2022												2023				
Task and Deliverables	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
D4.1 Ecology & TAC Review Period					4/30-5/30												
D4.2 Responses to Ecology & TAC Comments on D4.1						6/14											
D4.3 Final Ecology Signed QAPP[2]						6/14											
D4.4 Draft Construction Package				4/29													
D4.5 Responses to Ecology Construction Package Comments						6/14											
D4.6 Ecology Construction Package Acceptance Letter						6/30											
D4.7 Final Construction Package						6/30											
5. Construct Test Site																	
D5.1 Construction Quality Assurance Plan							7/29										
D5.2 Pre-Construction Conference Meeting Minutes							7/29										
D5.3 Construction Project Schedule							7/29										
D5.4 Change Orders										10/31							
D5.5 Biofiltration Swale Construction Materials & Equipment										10/31							
D5.6 Photographs of Construction Site										10/31							
D5.7 Construction Design Record and Oversight Notes										10/31							
6. Data Collection & Analysis																	
D6.1 Audit Forms											11/30						
D6.2 Lab sample results											11/30						
D6.3 Summarize Results, Tables and Graphs of Data/Results											11/30						
7. Reporting																	
D7.1 Draft Fact Sheet														D2/28			
D7.1 Draft Fact Sheet Ecology & TAC Review Period															3/1-14		
D7.2 Final Fact Sheet[2]; Respond to TAC/Ecology Comments																F3/21	
D7.3 Draft TER														D2/28			
D7.3 Draft TER Ecology & TAC Review Period															3/1-31		
D7.4 Final TER[2]; Respond to TAC/Ecology Comments																F4/14	
D7.5 Upload Data to International BMP Database																F4/28	

[1] Invoices and progress reports will be submitted monthly starting in February 2022 and ending in May 2023.
[2] Deliverables will be uploaded to PARIS, in addition to EAGL, for permit compliance.

5.3 Budget and Funding Sources

This study is funded by an Ecology GROSS Grant.

Table 5.3 Summary of Fees by Task

Task #	Task Name	City of West Richland	OCI	Total Fees
1	Task 1: Grant Administration & Management	$17,715	$9,850	$27,565
2	Task 2: Project Coordination	$3,200	$34,673	$37,873
3	Task 3: Develop Swale Design	$2,200	$14,628	$16,828
4	Task 4: Develop QAPP	$5,800	$35,753	$41,553
5	Task 5: Construct Test Site	$35,716	$16,742	$52,458
6	Task 6: Data Collection & Analysis	$9,552	$61,159	$70,711
7	Task 7: Reporting	$6,800	$38,957	$45,757
	Project Total:	**$80,983**	**$211,762**	**$292,745**

6.0 Quality Objectives

This section of the QAPP provides a roadmap of the quality assurance (QA) and quality control (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 QA and 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 (Table 6.1).

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 Structural 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

Data Quality Indicator (DQI)	Potential Approaches for Addressing DQI in Studies	Potential Approaches for Writing Measurement Performance Criteria (MPCs)
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, Weiss, & Gulliver, 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).	Staff will verify that influent flow meter is working properly prior to beginning each synthetic storm event.	The influent flow meter reading will be verified prior to each storm event according to the SOPs outlined in Section 8.1.
	Manufacturers' recommendations for equipment and/or instrument maintenance will be followed.	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). Data will be considered acceptable if the sampling staff are consistently following the SOPs.
	SOPs will be developed and consistently followed for collecting samples and measuring data	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.1. Data will be considered acceptable if the sampling staff are consistently following the SOPs.
	Laboratory method blanks and lab standards will be analyzed to check for bias.	Sample results will be accepted if the results of the method blanks and lab standard analyses are below the limits in Section 6.2 and Table 6.2.
Precision – A measure of agreement among repeated measurements of the same property taken under identical or substantially similar conditions (EPA, 2002a; EPA, 2006; Erickson, Weiss, & Gulliver, 2013). Data is considered precise when the measured values are consistently the same and imprecise when the measured values are consistently different (Erickson, Weiss, & Gulliver, 2013). Random error is a common cause of imprecise data and is always present because of	SOPs will be developed and consistently followed for collecting samples and measuring 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.
	Laboratory analytical duplicates will be reviewed to check that analyzed data is consistent.	If the results of the laboratory duplicates meet the relative percent difference (RPD) listed in Table 6.2, the results of the analytical testing will be considered acceptable. Reference Section 6.1.

Data Quality Indicator (DQI)	Potential Approaches for Addressing DQI in Studies	Potential Approaches for Writing Measurement Performance Criteria (MPCs)
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).	Staff will verify that influent flow meter is providing consistent flow measurements prior to beginning each synthetic storm event.	The influent flow meter reading will be verified prior to each storm event according to the SOPs outlined in Section 8.1. Data will be considered acceptable if readings are consistent.
Representativeness – A qualitative term that expresses the degree to which the data accurately and precisely represents the conditions being evaluated (EPA, 2002a). 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 representative of a typical location where a non-vegetated filtration swale could be installed. The non-vegetated filtration swales will be installed in an existing swale, which is not currently irrigated, behind the City of West Richland Municipal Services Building and adjacent to a parking lot.	These conditions reflect the characteristics of a location where a non-vegetated filtration swale would be installed: a semi-arid location or area where irrigation is not desired for part of the year; where basic treatment is required; and along a parking lot or roadway.
	Hydrologic conditions tested at the site should be representative of the water quality design event.	Hydrologic conditions will be considered acceptable if the peak flow rate for which the non-vegetated swale is designed is matched.
	Water quality samples should be collected to accurately represent conditions in the rock treatment layer.	The sampling design was developed to limit settling of TSS where samples are collected, thereby representing typical TSS removal by a non-vegetated filtration swale.
	Equipment at the site will be installed per manufacturer specifications.	Data will be considered acceptable if equipment at the site will be installed per manufacturer specifications.
Completeness - The amount of valid data needed to be obtained during the study to meet the project objectives (Lombard & Kirchmer, 2004).	Nine samples (one influent and eight effluent spaced 25-feet along the length of the swale) will be collected for 6 sample events for each swale design described in Section 3.3.	The data will be considered acceptable if less than 10% is missing or invalid. At least 5 of 6 samples at any sample location will need to be valid to determine whether treatment performance goals are being met.
	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 laboratory duplicates, method blanks, and lab standards, and results which are valid. Additionally, the samples must be received and analyzed within the appropriate holding times.

Data Quality Indicator (DQI)	Potential Approaches for Addressing DQI in Studies	Potential Approaches for Writing Measurement Performance Criteria (MPCs)
	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 completeness of the data set.
	Conduct maintenance for and verify equipment is working properly 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). Data will be considered acceptable if the sampling staff are consistently following the SOPs.
	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.	The data will be considered acceptable if less than 10% is missing or invalid.
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 are 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 an existing swale, which is not currently irrigated, located behind the City of West Richland Municipal Services Building.	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 non-vegetated filtration swale will be installed.
	SOPs will be developed, and 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 (written to match manufacturer's specifications). Data will be considered acceptable if the sampling staff are consistently following the SOPs.
	Standard testing methods will be used to analyze samples submitted to the lab.	SM 2540D will be used to conduct analysis of samples for TSS.
Sensitivity - denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense,	Analytical results for water quality samples will be reported if they are above the reporting limit.	Reporting limits for TSS is listed in Table 6.2. Data reported as below the detection limit will be calculated using the reporting limit shown in Table 9.1

Data Quality Indicator (DQI)	Potential Approaches for Addressing DQI in Studies	Potential Approaches for Writing Measurement Performance Criteria (MPCs)
it has the same meaning as the detection limit (EPA, 2002a). The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.	All water quality testing methods selected have detection limits below 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 equipment specifications in Appendix E.

6.1 Precision

Water quality sample and measurement precision will be assessed using laboratory duplicates. Precision for laboratory duplicates will be ±5% for TSS (Table 6.2).

6.2 Bias

Bias will be assessed based on analyses of lab standard analyses and method blanks. The lab standard analysis consists of testing the method and equipment on a lab standard (Mid-Level Solids CRM) with a known concentration, which is provided by a third party. The third party provides documentation with the lab standard which includes the known concentration and the range of allowable results. The lab standard analyses performed by the lab must give a result within the specified range. The method blank limit will be 1 mg/L for TSS.

6.3 Representativeness

Representativeness is the degree that the data accurately describe the conditions being evaluated based on the selected sampling locations, sample frequency, and sampling methods. The BMP location selected for the study is representative of an area that would preclude the use of a non-vegetated filtration swale, specifically in a semi-arid area and adjacent to a parking lot (Section 7.2). Due to the infrequent nature of storm events in the Quad-Cities area, a synthetic stormwater solution will be used to stimulate rainfall events with peak flow rates consistent with Washington water quality design flow rates. The synthetic stormwater solution will meet the Washington State TAPE influent criteria for basic treatment. Field and laboratory methods will have measurement ranges and reporting limits adequate to evaluate achievement of TAPE treatment performance goals (Ecology, 2011).

Table 6.2 Measurement Performance Criteria (MPC) for Water Quality

Total Suspended Solids (TSS)	
Units	mg/L
Method	SM 2540 D
RL	1 mg/L
Method Blank Limit	1 mg/L
Laboratory Standard Analysis	Acceptable Range Defined by Lab Standard Documentation
Laboratory Duplicate	±5%

7.0 Experimental Design

7.1 Study Design Overview

The goal of the study is to evaluate whether a non-vegetated filtration swale design (Section 3.1) can provide basic treatment (80% reduction of TSS) in accordance with Ecology treatment performance goals (Ecology, 2011). The intent of the project design is to meet the study goal and objectives. As described in Section 4.2, the study will develop draft and final design and maintenance guidance; determine the TSS removal efficiency of the BMP along the length of the swale and estimate the length needed to achieve 80% reduction of TSS; determine the design flow rate and velocity at which the measured TSS concentrations and pollutant removals are achieved; and determine whether the treatment performance goals were achieved by the BMP. The draft design and maintenance guidance were developed and reviewed by Ecology prior to the development of this document (see Appendix A) and will be refined following field testing and development of the TER. The following paragraphs describe the study design and how the remaining objectives will be met.

The test site is located behind the City of West Richland Municipal Services building. There is an existing 430-foot-long swale at the site which is located adjacent to a gravel parking lot. The swale will be re-graded into two 200-foot-long swales sloped at 1%. An impermeable liner will be placed on the bottom of each swale, and a catch basin or similar structure will be installed at the outlet of each swale to collect runoff. A total of 4 swale design alternatives, each consisting of a different combination of treatment rock layer, will be tested and include the alternatives described previously in Section 3.3.1. Two swale design alternatives will be installed at a time and following testing, the swales will be replaced with the remaining two design alternatives. After the 4 swale design alternatives are tested, the highest-performing alternative will be re-installed to verify performance without a liner and assess maintenance frequency. Maintenance frequency will be assessed by comparing water quality samples collected before and after annual loads of TSS are delivered to the swale, as described in this section and in Section 7.5. Appendix E includes a plan and profile view of the test site showing two swale alternatives within the footprint of the 430-foot-long swale. The site will be returned to its original condition following testing of the highest-performing alternative.

To test the swale design alternatives, controlled field experiments will be conducted. Synthetic stormwater will be created in a large tank and distributed to one swale at a time. The synthetic stormwater will contain tap water and SilCoSil 106, a laboratory standard for TSS, and will be mixed continuously to ensure the SilCoSil remains suspended. The tank and mixer are designed to maintain constant influent concentrations, and testing will be performed prior to conducting a simulated event at the site to confirm the influent remains consistent as the tank is emptied. Specifically, a batch of synthetic stormwater will be created in the tank while the mixer is running. The tank will be emptied, and grab samples will be collected at even intervals along the length of the swale and sent to a lab for analysis. A difference of 10% between samples will be targeted; if there is a larger variation between samples, the system will be modified to improve mixing of the synthetic stormwater.

The synthetic stormwater will be used in simulated storm events, which were designed to meet study objectives including measuring TSS concentrations at the influent and effluent locations, as well as informing the final maintenance guidance. A total of six simulated storm events will be conducted for each swale design alternative. Simulated storm events will be split into two phases (Section 7.5): 1) run the simulated event with a flow equivalent to the water quality event and collect samples to measure TSS concentrations and 2) deliver an approximate annual load of TSS to the swale, also at the water quality flow rate (to limit changes to the influent synthetic stormwater distribution system), to simulate one year having passed between simulated storm events. Nine grab samples will be collected during Phase 1 of each simulated storm event with one collected before the influent enters the swale and the other eight from sample locations in the swale. The samples will be sent to an analytical laboratory to be tested for TSS and the results will be used to evaluate treatment performance. An estimated annual load of TSS will be delivered to the swale during Phase 2. Following Phase 2, the next simulated storm event will begin with Phase 1, and the process will be repeated until six simulated storm events have been performed. The following paragraphs describe what will occur during the simulated storm events in more detail.

During the Phase 1 of a simulated storm event, the synthetic stormwater will be pumped from the tank to one of the two swales at the water quality design flow rate (Section 7.3), which will be measured using an inline flow meter (see Figure 7.1). Flow will enter the swale from a pipe. The synthetic stormwater will then flow through the treatment rock layer, allowing TSS to be filtered and settle out. As the synthetic stormwater flows through the swale, it will enter sample ports that are flush with the bottom of the swale and are located at 25-foot intervals. The sample ports contain automatic grab samplers designed by Nalgene (Appendix E). The automatic grab samplers fill as water flows over the top of the sampler, and when the sampler is filled, a float valve in the sampler prevents flow from continuing to enter the sampler. The samplers do not require power to operate. The sample ports consist of a PVC pipe installed belowground to house the automatic grab samplers and a wire mesh cylinder supported by rebar stakes aboveground, to keep rock out of the sample port and allow the samplers to be retrieved following each simulated storm event. Flow not collected by the automatic grab samplers continues to a catch basin at the end of the swale. A vactor truck or sump pump directing flow to a water truck will be located at the catch basin during the test to collect synthetic stormwater so flow does not enter the adjacent swale. Appendix D.1 contains detail drawings of the inlet, outlet, and sample ports.

Velocity through the treatment rock layer will also be estimated during Phase 1. Piezometers will be installed at the upstream and downstream ends of each swale and depth will be measured at both locations using a water level meter once the influent flow rate is the same as the water quality design flow rate. The depths will be used to calculate velocity using Darcy's Law (Section 7.4). The velocity will be used to define the design flow rate and velocity for which the BMP provides treatment.

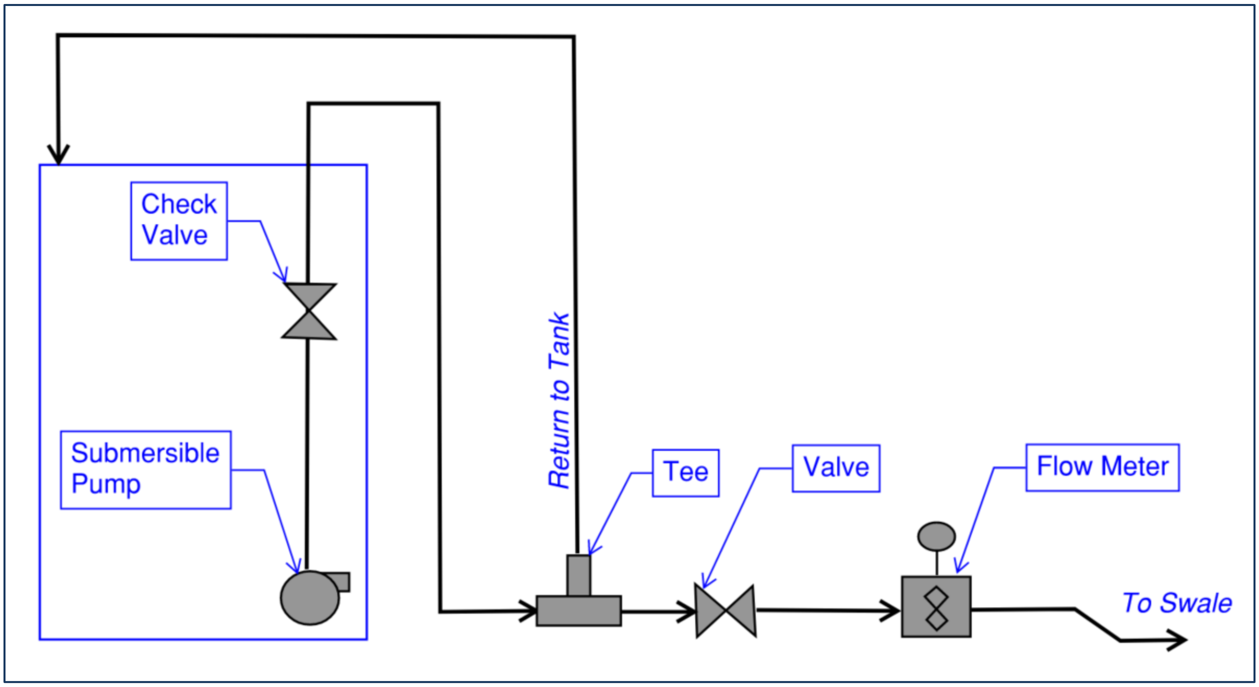


Figure 7.1 Influent Synthetic Stormwater Distribution System

During Phase 2 of a simulated storm event, synthetic stormwater will be pumped from a tank to the same swale at the water quality design flow rate, to limit adjustments to the influent distribution system. The synthetic stormwater created for Phase 2 will contain an estimated annual load of TSS in the same volume of water delivered during Phase 1. The sample ports will be closed prior to the start of Phase 2 using PVC caps so TSS from the loading portion of the simulated event does not enter the sample port. Water will be pumped from the tank until the tank is emptied. A vactor truck or sump pump will be used to collect runoff that discharges into a catch basin (at the end of the swale) and pump it to a water truck. Water collected in the vactor truck or water truck will be disposed in a manner that does not impact surface waters and is allowed to infiltrate. Because the purpose of Phase 2 is to simulate that annual loading of TSS expected to the swale, no flow or sample data will be collected during Phase 2.

The water quality data collected during the study will be evaluated to determine whether the swale design alternatives meet Ecology treatment performance goals for basic treatment (TSS), and the length of swale required to achieve basic treatment. Specifically, the length of the swale will be based on the distance from the inlet that TSS concentrations or removal percentages meet TAPE treatment performance goals (Section 14.1). If one of the swale design alternatives meets Ecology treatment performance goals, the final technical evaluation report for the study will recommend that the non-vegetated filtration swale be approved for inclusion in the SWMMEW and SWMMWW. If more than one swale design alternative meets the Ecology treatment performance goals, the performance, cost, and maintenance needs of both swales will be evaluated and reviewed with Ecology and the TAC , to determine the best alternative Ecology consideration. Maintenance of the swale, including frequency that sediment will need to be removed from the rock or when the rock will need to be replaced, will be determined through visual observation and comparison of sample results at the same location over six simulated storm events. The performance, cost, and maintenance needs of the remaining swale alternatives which did not meet treatment performance goals will also be reported in the final technical evaluation report for reference.

The final report and a fact sheet summarizing the study will also be submitted to Ecology at the end of the study to meet the MS4 Permit requirements for an effectiveness study. The design guidance will be finalized for the non-vegetated filtration swale and included with the final report. Annual reports will be developed and included in the City's annual stormwater report.

7.2 Test-Site(s) Selection Process

The proposed test site is located on the south side of the City of West Richland Municipal Services building. The test site includes an existing 430-foot-long swale and gravel parking lot. This site was selected because of the presence of the existing swale which was available to retrofit and because there is space available to run the simulated storm events. The site is owned and operated by the City of West Richland, which ensures access to the site and limits barriers to construction and operation of the test site. Additionally, the site was selected because of the semi-arid climate of the region. Summer months tend to be hot and dry and less than 10 inches of rain are received annually. Irrigation is therefore less desirable, as water is less readily available. As such, the site is representative of a typical location where a non-vegetated filtration swale would be installed.

7.3 The Structural BMP System Sizing

The non-vegetated filtration swale design is based on the design guidance for a biofiltration swale BMP in the SWMMEW (Ecology, 2019) and HRM (WSDOT, 2022). The design and maintenance guidance developed for the non-vegetated filtration swale is included in Appendix A. A non-vegetated filtration swale is sized to provide runoff treatment for the water quality design flow rate. The swale is sized to contain the flow in the treatment rock layer during the water quality event, while larger flows are conveyed through and above the rock. The methods and assumptions for sizing the BMP include:

- The BMP was sized for the Rational Method and 2-year, 24-hour storm as defined in the SWMMEW (Ecology, 2019)
- The swale bottom width is sized using Manning's equation.
- The Manning's n value for the water quality design flow through the treatment rock layer is 0.4. For larger events which produce flow above the treatment rock layer, a value of 0.036 is used. The Manning's n values will be verified during field testing.
- The maximum allowable flow depth in the swale is 7.5 inches (thickness of treatment rock layer). The effective depth in the swale is the allowable flow depth divided by the porosity of the treatment rock layer. This corresponds to the depth of flow if the treatment rock layer was not present and is equal to an effective depth of 3 inches for an assumed porosity of 40%. The swale bottom width is calculated based on the maximum effective depth of 3 inches.
- The maximum allowed velocity in the treatment rock layer is 1ft/s. The maximum allowed velocity above the treatment rock layer is 1.8 ft/s for swales with slopes of 1% to 2.5% and 2.5 ft/s for swales with slopes of 2.5% to 5%.
- Because this study will be conducted using controlled field experiments to test swale design alternative performance, the water quality design flow rate was calculated using Manning's

Equation, based on the assumption that the depth of flow would match the depth of the treatment rock layer and based on the dimensions which fit at the test site (swale bottom width of 2 feet and longitudinal slope of 1%). The water quality design flow rate was then used to back calculate the contributing basin area using the rational method equation and coefficients for Pasco and Kennewick as outlined in the WSDOT Hydraulic Manual (WSDOT, 2022). This contributing area was used to calculate TSS loading assuming a 100 mg/L concentration to the swale and the 25-yr flow rate to the swale. Table 7.1 contains a summary of the swale design, which is also shown in the plan sheets in Appendix D. The sizing calculations for the swale at the test site are contained in Appendix C.

Table 7.1 Summary of Test Site Swale Design

Swale Design Element	Value
Contributing Area	0.095 ac
Estimated TSS Loading	1.6 lbs per water quality event
Water Quality Design Flow Rate	0.101 cfs
Bottom Width	2’
Longitudinal Slope	1%
Side Slope	3:1
Stabilization Rock Layer Used	1.25” Coarse Gravel

Note: As described in Section 7.1, the existing swale at the site will be split into two, 200-foot-long swales for testing. The swale design in this table will be applied to each 200-foot-long swale at the site.

The swale is designed to limit the movement of rock for flow events up to the 25-year event. The movement of rock is expected to occur if the critical shear stress is exceeded, as shown on Table E.1 (Figure 7.2) from the United States Forest Service Stream Simulation Publication (Forest Service Stream-Simulation Working Group, 2008). During development of the design and maintenance guidance (Appendix A), the Federal Highway Administration’s (FWHA) Hydraulic Toolbox software was used to calculate the maximum shear stress values expected for worst-case swale configurations during the 25-year event. Using the maximum shear stress values, the 1.25” coarse gravel and 2.5” coarse gravel outlined in Section 3.3 were selected in order to limit rock movement for different longitudinal slope ranges (1% to 2.5% and 2.5% to 5%, respectively). The swale design alternatives utilize these gradations in the stabilization rock layer, which is placed on top of the 7.5-inch treatment rock layer depth (except for swale design alternative #1, see Section 3.3), to protect the treatment rock layer from erosion by flow events up to the 25-yr event. The swale installed at the test site was designed with a 1% longitudinal slope. As such, the 1.25” coarse gravel will be installed as the stabilization layer for each swale design alternative at the site.

Table E.1—Shield's parameter for different particle sizes. Modified from Julien 1995

Particle size classification	*Particle size, D (mm)*	*Angle of repose, ϕ (degrees)*	*Shield's parameter, τ^**	*Critical shear stress, τ_c (lb/ft^2)*
very large boulders	*> 2,048*	*42*	*0.054*	*37.37*
large boulders	*1,024-2,048*	*42*	*0.054*	*18.68*
medium boulders	*512-1,024*	*42*	*0.054*	*9.34*
small boulders	*256-512*	*42*	*0.054*	*4.67*
large cobbles	*128-256*	*42*	*0.054*	*2.34*
small cobbles	*64-128*	*41*	*0.052*	*1.13*
very coarse gravels	*32-64*	*40*	*0.050*	*0.54*
coarse gravels	*16-32*	*38*	*0.047*	*0.25*
medium gravels	*8-16*	*36*	*0.044*	*0.12*
fine gravels	*4-8*	*35*	*0.042*	*0.057*
very fine gravels	*2-4*	*33*	*0.039*	*0.026*

The equation used to determine the Shields parameter for gravels, cobbles, and boulders is $\tau^* = 0.06 \tan\phi$.

The Shield's parameter and critical shear stress values are for the smallest number in the particle-size interval.

Figure 7.2 Table E.1 from Appendix E Methods of Streambed Mobility/Stability Analysis

7.4 Type of Data Being Collected

This section identifies the various types of data that will be collected and defines the intended purpose for each type of data. Table 7.2 provides a summary of the type of data that will be collected along with the frequency of the data collection.

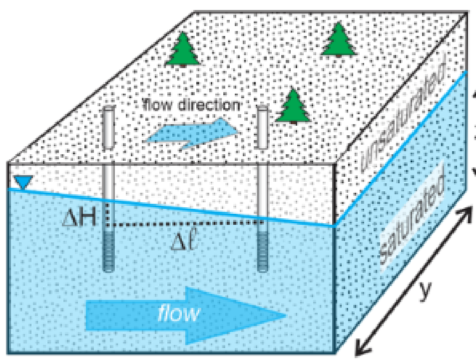
Table 7.2 Summary of Data to be Collected

Parameter	Frequency	Sampling Method and Sampling Location
Influent flow rate	Recorded three times during each simulated storm event (6 events per swale design alternative)	In-line flow meter; between pump and inlet to swale
TSS concentration	Once per simulated storm event	Grab sample; At influent and eight effluent locations in the swale spaced 25 feet apart
Depth of flow (for velocity)	Recorded three times each simulated storm event	Water level meter; Piezometers located at upstream and downstream end of each swale

The study is expected to take place during the dry season in 2022 in order to perform simulated rain events without interference from natural precipitation. Grab samples will be collected from the influent and at eight locations spaced every 25 feet in the swale. The effluent samples will be used to provide an estimate of pollutant removal as the synthetic stormwater travels through the swale and ultimately determine the length required to meet treatment goals. Grab samples will be analyzed for TSS at an analytical laboratory to assess whether Ecology treatment performance goals were met.

Influent flow rate data will be used to confirm that the flow rate entering the swale is consistent with the water quality design flow rate for the swale at the test site. The flow rate will be measured using an in-line flow meter (Appendix E) located in the pipe between the pump at the synthetic stormwater tank and the inlet to the swale. The influent flow meter readings should be verified prior to each synthetic storm event (procedures described in Section 8.1).

The velocity through the treatment rock layer will be calculated using water level data collected during simulated storm events. Water level will be measured at two piezometers installed at the upstream and downstream ends of the swale using a tape water level meter (Appendix E). The velocity will be calculated from the water level data using equations developed from Darcy's Law (Figure 7.3). These equations will be used as they provide flow through a horizontal, saturated rock or soil system, which is expected to match the conditions in the treatment rock layer. Additionally, these equations provide the velocity in situ (in the treatment rock layer). Figure 7.3 includes a conceptual figure and equations.



$$Q = -KA\frac{\Delta H}{\Delta \ell} \quad (1) \text{ Total discharge}$$

$$q = -K\frac{\Delta H}{\Delta \ell} \quad (2) \text{ Specific discharge (Darcy flux)}$$

$$v = -\frac{K}{n_e}\frac{\Delta H}{\Delta \ell} \quad (3) \text{ Seepage velocity (average linear velocity)}$$

$Q = total\ discharge\ (L^3T^{-1})$, $q = specific\ discharge\ (LT^{-1})$,

$K = hydraulic\ conductivity\ (LT^{-1})$, $A = cross - sectional\ area\ (L^2)$,

$\ell = distance\ in\ direction\ of\ flow\ (L)$, $H = hydraulic\ head\ (L)$,

$n_e (= effective\ porosity\ dimensionless)$

Figure 7.3 Darcy's Law Equations for Groundwater Flow (Devlin, 2020)

The Darcy's Law equations shown in Figure 7.3 will be rearranged to solve for velocity and are included following this paragraph. The hydraulic head will be estimated from depths measured in the piezometers in the swale plus the change in elevation due to the slope of the swale over the length of the swale (200 feet). Because total discharge flow and cross-sectional area will be known during testing, the measured hydraulic head can be used to solve for hydraulic conductivity, K. The effective porosity can be estimated in the field by filling a known volume of rock with a measured volume of water or may be obtained from specifications for the rock. Seepage velocity, or the velocity through the rock can be calculated once K and porosity are known. The equations arranged to solve for hydraulic conductivity and seepage velocity are shown below.

$$K = \frac{Q}{A} * \frac{\Delta l}{\Delta H}$$

Where:

Q	=	flow rate entering the swale
A	=	cross-sectional area of the treatment rock layer.
Δl	=	distance between the two piezometers
ΔH	=	change in water elevation between the two piezometers
K	=	hydraulic conductivity of the treatment rock layer

$$v = \frac{K}{n_e} * \frac{\Delta H}{\Delta l}$$

Where:

n_e	=	porosity of the treatment rock layer
v	=	velocity of flow through the treatment rock layer

7.5 Storm Event Simulation

As described in Section 7.1, the study will evaluate treatment performance of the non-vegetated swale by conducting controlled field experiments. Controlled field experiments include the use of simulated storm events, with known or controlled influent concentrations and flow rates. The study was designed to consist of controlled field experiments and use simulated storm events due to the infrequent nature of storm events in the region. The following paragraphs describe the simulated storm events to be conducted during this study.

As described in Section 7.1, six simulated storm events will be performed at each swale design alternative, and the simulated storm events will be split into two phases. The Phase 1 will consist of simulating a storm event with TSS concentrations that are consistent with TAPE influent concentration ranges (Ecology, 2018). Additionally, the flow rate entering the non-vegetated filtration swale will be consistent with the water quality design flow rate (Section 7.3). The purpose of the Phase 1 is to mimic the storm event for which the swale is designed and evaluate the treatment performance of the swale during that simulation. Phase 2 will consist of delivering the load of TSS that would be delivered by a basin to the swale annually. This phase is expected to result in TSS concentrations entering the swales that are higher than the TAPE influent concentration ranges. The purpose of Phase 2 is to understand how the swale performs over time by comparing the results of water quality samples at the same location between each storm event. Further, the loading can be correlated to a period of time to estimate maintenance frequencies. The following paragraphs describe the phases in more detail.

During Phase 1, the mass of SilCoSil needed to achieve an influent concentration between 100-200 mg/L will be added to a 1,000-gallon water tank. The solution will be constantly mixed using a sump pump or mixer placed in the tank. The water in the tank will be distributed to the swale using a separate pump operating at the water quality design flow rate. As the synthetic stormwater flows through the swale, it will be collected in automatic grab samplers (Section 7.6). The samples will be used to evaluate the treatment performance of the swale at each of the eight grab sample locations. Phase 1 will end after all automatic grab samplers are filled and the tank has been emptied.

Once the tank is emptied, the mass of SilCoSil equivalent to one year of loading that would be delivered to the swale will be added to the 1,000-gallon water tank. A copy of the calculations to estimate annual loading is included in Appendix C. . The SilCoSil will be mixed with another 1,000 gallons of water and constantly mixed in the tank using a sump pump or mixer. The water in the tank will be distributed to the swale using a pump operating at the water quality design flow rate to limit adjustments to the influent synthetic stormwater distribution system. The sample ports will be closed so the SilCoSil delivered to the swale does not enter the sample ports. Water will be pumped from the tank until the tank is emptied, and a vactor truck or sump pump directed to a water truck will be located at the catch basin at the end of the swale to collect synthetic stormwater leaving the swale. Once the tank is emptied, Phase 2 will conclude, and the site will be prepared to start a new simulated storm event. Phase 1 and Phase 2 will be repeated for each of the six simulated storm events, except that Phase 2 will not be performed for the sixth simulated storm event, as water quality samples will not be collected following that simulated storm event.

Because the purpose of Phase 2 is to simulate a year of TSS entering the swale, no flow or sample data will be collected during Phase 2. Instead, the water quality samples collected during each Phase 1 of the six simulated storm events will be compared to see if TSS concentrations or removal efficiencies change after each Phase 2 delivers an annual load of TSS to the swale. As Phase 2 is performed five times for each swale design alternative, approximately five years (five annual loads of TSS) will be simulated at each swale. The differences in concentration or percent removal will be used to estimate maintenance over the simulated 5-year period. Specifically, TSS effluent concentrations are expected to increase after TSS has filled the void spaces in the rock. Understanding when this occurs will be critical to extrapolate the frequency of long-term maintenance needs, such as flushing the TSS from rock or replacement of the treatment rock layer.

7.6 Water Quality Sampling

This section describes the water quality sampling methods that that will be used during the study. Influent and effluent samples will be collected as grab samples during the first phase (Section 7.5) of each simulated storm event. As mentioned in Section 7.1, six simulated storm events will occur for each swale design alternative and nine samples (one influent, eight effluent) will be collected during each simulated storm event. Influent grab samples will be collected at opening of the pipe distributing water to the swale. The sample will be collected manually by placing a sample bottle provided by the analytical laboratory under the opening of the pipe and filling the bottle.

Effluent grab samples are collected at locations spaced 25 feet apart in each 200-foot-long swale. The effluent grab samples will be collected using Nalgene Storm Water Samplers (Appendix E) placed in each sample port (described in Section 7.1). The Nalgene Storm Water Samplers are automatic grab samplers that collect one liter of water at a time. The samplers consist of a plastic (high density polyethylene) bottle attached to a device which limits debris from entering the bottle. The device also contains a float valve, which prevents additional water from entering the bottle once the bottle has been filled. During the first phase of the simulated storm event, the eight samplers will be filled as synthetic stormwater flows through the treatment rock layer in the swale. Once the samplers are filled, they will be collected, and sample will be transferred to bottles provided by the analytical laboratory. Procedures for collecting effluent as well as influent samples are described in detail in Section 8.1.

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 Standard Operating Procedures

Water quality samples will be collected during simulated storm events, following standard operating procedures (SOPs). The SOPs developed for this study define how to prepare for a simulated storm event, collect samples, perform site measurements, and perform equipment maintenance and verification in detail, including the frequency of the activity. SOPs included in this section are:

- Site Preparation for Simulated Storm Event
- Simulate Water Quality Storm Event
- Grab Sample Collection and Processing

8.1.1 Site Preparation for Simulated Storm Event

The purpose of this SOP is to define the procedures for preparing the site for a simulated storm event. The procedures include visual inspection of equipment at the site, verification of flow meter readings, and preparing of sampling equipment. This SOP is completed prior to performing the SOP in Section 8.1.2.

Equipment Needed:

- Portable vacuum cleaner
- Timer
- Bucket or container with known volume (for verifying influent and effluent flow meters, water level meter)
- Potable/tap water for decontamination
- Water truck or similar
- Vactor truck or similar

Summary of procedures:

1. Visually inspect the site and vicinity for any signs of damage or tampering. Note any findings on the Site Preparation Field Form (Appendix F).
2. Prior to the first simulated storm event at each swale, rinsing of the treatment rock layer will be needed to limit the presence of fines in the treatment rock layer. A water truck or the tank and submersible pump will be used to direct water to the swale. A vactor truck will be located at the catch basin at the downstream end of the swale to collect water leaving the swale. Visual observations of the water leaving the swale and entering the catch basin will be used to determine when the rinsing is complete.
3. Confirm submersible pump used to mix the tank contents is located inside the 1,000-gallon tank and is plugged in away from the tank. Confirm the pump used to distribute flow to the swale is also plugged in away from the tank. Begin to fill the 1,000-gallon tank with water.

4. Inspect the piezometers and confirm that the ports are empty.
5. Inspect all sampling ports and confirm that the ports are empty and clean. If SilCoSil, sediment, or other material is present in any of the PVC ports, use a vacuum to clean out the port.
6. Inspect the automatic grab samplers and confirm that the samplers are empty and clean. If SilCoSil, sediment, or other material is present in the sampler, rinse components with tap or potable water until no material is remaining.
7. Verify the influent meter is providing accurate measurements. The influent flow meter is located on the pipe leading to the swale, between the valve and outlet of the pipe (see Figure 7.1). The verification can be done by turning the pump used to distribute flow to the swale on and capturing the flow in a bucket or basin with a known volume while timing the time it takes to fill the bucket or basin. This verification should be repeated three times for a certain flow rate. It may be necessary to reduce the flow rate below the water quality design flow rate (what is distributed to the swale during a simulated storm event) to verify the flow rate. This can be done by adjusting the valve between the pump and flow meter. If the flow rate calculated during the verification is consistently off by a consistent amount, that should be noted on the Site Preparation Field Form (Appendix F). The flow meter is factory calibrated and does not require field calibration.
8. At the end of the verification, open the valve so the flow meter is reporting the water quality design flow rate is flowing through the pipe. Stop the pump and re-fill the tank as necessary.
9. Verify that the water level meter is reading depth correctly by placing the meter in a container with a known depth of water. If the meter provides a different depth than is present in the container, review the manufacturer's instructions to address the issue or contact the manufacturer. According to the manufacturer specifications, field calibration is not required.

8.1.2 Simulate Water Quality Storm Event

The purpose of this SOP is to define the procedures for simulating a water quality storm event at the site. The procedures include creation of the synthetic stormwater solution, pump operation, and sample collection. This SOP is performed after the SOP in Section 8.1.1.

Equipment Needed:

- 1.67 pounds of SilCoSil for Phase 1
- Additional 14 pounds of SilCoSil to simulate one year of TSS loading during Phase 2
- Water level meter
- Vactor truck or a sump pump and water truck

Summary of procedures:

<u>Phase 1 of Simulated Storm Event:</u>

1. Turn on the submersible pump intended to mix the SilCoSil in the 1,000-gallon tank. Add the amount of SilCoSil needed to achieve a concentration of 100 mg/L in 1,000 gallons (0.83lbs). Observe the mixture to ensure SilCoSil is not settling to the bottom of the tank.

2. Start a Simulate Water Quality Storm Event Field Form. Note the date and time as the start of the event.
3. Verify all flow meters are on. Position a vactor truck or a sump pump that discharges to a water truck at the catch basin at the downstream end of the swale.
4. To begin Phase 1 of a simulated storm event, start the pump intended to distribute flow to the swale. Verify that the influent flow meter is reading the water quality design flow rate and record the measurement on the Simulate Water Quality Storm Event Field Form. Confirm synthetic stormwater is being pumped from the tank and is entering the upstream end of the swale.
5. After the influent flow meter is reading the water quality design flow rate, place one of the automatic grab samplers (described in Section 7.1, specification in Appendix E) in each of the eight clean sampling ports.
6. Use the water level meter to record the depth of water in the piezometers at the upstream and downstream ends of the swale. Repeat this measurement two additional times while the tank is emptying.
7. Also, while the tank is emptying, record the influent flow rate two additional times to verify no variation in flow rate is occurring.
8. Wait for the automatic grab samplers to fill and tank to empty.
9. As soon as the tank is empty, turn off both pumps in the tank.
10. Collect the automatic grab samplers and prepare TSS samples for the laboratory as described in Section 8.1.3. After TSS samples are prepared as described in Section 8.1.3, set aside the automatic grab samplers for cleaning as described in Section 8.1.1.

<u>Phase 2 of Simulated Storm Event:</u>

11. Refill the 1,000-gallon tank with water to begin Phase 2 of the simulated storm event.
12. Turn on the submersible pump used to mix the contents of the tank, and slowly add SilCoSil equaling the amount of TSS loading the swale would receive in a year based on the design contributing basin area. This is estimated to be 14 lbs. Observe that the pump is continuously recirculating the water in the tank to prevent SilCoSil from settling in the bottom of the tank. Close the sample ports in the swale before starting the pump.
13. Following addition of the SilCoSil, turn on the pump intended to distribute flow to the swale. Distribute the entire tank volume to the swale. Turn off both pumps as soon as the tank is empty.
14. This concludes one simulated storm event.
15. Before beginning the next simulated storm event, the SOP in Section 8.1.1 must be performed. Once the steps in Section 8.1.1 are complete, the steps in this SOP (Section 8.1.2) can be performed for the next simulated storm event. This process is repeated for 6 storm events total at each site, except that Phase 2 is not repeated for the 6th event (because no water quality samples will be taken following the 6th event).

8.1.3 Sample Processing

The purpose of this SOP is to define the procedures for processing TSS samples for delivery to the analytical laboratory. This SOP can be performed at the same time as or after the SOP outlined in Section 8.1.2.

Equipment Needed:

- Sample Kit (bottles, bottle labels, plastic bags, Chain of Custody)
- Permanent, waterproof pen
- Nitrile gloves
- Cooler
- Ice

Summary of procedures:

1. At least one hour prior to departing for the site, place sample bottles in the plastic bag in a refrigerator or cooler filled with ice to keep the bottles cool.
2. If applicable, place labels on sample bottles provided by the analytical laboratory and fill in the sample ID, location, and sampler name or initials prior to starting each simulated event.
3. Following step 7 of Section 8.1.2, or the end of Phase 1 of a simulated storm event, put on clean nitrile gloves. Fill in the sample date and time on the sample bottles provided by the analytical laboratory.
4. Shake or swirl the sample collected in the automatic grab samplers to homogenize the sample. Carefully transfer each sample collected in automatic grab samplers to bottles provided by the laboratory. Set aside the automatic grab samplers for cleaning as described in Section 8.1.1. Replace the lids on the sample bottles.
5. Place the filled laboratory bottles in the plastic bags and place the plastic bag(s) in the cooler. The cooler should be filled with loose ice to maintain a sample temperature of less than 6°C. Spread the ice around so that the samples are fully covered by ice.
6. Fill out the Chain of Custody for the samples according to the procedures outlined in Section 8.5.
7. Transport the samples to Energy Northwest Environmental Services Lab.
    a. If samples have been collected after laboratory hours, keep samples below 6°C in a cooler or refrigerator until the laboratory reopens.

8.2 Containers, Preservation Methods, Holding Times

Clean sample bottles will be provided by Energy Northwest Environmental Services Lab (Lab) in Richland, WA for each simulated storm event, 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 TSS Sample containers, Preservation, and Holding Times

Method	SM 2540 D
Units	mg/L
Reporting Limits	1.0
Expected Range of Results	5 – 200
Sample Container & Volume	125 ml plastic bottle

Preservative	None
Pre-Filtration Holding Time	None
Total Holding Time	7 days from sample collection
Minimum Number of Sample Events	6
Samples Per Event	9

8.3 Equipment Decontamination

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

- Nalgene Storm Water Samplers
- Synthetic stormwater tank
- Pump and attached piping
- Influent and effluent sample bottles (performed by laboratory)

8.4 Sample Identification

All sample containers will be labeled with the following information, using waterproof labels and indelible ink.

- Sample Identification
- Date of sample collection (MM/DD/YYYY)
- Sample location
- Time of sample collection (military format)
- Sampler initials
- Parameter (TSS)

8.5 Chain of Custody

After samples have been obtained, a written record of 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:

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

After collection, samples will be immediately delivered to the Energy Northwest Environmental Services Lab in Richland, 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 principal investigator or lead entity project manager. The sampling staff will record the date and time of the sample deliveries for the project file. The chain of custody form is in Appendix G.

8.6 Field Log Requirements

Field observations and measurements associated with a monitoring event will be recorded on the field forms (Appendix F). The filed 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
- Equipment maintenance, calibration, and conditions
- Samples collected (checklist)
- Sample description and label information
- Grab sample location
- Number of samples collected
- Flow rate and velocity through the proposed BMP
- Comments on activities or issues that may influent 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 influent and effluent flow rates and for water quality (TSS). Flow measurements will be collected at the test-site as described in Section 8.1.2. Grab samples will be collected according to the procedures in Sections 8.1.2 and 8.1.3. TSS will be measured at the influent and every 25 feet in the swale (eight locations).

Field measurement quality will be evaluated in terms of precision and bias (See Section 6). Measurement bias will be assessed by evaluating laboratory method blanks and laboratory standard analyses and verifying that the influent flow meter is not providing skewed measurements. Measurement precision will be assessed by evaluating laboratory duplicates and verifying that the influent flow meter is providing consistent measurements prior to the simulated storm event. Detailed procedures to verify flow meter readings are in Section 8.1.1.

9.2 Laboratory Procedures

Laboratory analytical procedures will follow Standard Method 2540D for analysis of TSS. This method provides reporting limits that are below the TAPE criteria or guidelines and will allow direct comparison of the analytical results with these criteria; analytical methods, reporting limits, and sample holding times are presented in Table 8.1. Sampling staff will collect the samples and deliver the samples to the analytical laboratory within four hours of a simulated storm event. The samples will be stored at the temperature noted in Table 8.1 and delivered to the laboratory during their business hours (Monday-Friday, 7:00am to 4:00pm). Energy Northwest Environmental Services Lab, the laboratory identified for the water quality samples for this project, is certified by the Washington State Department of Ecology. 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.

9.3 Sample Preparation Methods

Field personal will collect the samples and transfer them to bottles provided by Energy Northwest Environmental Services Lab as described in Section 8.1.2. The samples will be kept refrigerated or on ice until delivery to the lab. No other sample preparation is needed for the samples.

9.4 Special Method Requirements

Energy Northwest Environmental Services Lab does not require any special methods for the parameters to be analyzed during the study.

9.5 Lab(s) Accredited for Methods

Energy Northwest Environmental Services Lab is accredited by the Washington State Department of Ecology for the stormwater parameter collected for this study (TSS).

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 SOP development, personnel training, equipment maintenance, and verification that instruments are measuring properly.

SOPs have been developed and are included in Section 8.1. At least two field staff will be trained to consistently follow field sampling procedures (Section 8.1) and measurement procedures (Section 9.0). Field staff must be familiar with SOPs 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.

Equipment maintenance and verification of instrument measurements will ensure that the BMP, the sampling equipment, and the flow meters are working properly. Equipment maintenance and verification of instrument measurements will occur before each field test. Details of equipment maintenance and calibration are provided in Section 8.1.1 and will consist of the following activities:

- Inspection of all equipment for damage.
- Cleaning and/or repair of all equipment, connections, piping, and grab sample collection ports.
- Verification of influent flow meter measurements (to check that the measurements are precise and unbiased).

Maintenance and calibration will be documented with the field forms in Appendix F. Recordkeeping procedures will be developed and consistently followed (see Section 11.0).

10.2 Laboratory QC Required

Laboratory quality control will be maintained for the water quality samples by running method blanks, laboratory standards analyses 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. 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.

Table 10.1 Laboratory Quality Control Performed for TSS

	Laboratory Control Sample	Method Blanks	Laboratory Duplicates
Number Per Batch[1]	1/batch	1/batch	1/batch
QC Limit	Defined by Lab Standard Documentation[2]	1 mg/L	±5%

[1] A batch is a minimum of 20 water quality samples.

[2] The laboratory standard is provided by a third party, who also provides documentation including the known concentration of the standard and the acceptable range of results.

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 are 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 (Appendix I) and revisions to the QAPP (Appendix H) will be kept throughout the study and included in the final report.

11.0 Data Management Plan Procedures

This section defines the data management plan. It specifically describes how the data and other important project documents will be managed, stored, and archived during the study. These procedures are developed to reduce the potential for errors and missing data 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 F). Field forms were developed for preparation of the site for simulated storm events and conducting simulated storm events at the test site. Information on the forms include the date and time, data collectors name(s), field measurements, field observations, sample information, and comment fields as applicable. All field measurements will be entered manually into the project database in Microsoft Excel or a similar program within 24 hours of sample collection. The QA/QC lead or principal investigator 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. The research team 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 SharePoint and transferred to City of West Richland after completion of the study.

Analytical results from Energy Northwest Environmental Services Lab are anticipated within 30 days of receipt of the samples by the laboratory. The laboratories will provide sample and quality control data in PDF reports that are suitable for evaluating the project data. The PDF will include all quality control results associated with the data. They 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. The QA/QC lead or principal investigator 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). The data verification will be performed in the Data Quality Form in Appendix K. The QA/QC lead or principal investigator for the project will perform an independent review to ensure that the data were entered into Excel 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 sample reports and independent data verification will be stored (archived) in the project SharePoint for 1-year after the technical evaluation report has been approved.

11.2 Electronic Transfer Requirements

All field forms will be scanned and electronically filed on SharePoint. The laboratory reports, verified reports, and data quality forms will be electronically filed on SharePoint. Verified laboratory reports will be uploaded into the project database for all subsequent data management and archiving tasks.

11.3 Laboratory Data Package Requirements

Energy Northwest Environmental Services Lab 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 flagged and will have a qualifier code 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 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 90% 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

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 first audit will be performed by the project manager or principal investigator (Section 5.1), and the additional field audit will be performed by the auditor for the study (Section 5.1). The field audit will verify that field staff are following the SOPs for sample collection, all field data are being recorded, and any equipment and instruments are being maintained and/or calibrated per manufacturer's requirements. Results from these audits will be documented in field audit worksheets (Appendix F) 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 (Section 6) 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 K) that will be prepared for each batch of samples.

In the event that a potential QA issue is identified through these audits, the QA/QC lead or principal investigator (Section 5.1) 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

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 of the laboratory report

Results from these data validation reviews will be summarized in data quality forms (Appendix K) that are prepared for each sample batch. The QA/QC lead or principal investigator will be responsible for identifying and initiating corrective action. Values associated with minor quality control problems will be considered estimates and assigned a qualifier or flag. Values associated with major quality control problems will be assigned a qualifier or flag and rejected. Estimated values may be used for evaluation purposes but rejected values will not be used.

13.2 Data Usability Assessment

The QA/QC lead 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 & Presentation

14.1 Data Analysis Methods

14.1.1 Statistical Comparison 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 at each sample location in the swale (8 total). This is expected to include evaluating whether the data was normally distributed using the Ryan-Joiner test (similar to Shapiro-Wilk test) (Helsel, Hirsch, Ryberg, Archfield, & Gilroy, 2020). 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).

14.1.2 Calculation of Pollutant Removal Efficiency

The effectiveness of each swale design alternative will be evaluated based on the average removal efficiency and mean concentration for TSS at each sample location in the swale (8 total). This will include calculating the removal efficiency for TSS from each individual simulated storm event from sampling port using the equation below. The bootstrapping method will be used to compute the upper 95th percent confidence interval for effluent limit performance goals, as influent TSS concentrations are expected to be 100 mg/L or slightly less and the TAPE treatment performance goal for influent TSS concentrations of 100 mg/L or less is 20 mg/L in the effluent. The bootstrapping 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.

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

Where:

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

14.1.3 Water Quality Treatment Performance

The water quality data will be evaluated for meeting the Ecology performance goals for basic, treatment. As TSS influent concentrations are expected to be 100 mg/L or slightly less, the evaluation will include comparing the mean effluent concentration at the upper 95% confidence interval to effluent concentrations to assess effluent limit performance goals (Table 14.1). The bootstrapping method will be used to compute the upper 95% confidence interval for the mean TSS effluent concentration. 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 TAPE Treatment Performance Goal

Performance Goal	Pollutant	Influent Concentration Range	Treatment Performance Criteria
Basic Treatment	Total Suspended Solids (TSS)	20-100 mg/L	Effluent <20 mg/L
		100-200 mg/L	≥80% Reduction

14.1.4 Length of Swale and Hydraulic Residence Time

The length of the proposed BMP needed to meet Ecology's requirements for basic treatment will be verified using data collected from field testing. A hydraulic residence time of 9 minutes was used for the design of the alternative. If, based on the bootstrapping analysis, concentrations meet the TAPE treatment performance criteria in Table 14.1 at one of the sample locations in the swale before the effluent, the length of swale at that sample location will be recommended for the final non-vegetated filtration design guidance along with a recommended residence time.

14.1.5 Manning's n Verification

The Manning's coefficient will be verified using data collected from field testing. A coefficient of n=0.40 was used for the design of the alternatives. The coefficient will be determined using the following equation:

$$n = \frac{1.49\, R^{2/3}\sqrt{S}}{v}$$

Where: n = Manning's Roughness Coefficient
R = Hydraulic Radius (ft)
S = Channel Slope (ft/ft)
v = Velocity (ft/s)

In the equation above, the velocity is calculated using the equation in Section 7.4.

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 are shown in Figures 14.1-14.2 and Tables 14.2-14.4 and are briefly described below.

- Figure 14.1 - Box and Whisker Plots display the distribution of data collected for each swale alternative 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 test. These graphs illustrate the trend in the treatment performance over the duration of the study.

- Table 14.2, 14.3, and 14.4 – A summary of the water quality results will be included in tables. The results will include the average influent and effluent concentrations, sample size, pollutant removal efficiencies, and bootstrap analysis results.

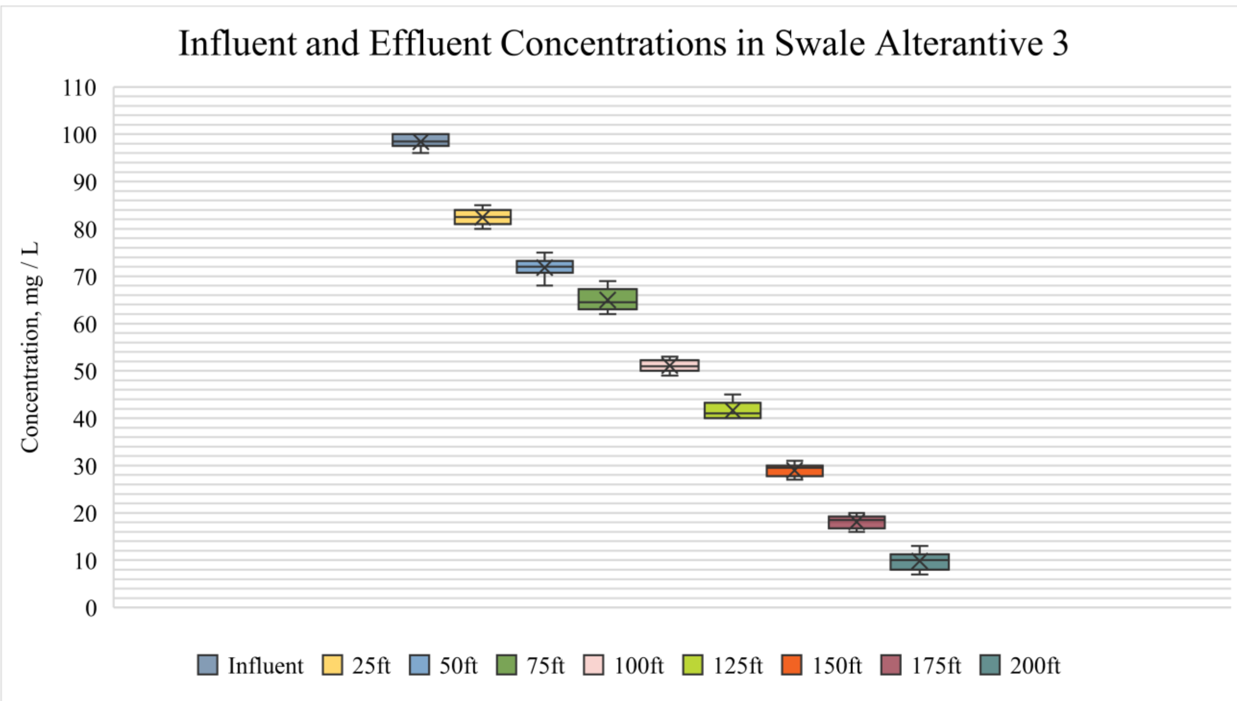


Figure 14.1 Example of Box Plot

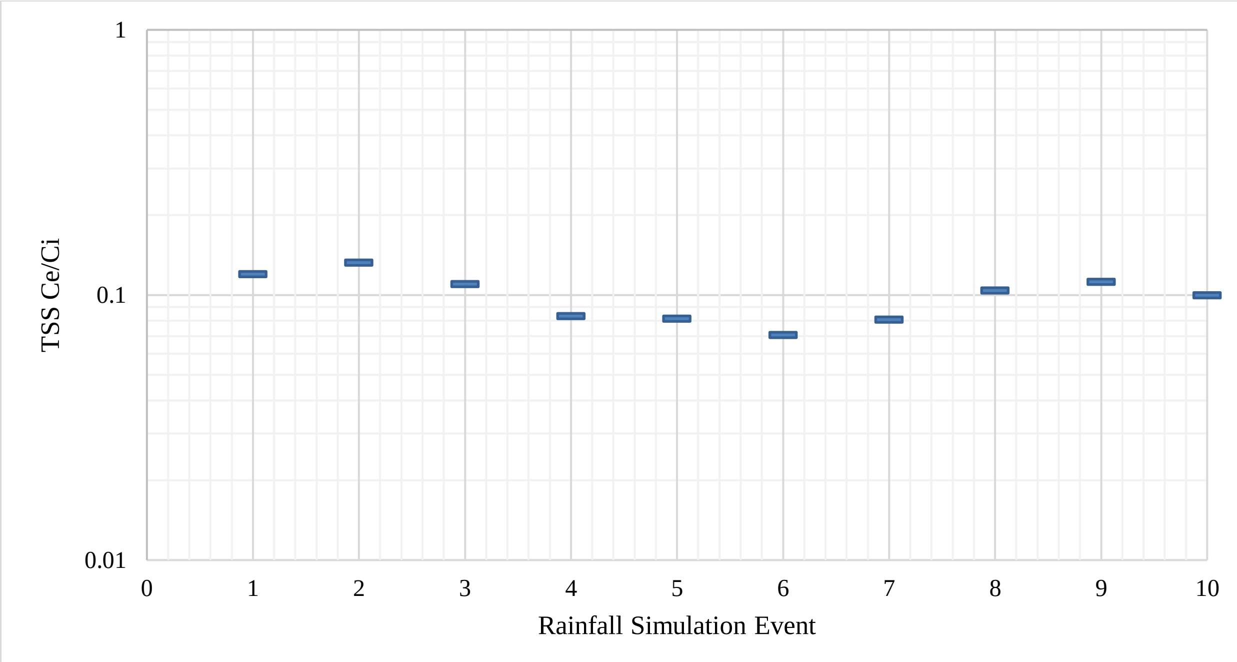


Figure 14.2 Example of Log-Normal Plot

Table 14.2 Example of Water Quality Results Summary for Influent Concentrations 20-100 mg/L

	Swale Alternative #1	Swale Alternative #2	Swale Alternative #3	Swale Alternative #4	Final Swale Alternative (no liner)
Average Influent Concentration	98	98	96	97	99
Average Effluent Concentration at 25ft	90	88	82	90	78
Average Effluent Concentration at 50ft	87	76	72	87	64
Average Effluent Concentration at 75ft	73	62	65	73	55
Average Effluent Concentration at 100ft	68	59	51	68	46
Average Effluent Concentration at 125ft	54	43	42	54	37
Average Effluent Concentration at 150ft	42	32	29	42	27
Average Effluent Concentration at 175ft	35	21	18	35	22
Average Effluent Concentration at 200ft	27	15	10	27	14
Sample Size at Each Location (n)	6	6	6	6	6

Note: all concentrations are in mg/L.

Table 14.2 Example of Water Quality Results Summary for Influent Concentrations 200 mg/L

	Swale Alternative #1	Swale Alternative #2	Swale Alternative #3	Swale Alternative #4	Final Swale Alternative (no liner)
Average Influent Concentration	198	198	196	197	199
Average Effluent Concentration at 25ft	90	88	82	90	78
Average Effluent Concentration at 50ft	87	76	72	87	64
Average Effluent Concentration at 75ft	73	62	65	73	55
Average Effluent Concentration at 100ft	68	59	51	68	46
Average Effluent Concentration at 125ft	54	43	42	54	37
Average Effluent Concentration at 150ft	42	32	29	42	27
Average Effluent Concentration at 175ft	35	21	18	35	22
Average Effluent Concentration at 200ft	27	15	10	27	14
Sample Size at Each Location (n)	6	6	6	6	6

Note: all concentrations are in mg/L.

Table 14.3 Example of Removal Efficiency for Influent Concentrations 100-200mg/L

	Swale Alternative #1	Swale Alternative #2	Swale Alternative #3	Swale Alternative #4	Final Swale Alternative (no liner)
Average Removal Efficiency at 25ft	8%	10%	15%	7%	21%
Average Removal Efficiency at 50ft	11%	22%	25%	10%	35%
Average Removal Efficiency at 75ft	26%	37%	32%	25%	44%
Average Removal Efficiency at 100ft	31%	40%	47%	30%	54%
Average Removal Efficiency at 125ft	45%	56%	56%	44%	63%
Average Removal Efficiency at 150ft	57%	67%	70%	57%	73%

Average Removal Efficiency at 175ft	64%	79%	81%	64%	85%
Average Removal Efficiency at 200ft	72%	85%	90%	72%	92%

Table 14.4 Example Bootstrap Analysis for Influent Concentrations 100-200mg/L

	Swale Alternative #1	Swale Alternative #2	Swale Alternative #3	Swale Alternative #4	Final Swale Alternative (no liner) #5
Bootstrap Result at 25ft	6%	9%	12%	6%	19%
Bootstrap Result at 50ft	9%	19%	23%	8%	30%
Bootstrap Result at 75ft	22%	35%	30%	22%	40%
Bootstrap Result at 100ft	29%	38%	45%	28%	53%
Bootstrap Result at 125ft	43%	54%	54%	40%	61%
Bootstrap Result at 150ft	55%	65%	68%	55%	70%
Bootstrap Result at 175ft	60%	76%	80%	63%	83%
Bootstrap Result at 200ft	70%	83%	90%	62%	90%

15.0 Reporting

This section describes how the study findings will be reported and disseminated.

15.1 Final Reporting

This section should identify the reports that are required for the project and the party responsible for preparing the reports. Reports required by the MS4 permit include:

Annual Reports (S8.B.1.a) – interim results will be described, and status of the study will be documented by the Lead Entity

Final Report (S8.B.1.b) – final results of the study, as well as the recommendations for future actions based on the findings will be documented by the Principal Investigator within the final report. An outline will also be provided that identifies the contents of the final report (see table 15.1 for proposed content)

Fact Sheet (S8.B.1.c) – key points of the study and study findings will be summarized by the Principal Investigator in a fact sheet.

Table 15.1 Proposed Effectiveness Study Report Content

Final Report Sections	Effectiveness Studies
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[2]	✓
6.0 Operation and Maintenance (O&M) Information	✓
7.0 Discussion	✓
8.0 Conclusions	✓
9.0 Future Action Recommendations	✓
10.0 Appendices	✓

1. The approved QAPP will be referenced for these sections. Any changes made to the study since the QAPP was approved will be described in these sections.
2.

15.2 Dissemination of Project Documents

The final report will be shared with those included on the Distribution List and posted to the City of West Richland website (https://www.westrichland.org/189/Stormwater) 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.

16.0 References

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17.0 Appendices

Appendix A. Design and Maintenance Guidance

BMP T5.X0: Non-Vegetated Filtration Swale Design Guidance

This document was developed by editing the SWMMEW BMP T5.40: Biofiltration Swale design guidance.

A non-vegetated filtration swale is a sloped, rock-lined swale that provides both conveyance and runoff treatment for stormwater runoff. This BMP is similar to a biofiltration swale except treatment occurs as runoff flows through a layer of rock in the swale instead of grass. The use of rock instead of grass eliminates the need for irrigation during dry periods. The swale bottom width and rock depth are sized to provide Basic (TSS) treatment during the water quality design storm (See Chapter 4 - Hydrologic Analysis and Design). It does not provide flow control but can convey runoff to Best Management Practices (BMPs) designed for that purpose.

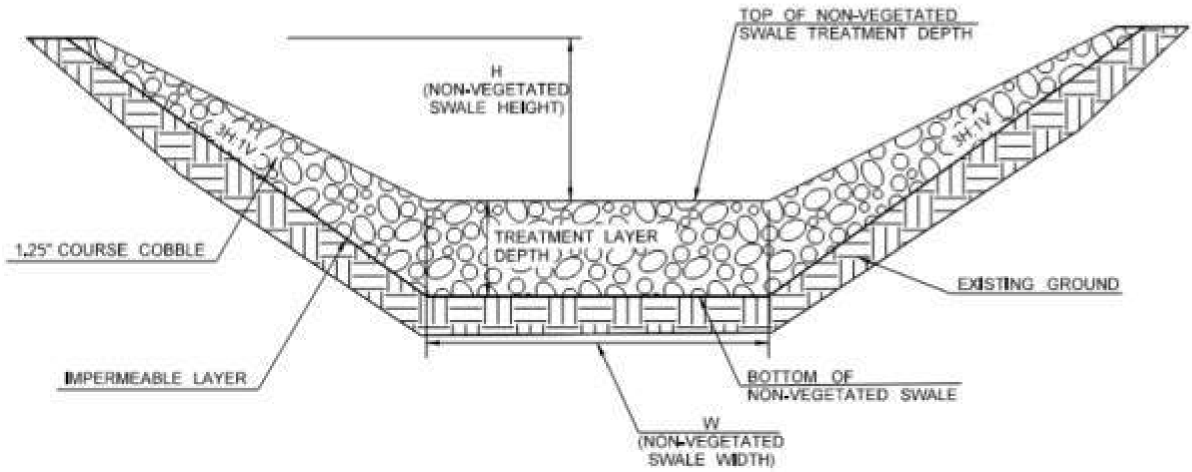


Figure 1: Non-Vegetated Filtration Swale Cross Section

Figure 1 shows a typical cross-section of a non-vegetated filtration swale[1]. Because the swale functions by passing flow through the rock treatment layer depth, the swale bottom width (W) is measured at the bottom of the treatment layer depth, where the rock meets the existing ground. The treatment layer depth provides removal of sediment and TSS through filtration as runoff flows through the treatment layer and sedimentation as the rock reduces the runoff velocities and sediment settles in the rock layer. The treatment layer depth is designed to contain the depth of the water quality flow rate. As such, higher flow rates would be partially conveyed above the surface of the rock.

[1] The impermeable liner is included for testing only and will not be included in the final BMP design.

General Criteria

This section provides design considerations and limits for the non-vegetated filtration swale. Specific criteria and steps to size a non-vegetated filtration swale can be found in the Design Procedure section of this document.

- The swale length is determined using a 9-minute hydraulic residence time through the swale with minimum length of 100 feet (to be verified during field testing).
- Calculate bottom width using Design Criteria. The minimum allowed bottom width of the swale is 2 feet; the maximum allowed bottom width of the swale is 10 feet.
- The channel slope should be greater than or equal to 1% or greater and less than or equal to 5%.
- Size the swale as a runoff treatment BMP using the methods in Chapter 4 Hydrologic Analysis and Design of the SWMMEW, and as a conveyance BMP to pass the peak hydraulic flows of the 25-year storm if it is located "online".

- The ideal cross section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1.
- If the swale has a continuous inflow, increase the swales length according to the guidance listed in BMP T9.30: Continuous Inflow Biofiltration Swale of the SWMMWW.
- If a flow splitter is used at the inlet, the spreader should utilize the entire width of the swale.
- If runoff enters the swale through one location, a forebay or pre-settling chamber is recommended upstream or at the inlet of the swale to reduce gross solids from entering the swale and swale maintenance. Depending on how the flow enters the swale, the forebay or pre-settling chamber can also be replaced with a standard catch basin inlet at the upstream end of the swale. Examples of forebays are shown in Figures 2 and 3.

Figure 2: Curb Extension with Concrete Forebay

Figure 3: Rock-Lined Forebay in Swale

- If flow is to be introduced through curb cuts, place pavement slightly above the swale elevation. Curb cuts should be ≥ 12 inches wide to prevent clogging.

- Filtration BMPs should generally not receive construction-stage runoff. If they do, pre-settling of sediments should be provided. See BMP C240E: Sediment Trap and BMP C241E: Sediment Pond (Temporary). Such filtration BMPs should be evaluated for the need to remove sediments and restore treatment rock layer following construction. The maintenance of pre-settling basins or sumps is critical to their effectiveness as pretreatment devices. See Element 13 Protect Low Impact Development BMPs of the Stormwater Pollution Prevention Plan.
- Where runoff diversion is not possible during construction, and runoff is directed to the swale, protect exposed soils with suitable erosion control measures.

Rock Sizing Criteria

Four alternative rock designs are proposed to provide filtration of stormwater through the swale and will be tested in the field to determine whether they meet Basic treatment performance goals such as total suspended solids (TSS). Each alternative includes an impermeable liner to prevent infiltration of flows that will be used only for testing purposes. Impermeable liners will not be included in the final design unless testing shows it’s necessary. The four designs provide a range of rock gradations (1.25-inch rock to sand media) to increase the likelihood of meeting basic treatment goals. Gradations were selected wherever possible to align with specifications in WSDOT specifications or the SWMMEW to specify rock that would be readily available in Washington. One of the specifications (AASHTO #2) was selected from AASHTO standard gradations, as gradations matching the targeted rock size were not found in the WSDOT or SWMMEW specifications. The following paragraphs describes the method used to size the rock designs.

In addition to meeting the basic performance treatment goal, the rock designs were sized to limit movement of rock during the 25-year event. Movement of rock was expected to occur if the critical shear stress was exceeded, according to Table E.1 from the United States Forest Service Stream Simulation Publication. The Federal Highway Administration’s (FWHA) Hydraulic Toolbox software was used to calculate the maximum shear stress values expected for different swale configurations during the 25-year event. The resulting gradations, the 1.25” Coarse Cobble and 2.5” Coarse Cobble, were selected for different longitudinal slope ranges (1% to 2.5% and 2.5% to 5%, respectively) to limit rock movement. The three remaining rock gradations were selected based on the 1.25” Coarse Cobble and were intended to be smaller gradations to increase filtration of TSS. The rock gradations recommended for this BMP are intended to provide filtration for the water quality design flow rate and to prevent erosion during the 25-year storm event. The depth of rock recommended in the swale alternatives below was sized to contain a maximum effective flow depth of 3 inches. The effective depth is the flow depth if it were unobstructed by the treatment rock layer. The actual rock depth exceeds 3 inches because the depth is based on available porosity of the selected rock.

Table 1 and Figure 4 outline the rock gradations selected for four rock designs to be tested in the field. Following field testing, the information in this section will be replaced with the gradations applicable to the selected alternative. The four alternative rock designs are described further in the following paragraphs.

Table 1: Rock Gradations for Swale Alternatives

Sieve Size	Diameter of Particle (mm)	2.5” Coarse Cobble[1]	1.25” Coarse Cobble	Gravel Backfill for Drywells	Pea Gravel	Sand Media
		AASHTO #2	AASHTO #4	WSDOT Standard Specification 9-03.12(5)	AASHTO #8	SWMMEW Sand Media Specification
3”	75	100				
2 ½”	63	90-100				
2	50	35-70	100	100		
1 ½”	37.5	0-15	99-100	99-100		
1”	25	-	20-55	50-100		
¾”	19	0-5	0-15	0-20	100	
½”	12.5		-		99-100	
3/8”	9.5		0-5	0-2	85-100	100
#4	4.75				10-30	95-100
#8	2.36				0-10	70-100
#16	1.18				0-5	40-90
#30	0.6					25-75
#50	0.3					2-25
#100	0.15					< 4
#200	0.075			0-1.5		< 2

[1] 2.5” coarse cobble should be placed at a depth of 2.5 inches above the treatment rock in swales with a 2.5% to 5% longitudinal slope. The 2.5” coarse cobble would replace the 2.5-inch layer of 1.25” coarse cobble for Swale Alternatives 2-4.

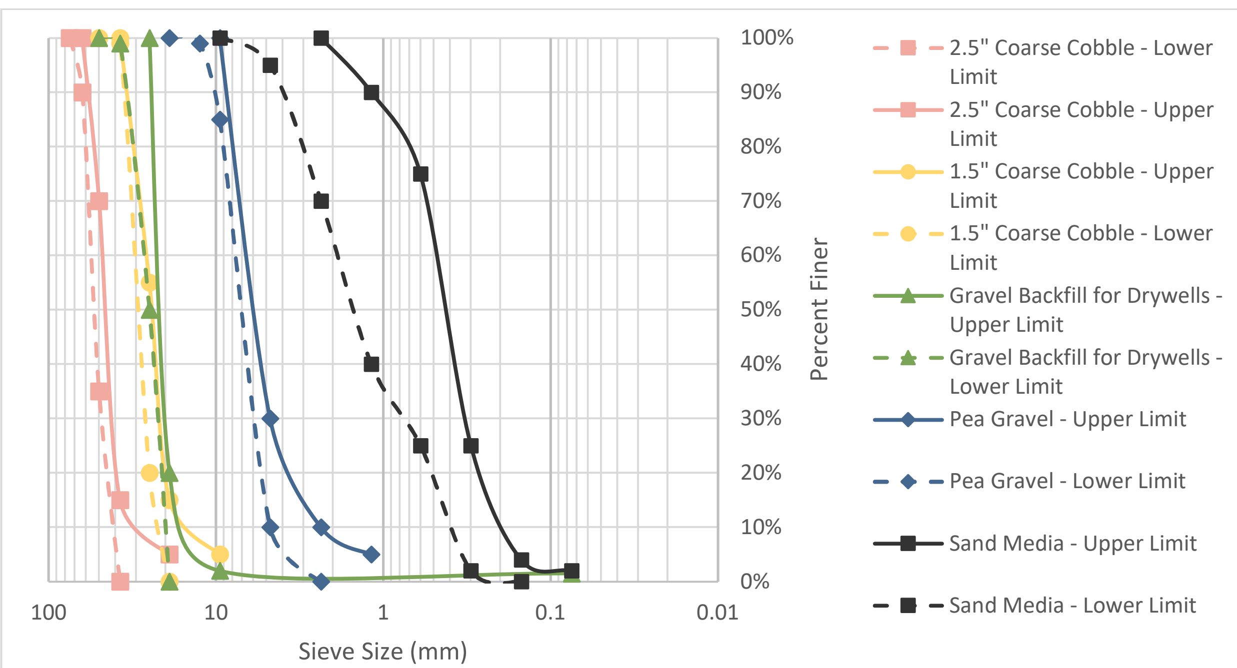


Figure 4: Particle Size Distribution Curves for Rock Gradations

Swale Alternative #1

This alternative proposes a depth of 7.5 inches of 1.25" Coarse Cobble as shown in Figure 5 for longitudinal slopes of 1% to 2.5%. If the longitudinal slope ranges from 2.5 to 5%, an additional 2.5 inches of 2.5" Coarse Cobble should be placed above the 7.5 inches of 1.25" Coarse Cobble to limit movement of rock during larger flow events.

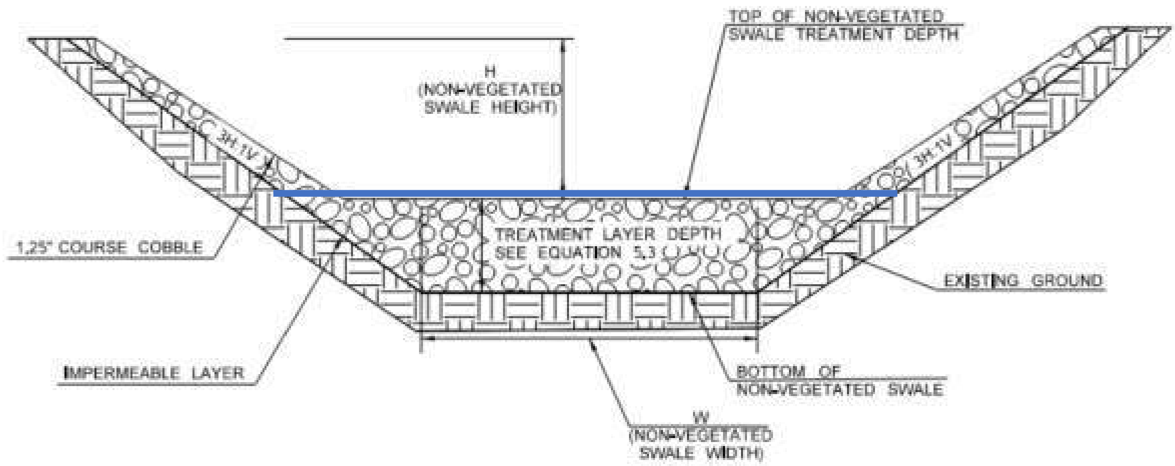


Figure 5: Profile of Swale Alternative #1

Swale Alternative #2

This alternative proposes a depth of 7.5 inches of Pea Gravel under 2.5 inches of 1.25" Coarse Cobble as shown in Figure 6 for longitudinal slopes of 1% to 2.5%. If the longitudinal slope ranges from 2.5 to 5%, the 1.25" Coarse Cobble should be replaced with 2.5" Coarse Cobble to limit movement of rock during larger flow events.

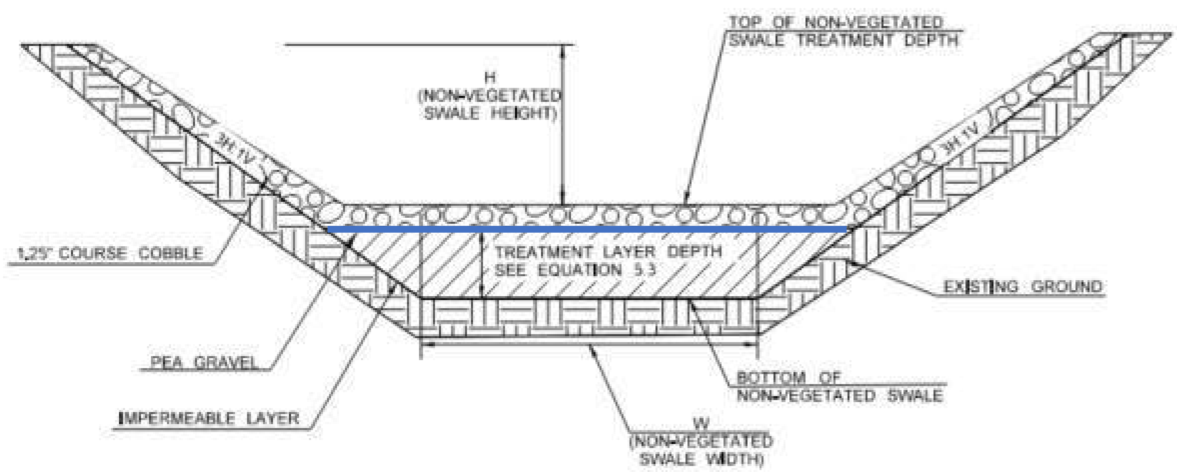


Figure 6: Profile of Swale Alternative #2

Swale Alternative #3

This alternative proposes a depth of 7.5 inches of Gravel Backfill for Drywells under 2.5 inches of 1.25" Coarse Cobble as shown in Figure 7 for longitudinal slopes of 1% to 2.5%. If the longitudinal slope ranges from 2.5 to 5%, the 1.25" Coarse Cobble should be replaced with 2.5" Coarse Cobble to limit movement of rock during larger flow events.

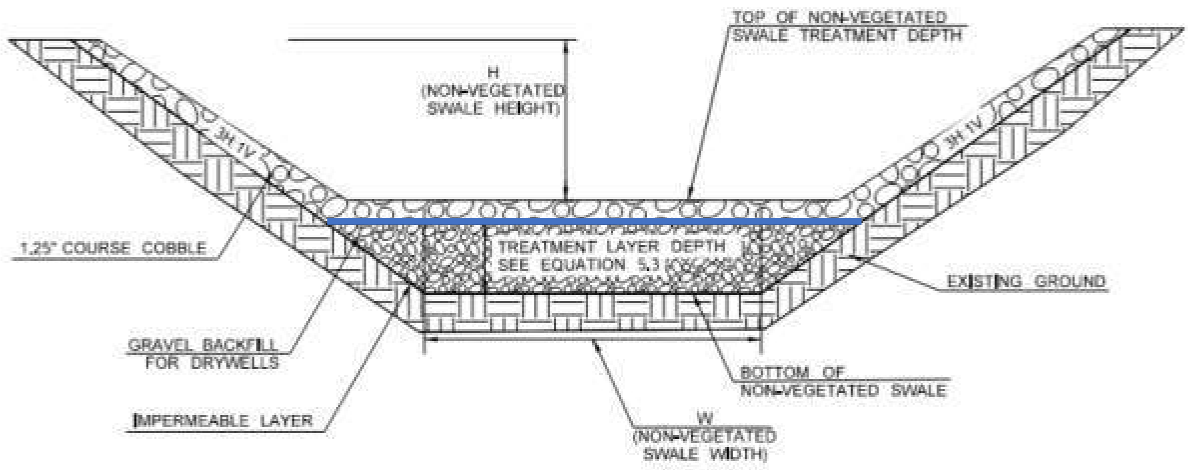


Figure 7: Profile of Swale Alternative #3

Swale Alternative #4

This alternative proposes a depth of 4.5 inches of sand media under 3 inches of pea gravel and covered by 2.5 inches of 1.25" Coarse Cobble as shown in Figure 8 for longitudinal slopes of 1% to 2.5%. If the longitudinal slope ranges from 2.5 to 5%, the 1.25" Coarse Cobble should be replaced with 2.5" Coarse Cobble to limit movement of rock during larger flow events.

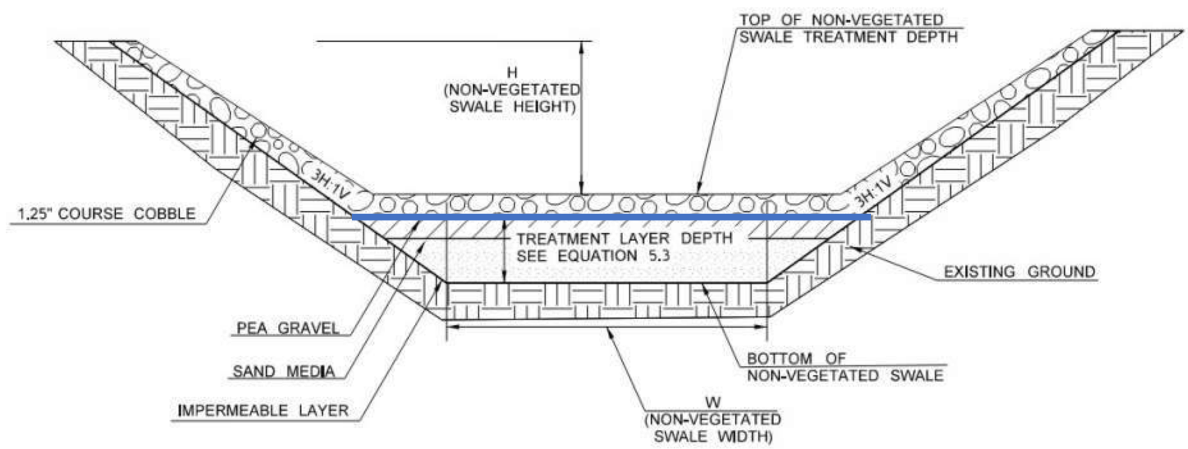


Figure 8: Profile of Swale Alternative #4

Design Procedure

The stepwise procedure for designing non-vegetated filtration swales for runoff treatment includes the following:

1. Determine the water quality design flow rate to the swale. See Chapter 4 -Hydrologic Analysis and Design.
2. Determine the slope of the swale.
3. Select a shape for the swale. The remainder of the design process assumes that a trapezoidal shape has been selected; however, a rectangular shape can also be used. Rectangular channels can be sized using the same equations and assumptions described in Steps 4 and 5.
4. Use Manning's Equation to estimate the bottom width of the swale. Assume y=0.25 ft for the maximum equivalent depth of flow in the treatment rock layer. Manning's Equation for English units is as follows:

Equation 5.1: Manning's Equation

$$Q = (1.486 * A * R^{0.667} * S^{0.5})/n$$

where:
Q = flow (cfs)
A = cross-sectional area of flow (square feet [sf])
R = hydraulic radius of flow cross section (feet [ft])
S = longitudinal slope of swale (feet per foot [ft/ft])
n = Manning's roughness coefficient.
Use n = 0.40 for the water quality design flow rate. This higher value represents flow through the treatment rock layer. This value will be verified during field testing.

For a trapezoid, Equation 5.1: Manning's Equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow, size the hydraulic radius to be equal to the depth of flow. Using this assumption, the typical Manning's Equation, Equation 5.1, was altered to Equation 5.2 to solve for the Swale Bottom Width.

Equation 5.2: Swale Bottom Width

$$B = \frac{(\left[\frac{n}{1.486}\right] * Q)}{(y^{1.667} * S^{0.5})} - (Z * y)$$

where:
B = bottom width of the swale (ft)
Q = flow (cfs)
y = equivalent depth of flow in the treatment rock layer (ft); the maximum allowed depth is 3 inches.
S = longitudinal slope of swale (ft/ft)
Z = the side slope of the swale in the form of z:1

5. The depth of rock needed is determined by Equation 5.3. Divide y from Equation 5.2 by the porosity of the treatment layer rock. Assume 40% porosity for poorly graded rock.

Equation 5.3: Treatment Rock Layer Depth

$$D = \frac{y}{\emptyset}$$

where:
D = depth of treatment rock layer (inches)
y = equivalent depth of flow in the treatment rock layer (ft) used in Equation 5.2
Ø = porosity of the treatment rock layer

6. Calculate the velocity of flow in the channel. Use Equations 5.4 and 5.5 with the swale dimensions determined earlier in the design procedure to determine the velocity at the water quality flow rate. If the average velocity is ≥ 1 ft/sec (to be verified during field testing) when using this water quality design flow rate, the swale will not function correctly. Increase the bottom width and recalculate the velocity.

Equation 5.4: Manning's Equation

$$V = \frac{1.49R^{2/3}S^{1/2}}{n}$$

Where:
V = velocity in the swale (ft/s)
R= hydraulic radius (ft)
S = longitudinal slope of the swale (ft/ft)
n = Manning's roughness coefficient.
Use n = 0.40 for the water quality design flow rate. This higher value represents flow through the treatment rock layer. This value will be verified during field testing.

For trapezoidal shapes, the hydraulic radius is described by Equation 5.5.

Equation 5.5: Manning's Equation

$$R = \frac{(B + zy)y}{B + 2y\sqrt{1 + z^2}}$$

Where:
B = bottom width of the swale (ft)
y = equivalent depth of flow in the treatment rock layer (ft)
Z = the side slope of the swale in the form of z:1

7. Use the average velocity found in step 6 and Equation 5.6 to calculate the length of the swale using a hydraulic residence time of 9-minutes (540 seconds).

Equation 5.6: Swale Length

$$L = V_{avg} * T$$

where:

T = Assumed 9-minute (540 second) hydraulic residence time (to be confirmed during testing)
V_{avg} = Average velocity (Step 6)
L = Length of swale

8. Select a location where a filtration swale with the calculated bottom width and length will fit. If the calculated length is not possible, consider the following solutions:
   - Divide the site drainage to flow to multiple non-vegetated filtration swales.
   - Use infiltration or dispersion upstream of the bioswale to provide lower flow into the swale.
   - Alter the design depth of flow if possible.
   - Reduce the developed surface area to gain space for the swale.
   - Reduce the longitudinal slope by meandering the biofiltration swale.
   - Nest the biofiltration swale within or around another stormwater BMP.

9. Determine the total depth of channel, to include freeboard above the depth of flow during the 25-year 24-hour storm (composite n value to be verified during field testing).

10. The maximum velocity in the total depth of the channel should also be checked to ensure the velocity above the treatment layer does not cause movement of rock. The maximum velocity must be less than 1.8 ft/sec for

longitudinal slopes of 1%-2.5% and less than 2.5 ft/sec for longitudinal slopes of 2.5%-5%. This step is skipped if all storms larger than the short-duration water quality storm bypass the filtration swale.

Table 2 summarizes the methods and assumptions for the above steps for sizing non-vegetated filtration swales.

Table 2: Sizing Methods and Assumptions for Non-Vegetated Filtration Swales

Steps	Variable	Methods and Assumptions
1	Water Quality Design Flow Rate (Q)	See Chapter 4 – Hydrologic Analysis and Design for methods for computing design storms. The SCS Type II 24-hour storm with a 6-month return frequency and Rational Method using the 2-year mean recurrence interval were used.
2	Bottom Slope (S)	• Minimum = 1% • Maximum = 5%
3	Shape of Swale	Trapezoidal; rectangular shapes can also be used.
4	Manning's n	• Use a Manning's n of 0.4 to represent flow through the treatment rock layer during the water quality design storm. • Typically, n =0.036 during the 25-year flow (composite n value to be verified during field testing).
4,5	Flow Depth (y)	• Default/Maximum of 3 inches of effective depth. This depth is contained in the depth of rock based on porosity estimates of the gradations proposed.
4,5,7	Bottom Width (B)	• Use Manning's Equation (Equation 5.2 Manning's Equation) to solve for bottom width (B) • Minimum = 2 feet • Maximum = 10 feet • For larger bottom widths, parallel swales should be used in conjunction with a device that splits the flow and directs the proper amount to each swale. • For very low flow rates, Manning's Equation may generate a negative value for B. B should be set to 2 feet in these cases
7	Length (L)	• Minimum = 100 feet[1] • If minimum length is not possible, increase the bottom width (B) so that the bottom area of the swale divided by the bottom width (B) is equal to the minimum length.
9	Freeboard	Minimum = 1 foot
10	Velocity at Total Depth of Channel (V_{max})	• For swales with a slope of 1% to 2.5%, Vmax ≤ 1.8 ft/sec • For swales with a slope of 2.5% to 5%, Vmax ≤ 2.5 ft/sec

[1] The length of the swale will be evaluated during field testing. Samples will be taken at different points in the swale and used to determine the appropriate length. As a result this value may be revised following field testing.

Construction Criteria

The non-vegetated filtration swale should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils can impede the flow of water in the swale and reduce swale treatment effectiveness. Thus, effective erosion and sediment control measures should remain in place until the swale is constructed per plans (see Chapter 7 - Construction Stormwater Pollution Prevention for erosion and sediment control BMPs). Avoid compaction during construction. Grade swales to attain uniform longitudinal and lateral slopes.

Operation and Maintenance Criteria

The following bullets list basic operation and maintenance actions for the non-vegetated filtration swale[1]. See Appendix 5-A: Recommended Maintenance Criteria for Runoff Treatment BMPs for detailed recommended maintenance criteria.

- Inspect non-vegetated filtration swales periodically, especially the 25 feet downstream of an inlet and upstream of an outlet, as well as after periods of heavy runoff. Remove sediments, trash and debris to keep swales free of external pollution.
- Clean curb cuts when soil and vegetation buildup interfere with flow introduction.
- Inspect for indicators that sediment is accumulating in the treatment rock layer. If sediment is accumulating in the treatment rock layer, the rock and sediment may need to be removed in the area of the indicator or throughout the swale. The following are potential indicators:
  - Ponded water in the swale
  - Water flowing above the surface of the rock during the water quality storm event or lower flow rates
  - Grass or weeds growing in the swale

[1] It is anticipated that additional maintenance guidance will be identified and developed during the field testing. The QAPP will include more details about the guidance will be developed

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation	Indicators of sediment accumulation include: • Flow above the surface of the rock during the water quality storm event or lower flow rates • Grass or weeds growing in the swale These indicators will likely occur within 25 feet of the inlet and outlet, so special attention is needed in those areas.	Remove the sediment and treatment rock layer around the indicator or throughout the swale as applicable. Replace with clean rock to match original rock gradations and depth.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Check the outlet of the swale for any debris or blockage.
	Flow Spreader (As Applicable)	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Poor Rock Coverage	When rock eroded channels occur in >10% of the swale bottom.	Determine why there are eroded channels and correct that condition. Add new rock to fix the eroded channel.
	Vegetation	When grass or weeds become visually present in the swale.	Remove grass or weeds so that flow not impeded. Check treatment rock layer for sediment buildup below the surface by removing rock down to the subsoil. If sediment is found in the rock, remove affected rock and replace with new clean rock to match original rock gradations and depth.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the swale.	Remove trash and debris from swale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas < 12 inches wide, repair the damaged area by replacing with the applicable rock gradations. If bare areas are large, generally > 12 inches wide, the swale should be regraded in the area. Consider increasing the size of/adding a layer of 2.5” coarse cobbles at a depth of 2.5 inches on top of the existing rock if erosion or scouring occurred during flow events with a lower flow rate than the 25-year.[1]

[1] If erosion is observed during smaller storms than the 25-year event, additional investigation may be needed to determine the cause of the erosion before the rock gradation is upsized. For example, it is possible that additional area has been diverted to the swale or that the land cover upstream has changed.

Appendix B. Ecology Comment Response Log

Commenter Initials	Page Number	Section Title	Comment	Response
AJ	cover	Cover Page	Update throughout document	Revised company name and address to reflect Evergreen StormH2O, LLC throughout report.
BL	i	Signature Page	Need to add me as Quality Assurance signature for Ecology.	Added Brandi Lubliner to signature page as "Ecology Reviewer for Quality Assurance".
DH	ii	Distribution List	What is meant by "Eastern Washington as the first item in the TOC?	This was due to a formatting issue. "Eastern Washington" and has been removed from the TOC.
DH	ii	Distribution List	You need to change your affiliation, emails, and phone numbers.	Revised company name and contact information to reflect Evergreen StormH2O, LLC throughout report.
DH	5	3.1	Add actual BMP number	Added BMP number T5.40 for Biofiltration Swale to the text.
BL	7	3.2	Spell out first time and put short in parenthesis	Defined MS4 and add acronym in parentheses after.
DH	7	3.2	Where did this come from? Currently EaWA permittees need to retain the 10-year storm on-site as a permit requirement. How does this swale provide stormwater infiltration and thus, provide for retaining stormwater on-site?	Revised to clarify that this BMP, if it meets treatment performance goals, would provide water quality treatment for runoff on-site (will not support retaining stormwater on-site). Also aded clarification that the BMP is sized to <u>convey</u> the 25-year, as required in the SWMMEW (based on BMP T5.40).
AJ	8	3.3.1	The GROSS Grant agreement references 5 swale designs. Where is the test design without the liner?	Added clarification to this paragraph that the most promising alternative will be installed at the end of testing as a fifth swale design that does not include an impermeable liner.
BL	8	3.3.1	1.25” is coarse “gravel” per Figure 7.4. Cobble doesn’t start until 2.52”+	Changed 1.25-inch and 2.5-inch sizes to "gravel" instead of "cobble".
BL	9	3.3.1	1.25” is gravel, but depending on what you’re meaning the 2.5” could be gravel or cobble. I think you mean gravel because you’ll place rock between the size range of 1.25 – 2.5” right, so gravel. Figures say cobble. If this causes a problem with the manuals (like these figures come from the manuals or WSDOT specs) then go with whatever the manuals say.	Used gravel instead of cobble based on Figure 7.4. WSDOT standard specifications refer to the sizes as either gravel or coarse aggregate, and cobbles are larger (4" or larger) size rock.
BL	11	3.3.1	Cobble starts at 2.5” and goes larger. Earlier edits made for gravel … whichever word used, be consistent	Used gravel instead of cobble based on Figure 7.4.
DH	13	4.2, Second Bullet	There is a max flow rate associated with this treatment capability. You will need to work with both. For example, a swale design may meet 80% removal for a flow rate of 1 cfs, but not for a flow rate of 2 cfs. This flow rate will need to be included in the final report.	Added text clarifying that the removal efficiency will be associated with a maximum flow rate and will explain how that flow rate will be measured in the following bullet.
BL	13	4.2, Second Bullet	Doesn’t match the yellow highlight below. Sounds like there is grab sampling throughout the swale length. I read in section 4.5 going to use synthetic stormwater, so now I am understanding that the test swales are in series likely… right?	Revised bullet so it is clear that there are eight effluent grab samples through the length of the swale. The test swales will be installed adjacent and within the footprint of the existing swale. The swales will receive separate batches of synthetic stormwater. Added an explanation of that configuration.
BL	13	4.2, Second Paragraph	And HRM?	Yes, added reference to HRM.
BL	13	4.2, Third Paragraph (First Sentence)	Odd sentence. The QAPP is for the whole study includes field, lab, site work, reporting requirements, etc.	Removed sentence and revised new first sentence of paragraph.
AJ	13	4.2, Third Paragraph	What about the 5th swale that is to be unlined?	Added a sentence or two about the fifth swale to be installed without a liner.
BL	13	4.2, Third Paragraph	There are two these swales in series, should be stated here. So need to clarify that each swale will get its own same synthetic storm influent and then the effluent of each of the swales is sampled along the length.	Added an explanation that the test swales will be installed adjacent and within the footprint of the existing swale. Also explained that the swales will receive separate, identical synthetic stormwater batches and will be sampled at the influent and along the length of the swales.
BL	13	4.2, Third Paragraph	Later it says 430ft swale?	The clarification about the two swales (see response to previous comment) explains that the two test swales will be installed adjacent within the existing 430-foot swale footprint.

Commenter Initials	Page Number	Section Title	Comment	Response
BL	14	4.3, First Paragraph	Ok, so not long enough for all 4 at once. How is this study being staged?	Added a brief description about how the study will be staged. For reference, two swale alternatives will be installed and tested. Then those swale alternatives will be removed and the remaining two swale alternatives will be installed and tested. Following the testing of the remaining two swale alternatives, the best performing (in terms of pollutant removal efficiency and estimated longevity) swale will be installed without a liner and tested. Following all testing, the swale will be returned to its original condition.
DH	16	4.5	Add return existing swale to it current condition following completion of the study?	Added a bullet for this to the list in Section 4.5.
BL	16	4.5	Oh, ok. This detail should be made more clear in intro and alleviates concerns with the test sites being in-series. The second swale in the series MUST get its own synthetic water as influent. Will you be running both swales on the same day? Effluent from #1 would enter #2 which isn't a big concern unless there is a lot of water and it dilutes swale #2's influent. Consider alternating days for testing the swales in series.	Agreed. Added explanation in Section 4.2 the that the test swales will be installed adjacent and within the footprint of the existing (430-foot) swale. Also explained that the swales will receive separate, identical synthetic stormwater batches and will be sampled at the influent and along the length (8 samples total) of the swales. Added text regarding how the study will be staged as well.
BL	16	4.5	Now I'm not understanding the design. Are there 9 sample every swale so 9x4= 36 samples?	There will be one influent sample, and eight effluent samples taken during each synthetic storm event. Each swale design alternative will receive six synthetic storm events. Added text clarifying.
BL	18	5.1, Table 5.1	Add me here.	Added you to the table as an Ecology Reviewer.
BL/AJ	20	5.2, Table 5.2	Completion of the study is when the all TAC comments have been addressed on the draft report. Compliance is defined by the permit - delivery of the final report and fact sheet to Ecology.	Thank you for this clarification, kept suggested revision.
AJ	21	5.2, Table 5.3	Note: West Richland upload to PARIS also for permit compliance	Added footnote indicating this is uploaded to PARIS.
AJ	21	5.2, Table 5.4	Note: West Richland upload final Fact Sheet and TER to PARIS for permit compliance	Added footnote indicating this is uploaded to PARIS.
BL	25	6.0, Table 6.1	Would really help with understanding if this was stated like this much earlier.	Incorporated this language into clarification added to Section 4.2.
KL	31	7.1	I'm not sure if combining the equation in Yuen and the manning's equation is the best approach to calculate flow in in a horizontal saturated (?) rock system. Yuen refers to a vertical unsaturated soil column. Also, there is a change in manning's n once the water leaves the rock matrix. Below are suggestions from our Groundwater Manager who is a hydrogeologist with regards to flow. I like his approach because you are measuring flow in situ and not once it comes out of the porous system with a change in manning's n. Generally, the equation we use to determine flow velocity in ground water is V = ki/ne where k is hydraulic conductivity, i = gradient and ne = effective porosity.	Included the equations and approach suggested by the Groundwater Manager and revised the QAPP to reflect this approach.
DH	31	7.1	Calculations using information from the flow meter will help to calculate the velocity through the treatment rock layer.	Will use piezometers at the upstream and downstream end of each swale to calculate flow rate and velocity through the treatment rock layer. Added text explaining this to sections discussing the study design and data collected during the study.
BL	31	7.1	Is effluent from the upper swale going to enter the lower swale?	Effluent from the upper swale will not enter the lower swale. The effluent will be collected in a catch basin or similar structure and pumped into a water truck or similar.
BL	33	7.1	Phase 1 and Phase 2 – don't need to designated these different but related goals this way.	Removed references to Phase 1 and Phase 2 here.
DH	33	7.1	Are we expecting constant influent concentration? Will you perform a test to confirm that this is the case?	The system to contain and mix the synthetic stormwater for the influent is being designed to create a constant influent concentration. Testing of the system will be conducted before storm events are simulated in the swales to confirm influent concentrations are constant over the time to empty the tank. This explanation was added to sections of the QAPP discussing the study design.

Commenter Initials	Page Number	Section Title	Comment	Response
BL	33	7.1	Why limit recommendations to only one. If more than one meets the treatment goals, they can be recommended. Additional info on costs etc is great, but this sounds like information will be held back.	Will revise text to indicate treatment performance of each swale will be reported and whether other swale design alternatives meet treatment performance goals.
DH	34	7.3, Sixth Bullet	Aren't you changing the bottom width to 2 feet?	Yes, the bottom width will be 2 feet. Updated references to 3.5 feet throughout the QAPP.
DH	34	7.3, Table 7.1	2 feet?	Revised to 2 feet.
BL	34	7.3, Table 7.1	gravel - per figure 7.4	Revised to gravel per Figure 7.4.
DH	36	7.4	Is this where the alternative equation comes in?	Yes, revised discussion of effluent flow rate measurement and equation to calculate effluent flow rate and velocity.
DH	37	7.5, Fourth Paragraph	Either “the tank is emptied” or “sufficient flow”, not “the tank sufficient flow”	Will revise to "the tank is emptied".
DH	37	7.5	What data will you get during the second round?	Flow and water quality data will not be collected during the second round. The purpose of the second round is to deliver loading of TSS, so that during the subsequent simulated storm events we can simulate years of time having passed, and evaluate the performance of the non-vegetated swale over (simulated) long periods of time. The performance will be evaluated by comparing visual observations and water quality results at each effluent grab sampling location between storms. Will add an explanation to clarify no data will be collected during the second round and how the performance of the swale will be evaluated.
DH	41	8.1.2, Equipment Needed	Why use the term "more" here? Isn't it sufficient to just say Sil-Co-Sil?	Will revise "more" to actual amount needed.
DH	41	8.1.2, Step 5	Will the automatic samplers fill with water before you reach the design flow rate? Could you set up a valve process to return water to the tank during pump startup and then switch water to the swale once the pump has reached operating level?	The automatic samplers will be placed into the swale after the influent flow rate has reached the water quality design flow rate. Revised study design and SOPs to reflect this.
BL	47	10.2	Don’t apply to TSS	Will remove references to matrix spike and matrix spike duplicate throughout.
BL	47	10.2, Table 10.1	Where are the values? Lab control sample acceptable range is 80-120% recovery. Lab blank should be non-detectable or below detection limit of 0.5mg/L (stated earlier), and the lab duplicate pair should be <= 20% of each other.	Values were in Table 6.2 and were added here. The lab selected performs a laboratory standard analysis instead of a laboratory control sample to check the accuracy of the method, and is included in Table 6.2.
DH	55	14.2	TAPE has specific requirements for data reporting. We use the bootstrap calculator to get the required percent removal.	Revised how example data is shown in Section 14.2 to align with TAPE requirements.
DH	57	14.2, Table 14.2	Average will need to be greater than 80% to meet TAPE bootstrap analysis requirements.	As discussed, one or two of the simulated storm events will have an influent concentration between 100-200 mg/L. Example values in Table 14.2 were updated to reflect this and content was added to sections discussing the study design to explain.
DH	59	15.1, Table 15.1	Make sure you include the information required in TAPE here.	Revised final report sections to match what is required by TAPE.
DH	59	15.2	Make sure you include the information required in TAPE here.	Revised information regarding dissemination of project documents to match what is required by TAPE.

Appendix C. Non-Vegetated Filtration Swale Sizing Calculations

Swale Sizing Calculations

Parameters	Variable	Units	Width = 2 Slope = 0.01 Value 1
Current Bottom Width	B	ft	6.5
Depth of Swale	D	in.	18
Current Side Slope of Channel	Z	X:1	2
Updated Side slope of Channel	Z	X:1	3
Updated Swale Bottom Width	**B**	**ft**	**2**
Updated Swale Width	B	ft	2
Mannings Value	n	-	0.4
Depth of flow	y	ft	0.25
Longitudinal Slope	S	ft/ft	0.01
XS Area of Flow	A	sf	0.688
Hydraulic Radius	Rh	ft	0.192
Water Quality Flow	Q_{WQ}	**cfs**	**0.085**
Depth of flow	y	ft	0.25
Porosity	p	-	0.4
Adjusted depth of Flow	Y	ft	0.625
Adjusted depth of Flow	**Y**	**in.**	**7.5**
Water Quality Flow	Q_{WQ}	cfs	0.085
Rationnal Method Coef.	m	-	2.89
	n	-	0.59
Time of Concentration	Tc	min.	5
Intensity	I	in./hr	1.12
Loss Coef.	C	-	0.95
Equivalent Basin Area	**A**	**ac**	**0.080**
Equivalent Basin Area	A	ac	0.080
Precipitation Depth (2-yr depth)	I	in.	0.8
Loss Coef.	C	-	0.95
Volume Required	**V**	**cf**	**221.3**
	V	**cf**	**1655.7**
Equivalent Basin Area	A	ac	0.080
Rationnal Method Coef.	m	-	9.43
	n	-	0.664
Time of Concentration	Tc	min.	5
Intensity	I	in./hr	3.24
Loss Coef.	C	-	0.95
High Flow (25-yr event)	Q_{25yr}	**cfs**	**0.247**
Side Slope 1	Z1	X:1	3
Side Slope 2	Z2	X:1	3
Channel Width	B	ft	2
Longitudinal Slope	S	ft/ft	0.01
Manning's Roughness	n	-	0.036
Flow (25yr)	Q_{25yr}	cfs	0.247
Max Shear Stress	τ_c		**0.279**
Selected Stabilization Rock	**Coarse Gravel**	**in.**	**1.25-2.5**

	Swale Bottom Width 2	
	GPM	GPH
2-year Flow Rate	38.25	2294.94
25-year Flow Rate	110.8	6647.5

Sil-Co-Sil Mass Calculations

100 mg/L Concentration					
Volume (gal)	Volume (L)	Concentration (mg/L)	Sil-Co-Sil (mg)	Sil-Co-Sil (lb)	Sil-Co-Sil needed for 6 events, 5 swale alternatives (lb)
1000	3785	100	378500	0.833	**24.981**

200 mg/L Concentration					
Volume (gal)	Volume (L)	Concentration (mg/L)	Sil-Co-Sil (mg)	Sil-Co-Sil (lb)	Sil-Co-Sil needed for 6 events, 5 swale alternatives (lb)
1000	3785	200	757000	1.665	**49.962**

Assumption : 1 mg TSS = 1 mg of Sil-Co-Sil 106

Sil-Co-Sil Mass Calculations

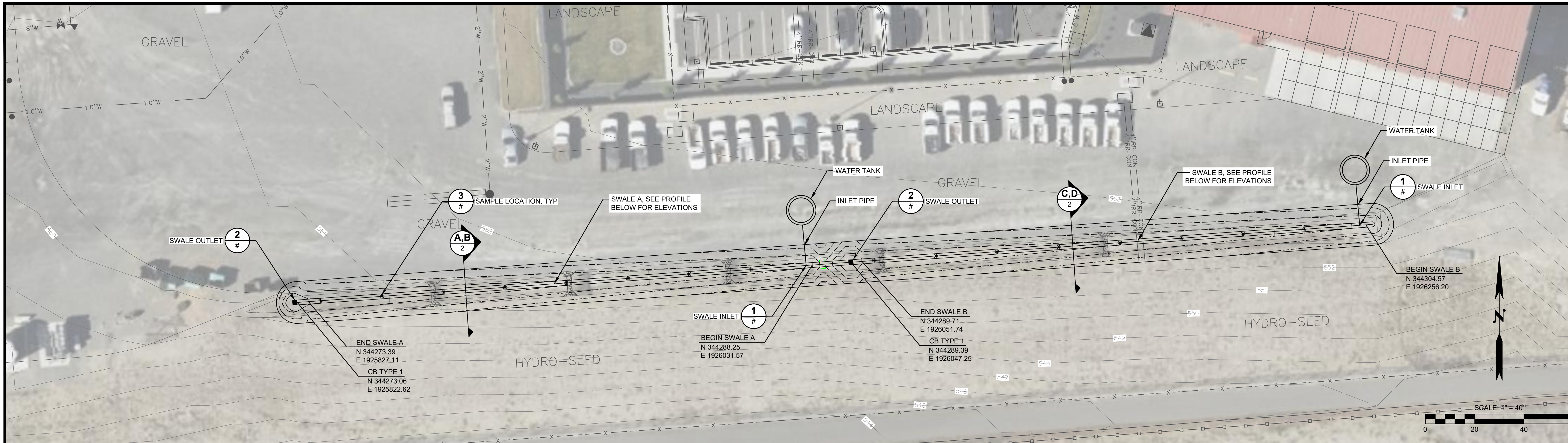
Annual TSS Load (lb/ac)	Basin (ac)	Annual TSS Load (lb)	Number of Phase 2 Events	Lb for X Events	Number of Swales	Total for Annual Loading (lb)	Total SilCoSil Needed (lb)	Number of 50lb containers
175	0.080	14.04	5	70.20	5	351.01	400.97	9.00

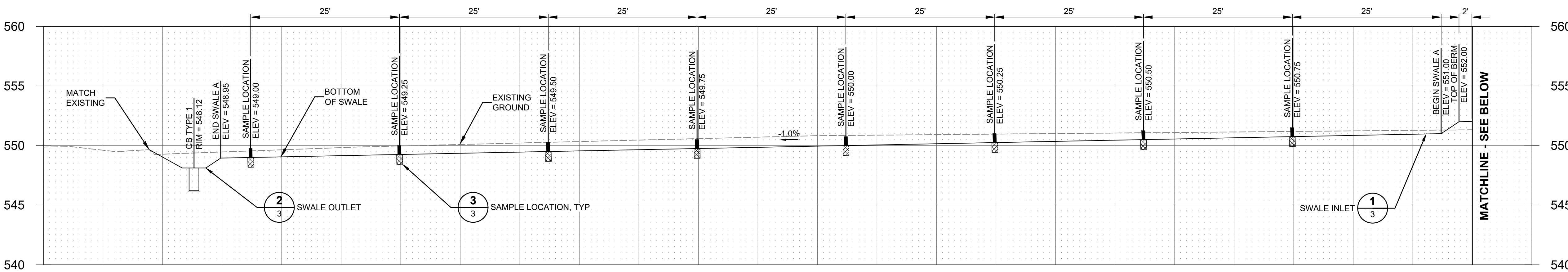
<u>Assumptions/Notes for Load Calc:</u>

1. Source for annual load: Correspondence with Ecology, 6/27/2022
2. Annual TSS load represents an average of loading from land use types
3. Basin area is from swale sizing calculations
4. Total SilCoSil needed includes the amount needed to simulate annual loading and perform 6 simulated storm events with influent concentrations of 200mg/L for each swale alternative.

Appendix D. Construction Plans & Cost

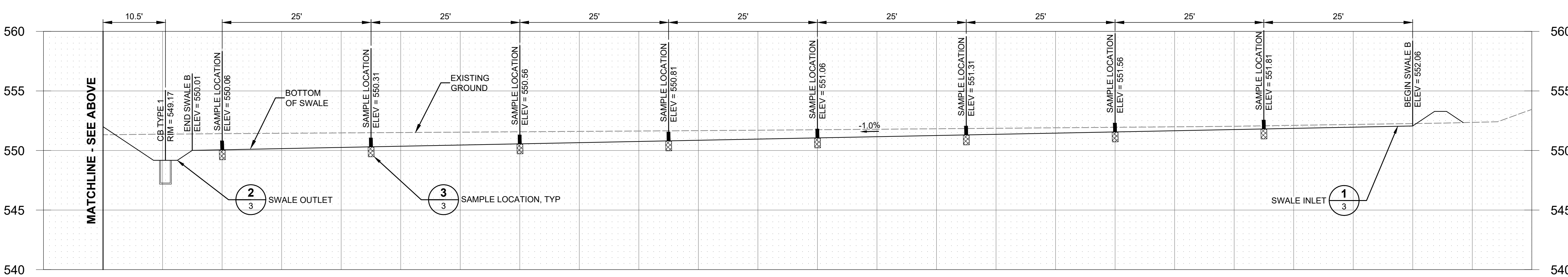
Appendix D.1 Construction Plans





SWALE A PROFILE

HORIZONTAL SCALE: 1" =10', VERTICAL SCALE: 1" = 5'



SWALE B PROFILE

HORIZONTAL SCALE: 1" =10', VERTICAL SCALE: 1" = 5'

811 Know what's below. Call before you dig.

FINAL SUBMITTAL

DESIGNED BY	THB
DRAWN BY	LJT
CHECKED BY	ANB

NO.	DATE	REVISION	BY

city of West Richland

NON-VEGETATED FILTRATION SWALE

CITY OF WEST RICHLAND

SWALE PLAN

JOB# / DWG	DATE
22006	6/30/2022
SCALE	SHEET
H: AS NOTED V: AS NOTED	1 of 3

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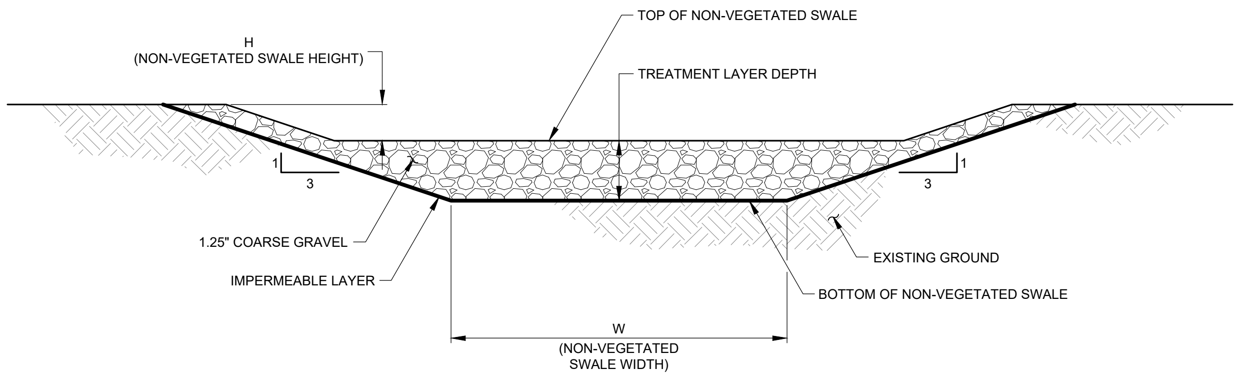
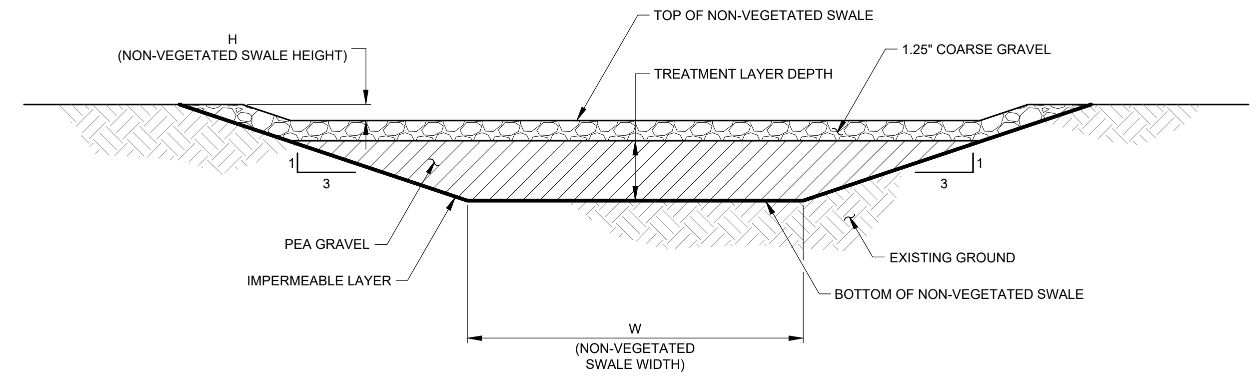


SWALE DESIGN #1 TABLE

W	L	H	LONGITUDINAL SLOPE	1.25" COARSE GRAVEL
FT	FT	IN	%	IN.
2.0	200	4.5 (MIN)	1	7.5

(A/1) NON-VEGETATED SWALE DESIGN #1 SECTION

N.T.S.

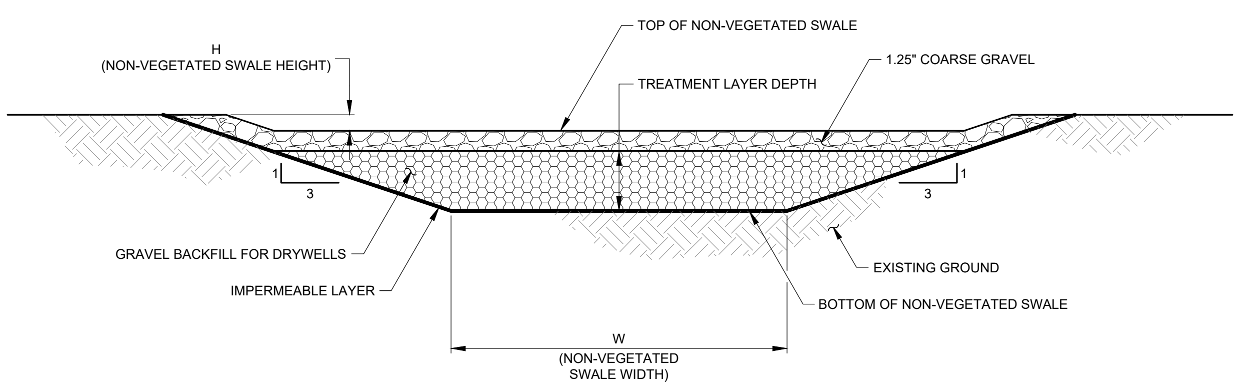


SWALE DESIGN #2 TABLE

W	L	H	LONGITUDINAL SLOPE	1.25" COARSE GRAVEL	PEA GRAVEL
FT	FT	IN	%	IN.	IN.
2.0	200	2.25 (MIN)	1	2.5	7.5

(B/1) NON-VEGETATED SWALE DESIGN #2 SECTION

N.T.S.

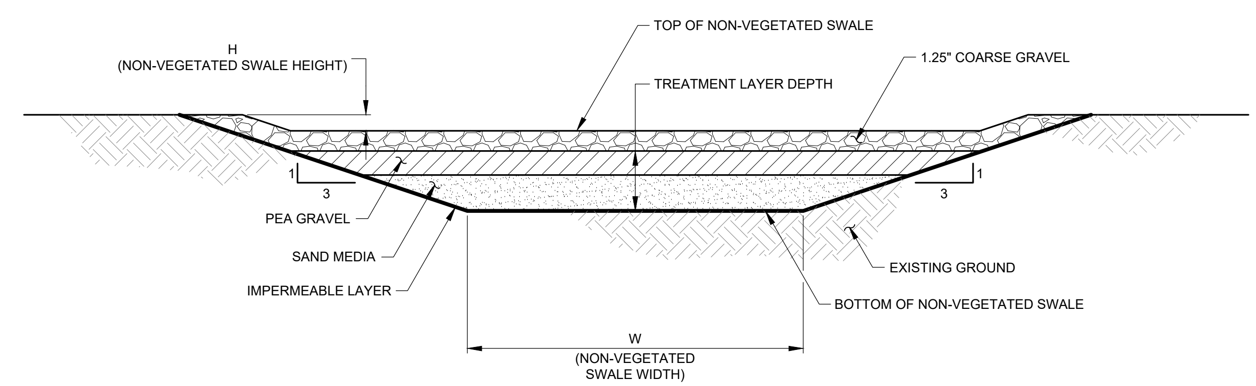


SWALE DESIGN #3 TABLE

W	L	H	LONGITUDINAL SLOPE	1.25" COARSE GRAVEL	GRAVEL BACKFILL FOR DRYWELLS
FT	FT	IN	%	IN.	IN.
2.0	200	2.25 (MIN)	1	2.5	7.5

(C/1) NON-VEGETATED SWALE DESIGN #3 SECTION

N.T.S.



SWALE DESIGN #4 TABLE

W	L	H	LONGITUDINAL SLOPE	1.25" COARSE GRAVEL	PEA GRAVEL	SAND MEDIA
FT	FT	IN	%	IN.	IN.	IN.
2.0	200	2.25 (MIN)	1	2.5	3.0	4.5

(D/1) NON-VEGETATED SWALE DESIGN #4 SECTION

N.T.S.

FINAL SUBMITTAL

DESIGNED BY THB	NO.	DATE	REVISION	BY	
DRAWN BY LJT					
CHECKED BY ANB					

city of West Richland

NON-VEGETATED FILTRATION SWALE
CITY OF WEST RICHLAND
SECTIONS AND DETAILS - 1

JOB# / DWG	22006
DATE	06/30/2022
SCALE	H: N/A V: N/A
SHEET	2 of 3

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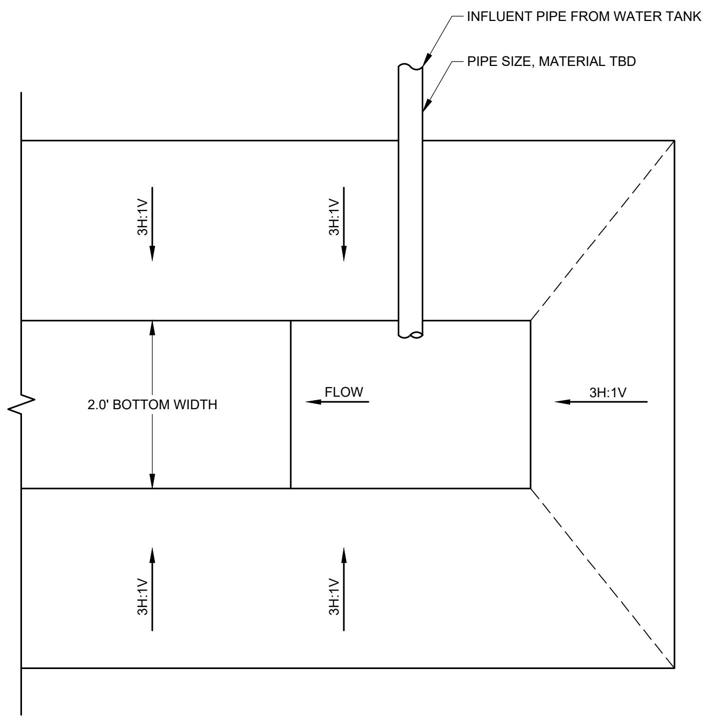
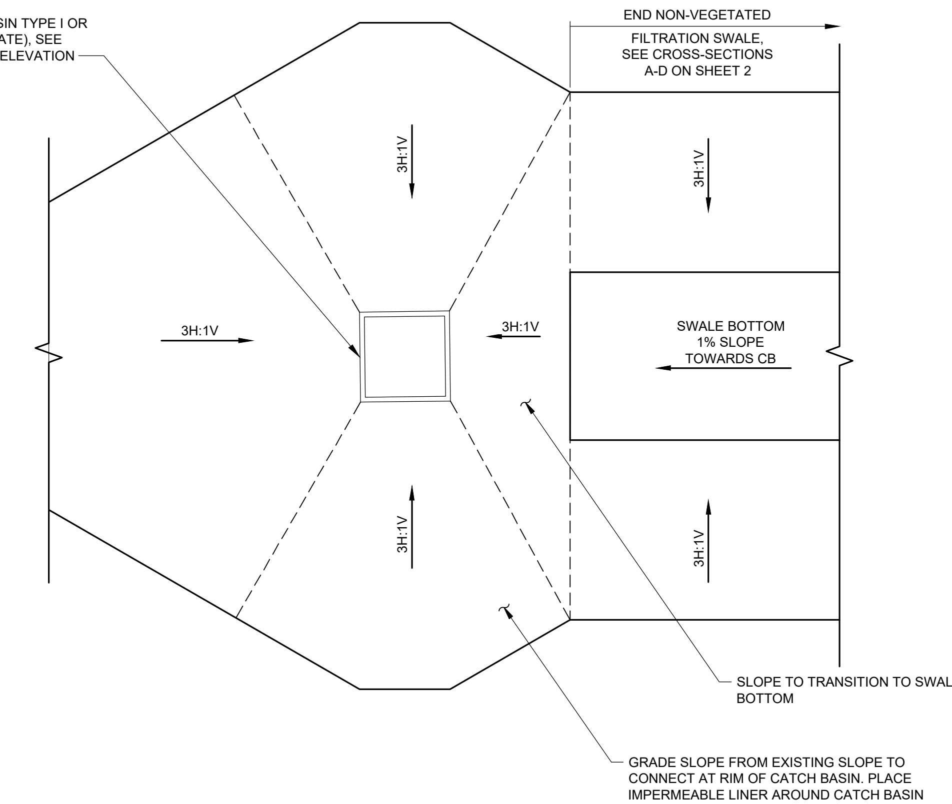
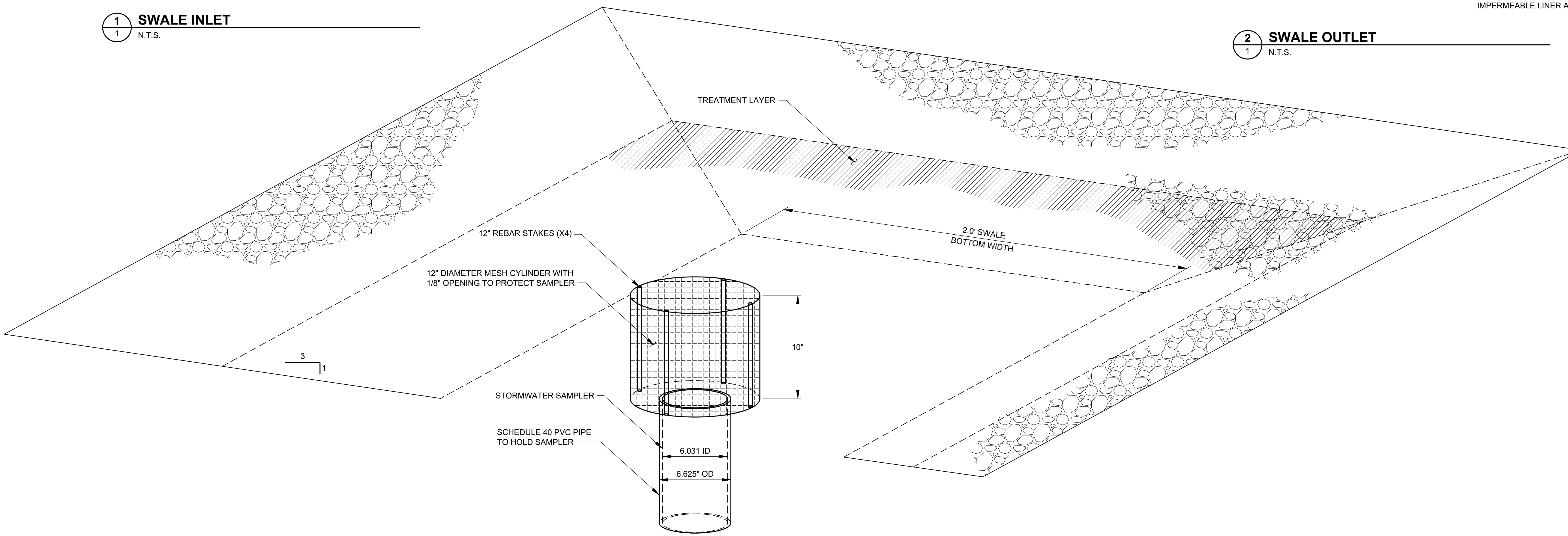


1 SWALE INLET
1 N.T.S.



2 SWALE OUTLET
1 N.T.S.



3 SAMPLE LOCATION
1 N.T.S.

FINAL SUBMITTAL

DESIGNED BY THB		NO.	DATE	REVISION	BY
DRAWN BY LJT					
CHECKED BY ANB					

City of West Richland

NON-VEGETATED FILTRATION SWALE
CITY OF WEST RICHLAND
SECTIONS AND DETAILS - 2

JOB# / DWG	DATE
22006	06/30/2022
SCALE H: N/A V: N/A	SHEET 3 of 3

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PLOT TIME: 6/29/2022 1:09 PM
USER NAME: TAYLOR HOFFMAN-BALLARD

Appendix D.2 Cost Estimate

Swale Rock Materials	Unit	Quantity	Cost Per Unit	Cost
1.25" Coarse Cobble (WSDOT Standard Spec 9-01.1(4)C, AASHTO #4)	TON	103	$ 20.00	$ 2,054.99
Pea Gravel (WSDOT Standard Spec 9-01.1(4)C, AASHTO #8)	TON	50	$ 24.00	$ 1,207.64
Gravel Backfill for Drywells (WSDOT Standard Spec 9-03.12(5))	TON	33	$ 20.00	$ 663.77
SWMMEW Sand Media Spec (likely medium or coarse sand)	TON	16	$ 15.00	$ 240.89
Total Delivery Cost	EA	NA	NA	$ 1,500.00
Construction Equipment	**Unit**	**Quantity**	**Cost Per Unit**	**Cost**
Excavator Monthly Rental	Month	2	$ 3,910.00	$ 7,820.00
Stormwater Distribution Materials	**Unit**	**Quantity**	**Cost Per Unit**	**Cost**
Blue-White F-1000 Paddlewheel Flow Meter	EA	1	$ 443.85	$ 443.85
Piezometers	EA	2	$ 30.00	$ 60.00
SilCoSil	50lb bucket	9.00	$ 22.25	$ 200.25
Plumbers Tape	EA	1	$ 2.58	$ 2.58
PVC Primer	8oz	3	$ 8.68	$ 26.04
PVC Cement	8oz	3	$ 10.28	$ 30.84
3" Male x Hub Schedule 40 Adapter	EA	1	$ 2.18	$ 2.18
3" Hub x Hub Schedule 40 Swing Check Valve	EA	1	$ 40.26	$ 40.26
3" Schedule 40 Pipe	10ft	2	$ 46.98	$ 93.96
3" Hub x 4" Hub Schedule 40 Adapter	EA	1	$ 4.98	$ 4.98
4" Schedule 40 Pipe	10ft	3	$ 38.96	$ 116.88
4" Hub x Hub Sch 40 45 deg elbow	EA	3	$ 9.58	$ 28.74
Ball Valve	EA	1	$ 298.85	$ 298.85
3" Male x Hub Schedule 40 Adapter	EA	2	$ 2.18	$ 4.36
Catch Basin	EA	2	$ 235.00	$ 470.00
Sampling Materials	**Unit**	**Quantity**	**Cost Per Unit**	**Cost**
Nagene Automatic Stormwater Sampler	Case of 4	2	$ 201.00	$ 402.00
Wire Mesh	36"x10' Roll	1	$ 34.99	$ 34.99
Rebar Stakes	EA	40	$ 9.38	$ 375.20
6" Schedule 40 PVC Pipe	LF	10	$ 17.92	$ 179.20
6" Spigot Plug Schedule 40 PVC	EA	16	$ 13.59	$ 217.44
			Subtotal	$ 16,519.89
			20% Contingency	$ 3,303.98
			Tax	$ 1,784.15
			Total	$ 21,608.02

Appendix E. Equipment Specifications

Flow Monitoring Equipment

Blue-White® Industries, Ltd.

DigiFlo Digital Paddlewheel Meters

Engineering and Technical Data

F-1000

Molded In-line Fitting

Three Model Variations:

- **Rate of flow display**
- **Total flow display**
- **Rate & Total display**

Features:

- High accuracy digital paddlewheel technology.
- 3/8", 1/2", 3/4", 1", 1-1/2", and 2" male pipe threads.
- Flow rate from .4 to 200 GPM
- Tamper proof factory programming.
- Easy to read 6 digit LCD display, up to 4 decimal places.
- Battery operated (2 AAA batteries included).
- Very low pressure drop.
- Total reset function can be disabled.

Specifications:

Max. working pressure:........300 PSI (20 bar) @ 70° F (21° C)
Max. fluid temperature: ....200° F (93° C) @ 0 PSI
Max. ambient temperature: ..14° to 110° F/ -10° to 43° C
Full scale accuracy:.............+/- 2%

Power requirement: ....2 AAA batteries (included)
Enclosure: ....NEMA 4X (IP56)
Maximum pressure drop: .....8 PSI (varies per model)
Approximate shipping wt: ...2 lb. (.91 kg)

Materials of Construction:

Pipe fitting: ....Polypropylene (options: PVDF)
Sensor, paddlewheel, axle: ..PVDF

Sensor O-ring seals:............Viton® (optional EP)
Enclosure: ....ABS

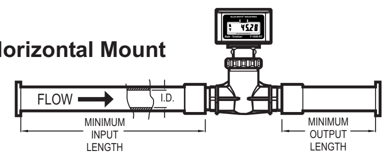
Installation Requirements:

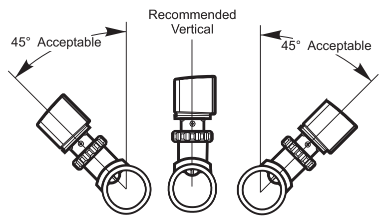
Minimum Straight Pipe Length Requirements

The meter's accuracy is affected by disturbances such as pumps, elbows, tees, valves, etc., in the flow stream. Install the meter in a straight run of pipe **as far as possible** from any disturbances. The distance required for accuracy will depend on the type of disturbance.

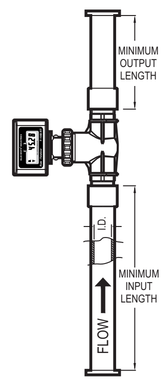
Type Of Disturbance	Minimum Inlet Pipe Length	Minimum Outlet Pipe Length
Flange	10 X Pipe I.D.	5 X Pipe I.D.
Reducer	15 X Pipe I.D.	5 X Pipe I.D.
90° Elbow	20 X Pipe I.D.	5 X Pipe I.D.
Two Elbows -1 Direction	25 X Pipe I.D.	5 X Pipe I.D.
Two Elbows -2 Directions	40 X Pipe I.D.	5 X Pipe I.D.
Pump Or Gate Valves	50 X Pipe I.D.	5 X Pipe I.D.

Horizontal Mount





Angle Mount on Horizontal Pipe



Vertical Mount

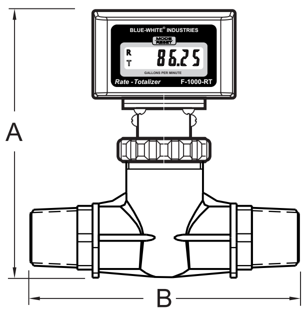
Mounting location

- The meter is designed to withstand outdoor conditions. A cool, dry location, where the unit can be easily serviced is recommended.
- The meter can be mounted on horizontal or vertical runs of pipe. Mounting at the vertical (twelve o'clock) position on horizontal pipe is recommended. Mounting anywhere around the diameter of vertical pipe is acceptable, however, the pipe must be completely full of water at all times. Back pressure is essential on downward flows. See the minimum straight length of pipe requirement chart above.
- The meter can accurately measure flow from either direction.

Blue-White® Industries, Ltd.

DigiFlo Digital Paddlewheel Meters

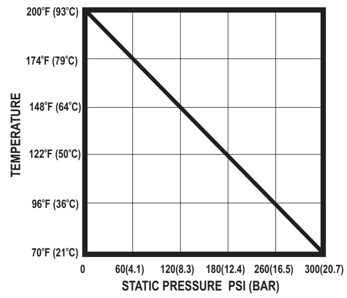
Dimensions:



Pipe Size	A	B
3/8"	5-3/8" (137)	4-3/4" (121)
1/2"	5-3/8" (137)	5-1/8" (130)
3/4"	5-5/8" (143)	5-1/4" (133)
1"	5-5/8" (143)	5-5/8" (143)
1-1/2"	6-1/8" (156)	6-1/2" (165)
2"	6-3/8" (162)	6-3/4" (171)

Inches (mm)

Maximum Temperature vs. Pressure



Flow Stream Requirements:

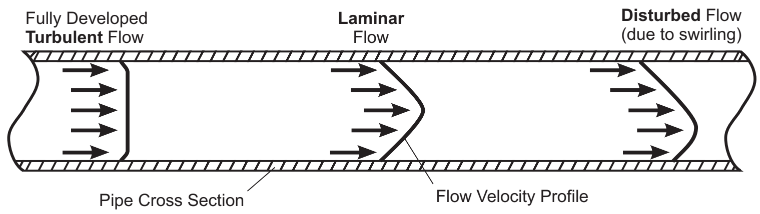
Measuring accuracy requires a fully developed ***turbulent*** flow profile. Pulsating, swirling and other disruptions in the flow stream will effect accuracy. Flow conditions with a ***Reynolds Number*** greater than 4000 will result in a fully developed ***turbulent*** flow. A Reynolds Number less than 2000 is ***laminar*** flow and may result in inaccurate readings.

REYNOLDS NUMBER EQUATION:

$$\text{REYNOLDS NUMBER} = \frac{3160 \times Q \times G}{D \times V}$$

Where:

Flow rate of the fluid in GPM = Q
Specific gravity of the fluid = G
Pipe inside diameter in inches = D
Fluid viscocity in centepoise = V



Pipe Size, Flow Range and Display Model Options:

Models with Polypropylene Pipe Fitting Material

Pipe Size M/NPT	GPM MODELS: GPM Range	GPM MODELS: RATE ONLY Model Number	GPM MODELS: TOTAL ONLY Model Number	GPM MODELS: RATE & TOTAL Model Number	LPM MODELS: LPM Range	LPM MODELS: RATE ONLY Model Number	LPM MODELS: TOTAL ONLY Model Number	LPM MODELS: RATE & TOTAL Model Number
3/8"	.8 to 8	RB-375MI-GPM1	TB-375MI-GPM1	RT-375MI-GPM1	3 to 30	RB-375MI-LPM1	TB-375MI-LPM1	RT-375MI-LPM1
3/8"	.4 to 4	RB-375MI-GPM2	TB-375MI-GPM2	RT-375MI-GPM2	1 to 10	RB-375MI-LPM2	TB-375MI-LPM2	RT-375MI-LPM2
1/2"	2 to 20	RB-500MI-GPM1	TB-500MI-GPM1	RT-500MI-GPM1	7 to 70	RB-500MI-LPM1	TB-500MI-LPM1	RT-500MI-LPM1
1/2"	.5 to 5	RB-500MI-GPM2	TB-500MI-GPM2	RT-500MI-GPM2	2 to 20	RB-500MI-LPM2	TB-500MI-LPM2	RT-500MI-LPM2
3/4"	3 to 30	RB-750MI-GPM1	TB-750MI-GPM1	RT-750MI-GPM1	11 to 110	RB-750MI-LPM1	TB-750MI-LPM1	RT-750MI-LPM1
3/4"	.8 to 8	RB-750MI-GPM2	TB-750MI-GPM2	RT-750MI-GPM2	3 to 30	RB-750MI-LPM2	TB-750MI-LPM2	RT-750MI-LPM2
1"	5 to 50	RB-100MI-GPM1	TB-100MI-GPM1	RT-100MI-GPM1	20 to 200	RB-100MI-LPM1	TB-100MI-LPM1	RT-100MI-LPM1
1"	2 to 20	RB-100MI-GPM2	TB-100MI-GPM2	RT-100MI-GPM2	7 to 70	RB-100MI-LPM2	TB-100MI-LPM2	RT-100MI-LPM2
1-1/2"	4 to 40	RB-150MI-GPM1	TB-150MI-GPM1	RT-150MI-GPM1	15 to 150	RB-150MI-LPM1	TB-150MI-LPM1	RT-150MI-LPM1
1-1/2"	6 to 60	RB-150MI-GPM2	TB-150MI-GPM2	RT-150MI-GPM2	25 to 250	RB-150MI-LPM2	TB-150MI-LPM2	RT-150MI-LPM2
1-1/2"	10 to 100	RB-150MI-GPM3	TB-150MI-GPM3	RT-150MI-GPM3	40 to 400	RB-150MI-LPM3	TB-150MI-LPM3	RT-150MI-LPM3
2"	4 to 40	RB-200MI-GPM1	TB-200MI-GPM1	RT-200MI-GPM1	15 to 150	RB-200MI-LPM1	TB-200MI-LPM1	RT-200MI-LPM1
2"	6 to 60	RB-200MI-GPM2	TB-200MI-GPM2	RT-200MI-GPM2	25 to 250	RB-200MI-LPM2	TB-200MI-LPM2	RT-200MI-LPM2
2"	10 to 100	RB-200MI-GPM3	TB-200MI-GPM3	RT-200MI-GPM3	40 to 400	RB-200MI-LPM3	TB-200MI-LPM3	RT-200MI-LPM3
2"	20 to 200	RB-200MI-GPM4	TB-200MI-GPM4	RT-200MI-GPM4	70 to 700	RB-200MI-LPM4	TB-200MI-LPM4	RT-200MI-LPM4

Models with PVDF Pipe Fitting Material

Pipe Size M/NPT	GPM Range	RATE ONLY Model Number	TOTAL ONLY Model Number	RATE & TOTAL Model Number	LPM Range	RATE ONLY Model Number	TOTAL ONLY Model Number	RATE & TOTAL Model Number
3/8"	.8 to 8	RB-375FI-GPM1	TB-375FI-GPM1	RT-375FI-GPM1	3 to 30	RB-375FI-LPM1	TB-375FI-LPM1	RT-375FI-LPM1
3/8"	.4 to 4	RB-375FI-GPM2	TB-375FI-GPM2	RT-375FI-GPM2	1 to 10	RB-375FI-LPM2	TB-375FI-LPM2	RT-375FI-LPM2
1/2"	2 to 20	RB-500FI-GPM1	TB-500FI-GPM1	RT-500FI-GPM1	7 to 70	RB-500FI-LPM1	TB-500FI-LPM1	RT-500FI-LPM1
1/2"	.5 to 5	RB-500FI-GPM2	TB-500FI-GPM2	RT-500FI-GPM2	2 to 20	RB-500FI-LPM2	TB-500FI-LPM2	RT-500FI-LPM2
3/4"	3 to 30	RB-750FI-GPM1	TB-750FI-GPM1	RT-750FI-GPM1	11 to 110	RB-750FI-LPM1	TB-750FI-LPM1	RT-750FI-LPM1
3/4"	.8 to 8	RB-750FI-GPM2	TB-750FI-GPM2	RT-750FI-GPM2	3 to 30	RB-750FI-LPM2	TB-750FI-LPM2	RT-750FI-LPM2
1"	5 to 50	RB-100FI-GPM1	TB-100FI-GPM1	RT-100FI-GPM1	20 to 200	RB-100FI-LPM1	TB-100FI-LPM1	RT-100FI-LPM1
1"	2 to 20	RB-100FI-GPM2	TB-100FI-GPM2	RT-100FI-GPM2	7 to 70	RB-100FI-LPM2	TB-100FI-LPM2	RT-100FI-LPM2
1-1/2"	4 to 40	RB-150FI-GPM1	TB-150FI-GPM1	RT-150FI-GPM1	15 to 150	RB-150FI-LPM1	TB-150FI-LPM1	RT-150FI-LPM1
1-1/2"	6 to 60	RB-150FI-GPM2	TB-150FI-GPM2	RT-150FI-GPM2	25 to 250	RB-150FI-LPM2	TB-150FI-LPM2	RT-150FI-LPM2
1-1/2"	10 to 100	RB-150FI-GPM3	TB-150FI-GPM3	RT-150FI-GPM3	40 to 400	RB-150FI-LPM3	TB-150FI-LPM3	RT-150FI-LPM3
2"	4 to 40	RB-200FI-GPM1	TB-200FI-GPM1	RT-200FI-GPM1	15 to 150	RB-200FI-LPM1	TB-200FI-LPM1	RT-200FI-LPM1
2"	6 to 60	RB-200FI-GPM2	TB-200FI-GPM2	RT-200FI-GPM2	25 to 250	RB-200FI-LPM2	TB-200FI-LPM2	RT-200FI-LPM2
2"	10 to 100	RB-200FI-GPM3	TB-200FI-GPM3	RT-200FI-GPM3	40 to 400	RB-200FI-LPM3	TB-200FI-LPM3	RT-200FI-LPM3
2"	20 to 200	RB-200FI-GPM4	TB-200FI-GPM4	RT-200FI-GPM4	70 to 700	RB-200FI-LPM4	TB-200FI-LPM4	RT-200FI-LPM4

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www.blue-white.com **Email:** sales@blue-white.com

Technical data sheet #85000-022 rev.080106

Level Measurement Device		Description	Probe Diameter	Tape/Cable Lengths
101 P7 Water Level Meter		Manually measure depth to water using flat tape marked each mm or 1/100 ft. 101 P7 Meters use laser-marked flat tape. Measure total well depth with a P7 Probe (submersible the full length of the tape).	16 mm (5/8")	30 - 600 m (100 - 2000 ft.)
101 P2 Water Level Meter		101 P2 Meters use heat-embossed polyethylene tape. The P2 Probe is simple to clean and repair.	14 mm (0.55")	30 - 300 m (100 - 1000 ft.)
101D Water Level DrawDown Meter		Manually measure depth to water and monitor drawdown using laser marked flat tape, laser-marked each mm or 1/100 ft. Probe is pressure-proof the full length of the submerged tape.	16 mm (5/8")	30 - 600 m (100 - 2000 ft.)
101B Water Level Meter		Manually measure depth to water using heat-embossed polyethylene flat tape, marked every centimeter. The P1 Probe is leak-proof.	12.7 mm (1/2")	30 m, 60 m, 100 m
102 Water Level Meter		Manually measure depth to water using narrow cable, laser-marked each mm or 1/100 ft.	P4: 4 mm (0.157") P10:10 mm (3/8")	30 -300 m (100 - 1000 ft.)
102M Mini Water Level Meter			P4: 4 mm (0.157") P10:10 mm (3/8")	25 m (80 ft).
104 Sonic Water Level Meter		Uses sound waves to detect the depth to static water level without lowering the probe down the well.	16 mm (5/8")	600 m (2000 ft) Detection Range
105 Well Casing & Depth Indicator		Detect where metal well casing starts and ends, and measure the total depth of a well or borehole. Measurements are taken using flat tape laser-marked each mm or 1/100 ft.	22 mm (7/8")	30 - 600 m (100 - 2000 ft.)
201 Water Level Temperature Meter		Manually measure water level and temperature. Water Level measurements are taken from flat tape laser-marked each mm or 1/100 ft.	16 mm (5/8")	30 - 600 m (100 - 2000 ft.)
107 TLC Meter		Manually measure water level, temperature, and conductivity. Water Level measurements are taken from flat tape laser-marked each mm or 1/100 ft.	19 mm (3/4")	30 - 300 m (100 - 1000 ft.)
122 Interface Meter		Manually measure water levels and detect oil/water interfaces. Allows measurement of DNAPL or LNAPL layers. Using the standard 122, levels are taken from flat tape laser-marked each mm or 1/100 ft. Using the 122M, levels are taken from cable laser-marked each mm or 1/100 ft. Intrinsically Safe and ATEX Certified.	16 mm (5/8")	15 - 300 m (50 - 1000 ft.)
122M Mini Interface Meter			16 mm (5/8")	Cable: 25 m (80 ft.)
103 Tag Line		Manually measure well depths using durable cable, laser-marked every 5 cm or 1/4 ft., or flat tape laser-marked every mm or 1/100 ft. (Also a marked support line for samplers, packers, and dataloggers)	19 mm (3/4") or 13 mm (1/2")	30 - 300 m (100 - 1000 ft.)

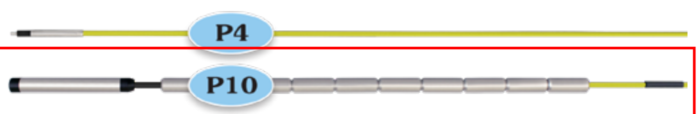
Level Measurement Devices

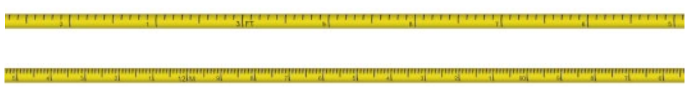
Model 102 Narrow Cable Water Level Meters

The Model 102 Water Level Meters use narrow cable to measure water levels in tight spaces. The segmented P10 Probe offers greater flexibility in angled piezometers and assist in bypassing down-hole restrictions or pumps when measuring draw-down.

The Model 102 Water Level Meters use the same reliable electronics and reel as the Model 101 Water Level Meters; the use of accurately marked cable makes it a more affordable option.

The cable has a tough polyurethane jacket with laser markings each millimeter or 1/100 ft. The braided copper outer conductor provides flexibility, while the stainless steel central conductor reduces stretch and resists corrosion. The cable is easy to repair and splice.





N2: Feet and tenths: with markings every 1/100 ft.
N3: Meters and centimeters: with markings every mm

There are two narrow probe options to choose from. Their probe tip designs minimize false signals in cascading water.

Helpful for reaching greater depths, and for use in the majority of level monitoring applications, the heavier 10 mm x 70 mm (3/8"x 2.75") P10 Probe weighs 6.14 oz. (174 g) with 10 segmented stainless steel weights for easy handling.

For the narrowest applications, the 4 mm x 38 mm (0.157" x 1.5") stainless steel P4 Probe is the choice. It weighs 0.35 oz. (10 g).

The 4 mm P4 stainless steel probe is ideal for measuring in the narrow channels of a Model 403 CMT® Multilevel System and the 10 mm (3/8") open tubes of a Model 401 Waterloo Multilevel System.

The Model 102M Mini Water Level Meter comes with either 25 m or 80 ft. of laser-marked cable on a more compact, portable reel that can fit in a backpack or Solinst mini carry case. The 102M Mini also comes with the choice of a P4 or P10 Probe.

102 Length Options:

Model 102 Water Level Meters are available on reels in the following standard lengths:

Mini Reel	25 m	80 ft.
Small Reel	30 m	100 ft.
	60 m	200 ft.
	100 m	300 ft.
	150 m	500 ft.
	250 m	750 ft.
	300 m	1000 ft.

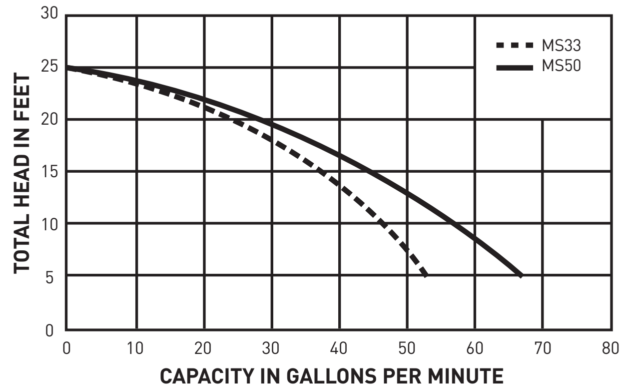
Pumps for Mixing Synthetic Stormwater
and Distributing Flow to Swale

MYERS® MS Series

Submersible Sump Pumps for Dewater

SPECIFICATIONS

Applications		Basement sumps, dewatering	
Capacities		1/2HP at 56 GPM 1/3HP at 45 GPM	212 LPM 170 LPM
Shut-off head		25′	7.6 m
Operation:			
Tethered:	On	14″	356 mm
	Off	5″	127 mm
Vertical:	On	7.5″	190.5 mm
	Off	3″	76 mm
Diaphragm:	On	9-1/2″	241 mm
	Off	5″	127 mm
Solids handling		1/4″	6.4 mm
Liquids handling		Drain water	
Intermittent liquid temp		up to 140°F	up to 60°C
Motor		1/3 HP or 1/2 HP, PSC Motor	
Electrical data		3000 RPM, 115V, 1Ø, 60Hz FLA 1/3 HP = 3.9, 1/2 HP = 4.1	
Acceptable pH range		6-9	
Shaft seal		Double lip	
Motor housing		Corrosion Resistant Material	
Volute case		Cast iron	
Power cord		10′	25.4 m
Discharge, NPT		1-1/2″	
Min. sump diameter Tethered Float:		14″	356 mm
Vertical Float or Diaphragm Switch:		10″	254 mm



FEATURES

- Versatility for many light-duty jobs
- Designed for drain water removal or permanent applications with small amounts of debris
- Maintenance-free operation
- Wide-angle for 14″ or larger sumps.Vertical switch or diaphragm switch for small 10″ or larger sumps.
- CSA Listed
- Dual ball-bearing motor and double lip seal provide durability and longer pump life
- Durable PSC motor for years of service
- Oil-filled motor for maximum heat dissipation, continuous bearing lubrication
- Thermal overload protection with automatic reset

C US

3 YEAR
WARRANTY

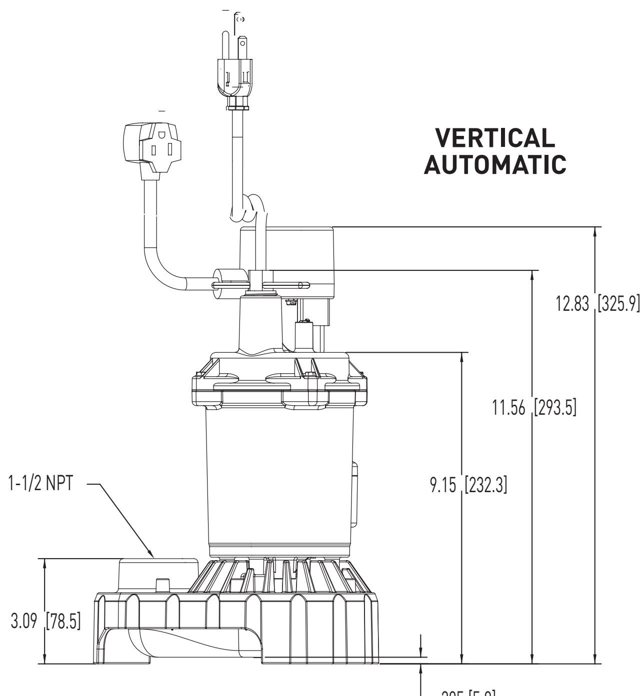
MODEL NUMBERS

MS33V10	MS33D10
MS50V10	MS50D10
MS33T10	
MS50T10	

MYERS® MS Series

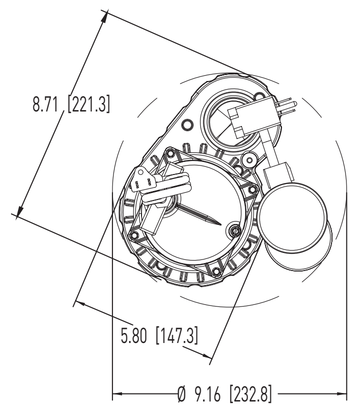
Sumbersible Sump Pumps for Dewater

DIMENSIONS



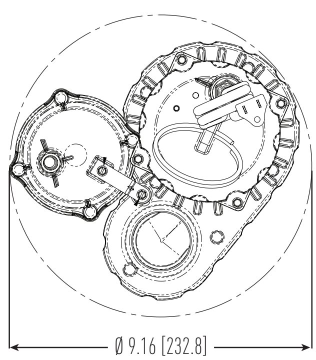
1/3 HP & 1/2 HP PUMP

VERTICAL AUTOMATIC

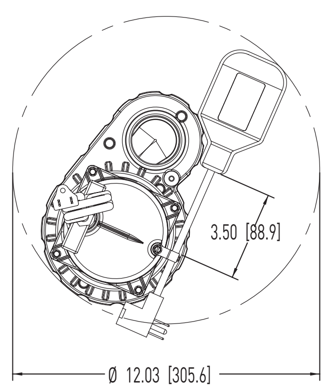


1/3 HP & 1/2 HP PUMP
WITH VERTICAL SWITCH

DIAPHRAGM AUTOMATIC



TETHERED AUTOMATIC



1/3 HP & 1/2 HP PUMP
WITH TETHERED SWITCH

PENTAIR

USA
293 WRIGHT STREET, DELAVAN, WI 53115 WWW.FEMYERS.COM
PH: 888-987-8677 ORDERS FAX: 800-426-9446

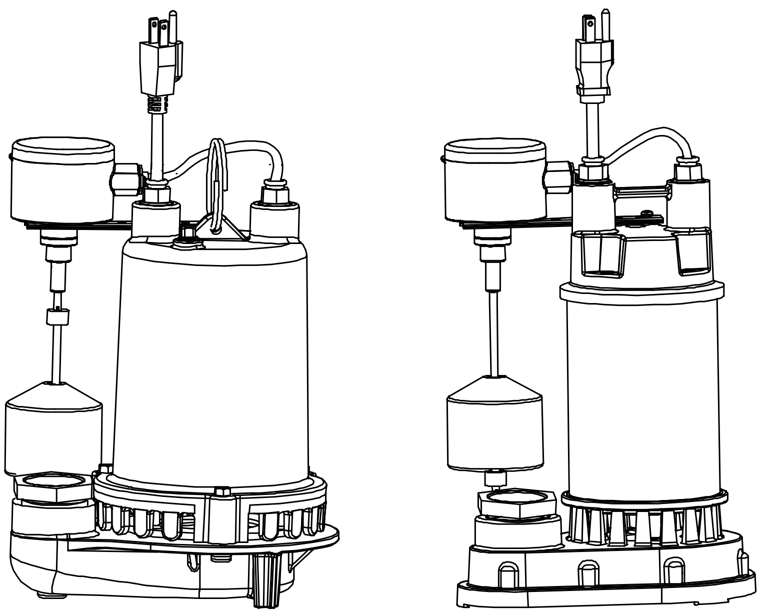
CANADA
490 PINEBUSH ROAD, UNIT 4, CAMBRIDGE, ONTARIO, N1T 0A5
PH: 800-363-7867 FAX # 888-606-5484

EVERBILT™

SKU# 1000026686 1000026682
1000026675 1000026662
Model# SP03302VD SP05002VD
PSSP07501VD PSSP10001VD

USE AND CARE GUIDE

SUBMERSIBLE SUMP PUMP



SKU # 1000026675 SKU #1000026662   SKU # 1000026686 SKU # 1000026682

Questions, problems, missing parts? Before returning to the store call
Everbilt Customer Service
8 a.m. - 6 p.m., EST, Monday-Friday

1-844-241-5521

HOMEDEPOT.COM

Rev.11/21/17

THANK YOU

We appreciate the trust and confidence you have placed in Everbilt through the purchase of this non-submersible sump pump. We strive to continually create quality products designed to enhance your home. Visit us online to see our full line of products available for your home improvement needs. Thank you for choosing Everbilt!

Table of Contents

Performance

SKU	HP	GPH of Water @ Total Feet Of Lift						Max. Lift
		0 ft.	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.	
1000026686	1/3	4000	3700	3300	2800	1860	0	25 ft.
1000026682	1/2	4200	4000	3600	3200	2400	1200	29 ft.
1000026675	3/4	5150	4800	4320	3660	2580	0	25 ft.
1000026662	1	5500	5160	4680	4200	3480	2340	30 ft.

Safety Information

DANGER: Do not pump flammable or explosive liquids such as oil, gasoline, kerosene, ethanol, etc. Do not use in the presence of flammable or explosive vapors. Using this pump with or near flammable liquids can cause an explosion or fire, resulting in property damage, serious personal injury, and/or death.

DANGER: ALWAYS disconnect the power to the pump before servicing.

DANGER: Do not touch the motor housing during operation. The motor is designed to operate at high temperatures. Do not disassemble the motor housing.

DANGER: Do not handle the pump or pump motor with wet hands or when standing on a wet or damp surface, or in water.

WARNING: Extension cords may not deliver sufficient voltage to the pump motor. Extension cords present a life threatening safety hazard if the insulation becomes damaged or the connection ends fall into water. The use of an extension cord to power this pump is not permitted.

WARNING: Secure the discharge line before starting the pump. An unsecured discharge line will whip, possibly causing personal injury, and/or property damage.

WARNING: Release all pressure and drain all water from the system before servicing any component.

WARNING: Wear safety goggles at all times when working with pumps.

WARNING: This unit is designed only for use on 115 volts (single phase),60 Hz, and is equipped with an approved 3-conductor cord and 3-prong grounded plug. Do not remove the ground pin under any circumstances. The 3-prong plug must be directly inserted into a properly installed and grounded 3-prong, grounding-type receptacle. Do not use this pump with a 2-prong wall outlet. Replace the 2-prong outlet with a properly grounded 3-prong receptacle (a GFCI outlet) installed in accordance with the National Electrical Code and local codes and ordinances. All wiring should be performed by a qualified electrician.

WARNING: Protect the electrical cord from sharp objects, hot surfaces, oil, and chemicals. Avoid kinking the cord. Do not use damaged or worn cords.

WARNING: Failure to comply with the instruction and designed operation of this unit may void the warranty. ATTEMPTING TO USE ADAMAGED PUMP can result in property damage, serious personal injury, and/or death.

Safety Information (continued)

WARNING: Ensure that the electrical circuit to the pump is protected by a15 Amp fuse or circuit breaker.

CAUTION: Do not lift the pump by the power cord.

CAUTION: Know the pump and its applications, limitations, and potential hazards.

CAUTION: Secure the pump to a solid base. This will aid in keeping the pump in a vertical orientation. This is critical in keeping the pump operating at maximum efficiency. It will also help prevent the pump from clogging resulting in premature failure.

CAUTION: Periodically inspect the pump and system components to ensure the pump suction screen is free of mud, sand, and debris. Disconnect the pump from the power supply before inspecting.

CAUTION: Follow all local electrical and safety codes, along with the National Electrical Code (NEC). In addition, all Occupational Safety and Health Administration (OSHA) guidelines must be followed.

IMPORTANT: The motor of this pump has a thermal protector that will trip if the motor becomes too hot. The protector will reset itself once the motor cools down and an acceptable temperature has been reached. The pump may start unexpectedly if it is plugged in.

IMPORTANT: Ensure the electrical power source is adequate for the requirements of the pump.

IMPORTANT: This pump is made of high-strength, corrosion-resistant materials. It will provide trouble-free service for a long time when properly installed, maintained, and used. However, inadequate electrical power to the pump, dirt, or debris may cause the pump to fail. Please carefully read the manual and follow the instructions regarding common pump problems and remedies.

Warranty

The manufacturer warrants the products to be free from defects in materials and workmanship for a period of five years (1000026675, 1000026662) and three years (1000026686, 1000026682) from date of purchase. This warranty applies only to the original consumer purchaser and only to products used in normal use and service. If within five years (1000026675, 1000026662) and three years (1000026686, 1000026682) this product is found upon examination by the manufacturer to be defective in materials or workmanship, the manufacturer's only obligation, and your exclusive remedy, is the repair or replacement of the product at the manufacturer's discretion, provided that the product has not been damaged through misuse, abuse, accident, modifications, alterations, neglect or mishandling. Your original receipt of purchase is required to determine warranty eligibility.

The purchaser must pay all labor and shipping charges necessary to replace the product covered by this warranty.

This Limited Warranty does not cover products which have been damaged as a result of an accident, misuse, abuse, negligence, alteration, improper installation or maintenance, or failure to operate in accordance with the instructions supplied with the products, or operational failures caused by corrosion, rust, or other foreign materials in the system.

Requests for service under this warranty shall be made by returning the defective product to the manufacturer as soon as possible after the discovery of any alleged defect. The manufacturer will subsequently take corrective action as promptly as reasonably possible.

The manufacturer does not warrant and especially disclaims any warranty, whether express or implied, of fitness for a particular purpose, other than the warranty contained herein. This is the exclusive remedy and any liability for any and all indirect or consequential damages or expenses whatsoever is excluded.

Some states do not allow the exclusion or limitation of incidental or consequential damages or limitations on how long an implied warranty lasts, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary from state to state.

For Professional Technical Support call 1-844-241-5521 or visit HOMEDEPOT.COM.

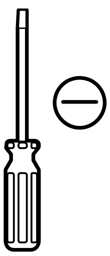
For warranty registration please go to www.gppumpsus.com

Pre-Installation

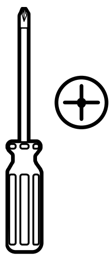
APPLICATION

- This submersible sump pump is designed for home sump applications. Use this pump only for pumping water.
- This unit is not designed as a waterfall or fountain pump, or for applications involving salt water or brine! Use with waterfalls, fountains, salt water or brine will void warranty.
- Do not use where water recirculates.
- Not designed for use as a swimming pool drainer.

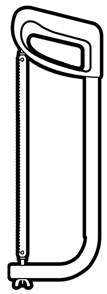
TOOLS REQUIRED



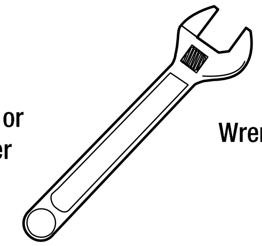
Flathead Screwdriver



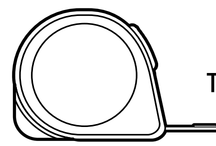
Phillips Screwdriver



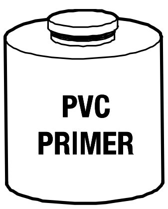
Hand Hacksaw or PVC Cutter

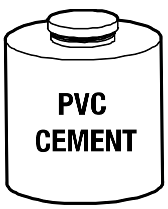


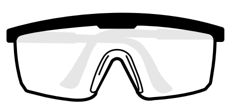
Wrench



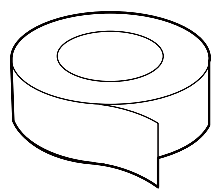
Tape Measure







Safety goggles

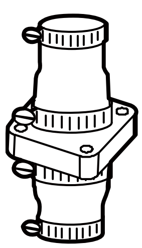


Thread Tape

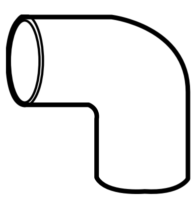
MATERIALS REQUIRED (NOT INCLUDED)

NOTE: Parts shown below not to scale.

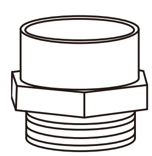
1-1/4 in. or 1-1/2 in. discharge pipe



1-1/4 in. or 1-1/2 in. check valve



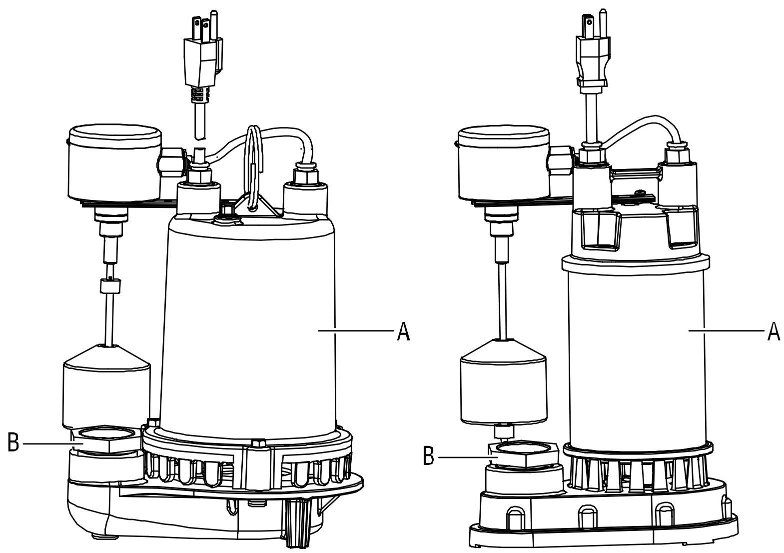
1-1/4 in. or 1-1/2 in. 90° elbow



adapter

Pre-Installation (continued)

PACKAGE CONTENTS



SKU # 1000026675 SKU #1000026662 SKU # 1000026686 SKU # 1000026682

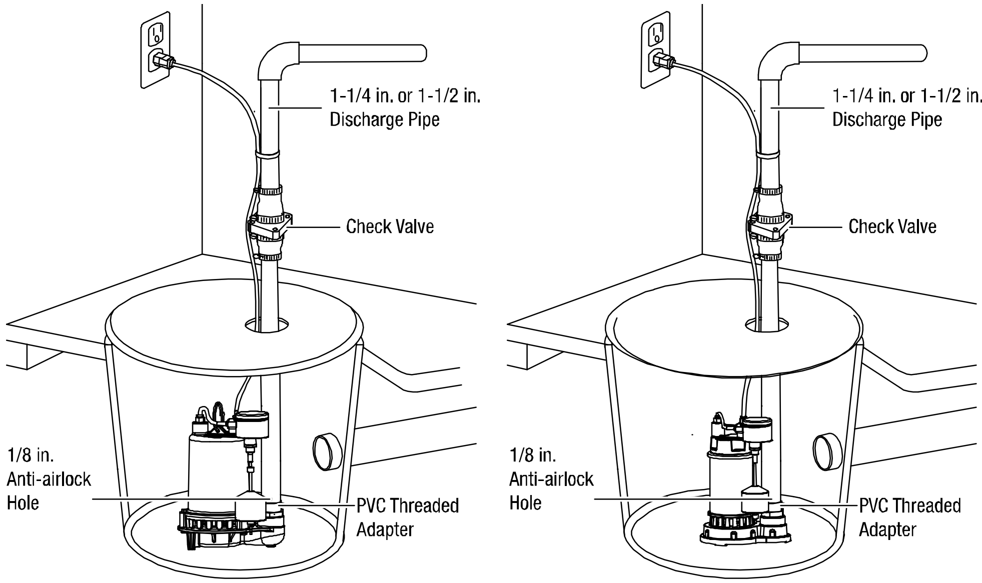
Part	Description
A	Pump
B	Adapter (1-1/2 in. MNPT X 1-1/4 in. FNPT)

SPECIFICATIONS

Power supply	115V, 60 HZ., 15 Amp Circuit
Liquid temp. range	32°F to 95°F(0°- 35°C)
Discharge size	1-1/2 in. FNPT or 1-1/4 in. FNPT (with adapter)
Sump basin	Minimum 10 in. (254 mm) diameter, 15 in. (381 mm) depth
Switch on/off (1000026686)	On: 7.1 in. (180 mm), Off: 3.7 in. (94 mm)
Switch on/off (1000026682)	On: 7.5 in. (191 mm), Off: 4.1 in. (104 mm)
Switch on/off (1000026675 1000026662)	On: 7.1 in. (180 mm), Off: 3.7 in. (94 mm)

NOTE: Do not reduce size of discharge pipe or hose below 1-1/4 in. diameter. If discharge is too small, pump will overheat and fail prematurely. This pump is designed for use in a residential sump only. Only pump water with this pump.

Installation



SKU # 1000026675 SKU #1000026662 SKU # 1000026686 SKU # 1000026682

1. Install the sump pump in a sump pit with a minimum diameter of 10 in. (254mm) and a minimum depth of 14 in. (356mm). Construct the sump pit of tile, concrete, steel or plastic. Check local codes for approved materials and for proper installation.
2. Install the pump in a pit so that the switch operating mechanism has maximum possible clearance.
3. The pump should not be installed on clay, earth or sand surfaces. Clean the sump pit of small stones and gravel which could clog the pump. Keep the pump inlet screen clear.

NOTE: Do not use ordinary pipe joint compound on plastic pipe. Pipe joint compound can attack plastics.

4. Install discharge plumbing. Use rigid plastic pipe and wrap threads with PTFE pipe thread sealant tape. Screw pipe into the pump hand tight plus 1-1/2 turns.

CAUTION: Risk of flooding. Can cause personal injury and/or property damage. If a flexible discharge hose is used, make sure the pump is secured in the sump to prevent movement. Failure to secure the pump may allow pump movement, switch interference and prevent the pump from starting or stopping.

5. To reduce motor noise and vibrations, a short length of rubber hose (1-7/8 in. (47.6mm) I.D., e.g. radiator hose) can be connected into the discharge line near the pump using suitable clamps.
6. Install an in-line check valve or an in-pump check valve to prevent flow backwards through the pump when the pump shuts off.

NOTE: If your check valve is not equipped with an air bleed hole to prevent air locking the pump, drill a 1/8 in.(3.2 mm) hole in the discharge pipe just above where the discharge pipe screws into the pump discharge. Be sure the hole is below the waterline and the check valve to prevent air locks.

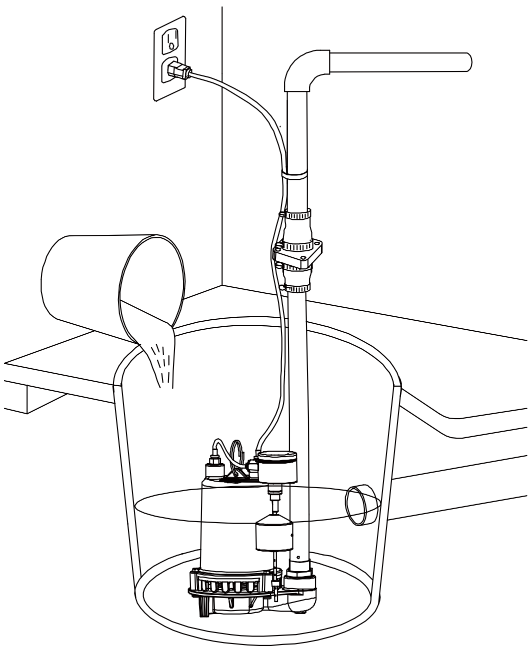
7. Power Supply: Pump is designed for 115 V, 60 Hz, operation and requires a minimum 15 amp individual branch circuit. Plug the power plug into a 115V GFCI power outlet.

WARNING: Risk of electric shock. Can shock, burn or kill. Pump should always be electrically grounded to a suitable electrical ground such as a grounded water pipe or a properly grounded metallic raceway, or ground wire system. Do not cut off the round ground pin.

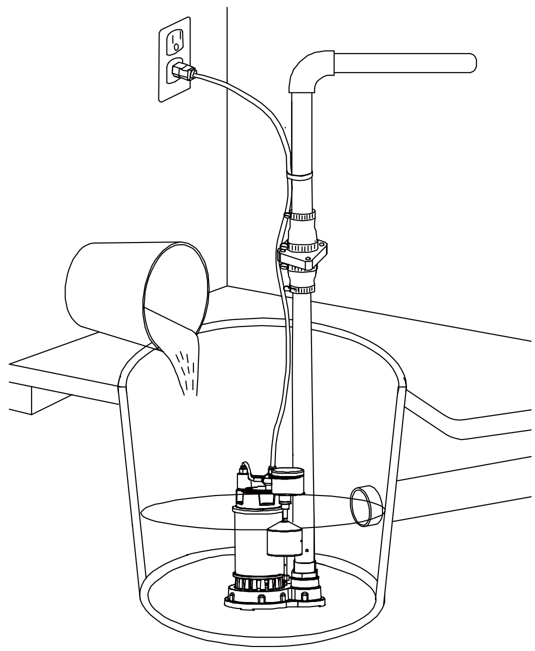
Installation (continued)

8. If the pump discharge line is exposed to outside subfreezing atmosphere, a portion of line exposed must be installed so any water remaining in the pipe will drain to the outfall by gravity. Failure to do this can cause water trapped in the discharge to freeze which could result in damage to the pump.
9. After the piping and check valve have been installed, the unit is ready for operation.
10. Check the pump operation by filling the sump with water and observing pump operation through one complete cycle.

CAUTION: Risk of flooding. Can cause personal injury and/or property damage. Failure to make this operational check may lead to improper operation, premature failure, and flooding.



SKU # 1000026675   SKU #1000026662



SKU # 1000026686   SKU # 1000026682

Operation

WARNING: Risk of electric shock. Can shock, burn or kill. Do not handle a pump or pump motor with wet hands or when standing on a wet or damp surface, or in water.

1. The shaft seal depends on water for lubrication. Do not operate the pump unless it is submerged in water as the seal may be damaged if allowed to run dry.
2. The motor is equipped with an automatic reset thermal protector. If temperature in the motor should rise unduly, the switch will cut off all power before damage can be done to the motor. When the motor has cooled sufficiently, the switch will reset automatically and restart the motor. If the protector trips repeatedly, the pump should be removed and checked. Low voltage, long extension cords, clogged impeller, very low head or lift, or a plugged or frozen discharge pipe, etc., could cause the protector to trip.
3. The pump will not remove all water. If operating a pump manually, and suddenly no water comes out of the discharge hose, shut off the unit immediately. The water level is probably very low and the unit has broken prime.

WARNING: Risk of electric shock. Can shock, burn or kill. Before attempting to check why the unit has stopped operating, disconnect power from the unit.

Care and Cleaning

CAUTION: Always use the handle to lift the pump. Never use the power cord to lift the pump. To avoid skin burns, unplug the pump and allow time for it to cool after periods of extended use.

Do

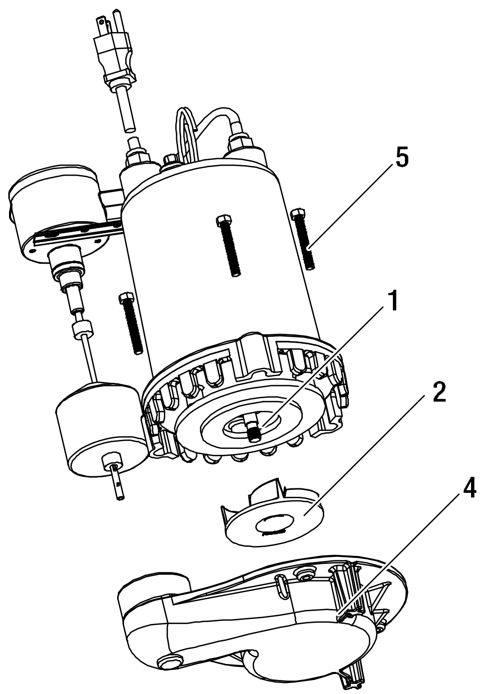
- ◻ When the power is disconnected, inspect the pump suction screen and remove all debris, then plug the pump back into the grounded (GFCI) outlet.

Do Not

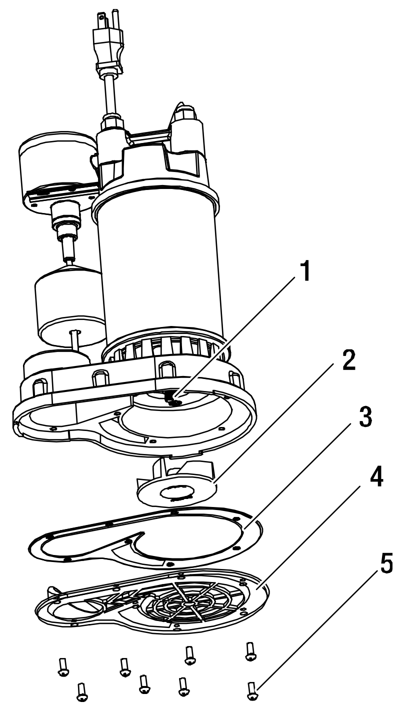
- ◻ Do not disassemble the motor housing. This motor has NO repairable internal parts, and disassembly may cause leakage or dangerous electrical wiring issues.
- ◻ Do not lift up the pump by the power cord.

To clean a pump clogged with debris:

- ◻ Unplug the pump from electrical power.
- ◻ Unscrew the stainless screws (5), and remove the volute (4).
- ◻ If necessary use a flathead screwdriver to hold the shaft (1), then turn the impeller (2) counterclockwise to release the impeller (2).
- ◻ Remove debris from around the shaft (1) and the impeller (2).
- ◻ Reassemble the pump.



SKU # 1000026675 SKU #1000026662



SKU # 1000026686 SKU # 1000026682

Troubleshooting

Problem	Possible Cause	Corrective Action
The pump does not start or run.	1. No power. 2. The impeller is blocked. 3. The float switch failed. 4. The motor failed.	1. Reset GFCI switch/Reset the breaker/Secure the plug/Clean the plug prongs. 2. Remove the debris around the impeller. 3. Replace the float switch. 4. Replace the pump.
The pump operates but pumps little or no water.	1. The screen is blocked. 2. Debris is caught in the impeller or discharge. 3. The impeller is broken.	1. Clean the screen. 2. Remove the debris. 3. Replace the impeller.
The pump starts and stops too often.	1. There is a backflow of water from the piping or the check valve is leaking. 2. The float switch is stuck. 3. The float switch failed.	1. Install a check valve or replace the check valve. 2. Clean the float switch. 3. Replace the float switch.
The pump will not shut off.	1. The float switch is tangled. 2. The float switch failed.	1. Reposition the pump and make sure the switch moves freely. 2. Replace the float switch.

EVERBILT™

Questions, problems, missing parts? Before returning to the store call
Everbilt Customer Service
8 a.m. - 6 p.m., EST, Monday-Friday

1-844-241-5521

HOMEDEPOT.COM

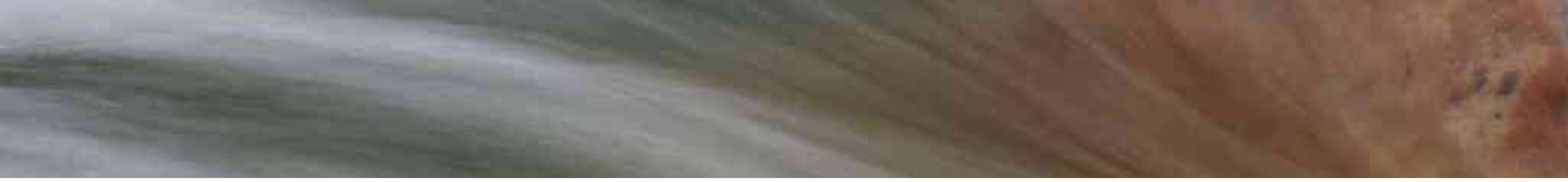
Automatic Grab Sampler

Thermo Scientific
Nalgene Storm Water Sampler

Easy. Affordable. Compliant.

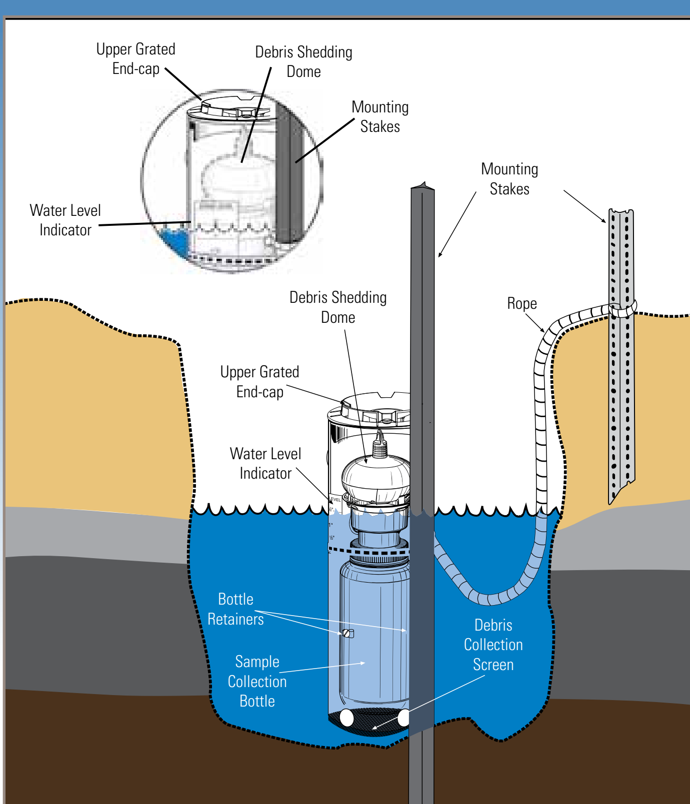
NALGENE

Thermo
SCIENTIFIC

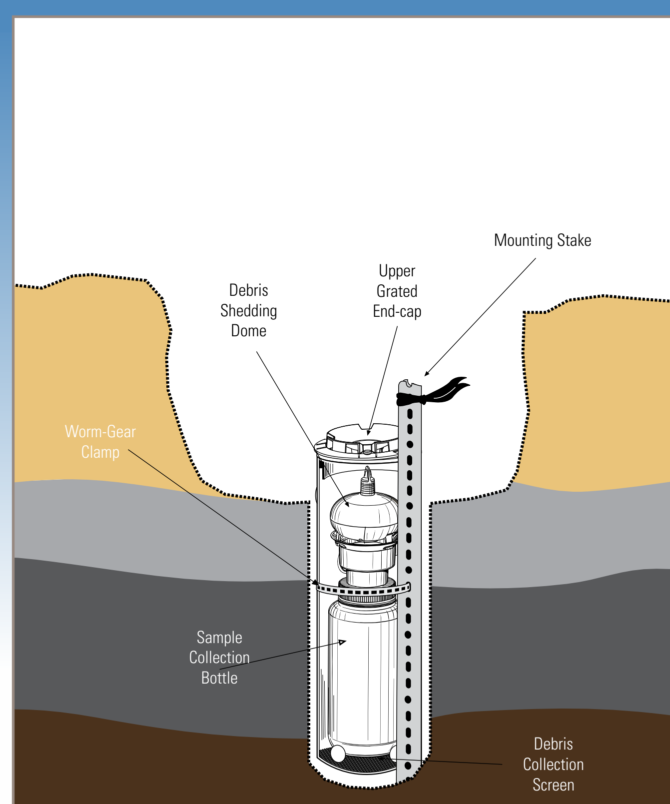


Thermo Scientific Nalgene Storm Water Sampler

The Nalgene® Storm Water Sampler is a convenient and affordable device for collecting quarterly storm water grab samples in compliance with EPA sampling requirements. No more standing in the rain waiting for water to flow or missed sampling events.



Stream Mount



Ditch Mount

Easy to Use

- Simply position the reusable mounting kit once, then reload with disposable samplers
- No programming or complicated trip-switches
- Floating ball valve automatically seals off the sample collection port when full

Affordable

- Compared with other EPA-compliant alternatives Nalgene Storm Water Sampler is a fraction of the price!

Compliant with EPA Sampling Requirements

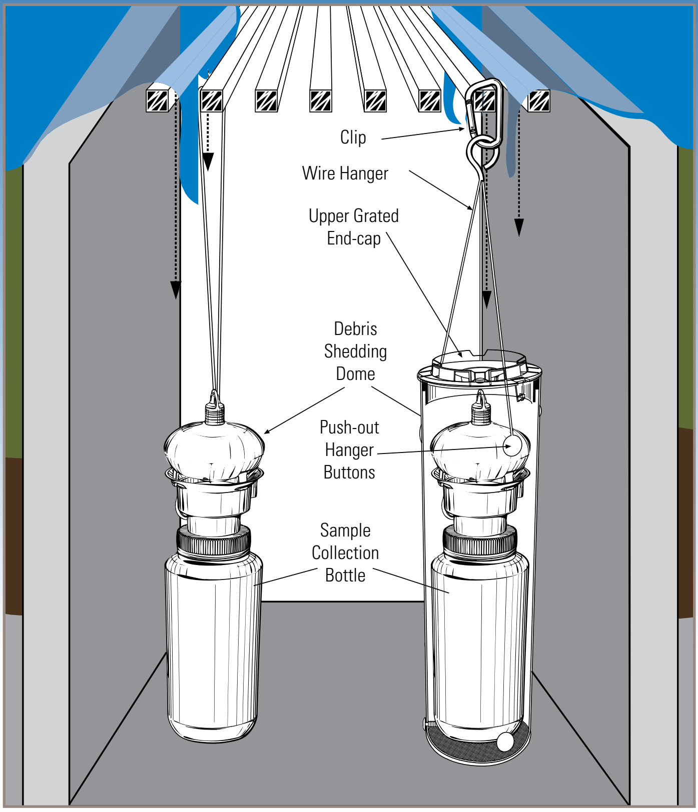
- Collects a full liter of sample within the first 30 minutes of a qualifying rain event
- Prevents co-mingling with later run-off or volatile analyte loss
- HDPE sampler unit for inorganic and visual analysis; amber glass bottle unit for organic analysis
- For a more detailed list of EPA requirements, see chart on back

Prevents Cross Contamination

- Disposable sampling device: use it once, and throw it away! No decontamination required!

Convenient

- Position the sampler in a storm water outfall prior to a qualifying rain event, and retrieve it at a convenient time after the storm



Grate Mount

The Storm Water Sampler can collect a full one liter grab sample of first flush storm water runoff through a storm water ditch, stream or storm grate outfall. Simply position the sampler in its protective mounting tube prior to a rain event, and leave it in place until after the storm.

Thermo Scientific
Nalgene Storm Water Sampler

EPA Requirement	Nalgene Feature
Collect a full 1L of sample	Both Nalgene HDPE and amber glass storm water samples have at least 1L sample capacity.
Sample must be a discreet grab from the outfall flow	The Nalgene storm water sampler collection funnel is equipped with a foating ball valve that seals off the sample chamber after the bottle is full preventing comingling and dilution by later run off. The mounting tube is designed to shed falling rain and collect only runoff when positioned in a ditch or stream outfall.
Sample must be collected within the first 30 minutes of outfall flow	Sample is collected immediately after water starts to flow over the device.
Sample must be collected during a qualifying rain event	Mounting kit can be positioned in a ditch or stream outfall at the critical level at which water will flow when a qualifying event occurs.
Samples for VOA analysis need to be protected from volitilization	The storm water sampler is equipped with a ball valve that closes off the sample chamber once the bottle is full; minimizing head space and volatile analyte loss.
Collect samples for organic analyses in a glass container with Teflon lined closure	The 1120-1000 Sampler is fluorinated to prevent organic analyte adhesion and is mounted on an amber glass bottle. A teflon-lined closure is supplied for sample transport to the lab.
Samples for inorganic and visual analysis may be collected in an HDPE container	The 1100-1000 sampler is mounted on a Nalgene HDPE shatterproof bottle. A Nalgene closure is supplied for guaranteed leak-proof sample transport to the lab.
Visual analyses should include observations of debris in the sample	The mounting tube is equipped with a disbris collection screen to collect disbris shed by the sample collection dome for visual notation.

Cat. No.	Description	Qty/Cs	Nominal Volume	Height, in./ mm	Outside Diameter, in./ mm	List Price/ Each	List Price/ Case
1100-1000	Storm Water Sampler single use, HDPE	4	1L	13.2/33.5	3.8/9.5	$36.50	$146.00
1120-1000	Storm Water Sampler single use, Glass	4	1L	13.2/33.5	3.8/9.5	$42.00	$168.00
1160-1000	Mounting Kit, reusable	1	NA	15.6/39.7	4.6/11.7	$50.00	$50.00

Visit www.thermoscientific.com/stormwater and view the Nalgene Storm Water Sampler demonstration video.

www.thermoscientific.com/stormwater

Asia: China Toll-free: 800-810-5118 or 400-650-5118; India: +91 22 6716 2200, India Toll-free: 1 800 22 8374; Japan: +81-3-5826-1616; Other Asian countries: 65 68729717
Europe: Austria: +43 1 801 40 0; Belgium: +32 53 73 42 41; Denmark: +45 4631 2000; France: +33 2 2803 2180; Germany: +49 6184 90 6940, Germany Toll-free: 08001-536 376; Italy: +39 02 02 95059 or 434-254-375; Netherlands: +31 76 571 4440; Nordic/Baltic countries: +358 9 329 100; Russia/CIS: +7 (812) 703 42 15; Spain/Portugal: +34 93 223 09 18; Switzerland: +41 44 454 12 12; UK/Ireland: +44 870 609 9203
North America: USA/Canada +1 585 586 8800; USA Toll-free: 800 625 4327
South America: USA sales support: +1 585 899 7198
Countries not listed: +49 6184 90 6940 or +33 2 2803 2180

VBLSPNUNCCF 0311

Thermo SCIENTIFIC

Appendix F: Field Forms

Site Preparation Field Form

Field staff names:	**Date:**
	Time:
SOP Name and Notes during site inspection (surrounding area, tank, pump, pipes, sample port, other equipment):	
Site Preparation for Stimulated event	
Notes (circle text as appropriate):	
Remove grab sampler ports and confirm that the samplers are empty and clean Y N	
Rinse out Sampler Y N	
Confirm that the piezometers are empty and clean Y N	
Influent flow meter verification performed? Y N	
If flow meter readings appear to be consistenly biased, what is the difference?	
Water level meter verification performed? Y N	
If water level meter readings are off, by how much?	

Simulate Storm Event Field Form

<table>
<tr><td colspan="6">Field staff names:</td><td colspan="2">Date:
Time:</td></tr>
<tr><td colspan="8">SOP Name and Notes during site inspection (surrounding area, tank, pump, pipes, sample port, other equipment):</td></tr>
<tr><td colspan="8" align="center">Simulated Event Information</td></tr>
<tr><td colspan="8">Notes (circle text as appropriate):</td></tr>
<tr><td rowspan="2">Record Influent Flow Rate:</td><td colspan="2">Time #1</td><td colspan="2">Time #2</td><td colspan="2">Time #3</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td rowspan="2">Record Depth at Upstream and Downstream Piezometers:</td><td>Time #1, US</td><td>Time #1, DS</td><td>Time #2, US</td><td>Time #2, DS</td><td>Time #3, US</td><td>Time #3, DS</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Were automatic grab samplers placed in the swale after the influent flow rate reached the water quality design flow rate? Y N</td></tr>
<tr><td colspan="7">Were samples collected from the influent and eight sample locations? Y N</td></tr>
<tr><td colspan="7">Note any issues encountered or observations made during the event:</td></tr>
</table>

Audit Form

Auditor Name:		Date:
Respondent Name:		Time:
Question	**Response**	**Notes:**
8.1.1 Site Preparation for Simulated Storm Event		
Was the treatment rock layer rinsed prior to beginning the first simulated storm event?	Yes No Modified	
Was the tank filled with 1,000 gallons of water before each simulated storm event?	Yes No Modified	
Were the piezometers and sample ports inspected prior to each simulated storm event?	Yes No Modified	
Were the automatic grab samplers inspected and cleaned as needed prior to each simulated storm event?	Yes No Modified	
Was the influent flow meter reading verified prior to each simulated storm event?	Yes No Modified	
Was the influent synthetic stormwater system set up to deliver the water quality design flow rate prior to each simulated storm event?	Yes No Modified	
Was the water level meter reading verified prior to each simulated storm event?	Yes No Modified	
Was the information collected during site preparation recorded on the site preparation field form?	Yes No Modified	
8.1.2 Site Preparation for Simulated Storm Event		
Was the appropriate amount of Sil Co Sil added to the 1,000 gallon tank for each Phase and mixed to ensure Sil Co Sil didn't settle out?	Yes No Modified	
Was the influent flow meter displaying the water quality design flow rate prior to installing the automatic grab samplers during Phase 1 of the simulated storm event?	Yes No Modified	
Were the automatic grab samplers installed after the water quality design flow rate was confirmed by the influent flow meter (during Phase 1)?	Yes No Modified	
Were a total of three depth measurements taken at each piezometer in the swale during Phase 1 of the simulated storm event?	Yes No Modified	
Were a total of three influent flow meter readings taken during Phase 1 of the simulated storm event?	Yes No Modified	
Was the tank fully emptied during Phase 1 and all automatic grab samplers collected after each Phase 1 of the simulated storm events?	Yes No Modified	
Were the sample ports closed (to limit TSS deposit into the sample ports) before Phase 2 begun?	Yes No Modified	
Was the information collected during the simulated storm event recorded on the simulated storm event field form?	Yes No Modified	
8.1.3 Site Preparation for Simulated Storm Event		
Were sample bottles placed in the fridge or cooler filled with ice prior to sampling to keep bottles cool?	Yes No Modified	
Were sample bottles labeled with sample ID, location, sample date, and sample time?	Yes No Modified	
Were samples shaken or swirled to homogenize the sample prior to transferring to sample bottles provided by the lab?	Yes No Modified	
Were samples kept in a cooler filled with loose ice or fridge to keep the samples below a temperature of 6 degrees Celsius?	Yes No Modified	
Was a Chain of Custody and any additional documentation filled out for the samples?	Yes No Modified	

Appendix G. Chain of Custody

ENERGY NORTHWEST

Services Sales Order / Chain of Custody

Environmental Services

350 Hills Street Suite 107, Richland, WA 99354

Phone: 509-377-8058 **FAX:** 509-377-8464

Customer contact:	Project ID	**Order ID:**
Business name:		
Address:	Rush TAT Y ☐ N ☐ # of days ______	
Email:	**Phone/FAX:**	

***Matrix:** NPDES: ☐ Solid waste: ☐ Drinking water: ☐ Other: ☐ Waste Water: ☐

Requested Tests

Lab Use Only	**Customer Sample ID** *(Unique identifier or code)*	**Collection Date**	**Collection Time**	***Matrix**	**Number of bottles**											**Comments**

By signing below, Customer agrees to and accepts the terms on the reverse side of this form.

Customer Signature/Date	**Name/Title/Telephone No.**	

CUSTODY Signature	**Date/Time**	**Signature**	**Date/Time**
Relinquished by:		Received by:	
Relinquished by:		Received by:	
Accepted by Lab:			

Sample Conditions at receipt:

Temperature (circle):

Ambient *Cold* *Frozen*

Containers intact/Lids tight: ☐

VOC vials without headspace: ☐

Labels match custody: ☐

Example Receipt and Preservation Form - a copy of this form will be included with each set of samples delivered to the lab.

MCF0357

Due: 06/23/22

Anatek Labs, Inc.

Sample Receipt and Preservation Form

Client Name: Energy NW

TAT: **(Normal)** RUSH: ______ days

Samples Received From: **(FedEx)** UPS USPS Client Courier Other: ________

Custody Seal on Cooler/Box: Yes **(No)** Custody Seals Intact: Yes No **(N/A)**

Number of Coolers/Boxes: 1 Type of Ice: Wet Ice **(Ice Packs)** Dry Ice None

Packing Material: Bubble Wrap Bags **(Foam/Peanuts)** Paper None Other: ________

Cooler Temp As Read (°C): 2.1 Cooler Temp Corrected (°C): – Thermometer Used: IR-5

				Comments:
Samples Received Intact?	**(Yes)**	No	N/A	
Chain of Custody Present?	**(Yes)**	No	N/A	
Samples Received Within Hold Time?	**(Yes)**	No	N/A	
Samples Properly Preserved?	**(Yes)**	No	N/A	
VOC Vials Free of Headspace (<6mm)?	**(Yes)**	No	N/A	
VOC Trip Blanks Present?	**(Yes)**	No	N/A	
Labels and Chains Agree?	**(Yes)**	No	N/A	
Total Number of Sample Bottles Received:	4			

Chain of Custody Fully Completed?	**(Yes)**	No	N/A	
Correct Containers Received?	**(Yes)**	No	N/A	
Anatek Bottles Used?	Yes	No	**(Unknown)**	

Record preservatives (and lot numbers, if known) for containers below:

MA/AA - VOC 524 - g 44mL x 3 + 1 TB

Notes, comments, etc. (also use this space if contacting the client - record names and date/time)

Received/Inspected By: JKT Date/Time: 6/9/22 12:40

Form F19.00 - Eff 8 Feb 2019

Appendix H: Summary of QAPP Revisions Table

Revision #	Revised By	Section and Page	Status of Revision (Draft/Approved)	Summary of Revision
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Appendix I: Corrective Action Plan Table

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

Appendix J: Treatment Rock Layer Material Information

Placeholder page for the stabilization rock layer gradation. This placeholder page is included as the current 1.25" coarse gravel gradation (next page) is a round gravel and is not angular.

AMERICAN ROCK PRODUCTS
A CRH COMPANY

Gradation for 1.25" Coarse Gravel

Basic Quality Statistical Summary Report

Plant	121_01162-Richland AGG
Product	2290-1 1/2" - 3/4" Drain Rock
Specification	ASTM C33 No. 4
Period	12/16/2021 - 06/16/2022

Sieve/Test	Tests	Average	St Dev	Target	Specification
1 1/2" (37.5mm)	6	100	0.0		90-100
1 1/4" (31.5mm)	6	93	6.2		
1" (25mm)	6	44	19.3		20-55
3/4" (19mm)	6	1	0.9		0-15
1/2" (12.5mm)	6	0	0.4		
3/8" (9.5mm)	5	0	0.0		0-5
1/4" (6.3mm)	5	0	0.0		
#4 (4.75mm)	5	0	0.0		
#8 (2.36mm)	5	0	0.0		
Pan	6	0.0	0.00		

At this time, this is the only supplier that has been located which provides a similar specification to the 1.25" coarse gravel, and the specification is for round rock instead of angular rock. As a result, this specification may be revised prior to construction.

Placeholder page for gravel backfill for drywells gradation.

Gradation for Pea Gravel

AAA Concrete, Inc Concrete Aggregate Gradations

Agg Name Pea Gravel

Date 6/27/2022

Sieve Size	Percent Passing
5/8"	100
½"	98.4
3/8"	81.9
#4	24.1
#8	4
#200	.9

Gradation for Sand Media

Basic Quality Statistical Summary Report

Plant 121_01162-Richland AGG
Product 2133-Concrete Sand (ASTM)
Specification ASTM C33 Sand
Period 12/16/2021 - 06/16/2022

Sieve/Test	Tests	Average	St Dev	Target	Specification
3/8" (9.5mm)	34	100	0.0		100-100
#4 (4.75mm)	34	98	0.5		95-100
#8 (2.36mm)	34	88	1.0		80-100
#16 (1.18mm)	34	73	2.1		50-85
#30 (.6mm)	34	48	2.5		25-60
#50 (.3mm)	34	18	1.6		5-30
#100 (.15mm)	34	4	0.4		0-10
#200 (75µm)	34	1.8	0.44		0-3
Pan	34	0.0	0.00		

Appendix K: Data Quality Form

Data Quality Form

Sample, Swale, Storm ID:		
Parameters	**Goal**	**Reported**
Method	SM 2540D	
Chain-of-Custody Issue?		
Completeness/Methodology		
Holding Times (days)		
Cooler Temperature		
Method Blanks		
Lab Standard Analysis		
Lab Duplicates		
Lab Notes on Instrument Calibration/ Performance		
Action		

Note: this form will be updated following confirmation with the lab on limits.