Quality Assurance Project Plan

Bioretention Hydrologic Performance Study II

Date: April 2019

Prepared by:

William J. Taylor
Taylor Aquatic Science

Douglas Beyerlein, P.E. Clear
Creek Solutions, Inc.

Prepared for:

City of Olympia, WA

Publication Information

Author and Contact Information

William J. Taylor, billtaylorv60@gmail.com, 206-755-3211
Douglas Beyerlein, beyerlein@clearcreeksolutions.com 425-225-5997

Available online at SAM Effectiveness Studies Website, under LID – BMPs.

https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies

1.0 Title Page, Table of Contents, and Distribution List

Quality Assurance Project Plan

Bioretention Hydrologic Performance

Study II

April 2019

Approved by:

Signature: ________________________________ Date: ________
Brandi Lubliner, SAM Coordinator, Washington Department of Ecology

Signature: ________________________________ Date: ________
Eric Christensen, City of Olympia Project Manager

Signature: ________________________________ Date: ________
Douglas Beyerlein, Clear Creek Solutions, Inc., Author/Project Manager

Signature: ________________________________ Date: ________
William J. Taylor, Taylor Aquatic Science, Principal Author/Principal Investigator

Signature: ________________________________ Date: ________
Bryan Berkompas, Aspect Consulting Co-author

Signature: ________________________________ Date: ________
Jenny Saltonstall, Associated Earth Sciences, Inc., Co-author

Signature: ________________________________ Date: ________
Anne Cline, Raedeke Associates, Inc., Co-author

Signature: ________________________________ Date: ________
Chris Wright, Raedeke Associates, Inc., Co-author

Table of Contents

Page

1.0 Title Page, Table of Contents, and Distribution List 1
2.0 Abstract 5
3.0 Background 7
  3.1 Study area and surroundings 7
  3.2 Logistical problems 8
  3.3 History of study area 8
  3.4 Contaminants of concern 8
  3.5 Results of previous studies 9
  3.6 Regulatory criteria or standards 9
4.0 Project Description 10
  4.1 Project goals 10
  4.2 Project objectives 10
  4.3 Information needed and sources 11
  4.4 Target population 11
  4.5 Study boundaries 11
  4.6 Tasks required 11
  4.7 Practical constraints 12
5.0 Organization and Schedule 13
  5.1 Key individuals and their responsibilities 13
  5.2 Special training and certifications 13
  5.3 Project schedule 13
  5.4 Limitations on schedule 14
  5.5 Budget and funding 14
6.0 Quality Objectives 15
  6.1 Decision Quality Objectives (DQOs) 15
  6.2 Measurement Quality Objectives 16
    6.2.1 Targets for Precision, Bias, and Sensitivity 16
      6.2.1.1 Precision and Percent Error 16
      6.2.1.2 Bias 17
      6.2.1.3 Sensitivity 18
    6.2.2 Targets for Comparability, Representativeness, and Completeness 18
      6.2.2.1 Comparability 18
      6.2.2.2 Representativeness 18
      6.2.2.3 Completeness 19
7.0 Sampling Process Design (Experimental Design) 20
  7.1 Study Design 20
    7.1.1 Field measurements 21
    7.1.2 Sampling location and frequency 22
    7.1.3 Parameters to be determined 22
  7.2 Maps or diagram 22
  7.3 Assumptions underlying design 22
8.0 Sampling Procedures 23
  8.1 Field measurement and field sampling SOPs 23

8.1.1 Water level and flow data collection 23
8.1.1.1 Inlet Monitoring 23
8.1.1.2 Outlet Monitoring 23
8.1.1.3 Groundwater and Ponding Depth Measurements 24
8.1.2 Rain Gauge 24
8.1.3 Site Maintenance 24
8.2 Geotechnical Engineering and Hydrogeologic Data Collection 25
8.2.1 Subsurface Exploration 25
8.2.2 Geotechnical Testing 25
8.2.3 Measure Infiltration Rates 26
8.3 Vegetation monitoring 26
8.4 Containers, preservation methods, holding times 27
8.5 Invasive species evaluation 27
8.6 Sample ID 27
8.7 Chain-of-custody, if required 27
8.8 Field log requirements 28
8.9 Other activities 28
9.0 Measurement Methods 29
9.1 Field procedures table/field analysis table 29
9.2 Lab Procedures 29
10.0 Quality Control (QC) Procedures 30
10.1 Field and lab QC required 30
10.2 Corrective action processes 30
11.0 Data Management Procedures 31
11.1 Data recording/reporting requirements 31
11.1.1 Data management and verification 31
11.2 Lab data package requirements 31
11.3 Electronic transfer requirements 31
11.4 Acceptance criteria for existing data 31
11.5 Data presentation procedures 32
12.0 Audits and Reports 33
12.1 Number, frequency, type, and schedule of audits 33
12.2 Frequency and distribution of report 33
12.3 Responsibility for reports 33
13.0 Data Verification 34
13.1 Field data verification, requirements, and responsibilities 34
13.2 Lab data verification 34
13.3 Validation requirements, if necessary 34
14.0 Data Quality (Usability) Assessment 35
14.1 Process for determining whether project objectives have been met 35
14.2 Data analysis and presentation methods 35
14.3 Treatment of non-detects 35
14.4 Sampling design evaluation 35
14.5 Documentation of assessment 35
15.0 References 37
16.0 Appendices 38

Distribution List

Name: Doug Howie
Title: Stormwater Engineer
Organization: Washington Department of Ecology
Contact Information: PO Box 47600, Olympia, WA 98504 360-407-6444

Name: Brandi Lubliner
Title: Stormwater Action Monitoring Coordinator
Organization: Washington Department of Ecology
Contact Information: PO Box 47600, Olympia, WA, 360-407-4170

2.0 Abstract

While the storage and infiltration capability of bioretention facilities is generally acknowledged, little data exists to verify the hydrologic performance of these facilities. Use of bioretention is widespread in the Puget Sound region and expected to increase as a result of requirements of the NPDES municipal permits. State and local governments are eager to evaluate and ensure that new bioretention facilities constructed under the Washington Department of Ecology's (Ecology) Stormwater Management Manual for Western Washington (SWMMWW; Ecology 2014) can be built to attain desired performance.

This study is the second of two related studies. The first Bioretention Hydrologic Performance (BHP) Study was a similar study of bioretention facilities designed using the design approaches in effect prior to the Ecology (2014) manual. The current BHP Study II is intended to document the hydrologic performance of bioretention facilities designed using the Western Washington Hydrology Model (WWHM) version 2012.

The result of the current study is intended to not only to show the apparent hydrologic performance of the facilities themselves, but the performance of the WWHM 2012 model in predicting the performance of the facility. Reasons for observed performance discrepancies will be identified to provide feedback on design, construction, maintenance, and/or modeling of bioretention facilities to attain desired performance.

Meeting expected infiltration and overflow conditions from bioretention facilities ensures downstream flows and groundwater receiving water are protected to the extent planned, and ensures water quality treatment is met for the desired treatment volume of runoff events to both streams and groundwater. Saturation levels and durations resulting from the actual performance in bioretention facilities may also affect survival, composition, and health and maintenance of the facility vegetation, which may, in turn, have further impacts on infiltration performance. Conducting a performance assessment of bioretention facilities as part of the "adaptive management" process is essential to ensuring implementation of effective low impact development (LID) facilities in the Puget Sound region.

The approach of the current research project is to conduct inflow and outflow hydrologic monitoring at ten qualifying bioretention facilities selected throughout the Puget Sound region. Geotechnical and hydrogeologic analyses of bioretention soil mix and native soil, ground water level monitoring, infiltration testing and vegetation monitoring will also be conducted. The flow monitoring and site conditions results will then be compared with the hydrologic design model predictions developed based on the design of the facility. Regional application of the project will come from the selection of facilities for study from a wide range of conditions around the Puget Sound region.

Based on the range of selected facilities (Appendix A), lessons drawn from the study will inform our understanding of the suitability of these LID BMPs across a range of soil conditions and micro-climates. We will learn site-specific scale lessons regarding design, construction, maintenance, and modelling of bioretention facilities. The final report will provide a qualitative analysis on the larger set of facilities that were assessed for monitoring in the study. If

appropriate, the final report may also include recommendations for improvements to the WWHM 2012 bioretention modeling algorithms to better and more accurately represent observed actual field conditions.

3.0 Background

The goal of this study is to implement a regional bioretention infiltration effectiveness study as part of the Stormwater Action Monitoring (SAM) program. Funding for this current project comes from the SAM which is a collection of Western Washington Stormwater Municipal Permittees. Prior lead-up work to this project, funded by Ecology, included a literature review and summary of low impact development performance, which includes a summary of findings on the hydrologic performance of bioretention facilities (Taylor and Cardno TEC, 2013) and the results of the first BHP study.

Findings from the Taylor and Cardno TEC (2013) report state:

“The literature review indicates substantial flow volume reduction and water quality improvements result from the use of LID technologies. Site specific volume reductions on the order of 50 to 90 percent are common for each of these technologies, with bioretention facilities appearing to show the highest degree of volume reduction, followed by permeable pavement and green roof facilities. Peak flow reduction and increased lag times coincidentally result from LID volume reduction. The critical design element to the ultimate volume reduction for any of these facilities is the design storage volume relative to the inflow volumes. Success of LID implementation will then depend on accurate sizing that takes site specific conditions into account.”

The report also recommends that the most important effectiveness study to be carried out should be to document “the accuracy of sizing of LID designs for volumetric performance relevant to the Puget Sound region, including local exfiltration conditions unique to the region.”

Prior to the SWMMWW (2012), the previous SWMMWW (2005) and the associated WWHM 3 did not include a module for modeling bioretention facilities. Since its inception in 2012, the newer model has been implemented and trainings provided for its use. The current study design then is intended to conduct performance studies that would indicate the accuracy of constructed bioretention facility performance relative to their design performance expectations based in the WWHM 2012 model, again for a geographically wide range of locations and conditions.

In addition to evaluation of the hydrologic model, the monitoring of flow through the facilities, in the shallow ground water, and the performance of the vegetation plantings will again provide performance monitoring to inform engineers

3.1 Study area and surroundings

Ten bioretention facilities have been recommended for monitoring and analysis compared to their designs. These facilities were selected from a range of approximately 25 projects containing approximately seventy different facilities from throughout the Puget Sound region (see Appendix A for a summary of the site selection process, and the sites selected). All seventy facilities were evaluated in the field, and using supporting design drawings, hydrologic modeling parameters, geotechnical reports, and technical information reports (TIRs) when available. The set of overall bioretention facilities selected represent facilities from Bellingham to Tumwater within the Puget Sound Basin. Corresponding to this geographic range, the selected facilities represent a wide range in surficial geology, rainfall, and contributing drainage areas.

3.2 Logistical problems

As with most environmental monitoring, the logistical problems anticipated for the project are related to operation of flow monitoring equipment under adverse weather and flow conditions, and exposure to public access with the threat of vandalism or accident. Typical logistical problems will be retrofitting problematic inflow and outflow hydraulic infrastructure to allow accurate measurement of stage and flow. Setup and downloading of electronic equipment will require access to the equipment immediately before and after predicted large storm events to ensure accurate and complete collection of data. The sites will be located in public areas, predominantly at roadways, parking lots, and driving lanes in public facilities.

Solutions to the logistical challenges will be through the use of innovation and protection of equipment based on the experience of the monitoring practitioners on the project team. This experience includes aptitude in constructing customized retrofit devices to focus flows for more accurate measurement, and the use of protective encasements where feasible. Temporary removal and redeployment may be used in some cases.

3.3 History of study area

Population growth and the coincident development of impervious stormwater draining surfaces has been significantly spreading throughout the Puget Sound region since the beginning of European settlement. The hydrologic impacts of stormwater runoff on receiving waters has been well documented for almost three decades. These include principally the increase in peak flows and volumes being discharged to receiving water stream channels resulting in sediment delivery to streams, stream channel incision, reduction in base flows, reduction in instream fish habitat diversity, and reduction in biotic complexity.

The response for improved control of these impacts is largely centered in the use of stormwater permits and the SWMMWW (Ecology 2014). The manual provides minimum requirements for new and redeveloped stormwater management systems that rely heavily on the use of bioretention. Taylor and Cardno TEC (2013) provide an extensive summary of literature findings on the hydrologic performance of bioretention, including some projects monitored in the Puget Sound region.

3.4 Contaminants of concern

Not applicable. No water sampling for pollutants or other water constituents will be conducted as part of the current study.

3.5 Results of previous studies

Taylor and Cardno TEC (2013) provide an extensive summary of literature findings on the hydrologic performance of bioretention, including some projects monitored in the Puget Sound region. The primary conclusions relevant to bioretention were that:

"Available volumetric storage (abstraction volume), together with the selected design storm duration - return interval, appears to be the key design element that will determine volumetric reduction performance of individual facilities. Water quality performance will largely follow this volumetric reduction sizing."

And,

"Knowledge of site specific local subsurface exfiltration rates and groundwater levels, appears to be a key to successful programmatic design of LIDs. Volume reduction in LIDs is largely seen for small to medium storms, but increasingly less so for larger storms."

The subject of this investigation is whether the designed volumetric storage and expected exfiltration conditions are attained in constructed bioretention facilities.

3.6 Regulatory criteria or standards

State regulatory standards for performance of bioretention facilities reside in the minimum requirements of the SWMMWW (2014 and previous versions).

The 2012 Ecology stormwater manual includes three minimum requirements for which bioretention facilities can be used, and actual performance of the facilities in meeting these requirements will be assessed. These minimum requirements are:

Minimum Requirement (MR) #5: Low Impact Development (LID) Performance Standard. This is a flow duration standard where developed mitigated flows cannot exceed predevelopment flows for the range of flows between 8% of the 2-year peak flow and 50% of the 2-year peak flow.

Minimum Requirement #6: Water Quality Treatment Performance Standard. This is a volume standard where at least 91% of the total developed mitigated runoff volume must be treated in a water quality treatment facility.

Minimum Requirement #7: Stream Protection Flow Control Performance Standard. This is a flow duration standard where developed mitigated flows cannot exceed predevelopment flows for the range of flows between 50% of the 2-year peak flow and the full 50-year peak flow.

Not all bioretention facilities are required to be designed to meet all three minimum requirements. However, the individual facility's ability to meet all three minimum requirements will be evaluated to quantify the actual performance of each facility monitored and modeled.

4.0 Project Description

The overall value in the use of bioretention (and other LID stormwater facilities) will depend on the accuracy with which constructed facilities meet their hydrologic performance expectations. If facilities do not infiltrate, retain, and release flows sufficiently, receiving waters will not be protected from hydrologic impacts, and contact with bioretention soil mix may not be adequate to provide water quality treatment. If facilities are oversized, the land space may have been inefficiently used, with unnecessary cost spent on the design and construction of the facility or related flood control facilities. There may be opportunity costs as well in the loss of other possible uses.

Evaluation of bioretention hydrologic performance will provide feedback to the SWMMWW modeling design process, and to engineers' design approaches, to help optimize designs for greater expected accuracy and resulting benefits.

4.1 Project goals

The project goal is to compare actual hydrologic performance of constructed bioretention facilities around the Puget Sound under a variety of storm conditions with the modeled performance from the same facility using WWHM2012. Results are anticipated to demonstrate the relative importance of site characteristics, design, construction, maintenance, and modelling variables.

Communication goals for the project are to provide presentations to the SWG and Ecology to elicit feedback on the project. These will be done at important junctures of the progress of the project. A draft report of the project findings will be provided to the SWQ and Ecology for feedback to the final.

4.2 Project objectives

The project objectives are to attain the goals stated above. Specific objectives toward the technical goals include obtaining and installing inflow and outflow monitoring instruments that accurately and precisely measure stage at a primary hydraulic device which can then be translated by a rating curve to flow. Obtaining and installing rain gages will be done to measure actual rainfall in the immediate area of the subject bioretention facility being monitored. Rainfall and flow will be measured continuously during a range of storm events to enable evaluation of the design model using the actual rainfall, runoff, and facility flow-through conditions observed. The change in the model parameters required to accurately reproduce the monitored data will reveal the accuracy of the model parameters used in the original engineering design. The comparison of the hydrologic results to the minimum requirements will also reveal the degree to which the results continued to meet or did not meet the hydrologic criteria of the SWMMWW.

Coincident with collecting flow data and comparing the design model with a model based on actual performance, the secondary objectives are to collect data characterizing the bioretention soil mix, shallow subgrade soils, infiltration rate, ponding depths, subsurface water depths, and vegetation community composition, density, root health, and maintenance activity. These additional data will be used in conjunction with hydrologic performance to support hypotheses regarding the possible mechanisms influencing the hydrologic results.

4.3 Information needed and sources

Information needed for this project include design drawings, as-built conditions, and design model parameters. Supporting information will include any other site assessments used to design the project being monitored, including geotechnical exploration logs and laboratory testing data, infiltration tests, original planting plan, construction monitoring reports, and subsequent maintenance activity. The source for all this information is expected to be from the project owner.

4.4 Target population

The target population is constructed bioretention facilities in the Puget Sound basin that were designed using the WWHM 2012 hydrologic model.

A site selection process for the ten facilities to be monitored was previously conducted, and is summarized in the technical memorandum in Appendix A.

4.5 Study boundaries

Study boundaries are the Puget Sound basin.

4.6 Tasks required

Detailed approaches and procedures for field data collection are provided in Section 8.1, Field Measurement and Field Sampling SOPs. The following tasks are required to enable field measurement and sampling.

Tasks to be conducted in this project include:

1. Specifying and obtaining rain gages, and flow and ground water monitoring equipment for all ten facilities to be monitored.
2. Installing flow and ground water monitoring equipment for all ten facilities to be monitored.
3. Operating and downloading electronic data collected at all ten facilities for the duration of monitoring.
4. Collect soil and plant information
5. Conduct data management and quality control for data collected.
6. Obtain design drawings, as-built conditions, technical information reports, construction monitoring records, and modeling parameters used in each facility design model.
7. Calibrate and run new computer models based on actual field performance data collected.

4.7 Practical constraints

Practical constraints include:

1. Retrofitting of inflow and outflow structures to enable more effective flow monitoring.
2. Travel time delays to the various site locations to maintain site equipment prior to storm events to be monitored.
3. Seasonality constraints may limit monitoring to wet season events.
4. Public exposure of the monitoring equipment may result in damage or vandalism.
5. Subsurface exploration is constrained by below ground utilities (underdrains) and difficulty in advancing hand tools in hand exploration borings.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

1. Eric Christensen, Planning and Engineer Supervisor, City of Olympia.
   Manage execution of the contract with Ecology, including invoicing and progress reporting.

2. Douglas Beyerlein, P.E., Prime Consultant and Hydrologic Modeling Lead Clear Creek Solutions, Inc.
   Provide consultant team management, and team administration with the City of Olympia. Conduct modeling tasks for the project.

3. William J. Taylor, Principal Investigator and Principal Author of Project Reports. Taylor Aquatic Science
   Lead design of overall project approach. Write project reports with contributions from team members.

4. Bryan Berkompas, Flow Monitoring and Data Collection Lead Aspect Consulting, Inc.
   Specify approaches and equipment, and conduct installation, maintenance, data collection, and management for all surface flow and rainfall data collection.

5. Jennifer H. Saltonstall, L.G., LHg., Hydrogeologic/ Geotechnical Data Collection and Bioretention Soil Assessment Lead
   Associated Earth Sciences, Inc.
   Specify approaches and equipment, and conduct installation, maintenance, data collection, and management for all well point and ponding data collection.

6. Anne Cline and Chris Wright, Vegetation Monitoring Leads Raedeke Associates, Inc.
   Specify approaches and equipment, and conduct field data collection and management for all vegetation monitoring procedures.

5.2 Special training and certifications

No specific certifications are required. All team members have the experience required for their role.

5.3 Project schedule

Because of the wet season requirement needed to obtain sufficient hydrologic data, the schedule revolves around the period October through May, for a maximum duration of five months. Subsurface water and surface water level data will be collected continuously and simultaneously with storm event monitoring. The sampling period may be extended as interest has been expressed by Ecology and the SWG to capture enough storm events to make the findings viable.

5.4 Limitations on schedule

Limitations on schedule will be related largely to completion of contracting to enable starting data collection from the beginning of the wet season, purchase of monitoring instrumentation, and the availability of storm events in a given wet season. In addition, the project monitoring duration is presently funded for five months of monitoring (Table 1). This will be the limit of the project monitoring period. The SWG has expressed interest in conducting a longer duration of monitoring, and has requested cost estimates for additional monitoring, including monitoring during the summer season, and monitoring for a complete year.

5.5 Budget and funding

Proposed scope task and budget levels for Study II monitoring and reporting are provided in Table 1. Funding is from the Stormwater Action Monitoring (SAM) Program which is a cooperative of municipal stormwater permittees, and is administered by Ecology. The scope of work and the budget for tasks is provided in Appendix B.

Table 1. Tasks and Budget

Task	Description	Consultant Budget
1	Project Management	$16,240.00
2	Site Selection	$55,545.80
3	QAPP Update	$4,600.00
4	Performance Monitoring	$269,359.20
5	Data Analysis and Modeling	$44,280.00
6	Report and Findings	$88,180.00
	Contingency	$47,821.00
Total		$526,026.00

6.0 Quality Objectives

6.1 Decision Quality Objectives (DQOs)

DQOs are qualitative and quantitative statements developed using a data quality objective process. This process clarifies study objectives and defines the appropriate types and amounts of data and tolerable levels of potential errors. The DQOs for this project are:

1. Sites selected have known designs and as-built information.

   Existing original designs and as-built conditions will be collected from the project jurisdictions and design engineers. These original design features and dimensions will be compared to existing conditions.

2. The data will be generated according to procedures for field sampling, sample handling, laboratory analysis, and recordkeeping.

   Standard operating procedures for hydrologic measurements (identified also in section 8.1) will be generally followed and documentation recorded. These include, but are not limited to, Ecology (2009, 2012) and manufacturer's manuals for proper use of instrumentation.

3. Data reporting and measurement sensitivities will be established and adequate for stormwater management decisions.

   Hydrologic data sensitivity and precision have been determined and reported by the manufacturers. Error estimates for the rain gages and Thel-mar weirs to be used are reported as 5% or less. Grain size distribution is likewise reported as 5% by the soil laboratory to be used.

4. Creation of site-specific bioretention hydrologic performance models using WWHM2012 with field-measured input.

   The model results will reflect field measurements, input data accuracy, and input model assumptions. If the model results do not accurately reflect the monitoring data results (within 10% outflow volume error for the entire monitoring period) then input data will be reviewed and possible sources of error identified. No calibration of WWHM2012 model parameters or algorithms will be attempted.

Once established, DQOs become the basis for measurement quality objectives (MQOs), which are discussed for both hydrological, precipitation, and soil data under each heading in this section.

6.2 Measurement Quality Objectives

MQOs are the acceptance threshold for data, based on the quality indicators (described below) and are specifically used to address instrument and analytical performance. For this project the MQOs will focus on completeness, sensitivity and accuracy of measuring a wide range of hydrologic conditions in Western Washington.

6.2.1 Targets for Precision, Bias, and Sensitivity

6.2.1.1 Precision and Percent Error

Level of precision, or repeatability, for the instantaneous stage measurements for flow, ponding, and subsurface water elevations are expected to be 2 mm or less based on experience of the hydrologic monitoring field staff. Translation of the stage measurements for inflows and outflows to flow rate will result in flow rates within 3 to 5 percent of the true flow rate as reported by the manufacturers of Thel-mar weirs as percent error (Thel-mar Company 1995) and Harmel et al. (2006).

Precision will be tracked by recording observed depths in the field, replacing the measurement instrument, and recording the repeated observation in the field.

Precision for precipitation is also expected to be highly repeatable, within 1 mm rainfall, and is also reported to be within 5 percent error of the true rainfall, as reported in the product specifications by Hydrological Services (Hydrological Services 2008).

While the inherent percent error of the instruments is stated based on the manufacturers' claims for precision and accuracy, the most important means for maintaining the accuracy of the measurements will be field maintenance of the instrumentation (Harmel et al. 2006). Maintenance of equipment in the field will generally follow Ecology (2009) standard operating procedures for conducting stream hydrology site visits. In addition, site visitation for downloading data from each site will be roughly every two weeks during the five month monitoring period, but site visits will be adapted to be conducted immediately prior to anticipated large storm events as possible within the budget.

Subsurface exploration, geotechnical laboratory and infiltration testing is used to characterize bioretention soil and underlying native subgrade. Variability in bioretention soil exists due to the type and quality of compost and aggregate, the supplier's method of mixing, the method of placement during construction, and post-placement changes due to planting, saturation and natural soil processes that occur as soil ages. Variability in native subgrade materials exists both laterally and vertically due to the nature of sediment erosion and deposition through geologic time. Conditions should be expected to vary between explorations.

Soil analyses will include organic matter content of the bioretention soil mix, soil sieving for grain size distribution. Percent error for these measurements is approximately 5% as reported by the project analytical laboratory, NW Agricultural Consultants. A summary of laboratory reporting methods, sensitivity, and detection limits is presented in Table 2.

Vegetation identification precision will be based on the plant ecologist's knowledge of common plants used in bioretention facilities, or identified in the field with field guides. Stem density and estimates of percent cover will be collected for a minimum of twenty five percent of the bioretention area. Within these sampled areas, percent error of stem density and percent cover is expected to be within 5 percent.

Table 2. Laboratory methods, sensitivity, detection limits, and lab accreditation for soil samples to be collected from each of the ten bioretention facilities to be monitored.

Analyte	Matrix	Number of Samples	Expected Range of Results	Analytical Method	Sample Preparation Method/ Special Methods	Sensitivity/ Detection Limit	Lab/ Accreditation
Organic Matter	Soil	3	Depende nt on Soil Type	ASTM D2974	No separate preparation method	A scale meeting the requirement s of ASTM D 4753 and a 0.01 g readability	AASHTO, A2LA
Particle Size Analysis of Soils	Soil	3	Depende nt on Soil Type	ASTM D422	ASTM D421	A scale sensitive to 0.1 percent of the mass of the sample retained on the No. 10 sieve.	AASHTO, A2LA

6.2.1.2 Bias

Flow during each storm flow event, and pond and ground water levels, will be measured with stage recorders for the inflow, outflow and water surface stages. Drift can occur as a source of bias in the sequence of measurements, and will be evaluated and corrected for during data quality assurance review. Other sources of bias include physical disturbance or debris obstruction of the weirs, or the pond and ground water level stage measurement instruments. Avoidance of bias will be achieved through field checking of the sites' equipment and calibration either on a regular or storm event basis.

For the geotechnical engineering and hydrogeologic data collection, the primary concern for bias relates to number and frequency of soil sample collection. Soil sample frequency will be determined by budget. At a minimum, three samples of bioretention soil and two samples of native subgrade soil will be collected for each facility. One set of samples from each facility will be tested for grain size distribution.

Bias in vegetation stem density and percent cover will be minimized by estimates being conducted by a single ecologist in the field, with plant identification cross checked with other staff ecologists. Twenty five percent of each bioretention facility will be sampled for vegetation parameters.

6.2.1.3 Sensitivity

Flow, ponding and groundwater levels will be detected by electronic instrumentation. The limit to sensitivity of detection is based primarily on whether the instrument is electronically functional at the time. Equipment malfunction will cause either lack of detection at all or large errors due to obstructions in the field. While sensitivity of stage recording devices may be recorded by the instruments at greater than 0.01 feet, the results will be reported to the nearest 0.01 feet.

Soil analyses to be conducted include organic content and gradation for both bioretention soil mix and subsurface soils. Sensitivity for both of these is 0.1%.

6.2.2 Targets for Comparability, Representativeness, and Completeness

6.2.2.1 Comparability

Comparability of results from this project will be from the storm-based measurements at each of the inflows and outflows from each facility. This is the primary basis of the evaluation of the hydrologic performance of bioretention facilities in the scientific literature (Taylor and Cardno, 2013). Flow measurements will utilize calibrated manufactured weirs or similar primary devices for comparability to similar studies.

Numerous candidate sites were evaluated in the field, and by reviewing design drawings, to best assure the sites chosen were accessible and suitable for accurate flow monitoring for comparison to other similar monitoring projects. A summary of this selection process is provided in Appendix A.

The subsurface exploration and geologic/hydrogeologic characterization will be conducted in accordance with methods discussed in “Guidelines for Preparing Engineering Geology Reports in Washington,” prepared by: Washington State Geologist Licensing Board, November, 2006.

6.2.2.2 Representativeness

Representativeness of this project site selection is based on geographic distribution of subject facilities, representativeness of storm sizes monitored for model performance evaluation, range and duration of storm event and water surface levels, and direct collection of additional soil and vegetation data from each facility.

- Sites to be monitored are distributed from Bellingham in the north to Tumwater in the south. See Appendix A for distribution of proposed facilities.
- Storm flow monitoring will be conducted for the duration of five months, with the goal to collect flow data for five storm events at each of the ten facilities.
- Ground water and pond stages will also be monitored continuously during five months of the wet season to provide representativeness of continuity of stages during the wet season.
- Surface infiltration rates will be measured at each of the facilities at least at one location, and soil samples will be collected at three locations within each facility.
- Vegetation will be assessed for during mid to late summer, prior to leaf fall.

6.2.2.3 Completeness

Because the hydrologic data to be collected will be used to evaluate the WWHM bioretention input parameters for each of the ten facilities, the degree of data collected will affect the evaluation analysis. Data collection goals include:

- Inflow and outflow measurements from a minimum of five storm events collected during the five-month monitoring period is recommended for the completeness needed for evaluation of the modeled bioretention results.
- Storm sizes to be monitored should range from approximately 0.25 to at least 1.0 inches over 24 hours.
- Ponding depths and subsurface water elevations will be collected for at least five months during the wet season to provide additional model information along with the inflow and outflow monitoring.
- Infiltration rates and soil samples will be collected from each facility.
- Vegetation composition and density will be collected at each facility.

7.0 Sampling Process Design (Experimental Design)

7.1 Study Design

The project study design is a modeling-based assessment established on field measurements of inflow, outflow, ponding and groundwater levels, bioretention soil infiltration rates, soil composition, and vegetation type, density, and maintenance. The intent is to provide adaptive management feedback to the bioretention design modeling process using the WWHM 2012. The intended benefits of the project are to identify bioretention facility conditions that affect the actual hydrologic performance of the facility, and use that information to help improve future bioretention designs.

Additionally, because the study population is bioretention facilities designed using WWHM 2012, field measurement of flows and subsurface groundwater conditions will allow direct evaluation of the performance of these facilities designed using WWHM 2012. In this way, this study provides feedback to both the constructed facility and the design model.

The project objective is to compare actual hydrologic performance of constructed bioretention facilities with the modeled performance from the same facility. Modeled results from the as-built facility will be compared to monitored performance data.

The comparison of the model results with the field results will either demonstrate the ability of the model algorithms to accurately represent real-world bioretention facility conditions or will identify limitations in the modeling that may require future changes in computational techniques or parameter input values. With a range of facilities the comparisons will test the strengths and weaknesses of bioretention facility performance over a wide-range of conditions involving local bioretention soil mix composition, surficial geology, infiltration rates, groundwater fluctuation, actual constructed site geometry, and vegetation density, health and maintenance.

The final product will be a set of performance comparisons between the model and observed performance. Key factors such as native soil types, climatic conditions, errors in planning/modeling or model input values that best describe observed differences will be discussed in a final report. In addition, recommendations may be made for changes needed in the design, construction, and maintenance of bioretention facilities to improve their hydrologic performance.

If unable to explain observed differences through construction, maintenance or site characteristics, then a recommendation may be made to the WWHM 2012 model input. The recommendations will include potential parameter value changes (for example, for the engineered soil mix), regulatory modeling changes (for example, use of the KSat Safety Factor), and changes in field measurements techniques (for example, native soil infiltration rates). All of these recommendations will assist state and local governments in improving and updating their stormwater LID regulations.

The assessment of the facilities' performance in terms of the three minimum performance requirements in the SWMMM (see Section 3.1.5) will allow us to quantify how well these facilities are performing (even if they were not specifically designed to meet all three minimum requirements). Any deficiencies noted will not be considered a failure of a specific facility but an indication of what key factors significantly influence the actual performance of the facility. This will assist in focusing on possible future changes to the design standards and/or the performance standards.

For each bioretention facility the evaluation procedures to be followed include:

1. The contributing drainage area described in the technical information report (TIR) will be compared with the contributing drainage area observed at the site. The relative pervious and impervious areas draining to the site will be compared to the original model input. Apparent discrepancies in the contributing area as indicated by volume of inflow will be addressed through re-evaluating the measured rainfall and flow data, and measuring the contributing area through field measurements or satellite imagery provided by google earth.
2. The physical dimensions of the bioretention facility will be measured in the field and used to create the model for comparison.
3. The physical outlet structure configuration and dimensions of the bioretention facility will be measured in the field and used to create the model for comparison. Plan drawings will be used where measurements cannot be made due to access or other issues.
4. A new WWHM2012 model of the drainage area and bioretention site will be constructed based on the information collected in procedures 1-3 above.
5. Monitored rainfall data and runoff inflow data (if available) will be input in the WWHM2012 model. If inflow data are not available then simulated inflow data will be used instead.
6. The WWHM2012 model will be run for the monitoring period to compare simulated model results from the bioretention facility with monitored outflow data.
7. Discrepancies between the above collected data and the model data will be noted.
8. Based on all of the above information, and the results of the actual hydrologic performance of the bioretention facility, individual facility performance of the ten monitored facilities will be described in both qualitative and quantitative terms.
9. The comparison of simulated model results from the bioretention facility with monitored outflow data may result in the need to adjust the model input native infiltration rate or other parameters (for example facility dimensions or contributing area) to more accurately replicate the measured outflow data.
10. The adjusted final WWHM2012 model will be run for the entire standard WWHM2012 simulation period (40-60 years) and the model outflow results will be compared with the Ecology minimum requirements described above.

7.1.1 Field measurements

Field measurements to be collected include:

- Inflow and outflow flow measurements. These data will be collected continuously over a five month or longer period. A range of storm event conditions are sought for the study, with a goal of a minimum of five storm events.
- Precipitation.
- Ponding level and groundwater levels.
- Soil borings and associated observations of bioretention soil, underdrain aggregate, subsurface soil, geology, and groundwater.
- Bioretention soil and subsurface sediment character and thicknesses, depth to ground water and field permeability estimates.
- Soil infiltration rates.
- Vegetation composition and density.

7.1.2 Sampling location and frequency

The location of facilities to be monitored are presented in Appendix A. All the field sampling described is to be carried out within each facility.

7.1.3 Parameters to be determined

The model to be used in this study is the WWHM 2012. The bioretention modeling module will be used with assignment of parameters in the model based on the as-built dimensions, and site conditions.

The parameters to be determined as part of the geotechnical engineering and hydrogeologic data collection include bioretention soil mix organic content and gradation, subsurface soil gradation, geologic unit, shallow ground water conditions, permeability, and fate of infiltrated water. These parameters are used to characterize shallow subgrade soil and ground water conditions, including infiltration rate.

7.2 Maps or diagram

A map of the location of the facilities to be monitored is presented in Appendix A.

7.3 Assumptions underlying design

Assumptions for this study design are that infiltration rate, soil characteristics, groundwater, and vegetation characteristics and maintenance are the primary factors affecting the hydrologic performance of bioretention facilities. We further assume that infiltration rate can be estimated by direct field measurements and compared with infiltration estimates derived from flow monitoring data. A final assumption is that each of the bioretention facilities selected to be monitored will prove to be monitorable and continue to meet the selection process criteria already carried out.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

8.1.1 Water level and flow data collection

This study will collect water level and/or flow data from several points within each bioretention facility. Flow rates will be measured at any inlet or outlet from the facility. Water level will be measured in shallow groundwater wells as well as within the facilities themselves to determine ponding depths. Some facilities may not include all of these elements and the monitoring system will be adjusted accordingly.

8.1.1.1 Inlet Monitoring

Bioretention facilities in this study have three types of inlets: pipes, curb cuts or modeled inlets. Flow rates in piped inlets will be measured using Thel-mar weir inserts sized to fit the inlet pipes. A pressure transducer will measure water level behind the weir to determine the inlet flow rates. Curb cuts will require some modification as the flow through the cut will likely be too shallow to measure directly under all but the most extreme storm conditions. A plastic or rubber sheet will be used to line the curb cut and funnel the flow into a section of pipe. A pressure transducer and a Thel-mar weir insert at the downstream end of the pipe will be used to measure the inlet flow rate. There are a variety of shapes, sizes and expected flow rates for the curb cut inlets at the selected sites and the sheeting, pipes and Thel-mar weirs will need to be custom sized to each inlet.

Additionally a small splash pad may be required at the end of the pipe to prevent erosion from the concentrated flow point. Some inlet flows may be estimated using a model rather than measurement. Some facilities have multiple roof drain inlets and the cost to monitor all of the inlets may prove prohibitive. In such cases one or two inlet monitoring systems may be rotated to each inlet for one or two rainfall events to help adjust a runoff model based on rainfall. This adjusteded model will then estimate inflow into the bioretention facility based on the measured rainfall for an event.

8.1.1.2 Outlet Monitoring

Not all of the bioretention facilities have an outlet but those that do will require outlet monitoring. Six of the facilities in this study with an outlet pipe has an overflow structure with an outlet pipe and a sump below the pipe. Additionally, some facilities have an underdrain pipe that connects to this structure. A Thel-mar weir will be installed in the outlet and a transducer will be installed in a stilling well within the sump of the outlet structure to measure the water depth behind the weir. Two of the facilities (M1C and SSW) in the study have an outlet structure that comingles any outflow from the facility with flow from other adjacent facilities. Outflow at these sites will only occur if the facility ponds to the point of overflow and any overflow will be estimated using a morning glory weir equation based on the size and shape of the overflow structure. The last two facilities (MPP and TBM) do not have an outflow structure and would only discharge if the entire facility filled up and overflowed into the surrounding landscaping.

8.1.1.3 Groundwater and Ponding Depth Measurements

Monitoring wells may be installed at the facilities to measure ponding depth and groundwater surface elevations at various depths within the facility. The design of each facility will ultimately determine the number and types of monitoring wells needed at each facility. Three different types of monitoring wells may be required at a given facility. The first type of well would be installed to continuously measure the ponding depth on the surface of the bioretention cell. The ponding depth will be used in the analysis of both infiltration rates of the bioretention soil mix and overflow events at each facility. The second type of well will be installed to measure the groundwater surface level at the base of the bioretention soil mix. Data from the bioretention soil mix monitoring well will be used to track infiltration rates within the bioretention soil mix or aggregate layer (if present). The third type of well would be installed in the shallow native soils underlying the facility to monitor groundwater levels beneath the facility. The data from the wells installed into the native soils will provide information about the influence of shallow ground water conditions (if present) on the infiltration rates into the underlying soils at each facility.

The shallow ground water conditions are an important site variable. One screened well point will be installed in the foot print of the facility within the soil boring hole to obtain depth to ground water level measurements and provide a long-term ground water level monitoring station. Additional well points or wells can potentially be installed around the outside of the facility. The well point(s) will be equipped with a datalogger and then used to obtain information on ground water response to stormwater inflow and precipitation. This data will be compared to staff gauge water level data within the facility.

8.1.2 Rain Gauge

Precipitation data is an important part of the modeling and inlet flow verification analysis. Each site will require a nearby or on-sight rain gauge. Where possible an existing municipal rain gauge will be utilized. In order for an existing rain gauge to be applicable to this study it must be located close to the facility, be in the same isohyet as the facility, and it must be regularly maintained and calibrated by the owner. Data from the existing rain gauges will be collected from the municipality that operates the gauge. Sites that do not have a suitable rain gauge nearby will require a rain gauge to be installed as part of the monitoring system. The rain gauges installed as part of this study will be sited at or very near to the facility and will be located in an area that accurately represents the rainfall in the drainage basin of the facility.

8.1.3 Site Maintenance

All monitoring sites are budgeted to be visited at twice a month for routine maintenance, calibration and downloading. Some sites may require more frequent visits depending on site conditions such as sediment deposition, animals, security concerns etc. and others less. All study-related monitoring equipment will be operated and maintained per manufacturer recommendations. During each maintenance visit the field crew will:

- Download all monitoring data to a laptop and copied to a USB storage drive in the field as a backup.
- Each Thel-mar weir, pipe, and collection sheet (for curb cuts) will be inspected, cleaned and the weir will be leveled if needed.
- Each stage recording instrument and weirs will be inspected, cleaned and calibrated as necessary. Prior to removing and inspecting each transducer a level measurement will be collected behind the weir or within the well.
- Once the transducer is reinstalled a second level measurement will be collected. These level measurements will serve as the starting and ending points for any data corrections associated with sensor drift or offsets.
- Any study-owned rain gauges will be inspected to ensure that is it clean and level per the manufacturer's specifications.

Upon completion of the maintenance visit all project data will be transferred to the project database on the consultant's server. All field forms will be scanned and saved. Some sites may be maintained by the municipality that owns the facility. In these cases, the municipality will send the electronic data to the consultant for storage on the consultant's server.

8.2 Geotechnical Engineering and Hydrogeologic Data Collection

8.2.1 Subsurface Exploration

Limited information on subsurface conditions will be obtained from hand auger samples and soil probe penetration measurements at about 2-foot increments in each hand-augered borehole. One hand boring will be performed in the facility bottom and advanced to a depth of 8 to 10 feet or refusal. A second hand boring will be completed to a depth of 4 feet or refusal. Representative samples will be collected, visually classified in the field, stored in water-tight containers and transported to AESI's offices for additional classification, geotechnical testing and study. A detailed record of the observed bioretention soil, underdrain aggregate (if applicable), subsurface soil, geology and ground water conditions will be made.

The sediments will be described by visual and textural examination using the soil classification in general accordance with ASTM D2488, Standard Recommended Practice for Description of Soils. Hydrogeologic analysis and geologic unit assignment will be conducted to estimated infiltration capacity of the native subgrade sediments. At the conclusion of the excavation, each borehole will be immediately backfilled with the excavated material or completed as a monitoring well and the bioretention soil replaced.

8.2.2 Geotechnical Testing

The bioretention soil and native subgrade sediments will be further classified using geotechnical laboratory testing procedures. The bioretention soil will be tested for organic matter content using the Loss on Ignition test method (ASTM D2974) to estimate the percent organic matter, and the burned material will then be sieved in accordance with ASTM D422 test procedures. The native subgrade sediments will be sieved in accordance with ASTM D422 test procedures. Hydrometer analyses will only be conducted if the native material is composed of greater than 15 percent (by weight) silt/clay.

8.2.3 Measure Infiltration Rates

Infiltration rates will be measured in one of two ways:

1. If adequate water supply is available and the facility footprint is relatively small, infiltration rates will be measured by full-scale testing (maintaining a constant level of water across the facility at a constant flow rate, and accurately measuring the wetted pool); or

2. When full-scale testing is not practical, infiltration rates will be measured using the Pilot Infiltration Test (PIT). The PIT is not a standard test but rather a practical field procedure recommended by Ecology. A PIT will be performed in the footprint of each bioretention facility per the guidelines for a Small- Scale Test as described in the SWMMWW (Ecology 2014).

For some facilities with underdrains, the measured infiltration rate from the above described testing will be the rate of the bioretention soil, not the underlying native subgrade. The underdrain, if present, will be observed for discharge. The field measurements will be compared to the native subgrade infiltration rate estimated based on grain size distribution methods that account for natural compaction, observations of water level response to testing in the well point, and from a review of prior relevant data for the facility, if available.

8.3 Vegetation monitoring

Bioretention facility plant composition and density will be measured for selected monitoring sites in one of three possible approaches depending on site conditions. Only the bottom (area subject to inundation) of the bioretention cell will be sampled for vegetation.

1. For bioretention facilities that only have woody vegetation (shrubs and trees), the number of stems will be counted within the facility (density). A woody plant is considered and inventoried as a single individual, regardless of the number and size of stems emerging from a common root system. A woody sapling/tree with a single stem is also considered and inventoried as a single individual. However, a woody sapling/tree with multiple stems may be considered and inventoried as multiple individuals if the stems split below 50cm in height (along the stem). In addition to a count of the number of stems within the facility, an estimation of the percent cover of the woody vegetation within the study area will be made. The genus and species of the woody plants will be recorded as well as the wetland indicator status of the species observed.

2. For bioretention facilities with only herbaceous plant species, a quadrat along pre-determined points along a transect line(s) will be used to measure density. A 25 cm x 25 cm quadrat will be used to record the percentage of herbaceous vegetation versus the percentage of bare ground that covers each quadrat. Species will be identified to genus and species and note made of the wetland indicator status of the observed species. At a minimum 25% of the unit will be sampled.

3. For bioretention units with woody and herbaceous species, both sampling methods will be used. Stem density will be counted for the woody species and quadrats will be used to estimate density of herbaceous vegetation.

4. For maintenance activity, the owning jurisdiction or private parties will be contacted to define and document the regular routine activities and schedule of maintenance for each facility.

Summary presentation and discussion of results will be used to provide qualitative inference on the possible role of vegetation and maintenance on the hydrologic performance at each of the monitored facilities.

Comparisons will be made to the observed composition of the vegetation community and the originally designed plant community where planting plans exist. Composition of the plant community can be used to infer the duration and frequency of inundation within the bioretention facility to further understand the hydrologic performance of the system.

8.4 Containers, preservation methods, holding times

Soil samples will be the only sample matrix collected for delivery to a laboratory for analysis. Soil samples will be collected with hand tools (shovels) and placed in one gallon zip locked plastic bags. No preservation, cooling, or holding time is applicable for these samples.

8.5 Invasive species evaluation

Equipment used in flow monitoring will be visually evaluated for debris and cleaned as needed between uses at different sample sites.

8.6 Sample ID

Subsurface explorations will be identified with GPS coordinates. Soil samples will be labeled with an exploration identification number, date, and the depth below ground surface.

8.7 Chain-of-custody, if required

Chain-of-custody protocols for soil samples collected will follow protocols used by the geotechnical consultant and soils lab. These procedures include using a chain-of-custody form documenting the delivery and disposition of the samples as they are delivered from the field collection team to the laboratory staff.

8.8 Field log requirements

Field logs containing all the following information will be maintained for all field visits, and will otherwise generally follow Ecology 2009 standard operating procedure for conducting stream hydrology site visits.

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Unusual circumstances that might affect interpretation of results

8.9 Other activities

No other sampling activities are anticipated.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Field procedures for flow monitoring are described in Section 8.1.1, Water level and flow data collection, and 8.8 Field log requirements above. These procedures will generally be followed for routine maintenance of flow over weirs, calibration of stage measurement instrumentation for weirs and well points, and downloading of data.

It is recognized that these field procedures for maintaining the equipment for accurate measurements are the most important elements to obtaining precise measurements.

Similarly, soils sampling, infiltration rates measurements, and related observation procedures in the field will follow the ASTM and Ecology (2014) procedures identified in section 8.4 above.

9.2 Lab Procedures

The only laboratory procedures will be for soils samples. Soils lab procedures for organic matter and organic matter content will use the Loss on Ignition test method (ASTM D2974) to estimate the percent organic matter, and the burned material will then be sieved in accordance with ASTM D422 test procedures. Details of the laboratory procedures are provided in Table 2.

The native subgrade sediments will be sieved in accordance with ASTM D422 test procedures. Hydrometer analyses for particle size analysis will only be conducted if the native material is composed of greater than 15 percent (by weight) silt/clay.

10.0 Quality Control (QC) Procedures

10.1 Field and lab QC required

Soil samples quality control measures will include comparison of laboratory results with the visual manual classification as described above in Section 8.1. Apparent inconsistencies in these analyses may warrant reanalysis of archived soil samples.

For infiltration testing quality, estimated permeability (infiltration rate) from the grain size testing will compare with the field infiltration test results for consistency. If observed subsurface water levels suggest much different infiltration rates than measured, the groundwater and flow data will be reviewed to attempt to resolve any discrepancies due to water level data inaccuracy.

10.2 Corrective action processes

Corrective actions will generally be required to respond to either (1) physical failure of the precipitation and stage recording instrumentation or weirs (e.g. due to damage, vandalism, obstructions, etc.), or (2) apparently erroneous data has been collected (e.g. data gaps in data collection, bias due to drift, etc.).

Corrective actions to correct physical failures of the monitoring equipment will be implemented through inspection of monitoring equipment prior to anticipated storm events (as possible within the budget allotment and with assistance of local municipalities). If physical failures of equipment are identified prior to or during storm events, simple actions to correct the issue will be taken immediately (e.g. removing debris or reinstallation). Reinstallation of monitoring equipment will otherwise be conducted when best feasible either during or between storm events.

Identification of erroneous data will not occur until data is downloaded from each site (semi-monthly). Correction of erroneous data will be conducted through the data review and correction process (see Section 11.1).

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

11.1.1 Data management and verification

All project related data will be stored on the consultant server and backed up offsite on a daily basis. All flow, rainfall, and groundwater data will be reviewed within a week of the site maintenance visits to identify potential problems and address them to minimize data gaps or errors.

All project related flow and rainfall data will be verified using the following steps.

- Data will be reviewed for gaps and determine if the gaps can be filled with estimated or alternate data. For example, if the facility rain gauge is offline a nearby rain gauge might be used to fill in the gap. The process for filling in each gap will be documented
- Anomalies or spikes will be identified. Examples of anomalies are sudden changes in level, heavy rainfall with no measured inflow, data flatlines, etc. The process for addressing each anomaly will be documented.
- All data will be cross checked against field forms and calibration records. Sensors may need to be adjusted for drift or offset and the flow rates recalculated.
- Data may also be compared across rainfall events. Are expected yields/patterns across events consistent? Do rainfall and inlet flow rates coincide?

11.2 Lab data package requirements

Soil samples analysis results will be reported in accordance with the ASTM geotechnical testing protocols. Lab data package requirements for the soil sample analyses include the weight retained on sieves, and the quality control steps of calibration and washing of the sieves prior to analysis was completed.

11.3 Electronic transfer requirements

Laboratory data results for soil analyses are delivered as a portable document format (.pdf) file, and stored as electronic files locally on the geotechnical consultant's server.

11.4 Acceptance criteria for existing data

Existing data to be used in the project include record drawings (as-builts) for each facility, existing hydrologic model, engineering design, and infiltration tests as described above in section 4.3. These data will be used as presented, unless method or results inconsistencies are apparent, as judged by the individual discipline leads. Otherwise no other existing sample data (such as rainfall or flow data) is required for completion of the project.

11.5 Data presentation procedures

Field data results and WWHM Model output will be delivered in tables and graphically in the final report for the project. Electronic copies of raw data files will also be provided to Ecology.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

The Olympia PM will be conducting audits during the project, with a monthly frequency during the five months of active monitoring and for any subsequent data processing. The auditing process will be in regard to the active field and data processing QC steps already detailed in Sections 8.1 and 11.1 above.

12.2 Frequency and distribution of report

Project status reports will be provided to the City of Olympia during the course of the study. A single draft report will be prepared for review by the City of Olympia and Department of Ecology. Comments obtained for the draft report will be addressed and changes made to produce a final report. The final report will be available from the SAM Coordinator at Ecology.

12.3 Responsibility for reports

The final report will be co-authored by William J. Taylor and Douglas Beyerlein, with contributions from the other team co-authors.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

All data generated will also be reviewed by other in-house staff associated with each discipline than those collecting the data (i.e. flow monitoring, geotechnical, hydrologic modeling, and vegetation).

13.2 Lab data verification

Laboratory soil data will be verified through review of the data results and laboratory quality control process by the project geotechnical engineer for completeness and reasonableness of results (based on the engineer's visual knowledge of the samples).

13.3 Validation requirements, if necessary

Not applicable to this study.

14.0 Data Quality (Usability) Assessment

Upon completion of the data verification the project data manager will make a final determination of the data usability. If the data meets the Data Quality Objectives (DQO) stated in this QAPP then the data will be deemed useable for meeting the study objectives. The project data manager will look at qualified data and evaluate its impact to the overall DQO. If data are rejected a determination must be made of whether the quantity and quality of the valid data are sufficient to meet the study objectives. Thorough documentation will be made of any decision to reject data as it may require additional effort to replace the intended data. Usable data is acceptable for all study related analysis.

14.1 Process for determining whether project objectives have been met

Data objectives will be met for the proposed data to be collected based on completeness and data quality of the data sets desired. These include the storm event samples (5 storms minimum), and data reviewed and corrected where needed for use in evaluation of the bioretention facility's performance; and for the minimum five month range of continuous data for pool and ground water stage data. Completeness and data quality for soil samples and vegetation characterization for each bioretention unit as described above will be required for all ten units monitored.

14.2 Data analysis and presentation methods

The results of the modeling and data collection will be presented in a methods, results, and discussion sections of the final report. Data will be presented in tabular and graphical form, and summary descriptive statistics provided. Modeling results will be presented through projected flow duration curves of the calibrated model results, as well as identification of whether the modeled results meet the minimum requirements of the SWMMWW.

Results of the study will be discussed through apparent field conditions (soil density and composition, subsurface infiltration conditions, vegetation conditions and maintenance) contributing to the end results, and referenced against peer reviewed literature.

14.3 Treatment of non-detects

Not applicable. No water sampling for pollutant or other water constituents will be conducted as part of the current study.

14.4 Sampling design evaluation

Recommendations for any perceived needed change in the study design will be provided as data is collected and reported in the monthly progress reports.

14.5 Documentation of assessment

Hydrologic performance of 10 bioretention facilities in the Puget Sound basin will be monitored during storm events and compared to the predicted modeled results for each facility. Using this comparison, and drawing from additional site data such as local bioretention soil mix composition, surficial geology, infiltration rates, groundwater fluctuation, actual constructed site geometry, and vegetation density, health, and maintenance, working hypotheses will be proposed for factors leading to the hydrologic performance observed. These working hypotheses will be supported by published literature on bioretention hydrologic performance.

15.0 References

Harmel, R.D., R. Cooper, R. Slade, R. Haney, J. Arnold. 2006. Cumulative uncertainty in measured streamflow and water quality data for small watersheds. Trans. ASABE 49(3): 689-701.

Hydrological Services. 2008. Instruction manual, tipping bucket rain gauge, model TB6. Hydrological Services, Liverpool B.C.

Thel-mar Company. 1995. Letter from Lehigh University to Thel-mar Company stating overall accuracy of Thel-mar weirs at +/- 5%. Thel-mar Company, Lansdale, PA.

Taylor, W.J. and Cardno TEC Inc. 2013. White paper for stormwater management program effectiveness literature review. Low impact development techniques. Prepared for Association of Washington Cities and Washington State Department of ecology.

Washington State Department of Ecology. 2014. Stormwater Management Manual for Western Washington. As amended in December, 2014. Publication number 21-10-030. Olympia, WA.

Washington State Department of Ecology. 2009. Standard operating procedures for conducting stream hydrology site visits. EAP057. Olympia, WA.

Washington State Department of Ecology. 2012. Standard operating procedures for correction of continuous stage records subject to instrument drift, analysis of instrument drift, and calculations of potential error in continuous stage records. EAP082. Olympia, WA.

16.0 Appendices

Appendix A. Bioretention Hydrologic Performance (BHP) Study II Site Selection Process and List of Selected Sites. Technical Memo – Deliverable 2.2 and 2.3 Combined.

Appendix B. Contracted Scope of Work, City of Olympia and Washington Department of Ecology. 2017.

Appendix C. Glossary, Acronyms, and Abbreviations

Appendix A

Bioretention Hydrologic Performance (BHP) Study II Site Selection Process and List of Selected Sites. Technical Memo – Deliverable 2.2 and 2.3 Combined.

Taylor Aquatic
Science and Policy

Technical Memo

To:	Andy Haub, Eric Christensen, City of Olympia Brandi Lubliner, WDOE
From:	William J. Taylor
Date:	February 5, 2019
Re:	Bioretention Hydrologic Performance (BHP) Study II Site Selection Process and List of Selected Sites Technical Memo – Deliverables 2.2 and 2.3 Combined

---

This memo provides a summary of the site selection process and results of the site evaluations combined into one memo. As the selection process and recommended sites for selection are connected, it made sense to combine these into one product.

Background

The BHP Study II follows the BHP Study I (conducted with the City of Bellingham) and again involved contacting Puget Sound Basin jurisdictions to identify "candidate" bioretention facilities to be recommended for evaluation and possible selection in a set of ten facilities for performance monitoring.

The difference in the BHP II selection criteria from the first BHP Study was specifically to select sites designed using the Western Washington Hydrology Model version 2012 (WWHM 2012). The goal of this project is to evaluate the performance of the model, in addition to observe how the bioretention facilities are performing in the field.

As before, the selected sites are being monitored for inflow and outflowing stormwater flows. Site data is also being collected for groundwater and ponding levels, bioretention soil mix composition and infiltration rate, subsurface soil conditions, and vegetation composition and density as supporting information to evaluate the site performance.

Outreach to Jurisdictions, and Candidate Sites Identified and Evaluated in the Field

Jurisdictions, and this time public school districts, selected for contact to nominate potential sites came from four different sources:

1. Jurisdictions indicating interest in the BHP study from previous contact or during the current SAM project selection process,

2. Public School Districts identified through the Office of Superintendent of Public Instruction

3. Jurisdictions identified through the Ecology Water Quality Grant program as having funded construction of a bioretention facility as part of their grant funded project, and

4. Jurisdictions that contacted the consultant team as a result of group emails from the Stormwater Work Group, the APWA Stormwater Managers Committee, and from the NPDES Stormwater Permit Coordinators forum.

Over thirty school districts and over 15 jurisdictions were contacted through direct telephone contact with stormwater managers or associated engineers and water quality specialists to discuss the BHP study, and their recommendations on possible candidate sites within their jurisdiction.

Based on the initial criterion that candidate sites had to be designed using WWHM 2012, almost thirty facilities were recommended for site evaluation. Site design plans (including planting plans), technical information reports (TIRs) and modeling information was gathered for most of these facilities. Twenty-five facilities were then identified for conducting a site visit for final evaluation. Because most of the sites contained multiple cells each with their own conditions, the site visits for these twenty-five facilities resulted in visual evaluation of approximately seventy individual cells.

Site Field Evaluation

After receipt of design drawings, TIRs, and hydrologic modeling results, each consultant discipline leader evaluated their background material before assessing each site in the field. Information then assessed in the field related to each of the main disciplines for selection of the sites:

- Assessment of inflow and outflow locations for flow monitoring feasibility
- Qualitative soil media composition and soil probe depths

In a different process from the previous BHP study, we did not conduct vegetation assessments as all the sites were recently constructed, or were still unplanted as we were visiting the sites. It was decided to conduct the vegetation assessment in the following spring to allow final planting and an assessment of initial survival.

Site Selection Criteria

The same site selection criteria developed in the BHP I was used as a reference to review and make note of many of the site design conditions and parameters for the candidate sites. Attachment 1 also provides a list of monitoring, modeling, and geotechnical information for each of the candidate sites.

As with the BHP I study, the accessibility of flow monitoring to attain accurate hydrologic results was almost exclusively the deciding factor. The remaining criteria checklist items were nonetheless useful as a checklist reminder of factors affecting site performance and additional data collection needs.

Separate from the criteria checklist, we used the surficial geologic and jurisdictional representation as guides to select sites that represented a wide range in geologic and jurisdictional participation.

Final Sites Selected for Monitoring

The geographic distribution of the full set of 25 sites visited is presented in Figure 1, and the final set of selected sites is listed in Table 1 below, and shown in Figure 2. Attachment 1 provides a full list of the sites visited, selected, addresses and the associated jurisdiction contacts.

Table 1. The final set of sites selected under the BHP II project.

Jurisdiction	Project Name
Bellingham (BUW)	Columbia WQ Improvements
Bellingham (BCK)	Nevada – Kentucky Bike Boulevard
Marysville (M3Q)	1st and 3rd Street SW Retrofit
Marysville (M1C)	1st and 3rd Street SW Retrofit
Monroe S.D. (MPP)	Park Place Middle School
Monroe S.D. (SSW)	Salem Woods Elementary
Renton (RSH)	Green Connections
Tacoma S.D. (FWI)	Wainwright Intermediate
Tacoma S.D. (TWH)	Wilson High School
Tumwater S.D. (TBM)	Bush Middle School

Seasonal Schedule for Monitoring

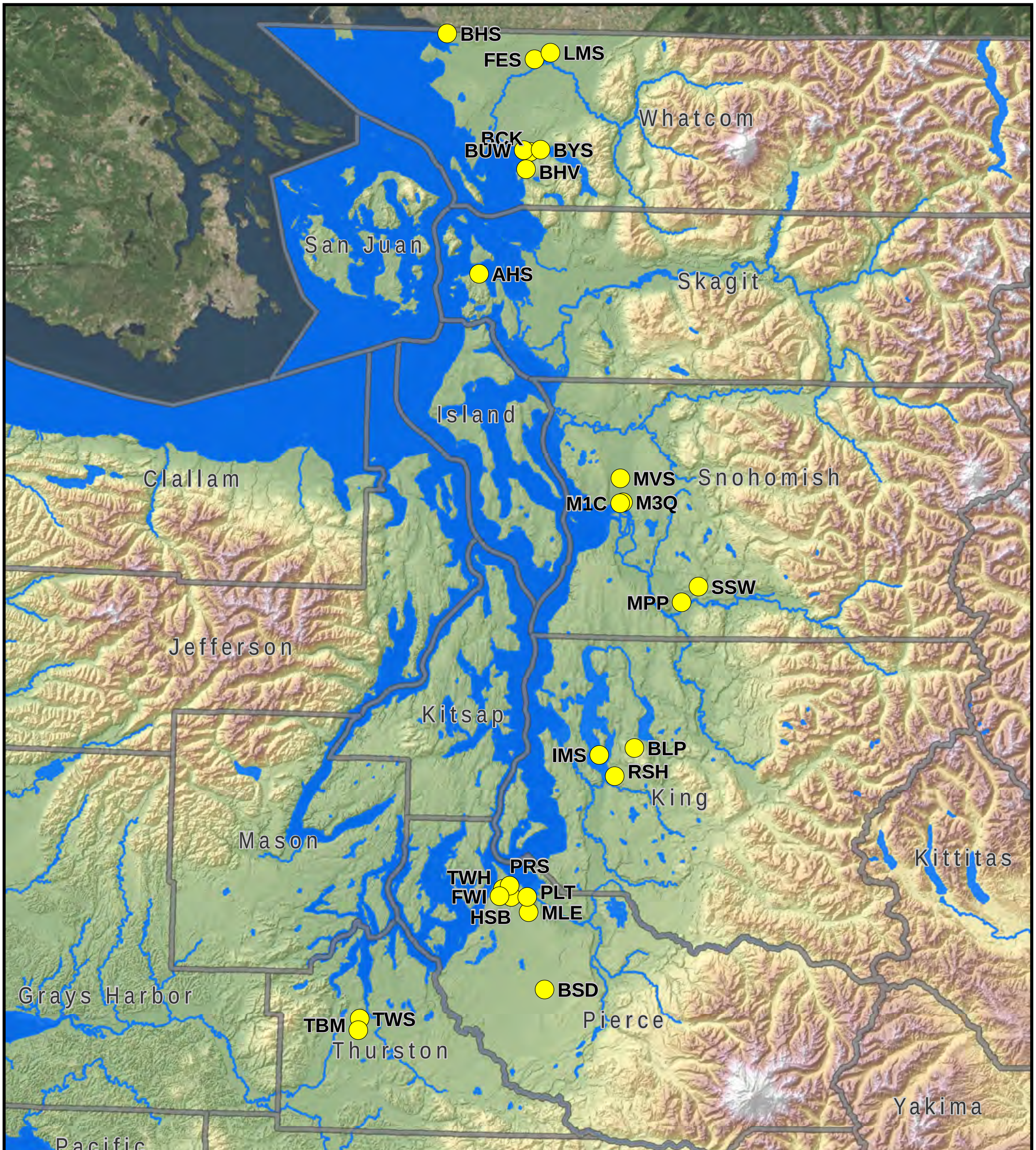
The monitoring phase of the project has begun, with virtually all the sites were installed and collecting continuous flow and rainfall data by October 15, 2018. The only exception was the two Bellingham sites which were installed on 10/22/18; and at the Bellingham BUW site one of the two inlet weirs was not installed until 11/6/18. The geotechnical site assessment work and field infiltration testing was completed during October and November 2018.

As with the BHP I Study, we recommend extending the period of monitoring from the current five months to eight months. The added value of observed groundwater conditions at many of the sites added value to analysis of the spring groundwater transition season.

If you have any questions, please feel free call me or Doug Beyerlein.

Bill Taylor

Taylor Aquatic Science and Policy



LEGEND:

- ALL SITES
- COUNTY

N

0 10 20

MILES

DATA SOURCES / REFERENCES:
AERIAL: WORLD IMAGERY, ESRI, DIGITAL GLOBE 2017
UNIVERSITY OF WASHINGTON 10 METER COMPILED DEM FROM USGS1998 DEM QUARTER QUADS
WADNR: COUNTY BOUNDARY

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

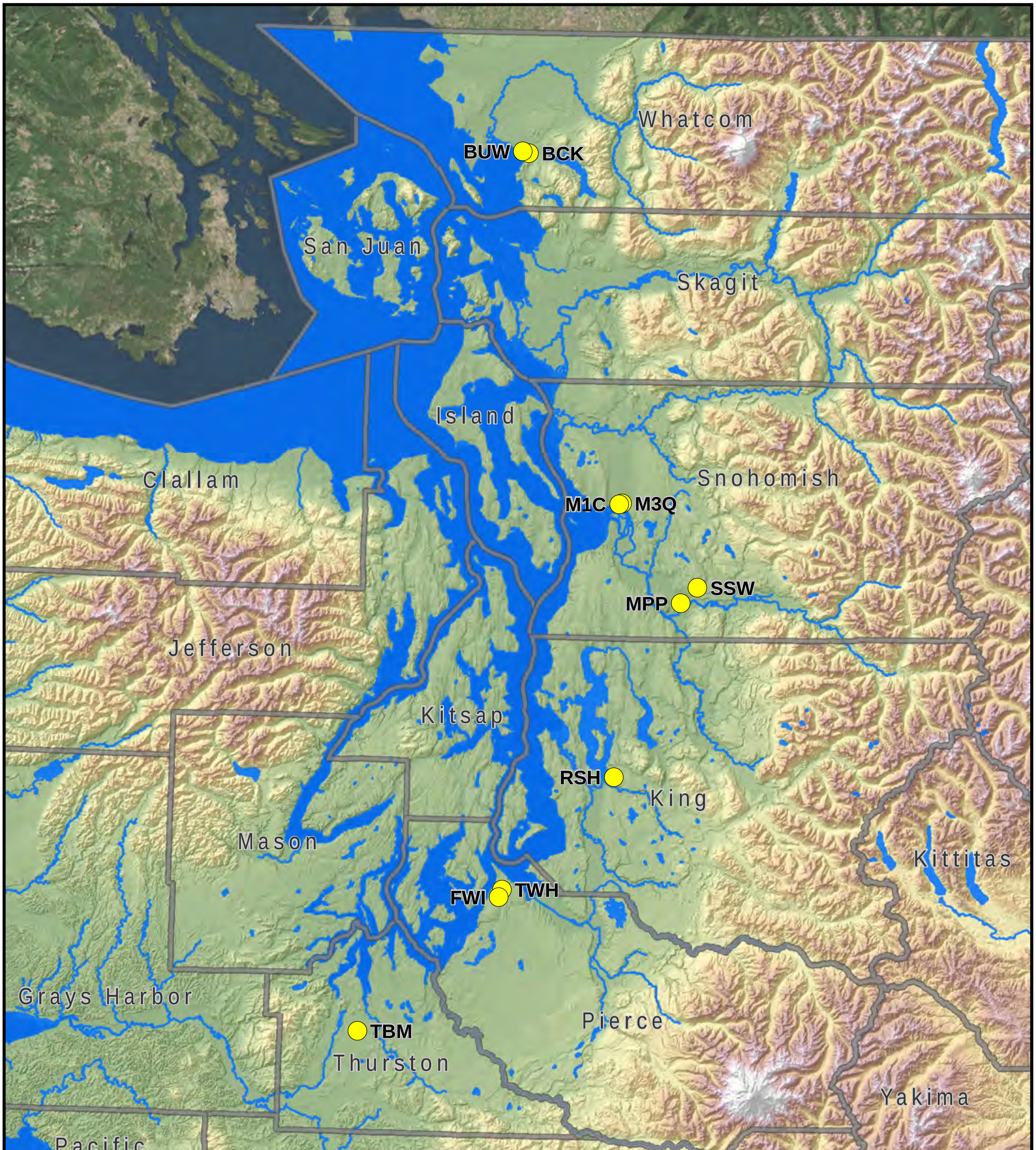
associated earth sciences incorporated

BIORETENTION SITES

BIORETENTION HYDROLOGIC PERFORMANCE MONITORING STUDY
PUGET LOWLAND, WASHINGTON

PROJ NO.	DATE:	FIGURE:
150387H007	1/19	1

Document Path: G:\GIS_Projects\aY15post0716\150387 Bioretention Hydro Performance Monitoring\mxd\H007\150387H007 F1 BHPS_ALL.mxd



LEGEND:

SELECTED SITES

COUNTY

DATA SOURCES / REFERENCES:
AERIAL: WORLD IMAGERY, ESRI, DIGITAL GLOBE 2017
UNIVERSITY OF WASHINGTON 10 METER COMPILED DEM FROM USGS1998 DEM QUARTER QUADS
WADNR: COUNTY BOUNDARY

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 10 20
MILES

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

associated earth sciences incorporated

BIORETENTION SITES

BIORETENTION HYDROLOGIC PERFORMANCE MONITORING STUDY
PUGET LOWLAND, WASHINGTON

PROJ NO.	DATE:	FIGURE:
150387H007	1/19	2

Document Path: G:\GIS_Projects\aY15\post0716\150387 Bioretention Hydro Performance Monitoring\mxd\H007\150387H007 Fx BHPS.mxd

Attachment 1. List of candidate bioretention monitoring sites visited and assessed for selection as a site to be monitored during the BHP II study. Sites highlighted in yellow are selected for monitoring.

Jurisdiction	Project Name	Location	Contact Name	Contact Phone
Anacortes (AHS)	Anacortes High School	1600 20th St, Anacortes	Marty Yates	360-293-1228
Bellevue (BLP)	Lewis Cr. Park Picnic Area	Lewis Creek Park	Kit Paulsen	425-452-4861
Bellingham (BUW)	Columbia WQ Improvements	Utter St. and Washington St.	Eli Mackiewicz	360-778-7955
Bellingham (BCK)	Nevada – Kentucky Bike Boulevard	Kentucky St. and Cornwall Avenue	Eli Mackiewicz	360-778-7955
Bellingham (BYS)	Yew St. SW Improvements	Yew St. between Texas and Alabama St.	Eli Mackiewicz	360-778-7955
Bellingham S.D. (BHV)	Happy Valley Elementary	1041 24th St., Bellingham	Eli Mackiewicz	360-778-7955
Bethel S.D. (BSD)	Shining Mountain Elementary	21615 38th Ave E, Spanaway	David Wells	253-683-6085
Blaine S.D. (BHS)	Blaine High School	1055 H Street, Blaine	Alan Pomeroy	360-332-0738
Lynden S.D. (FES)	Fisher Elementary	501 14th St., Lynden	Patty Fairbanks	360-303-0927
Lynden S.D. (LMS)	Lynden New Middle School	8750 Line Rd., Lynden	Patty Fairbanks	360-303-0927
Marysville (M3Q)	1st and 3rd Street SW Retrofit	3rd and Quinn St.	Adam Benton	360.363.8283
Marysville (M1C)	1st and 3rd Street SW Retrofit	1st and Cedar St.	Adam Benton	360-363-8283
Marysville (MVS)	Sonic Drive-In	3802 116th St NE	Adam Benton	360-363-8283
Mercer Island S.D. (IMS)	Islander Middle School	7447 84th Ave SE, Mercer Island	Tony Kuhn	206-230-6339
Monroe S.D. (MPP)	Park Place Middle School	1408 W Main St., Monroe	Heidi Hansen	360.804.2677
Monroe S.D. (SSW)	Salem Woods Elementary	12802 Wagner Rd., Snohomish Co.	Heidi Hansen	360.804.2677
Renton (RSH)	Green Connections	Harrington at NE 8th St.	Ron Straka	425-430-7248
Tacoma (HSB)	Homestreet Bank	1501 S. Union Ave.	Mieke Hoppin	253-573-2332
Tacoma (PLT)	Prairie Line Trail	S. Hood and Dock St.	Mieke Hoppin	253-573-2332
Tacoma	Proctor South Development	N. 25th Street and N. Madison Street	Mieke Hoppins	253-573-2332
Tacoma S.D. (MLE)	Mary Lyon Elementary	101 E. 46th St., Tacoma	Mieke Hoppin	253-573-2332
Tacoma S.D. (FWI)	Wainright Intermediate	130 Alameda Ave., Fircrest	Michael Knaack	253-571-3316
Tacoma S.D. (TWH)	Wilson High School	1202 N Orchard St., Tacoma	Michael Knaack	253-571-3316
Tumwater S.D. (TBM)	Bush Middle School	2120 83rd Ave SW, Tumwater	Tanya Baker	360-709-7009
Tumwater S.D.(TWS)	Tumwater Middle School	6335 Littlerock Rd SW, Tumwater	Tanya Baker	360-709-7009

Site Information for Monitoring Assessment

	Label	Jurisdiction	Site	Site Visit Date	Can inflow be easily monitored; 1 = Yes; 0 = No	Can inflow be monitored with simple modifications; 1 = Yes; 0 = No or Not applicable	Overall monitoring rating	Comments
1	M3Q	Marysville	3rd Street LID and Roadway improvement Project	4/30/18, 5/1/18	0	1	Tier 1	1 inlet and 1 outlet both with easy weir installs or curb cut modification
2	M1C	Marysville	Marysville 1st Street LID	4/30/18, 5/1/18	0	1	Tier 1	Only 1 inlet from curb, can't monitor outlet flow excpet via morning glory weir if riser overtops. Can't monitor sidewalk inputs but they are likely very small
3	MVS	Marysville	Sonic Drive-In	4/30/18, 5/1/18	1	1	No-Go	Received plan set only. Seasonal high GW depth ~5ft. owner said no
4	WHS	Tacoma	Wilson High School	4/30/18	1	1	Tier 1	Underdrained 2 inlets and 1 outlet pipe
5	HSB	Tacoma	Homestreet Bank	4/30/18	1	0	Tier 2	Underdrained could be monitored but lots of inputs Outlet comingled, owner status unknown
6	PRS	Tacoma	Proctor South	4/30/18	unk	unk	No-Go	Construction not finished at time of study
7	MLE	Tacoma	Mary Lyon Elementary School	7/31/2018	unk	unk	No-Go	Constuction not finished at time of study
8	PLT	Tacoma	Prarie Line Trail	4/30/18	0	0	No-Go	Complcated stone weir walls and other confusion
9	BHV	Bellingham SD	Happy Valley Elementary School	7/20/19	0	0	No-Go	Too many inlets and comingled outflow, other cell lined, parking lot too many linked cells
10	AHS	Anacortes	Anacortes High School	10/1/18	unk	unk	No-Go	Constuction not finished at time of study
11	FES	Lynden	Fisher Elementary School	7/20/2018	0	0	Tier 2	Lots of inlets, would need to monitor 1 and model 16, otherwise good
12	LMS	Lynden	Lynden New Middle School	7/20/2018	0	0	Tier 2	Can't monitor inflow as it is all sheet flow but very clearly defined drainage area likely best case for modeling inflow
13	BCK	Bellingham	Cornwall Kentucky	7/20/2018	1	1	Tier 1	2 inlets, 1 outlet. 1 inlet subject to some backwater
14	IMS	Mercer Island	Islander Middle School	8/15/2018	0	0	Tier 2	Multiple buried inlets with inverts below BSM level in cell
15	BYS	Bellingham	Yew St	7/20/2018	0	0	No-Go	Adjacent to permeable pavement sidewalk, likely recieves flow from sidewalk base-course. Too many ins and Outs
16	BHS	Blaine	Blaine High School	7/20/2018	1	0	No-Go	Owner said no
17		Tumwater	Tumwater Middle School	7/31/2018	1	0	No-Go	All sites either comingled outlfow or sheet flow to gravel to grass strip inflow
18	TBM	Tumwater	George Washington Bush Middle School	7/31/2018	1	1	Tier 1	Small cell in back with 1 inlet is good candidate
19	MPP	Monroe SD	Park Place Middle School	7/31/2018	1	1	Tier 1	Cell 6 has 1 inlet, no outlet, Cells 5 and 7 also considered but more complicated and more visible accessible for potential vandalism
20	SSW	Monroe SD	Salem Woods Elementary School	7/31/18	1	1	Tier 1	Cell 2, 1 inlet, outlet is high overflow
21	BLP	Bellevue	Lewis Creek Park	8/15/2018	0	1	No-Go	2 cells. One has sheet flow from pervious & basecourse. Second has overflow from 1st plus 2 curb cuts from pervious. Inflow may be low.
22	FWI	Tacoma SD	Wainwright Intermediate	8/15/2018	0	1	Tier 1	Cell 4 with two inlets selected. Cell 1 underlain by utility. Cell 2 has some minor inflow from sheet flow. Cell 3 extends to include a narrow, vegetated ditch (part of bioretention cell?)
23	BSD	Bethel SD	Shining Mountain ES	8/15/2018	0	0	Tier 2	Primarily sheet flow. Combined with piped inflow and outflow
24	BUW	Bellingham	Utter and Washington	9/28/2018	0	1	Tier 1	2 inlets 1 outlet, inlets are low but should work
25	RSH	Renton	Sunset Harrington	9/28/2018	0	1	Tier 1	2 inlets, unique underdrain with orifice flow control, outlet

Site Information for Modeling Assessment

	Label	Jurisdiction	Site	Site Visit Date	SWDM	SWM	Under-drains	Liner	Overflow	BSM Rate	BSM b	BSM n	Subgrade Design Rate	TIR Civil
1	M3Q	Marysville	3rd Street LID and Roadway improvement Project	4/30/18, 5/1/18	Ecology 2014	WWHM 2012	no	No	Yes		1.5		2	Gray and Osborne, Inc
2	M1C	Marysville	Marysville 1st Street	4/30/18, 5/1/18	Ecology 2014	WWHM 2012	no	no	Yes		1.5		2	Gray and Osborne, Inc
3	MVS	Marysville	Sonic Drive-In	4/30/18, 5/1/18		WWHM 2012	Yes	No	Yes		1.5		3.1	
4	TWH	Tacoma	Wilson High School	4/30/18	Tacoma SWMM 2012	WWHM 2012	Yes	No	Yes		1.5	0.4	1.5	Sitts & Hill Engineers, Oct 2014
5	HSB	Tacoma	Homestreet Bank	4/30/18	Tacoma SWMM 2016	WWHM 2012	Yes	No	Yes	12	>1.5			PACE, Oct 17, 2016
6	PRS	Tacoma	Proctor South	4/30/18	Tacoma SWMM 2016	WWHM 2012	Yes	No	Yes		1.5			BCRA, Oct 2016
7	MLE	Tacoma	Mary Lyon Elementary School	7/31/2018		WWHM 2012								AHBL, Oct 2017
8	PLT	Tacoma	Prarie Line Trail	4/30/18		WWHM 2012								BCRA, June 2016
9	BHV	Bellingham SD	Happy Valley Elementary School	7/20/19		WWHM 2012	yes	NE cell is lined						Freeland & Associates, May 2015
10	AHS	Anacortes	Anacortes High School	10/1/18		WWHM 2012								
11	FES	Lynden	Fisher Elementary School	7/20/2018	Ecology 2005, 2014	WWHM 2012	no	no		3			27.1	Freeland and Associates
12	LMS	Lynden	Lynden New Middle School	7/20/2018	Ecology 2005, 2014	WWHM 2012	no	no		3			14.73	Freeland and Associates
13	BCK	Bellingham	Cornwall Kentucky	7/20/2018	Ecology 2005, 2014	WWHM 2012	yes	no	yes	15	1.5		3 cells with 3 different design rates	City of Bellingham Public Works
14	IMS	Mercer Island	Islander Middle School	8/15/2018		WWHM 2012	yes	no	yes					LPD
15	BYS	Bellingham	Yew St	7/20/2018		WWHM 2012								
16	BHS	Blaine	Blaine High School	7/20/2018		WWHM 2012	yes							Freeland and Associates
17	TWS	Tumwater	Tumwater Middle School	7/31/2018	Tumwater DDECM 2010 and Ecology 2005	WWHM 2012, modeled not using bioretention settings	No - but design includes a rock-filled trench beneath BSM			3	1.5		6 biocells: Bio cell 2 and 5 have the highest % imp; bio cell 2: 1.7 iph; Bio cell 5: 2.0 iph	BCRA
18	TBM	Tumwater	George Washington Bush Middle School	7/31/2018	Tumwater DDECM 2010 and Ecology 2005	WWHM 2012	No	No	No		1.5		0.9	BCRA
19	MPP	Monroe SD	Park Place Middle School	7/31/2018	Ecology 2005, 2014	WWHM 2012	No	No	No	2	1.5			Harmsen
20	SSW	Monroe SD	Salem Woods Elementary School	7/31/2018	Snohomish County Drainage Manual 2016	WWHM 2012	No	No	No	1.5	1.5			Harmsen
21	BLP	Bellevue	Lewis Creek Park	8/15/2018			Yes	r Fabric						SvR Design
22	FWI	Tacoma SD	Wainwright Intermediate	8/15/2018	Ecology 2014	WWHM 2012	Yes	No	Yes		1.5		1.5	AHBL
23	BSD	Bethel SD	Shining Mountain ES	8/15/2018			no		yes					
24	BUW	Bellingham	Bellingham Columbia Neighborhood	9/28/2018	Ecology 2014	WWHM2012	Yes	No	Yes	12	1.75		0	PSE
25	RSH	Renton	Renton	9/28/2018	Ecology 2014	WWHM4	Yes	No	Yes	5	1.5		1.2	CH2MHILL

Site Information for Geotechnical Assessment

	Label	Jurisdiction	Site	Site Visit Date	Geotech	CF	Geology	Explorations	Inf Test Type	Hydrogeo	BSM rate < Native iph	Estimated Construction	Comments
1	M3Q	Marysville	3rd Street LID and Roadway improvement Project	4/30/18, 5/1/18	PanGEO	NA	Rec. OW (per regional mapping)	EB	grain size	A1	no	2017	Shallow groundwater, less than 10 feet.
2	M1C	Marysville	Marysville 1st Street	4/30/18, 5/1/18	PanGEO	NA	Rec. OW (per regional mapping)	EB	grain size	A1	no	2017	Shallow groundwater, less than 5 feet, tidal influence
3	MVS	Marysville	Sonic Drive-In	4/30/18, 5/1/18	Unk	unk	Rec. OW (per regional mapping)	unk	Infil. test indicated on plan sheet	unk	unk	2017	Received plan set only. Seasonal high GW depth ~5ft.
4	TWH	Tacoma	Wilson High School	4/30/18	AESI 2000, 2004, 2014	None	Till/Adv. OW	EB, EP	None	B2	no	2016	Underdrained. 2 inlets, only one shown on plans.
5	HSB	Tacoma	Homestreet Bank	4/30/18	Zipper Geo Associates, LLS.	None, "not suitable"	Fill/Till	EB	None, "not suitable"	B2	no	2017	Underdrained
6	PRS	Tacoma	Proctor South	4/30/18	GeoResources 4/21/2016 (referenced, not attached)	unk	Fill/Till	unk	unk	B2	no	NA	Not yet constructed at time of study. Geotech report not included in PDF attachments.
7	MLE	Tacoma	Mary Lyon Elementary School	7/31/2018	GeoEngineers, Inc.	0.45	Rec. OW?/Till	EB	PIT	B2	no	NA	Not yet constructed at time of study.
8	PLT	Tacoma	Prarie Line Trail	4/30/18	unk	unk	unk	unk	unk	unk	unk	2017	Geotech report not included.
9	BHV	Bellingham SD	Happy Valley Elementary School	7/20/19	Geotest	NA	Till over outwash	EB, EP	PIT	B2	No - zero field rate in till; did not test the advance	2016	Not suitable for flow monitoring; shallow ground water - one cell lined.
10	AHS	Anacortes	Anacortes High School	10/1/18	AESI	NA	hard silt	EB	none	EX		NA	Not yet constructed at time of study.
11	FES	Lynden	Fisher Elementary School	7/20/2018	Geotest	0.252	Rec outwash (Sumas)	EB, EP	grain size	A1/A2	Yes	2018	City conditioned the project to conduct PIT at the time of construction; no documentation of test received. GW ATD 19 to 20' bgs; mottled at 1.5, 4.5 to 5.5, not interpreted as gw per geotech.
12	LMS	Lynden	Lynden New Middle School	7/20/2018	Geotest	0.252	Rec outwash (Sumas)	EB, EP	grain size	A1/A2	Yes	2018	GW ATD 13 to 18' bgs; mottled at 10.5'.
13	BCK	Bellingham	Cornwall Kentucky	7/20/2018	MTC	0.18	B'ham drift and Fill	HA	grain size	EX	2 cells in GMD - no; 1 cell in fill - possibly	2017	Cells "field fit", may differ from plans. Overflow/underdrain present.
14	IMS	Mercer Island	Islander Middle School	8/15/2018	AESI	NA	pre-Vashon nonglacial	EB	none	F	No	2016	Qpvn at biocell #3, gw at ~10' in EB-7 ATD near Biocell #3; an MW was installed in the parking lot area. One inlet not field located, may join other inlet (but plans show separate).
15	BYS	Bellingham	Yew St	7/20/2018	unk	unk	fill	unk	unk	unk	unk	2016	Adjacent to permeable pavement sidewalk, likely recieves flow from sidewalk base-course. No geotech report received.
16	BHS	Blaine	Blaine High School	7/20/2018	unk	unk	unk	unk	unk	unk	unk	2018	Facility may not be complete - may be waiting on landscapers. Recieved plan sheet only.
17	TWS	Tumwater	Tumwater Middle School	7/31/2018	Landau	not stated	Rec. OW	EB, HA, direct push	grain size	A1	No	2016	Groundwater 10' bgs at time of report, monitoring ongoing. Groundwater TM calculated adjusted rates based on 1999 groundwater condition.
18	TBM	Tumwater	George Washington Bush Middle School	7/31/2018	Landau	not stated	Rec. OW	EB	grain size	A1	No	2016	shallow groundwater; high groundwater hazard area
19	MPP	Monroe SD	Park Place Middle School	7/31/2018	AESI	0.4	Alluvium	EP, IT, EB	PIT	D1	No	2017 and 2018	Two phases of construction - 1st set of cell was 2017, second set was 2018
20	SSW	Monroe SD	Salem Woods Elementary School	7/31/2018	AESI	0.315	Rec. OW	EP, IT, EB	PIT	A1	no	2018	Only one inlet appears to be present, plans show two
21	BLP	Bellevue	Lewis Creek Park	8/15/2018	unk	unk	unk	unk	unk	unk	unk	2017	Received plan sets only.
22	FWI	Tacoma SD	Wainwright Intermediate	8/15/2018	AESI	.45, .045	Rec. OW., till	EP	PIT	A2	no	2016	Cell 1 underlain by utility. Cell 2 has some minor inflow from sheet flow. Cell 3 and 4 have inflow from 2 curb cuts each. Cell 3 extends to include a narrow, vegetated ditch (part of bioretention cell?)
23	BSD	Bethel SD	Shining Mountain ES	8/15/2018	unk	unk	unk	unk	unk	unk	unk	2012-2013	No documents received.
24	BUW	Bellingham	Bellingham Columbia Neighborhood	9/28/2018	Element solutions	not stated	Fill, GMD and outwash	EB, EP	grain size, PIT	E2	no	2016	Underdrained.
25	RSH	Renton	Renton	9/28/2018	CH2MHILL	8 (or 0.125)	fill/ rec OW	EB, EP	PIT	A3	no	2017	Underdrained, through orifice.

Appendix B

Contracted Scope of Work, City of Olympia and Washington Department of Ecology. 2017.

PROFESSIONAL SERVICES AGREEMENT
FOR
STORMWATER MANAGEMENT SERVICES

This Professional Services Agreement ("Agreement") is effective as of the date of the last authorizing signature affixed hereto. The parties ("Parties") to this Agreement are the City of Olympia, a Washington municipal corporation ("City"), and Clear Creek Solutions, Inc., a Washington corporation ("Contractor").

A. The City seeks the temporary professional services of a skilled independent contractor capable of working without direct supervision, in the capacity of stormwater treatment investigations; and

B. The Contractor has the requisite skill and experience necessary to provide such services.

NOW, THEREFORE, the Parties agree as follows:

1. Services.

Contractor shall provide the services more specifically described in Exhibit "A," attached hereto and incorporated by this reference ("Services"), in a manner consistent with the accepted practices for other similar services, and when and as specified by the City's representative.

2. Term.

The term of this Agreement shall commence upon the effective date of this Agreement and shall continue until the completion of the Services, but in any event no later than January 1, 2020 ("Term"). This Agreement may be extended for additional periods of time upon the mutual written agreement of the City and the Contractor.

3. Termination.

Prior to the expiration of the Term, this Agreement may be terminated immediately, with or without cause by the City.

4. Compensation.

A. Total Compensation. In consideration of the Contractor performing the Services, the City agrees to pay the Contractor an amount not to exceed Five Hundred Twenty-Six Thousand, Twenty-Six and No/100 Dollars ($526,026) as described in Exhibit "B".

B. Method of Payment. Payment by the City for the Services will only be made after the Services have been performed, a voucher or invoice is submitted in the form specified by the City, which invoice shall specifically describe the Services performed, the name of Contractor's personnel performing such Services, the hourly labor charge rate for such personnel, and the same is approved by the appropriate City representative. Payment shall be made on a monthly basis, thirty (30) days after receipt of such voucher or invoice.

C. Contractor Responsible for Taxes. The Contractor shall be solely responsible for the payment of any taxes imposed by any lawful jurisdiction as a result of the performance and payment of this Agreement.

5. Compliance with Laws.

Contractor shall comply with and perform the Services in accordance with all applicable federal, state, and City laws including, without limitation, all City codes, ordinances, resolutions, standards and policies, as now existing or hereafter adopted or amended.

6. Assurances.

The Contractor affirms that it has the requisite training, skill and experience necessary to provide the Services and is appropriately accredited and licensed by all applicable agencies and governmental entities, including but not limited to being registered to do business in the City of Olympia by obtaining a City of Olympia business registration.

7. Independent Contractor/Conflict of Interest.

It is the intention and understanding of the Parties that the Contractor is an independent contractor and that the City shall be neither liable nor obligated to pay Contractor sick leave, vacation pay or any other benefit of employment, nor to pay any social security or other tax which may arise as an incident of employment. The Contractor shall pay all income and other taxes due. Industrial or any other insurance that is purchased for the benefit of the City, regardless of whether such may provide a secondary or incidental benefit to the Contractor, shall not be deemed to convert this Agreement to an employment contract. It is recognized that Contractor may be performing professional services during the Term for other parties; provided, however, that such performance of other services shall not conflict with or interfere with Contractor's ability to perform the Services. Contractor agrees to resolve any such conflicts of interest in favor of the City.

8. Equal Opportunity Employer.

A. In all Contractor services, programs or activities, and all Contractor hiring and employment made possible by or resulting from this Agreement, there shall be no unlawful discrimination by Contractor or by Contractor's employees, agents, subcontractors or representatives against any person based on any legally protected class status including but not limited to: sex, age (except minimum age and retirement provisions), race, color, religion, creed, national origin, marital status, veteran status, sexual orientation, gender identity, genetic information or the presence of any disability, including sensory, mental or physical handicaps; provided, however, that the prohibition against discrimination in employment because of disability shall not apply if the particular disability prevents the performance of the essential functions required of the position.

This requirement shall apply, but not be limited to the following: employment, advertising, layoff or termination, rates of pay or other forms of compensation, and selection for training, including apprenticeship. Contractor shall not violate any of the terms of Chapter 49.60 RCW, Title VII of the Civil Rights Act of 1964, the Americans with Disabilities Act, Section 504 of the Rehabilitation Act of 1973 or any other applicable federal, state or local law or regulation regarding non-discrimination. Any material violation of this provision shall be grounds for termination of this Agreement by the City and, in the case of the Contractor's breach, may result in ineligibility for further City agreements.

B. In the event of Contractor's noncompliance or refusal to comply with the above nondiscrimination plan, this Contract may be rescinded, canceled, or terminated in whole or in part, and the Contractor may be declared ineligible for further contracts with the City. The Contractor, shall, however, be given a reasonable time in which to correct this noncompliance.

C. To assist the City in determining compliance with the foregoing nondiscrimination requirements, Contractor must complete and return the *Statement of Compliance with Non-Discrimination* attached as Exhibit C. If the contract amount is $50,000 or more, the Contractor shall execute the attached Equal Benefits Declaration - Exhibit D.

9. Confidentiality.

Contractor agrees not to disclose any information and/or documentation obtained by Contractor in performance of this Agreement that has been expressly declared confidential by the City. Breach of confidentiality by the Contractor will be grounds for immediate termination.

10. Indemnification/Insurance.

A. Indemnification / Hold Harmless. Contractor shall defend, indemnify and hold the City, its officers, officials, employees and volunteers harmless from any and all claims, injuries, damages, losses or suits including attorney fees, arising out of or resulting from the acts, errors or omissions of the Contractor in performance of this Agreement, except for injuries and damages caused by the sole negligence of the City.

Should a court of competent jurisdiction determine that this Agreement is subject to RCW 4.24.115, then, in the event of liability for damages arising out of bodily injury to persons or damages to property caused by or resulting from the concurrent negligence of the Contractor and the City, its officers, officials, employees, and volunteers, the Contractor's liability, including the duty and cost to defend, hereunder shall be only to the extent of the Contractor's negligence. It is further specifically and expressly understood that the indemnification provided herein constitutes the Contractor's waiver of immunity under Industrial Insurance, Title 51 RCW, solely for the purposes of this indemnification. This waiver has been mutually negotiated by the parties. The provisions of this section shall survive the expiration or termination of this Agreement.

B. Insurance. The Contractor shall procure and maintain for the duration of the Agreement, insurance against claims for injuries to persons or damage to property which may arise from or in connection with the performance of the work hereunder by the Contractor, its agents, representatives, or employees.

C. No Limitation. Contractor's maintenance of insurance as required by the agreement shall not be construed to limit the liability of the Contractor to the coverage provided by such insurance, or otherwise limit the City's recourse to any remedy available at law or in equity.

D. Minimum Scope of Insurance. Contractor shall obtain insurance of the types described below:

1. Automobile Liability insurance covering all owned, non-owned, hired and leased vehicles. Coverage shall be at least as broad as ISO occurrence form (ISO) form CA 00 01 or a substitute form providing equivalent liability coverage. If necessary, the policy shall be endorsed to provide contractual liability coverage.

2. Commercial General Liability insurance shall be at least as broad as ISO occurrence form CG 00 01 and shall cover liability arising from premises, operations, independent contractors, stop gap liability, personal injury and advertising injury. The City shall be named as an additional insured under the Contractor's Commercial General Liability insurance policy with respect to the work performed for the City using an additional insured endorsement at least as broad as ISO CG 20 26.

3. Workers' Compensation coverage as required by the Industrial Insurance laws of the State of Washington.

4. Professional Liability insurance appropriate to the Contractor's profession.

E. Minimum Amounts of Insurance. Contractor shall maintain the following insurance limits:

1. Automobile Liability insurance with a minimum combined single limit for bodily injury and property damage of $1,000,000 per accident.

2. Commercial General Liability insurance shall be written with limits no less than $1,000,000 each occurrence, $2,000,000 general aggregate.

3. Professional Liability insurance shall be written with limits no less than $1,000,000 per claim and $1,000,000 policy aggregate limit.

F. Other Insurance Provisions. The Contractor's Automobile Liability and Commercial General Liability insurance policies are to contain, or be endorsed to contain that they shall be primary insurance as respect the City. Any Insurance, self-insurance, or insurance pool coverage maintained by the City shall be excess of the Contractor's insurance and shall not contribute with it.

G. Acceptability of Insurers. Insurance is to be placed with insurers with a current A.M. Best rating of not less than A:VII.

H. Verification of Coverage. Contractor shall furnish the City with original certificates and a copy of the amendatory endorsements, including but not necessarily limited to the additional insured endorsement, evidencing the insurance requirements of the Contractor before commencement of the work.

I. Notice of Cancellation. The Contractor shall provide the City with written notice of any policy cancellation, within two (2) business days of their receipt of such notice.

J. Failure to Maintain Insurance. Failure on the part of the Contractor to maintain the insurance as required shall constitute a material breach of contract, upon which the City may, after giving five (5) business days' notice to the Contractor to correct the breach, immediately terminate the contract or, at its discretion, procure or renew such insurance and pay any and all premiums in connection therewith, with any sums so expended to be repaid to the City on demand, or at the sole discretion of the City, offset against funds due the Contractor from the City.

K. City's Full Access to Contractor Limits. If the Contractor maintains higher insurance limits than the minimums shown above, the City shall be insured for the full available limits of Commercial General and Excess or Umbrella liability maintained by the Contractor, irrespective of whether such limits maintained by the Contractor are greater than those required by this contract or any certificate of insurance furnished to the City evidences limits of liability lower than those maintained by the Contractor.

11. Work Product.

Any deliverables identified in the Scope of Work or otherwise identified in writing by the City that are produced by Contractor in performing the Services under this Agreement and which are delivered to the City shall belong to the City. Any such work product shall be delivered to the City by Contractor at the termination or cancellation date of this Agreement, or as soon thereafter as possible. All other documents are owned by the Contractor.

12. Treatment of Assets.

A. Title to all property furnished by the City shall remain in the name of the City.

B. Title to all nonexpendable personal property and all real property purchased by the Contractor, the cost of which the Contractor is entitled to be reimbursed as a direct item of cost under this Contract, shall pass to and vest in the City, or if appropriate, the state or federal department supplying funds therefor, upon delivery of such property by the vendor. If the Contractor elects to capitalize and depreciate such nonexpendable personal property in lieu of claiming the acquisition cost as a direct item of cost, title to such property shall remain with the Contractor. An election to capitalize and depreciate or claim acquisition cost as a direct item of cost shall be irrevocable.

C. Nonexpendable personal property purchased by the Contractor under the terms of this Contract in which title is vested in the City shall not be rented, loaned or otherwise passed to any person, partnership, corporation/association or organization without the prior expressed written approval of the City or its authorized representative, and such property shall, unless otherwise provided herein or approved by the City or its authorized representative, be used only for the performance of this Contract.

D. As a condition precedent to reimbursement for the purchase of nonexpendable personal property, title to which shall vest in the City, the Contractor agrees to execute such security agreements and other documents as shall be necessary for the City to perfect its interest in such property in accordance with the "Uniform Commercial Code--Secured Transactions" as codified in Article 9 of Title 62A, the Revised Code of Washington.

E. The Contractor shall be responsible for any loss or damage to the property of the City including expenses entered thereunto which results from negligence, willful misconduct, or lack of good faith on the part of the Contractor, or which results from the failure on the part of the Contractor to maintain and administer in accordance with sound management practices that property, to ensure that the property will be returned to the City in like condition to that in which it was furnished or purchased, fair wear and tear excepted.

F. Upon the happening of loss or destruction of, or damage to, any City property, the Contractor shall notify the City or its authorized representative and shall take all reasonable steps to protect that property from further damage.

G. The Contractor shall surrender to the City all property of the City within thirty (30) days after rescission, termination or completion of this Contract unless otherwise mutually agreed upon by the parties.

13. Books and Records.

The Contractor agrees to maintain books, records, and documents which sufficiently and properly reflect all direct and indirect costs related to the performance of the Services and maintain such accounting procedures and practices as may be deemed necessary by the City to assure proper accounting of all funds paid pursuant to this Agreement. These records shall be subject, at all reasonable times, to inspection, review or audit by the City, its authorized representative, the State Auditor, or other governmental officials authorized by law to monitor this Agreement.

Records owned, used, or retained by the City that meet the definition of a "public record" pursuant to RCW 42.56.010 are subject to disclosure under Washington's Public Records Act. Should the Contractor fail to provide records created or used by Contractor in its work for the City within ten (10) days of the City's request for such records, Contractor shall indemnify, defend, and hold the City harmless for any public records judgment, including costs and attorney's fees, against the City involving such withheld records.

14. Non-Appropriation of Funds.

If sufficient funds are not appropriated or allocated for payment under this Agreement for any future fiscal period, the City will not be obligated to continue the Agreement after the end of the current fiscal period, and this Agreement will automatically terminate upon the completion of all remaining Services for which funds are allocated. No penalty or expense shall accrue to the City in the event this provision applies.

15. General Provisions.

A. Entire Agreement. This Agreement contains all of the agreements of the Parties with respect to any matter covered or mentioned in this Agreement and no prior agreements shall be effective for any purpose.

B. Modification. No provision of this Agreement, including this provision, may be amended or modified except by written agreement signed by the Parties.

C. Full Force and Effect; Severability. Any provision of this Agreement that is declared invalid or illegal shall in no way affect or invalidate any other provision hereof and such other provisions shall remain in full force and effect. Further, if it should appear that any provision hereof is in conflict with any statutory provision of the State of Washington, the provision appears to conflict therewith shall be deemed inoperative and null and void insofar as it may be in conflict therewith, and shall be deemed modified to conform to such statutory provision.

D. Assignment. Neither the Contractor nor the City shall have the right to transfer or assign, in whole or in part, any or all of its obligations and rights hereunder without the prior written consent of the other Party.

1. If the Contractor desires to assign this Contract or subcontract any of its work hereunder, the Contractor shall submit a written request to the City for approval not less than fifteen (15) days prior to the commencement date of any proposed assignment or subcontract.

2. Any work or services assigned or subcontracted for hereunder shall be subject to each provision of this Contract.

3. Any technical/professional service subcontract not listed in this Contract, which is to be charged to the Contract, must have prior written approval by the City.

4. The City reserves the right to inspect any assignment or subcontract document.

E. Successors in Interest. Subject to the foregoing Subsection, the rights and obligations of the Parties shall inure to the benefit of and be binding upon their respective successors in interest, heirs and assigns.

F. Attorney Fees. In the event either of the Parties defaults on the performance of any term of this Agreement or either Party places the enforcement of this Agreement in the hands of an attorney, or files a lawsuit, the prevailing party shall be entitled to its reasonable attorneys' fees, costs and expenses to be paid by the other Party.

G. No Waiver. Failure or delay of the City to declare any breach or default immediately upon occurrence shall not waive such breach or default. Failure of the City to declare one breach or default does not act as a waiver of the City's right to declare another breach or default.

H. Governing Law. This Agreement shall be made in and shall be governed by and interpreted in accordance with the laws of the State of Washington.

I. Authority. Each individual executing this Agreement on behalf of the City and Contractor represents and warrants that such individuals are duly authorized to execute and deliver this Agreement on behalf of the Contractor or the City.

J. Notices. Any notices required to be given by the Parties shall be delivered at the addresses set forth below. Any notices may be delivered personally to the addressee of the notice or may be deposited in the United States mail, postage prepaid, to the address set forth below. Any notice so posted in the United States mail shall be deemed received three (3) days after the date of mailing.

K. Captions. The respective captions of the Sections of this Agreement are inserted for convenience of reference only and shall not be deemed to modify or otherwise affect any of the provisions of this Agreement.

L. Performance. Time is of the essence in performance of this Agreement and each and all of its provisions in which performance is a factor. Adherence to completion dates set forth in the description of the Services is essential to the Contractor's performance of this Agreement.

M. Remedies Cumulative. Any remedies provided for under the terms of this Agreement are not intended to be exclusive, but shall be cumulative with all other remedies available to the City at law, in equity or by statute.

N. Counterparts. This Agreement may be executed in any number of counterparts, which counterparts shall collectively constitute the entire Agreement.

O. Equal Opportunity to Draft. The parties have participated and had an equal opportunity to participate in the drafting of this Agreement, and the Exhibits, if any, attached. No ambiguity shall be construed against any party upon a claim that that party drafted the ambiguous language.

P. Venue. All lawsuits or other legal actions whatsoever with regard to this agreement shall be brought in Thurston County, Washington, Superior Court.

Q. Ratification. Any work performed prior to the effective date that falls within the scope of this Agreement and is consistent with its terms is hereby ratified and confirmed.

R. Certification Regarding Debarment, Suspension, and Other Responsibility Matters.

1. By signing the agreement below, the Contractor certifies to the best of its knowledge and belief, that it and its principals:

a. Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any federal department or agency;

b. Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission or fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (federal, state, or local) transaction or contract under a public transaction; violation of federal or state antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

c. Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (federal, state, or local) with commission of any of the offenses enumerated in paragraph 1.b. of this certification; and

d. Have not within a three (3) year period preceding this application/proposal had one or more public transactions (federal, state, or local) terminated for cause or default.

2. Where the Contractor is unable to certify to any of the statements in this certification, such Contractor shall attach an explanation to this proposal.

S. Early Retirement from the State of Washington- Certification. By signing this form, you certify that no one being directly compensated for their services pursuant to this Agreement has retired from the Washington State Retirement System using the 2008 Early Retirement Factors with restrictions on returning to work.

CITY OF OLYMPIA

By: ______________________
Steven Hall, City Manager
P.O. Box 1967
Olympia WA 98507-1967
Date of Signature: 12/2/2017

APPROVED AS TO FORM:

____
City Attorney

I certify that I am authorized to execute this contract on behalf of the Contractor.

CLEAR CREEK SOLUTIONS, INC.

By: ______________________
Douglas Beyerlein, P.E.
Chief Financial Officer
15800 Village Green Drive #3
Mill Creek, WA 98012
(425) 225-5997
Date of Signature: 12/1/2017

EXHIBIT A

CLEAR CREEK SOLUTIONS, INC.

Bioretention Hydrologic Performance (BHP) Study II - Monitoring Facilities Designed Using the 2012 Ecology SWM Manual

Scope of Work

<u>Task 1 Project Management</u> ($16,240 November 2017 – December 2019)

1. Prepare consultant contract scopes and contracting.
   This task will involve conducting the process to procure and manage consultant services for the project.

2. Prepare quarterly progress reports.
   This task will involve completing reporting responsibilities to Ecology.

3. Coordinate communication with Ecology and partner jurisdictions and consultants.
   This task is to communicate with jurisdictions and consultants related to administration of the contract.

Deliverable 1.1: Document contracting, coordination with team, and communications via quarterly progress report by City of Olympia with consultant support.

<u>Task 2 Prepare Site Selection Criteria and Conduct Selection Process</u>
($54,540 November 2017 – January 2018)

1. Develop site selection criteria checklist.
   This task will be to update the existing site selection criteria checklist in coordination with Ecology staff, consultants, and participating jurisdiction partners.

Deliverable 2.1: Site selection criteria checklist submitted to Ecology. Target date: December 2017.

2. Communicate selection criteria to partners; receive and organize candidate sites; visit sites.
   This task will involve communicating with the individual partners submitting candidate sites; collecting and evaluating background engineering and construction data; visiting candidate sites to conduct the on-site selection checklist, scoring the complete list of

candidate sites and making selections of sites to be monitored. Nominal goals are to identify up to 20 candidate sites and select up to ten sites to be monitored for five months.

Deliverable 2.2: Summary of results of site evaluation and list of final sites submitted to Ecology. Target date: January 2018.

3. Write report on the site selection process and results including sections on: site selection criteria, candidate sites, site visit checklist results, scoring results, and proposed list of sites to be monitored.

Deliverable 2.3: Report on the site selection process submitted to Ecology. Target date: January 2018.

<u>Task 3 Update Quality Assurance Project Plan (QAPP)</u> ($4,600 November 2017 – February 2018)

1. Update the QAPP used for phase I of the BHP Study for all sites and overall project analysis. The revised QAPP will follow Ecology's *Guidelines and Specifications for Preparing Quality Assurance Project Plans for Environmental Studies*, February 2001 (Ecology Publication No. 01-03-003). The revised QAPP will be submitted to the Department of Ecology with time for revision, comment and approval.

Deliverable 3.1: BHP Study II draft QAPP for all sites addressing monitoring methods and analysis delivered to Ecology. Target date: January 2018.

2. Respond to Ecology's and other technical reviewers' comments and finalize QAPP and Phase II scope.

Deliverable 3.2: Final QAPP delivered to Ecology. Target date: February 2018.

<u>Task 4 Monitoring Implementation: Site Sampling, Monitoring Installation, and Downloading; Multiple Technical Memos</u> ($270,865, January - June 2018)

1. Based upon the QAPP, select and procure monitoring equipment capable of meeting the requirements of this study. Utilize existing equipment where possible if it meets the

study requirements and objectives.

Deliverable 4.1: Proposed equipment list and approximate cost. Target Date: January 2018.
Deliverable 4.2: Proposed purchase plan meeting State open bidding and procurement processes where applicable. Target Date: January 2018. CITY OF OLYMPIA task.
Deliverable 4.3: Documentation of bidding process showing the bid selection and reasoning for any deviation from use of the lowest responsible bidder. Target Date: February 2018. CITY OF OLYMPIA task.
Deliverable 4.4: Invoice and receipt of procured equipment. Target Date: February 2018. CITY OF OLYMPIA task.

2. Based upon the QAPP, testing of the sites shall be conducted to provide the information necessary to meet the goals of this study. This includes but is not limited to:

    a) Geotechnical/soils design and current conditions, infiltration tests
    b) Review of facility hydrologic design and current conditions
    c) Sampling and analysis of vegetation design and current condition

Deliverable 4.5: Testing and memo report on geotechnical review with attached individual facility site testing reports. Target Date: March 2018.
Deliverable 4.6: Review and memo report on hydrologic design review with individual reports for each facility. Target Date: March 2018.
Deliverable 4.7: Sampling and memo report on vegetative investigations with individual reports for each facility. Target Date: March 2018.

3. Equipment shall be installed in conformance with the QAPP to provide monitoring at up to ten bioretention stormwater cells for up to five months. Monitoring of facility performance shall include:

    a) Rainfall, continuous
    b) Temperature, continuous
    c) Evapotranspiration factors, calculated
    d) Groundwater elevation, observation
    e) Water input to the facility, continuous
    f) Water output from the facility, observation or continuous – by facility

    Completed Monitoring Installation: Target Date: February 2018.

Deliverable 4.8: Monitoring quarterly report section: A monitoring section of the quarterly reports (Deliverable 1.1) will be included once monitoring begins to summarize the status of flow, rainfall and soil monitoring. Information provided will include the number of monitoring events and sites, relevant issues with monitoring, reasons why events were missed, and electronic spreadsheet of raw data files. Target Date: Quarterly 2018-2019.

<u>Task 5 Data Analysis, Modeling, and Technical Memos</u> **($44,280, July - December 2018)**

This task consists of maintaining, managing and utilizing data from the study to provide relevant information on the hydrologic function of bioretention facilities. Analysis of the individual facilities should be used to inform and support conclusions for the design, use, and hydrologic performance of bioretention facilities on a wide scale for Western Washington.

Deliverable 5.1: Meeting with Stormwater Work Group members, Ecology staff and City of Olympia staff to discuss results of monitoring, adequacy of data set and next steps for analysis. Target Date: September 2018 or as determined by Ecology.

Deliverable 5.2: Provide technical memo summarizing the development of models for each bioretention based on as-built construction, confirmed drainage area and site field conditions (depth of soil mix, groundwater, native soil infiltration, etc.). The memo will also propose analysis framework and endpoints. Target Date: September 2018 or as determined by Ecology.

Deliverable 5.3: As-Built WWHM2012 (or agreed upon newer version) model of each bioretention facility in the study. Target Date: September 2018.

Deliverable 5.4: Technical memo on the conclusions of the study for review and comments prior to creation of final report. This should include:

- Issues with existing designs or construction practices
- Recommendations for bioretention designs and design methodologies
- Recommendations for revised construction practices
  Development of an anticipated hydrologic performance matrix based on multiple variables of design, soils, vegetation, etc. Target Date: November 2018.

Deliverable 5.5: Meeting with Stormwater Work Group members, Ecology staff and City of Olympia staff to discuss Technical Memo and provide feedback prior to final reporting. Target Date: December 2018 or as determined by Ecology.

<u>Task 6 Final Report and Findings Communication</u> **($87,680, January – December 2019)**

This task is the provision of a final report that provides information on the totality of this project. This task has added conducting county-based presentations for counties and their associated cities throughout the sampling area. The final report will at a minimum contain the following:

- Design study goals
- Selections process
- A synopsis of the QAPP along with information on any necessary deviations from the proposed plan
- Study results from the monitoring with explanation of any uncharacteristic or any unexpected results
- Site information for each of the facilities with location and photo. The information should include at a minimum: design performance versus actual performance, deviations between design and construction that led to the differential
- Final recommendations from the technical memo and meetings in Task 5.

Deliverable 6.1: Electronic Draft Final Report for review and comments by Ecology, City of Olympia and SWG. Target Date February 2019.
Deliverable 6.2: Presentation to the SWG. Target Date March 2019.
Deliverable 6.3: Three printed copies of Final Report, one electronic version of Final Report plus all data files, reports and miscellaneous data relevant to the project. Target Date May 2019.
Deliverable 6.4: Communication flyer and fact sheet for SAM Communications and website. Target Date: June 2019.
Deliverable 6.5: Conduct a "road show" presenting results for counties and associated cities in each county. Target Date: September 2019.

End of Exhibit A

Exhibit B

CLEAR CREEK SOLUTIONS, INC.
Bioretention Hydrologic Performance (BHP) Study II - Monitoring Facilities Designed Using the 2012 Ecology SWM Manual

Project Budget and Schedule

A summary of the project task budgets and schedule is as follows (see above for greater detail). The project costs are based on an even finer resolution breakdown of each task in a detailed costing spreadsheet (not presented here but available):

Task	Budget	Schedule
Task 1. Project Management	$16,240	November 2017 – December 2019
Task 2 Prepare Site Selection Criteria and Conduct Selection Process	$54,540	November 2017 – January 2018
Task 3 Update Quality Assurance Project Plan (QAPP)	$4,600	November 2017 – February 2018
Task 4 Monitoring Implementation; Site Sampling, Monitoring Installation, and Downloading; Multiple Discipline Technical Memo Summaries	$270,865 (includes equipment cost of $9,993 and ODCs of $16,214)	January 2018 – June 2018
Task 5 Data Analysis, Modeling, and Technical Memos	$44,280	July – December 2018
Task 6 Final Report and Findings Communication	$87,680	January – December 2019
Total Project Cost	$478,205	November 2017 – December 2019
10% Contingency	$47,821	
Total Project Cost w/Contingency	$526,026	

Total project costs are $526,026. This includes hourly labor costs, travel, supplies, lab analysis and 10% contingency.

Exhibit C

STATEMENT OF COMPLIANCE WITH NON-DISCRIMINATION REQUIREMENT

The Olympia City Council has made compliance with the City's *Non-Discrimination in Delivery of City Services or Resources* ordinance (OMC 1.24) a high priority, whether services are provided by City employees or through contract with other entities. It is important that all contract agencies or vendors and their employees understand and carry out the City's non-discrimination policy. Accordingly, each City contract for services contains language that requires an agency or vendor to agree that it shall not unlawfully discriminate against an employee or client based on any legally protected status, which includes but is not limited to: race, creed, religion, color, national origin, age, sex, marital status, veteran status, sexual orientation, gender identity, genetic information, or the presence of any disability. Indicate below the methods you will employ to ensure that this policy is communicated to your employees, if applicable.

Clear Creek Solutions, Inc. affirms compliance with the City of Olympia's non-discrimination ordinance and contract provisions. **Please check all that apply:**

☐ Non-discrimination provisions are posted on printed material with broad distribution (newsletters, brochures, etc.).
What type, and how often? ____________

☐ Non-discrimination provisions are posted on applications for service.

☐ Non-discrimination provisions are posted on the agency's web site.

☒ Non-discrimination provisions are included in human resource materials provided to job applicants and new employees.

☐ Non-discrimination provisions are shared during meetings.
What type of meeting, and how often? ____________

☐ If, in addition to two of the above methods, you use other methods of providing notice of non-discrimination, please list:

____

____

☐ If the above are not applicable to the contract agency or vendor, please check here and sign below to verify that you will comply with the City of Olympia's non-discrimination ordinance.

Failure to implement the measures specified above or to comply with the City of Olympia's non-discrimination ordinance constitutes a breach of contract

By signing this statement, I acknowledge compliance with the City of Olympia's non-discrimination ordinance.

[signature] 12/1/2017
(Signature) (Date)

Douglas Beyerlein
Print Name of Person Signing

Alternative Section for Sole Proprietor: I am a sole proprietor and have reviewed the statement above. I agree not to discriminate against any client, or any future employees, based on any legally protected status.

____________ ____________
(Sole Proprietor Signature) (Date)

Exhibit D

EQUAL BENEFITS COMPLIANCE DECLARATION

Contractors on City contracts estimated to cost $50,000 or more shall comply with the City of Olympia Municipal Code, Chapter 3.18. This provision requires that if contractors provide benefits, they do so without discrimination based on age, sex, race, creed, color, sexual orientation, national origin, or the presence of any physical, mental or sensory disability, or because of any other status protected from discrimination by law. Contractors must have policies in place prohibiting such discrimination, prior to contracting with the City.

I declare that the Contractor listed below complies with the City of Olympia Equal Benefits Ordinance, that the information provided on this form is true and correct, and that I am legally authorized to bind the Contractor.

Clear Creek Solutions, Inc.
Contractor Name

[signature]
Signature

Douglas Beyerlein
Name (please print)

12/1/2017
Date

CFO
Title

Appendix C

Glossary, Acronyms, and Abbreviations

Appendix C -- Glossary, Acronyms, and Abbreviations

Quality Assurance Glossary

Accreditation - A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy - the degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Bias - The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Comparability - The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness - The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV) - A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Dataset - A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation - An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the dataset. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation
- Use of third-party assessors
- Dataset is complex
- Use of EPA Functional Guidelines or equivalent for review

Examples of data types commonly validated would be:

- Gas Chromatography (GC)

- Gas Chromatography-Mass Spectrometry (GC-MS)
- Inductively Coupled Plasma (ICP)

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:
- No qualifier, data is usable for intended purposes
- J (or a J variant), data is estimated, may be usable, may be biased high or low
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004)

Data verification - Examination of a dataset for errors or omissions, and assessment of the Data Quality Indicators related to that dataset for compliance with acceptance criteria (MQO's).
Verification is a detailed quality review of a dataset. (Ecology, 2004)

Detection limit (limit of detection) - The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Measurement Quality Objectives (MQOs) - Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Method - A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method Detection Limit (MDL) - This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Parameter - A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters" (Kammin, 2010; Ecology, 2004)

Population - The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision - The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA) - A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP) - A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC) - The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Representativeness - The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field) – A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sensitivity - In general, 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, it has the same meaning as the detection limit. (Ecology, 2004)

Standard Operating Procedure (SOP) – A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

References

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. http://www.ecy.wa.gov/biblio/0403030.html

USEPA, 1997. Glossary of Quality Assurance Terms and Related Acronyms. http://www.ecy.wa.gov/programs/eap/qa.html

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. http://www.epa.gov/quality/qs-docs/g4-final.pdf

Kammin, 2010. Definition developed or extensively edited by William Kammin, 2010.

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf

Glossary – General Terms

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this

report.

Ecology Washington State Department of Ecology
et al. And others
MQO Measurement quality objective
NPDES (See Glossary above)
QA Quality assurance
RM River mile
SOP Standard operating procedures
SWMMWW Stormwater Management Manual for Western
Washington

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cms	cubic meters per second, a unit of flow.
dw	dry weight
ft	feet
g	gram, a unit of mass
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams.
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters. l/s liters per second (0.03531 cubic foot per second) m meter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliters
mm	millimeter
mmol	millimole or one-thousandth of a mole. A mole is an S1 unit of matter.
ng/g	nanograms per gram (parts per billion)
ng/Kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)

NTU	nephelometric turbidity units pg/g
picograms per gram (parts per trillion)	
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units
s.u.	standard units
ug/g	micrograms per gram (parts per million)
ug/Kg	micrograms per kilogram (parts per billion)
ug/L	micrograms per liter (parts per billion)
um	micrometer
uM	micromolar (a chemistry unit)
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight