Quality Assurance Project Plan for Best Management Practice Effectiveness Monitoring

Conducted under Section S8.F of the Phase I Municipal Stormwater Permit

by

Clark County

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Title and Approval Sheet

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Internal Review and Approval

External Review and Approval

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Quality Assurance Project Plan

This Quality Assurance Project Plan (Plan) was prepared by U.S. Geological Survey and revised by Clark County's Department of Environmental Services Clean Water Program. The Plan describes the quality assurance and quality control (QA/QC) procedures for field activities and laboratory analyses associated with best management practice (BMP) effectiveness monitoring conducted by Clark County, as required by Section S8.F of the National Pollutant Discharge and Elimination System and State Waste Discharge General Permit for Discharges from Large and Medium Municipal Separate Storm Sewer Systems (Phase I Permit or Permit). The primary goal of this Plan is to assure the quality and integrity of the collected samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and the delivery of defensible products and decisions.

This document was developed with guidance from the Department of Ecology: specifically, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004), and Guidance for Evaluating Emerging Stormwater Treatment Technologies (Ecology, 2008) plus the Modification: Evaluating Stormwater Treatment Technologies with Long Detention Times (Ecology, draft, April 2008).

This Plan is organized into the following sections:

A. Goals and objectives of BMP effectiveness monitoring program
B. Type, quality, and quantity of data needed to meet program objectives
C. Sampling and measurement procedures needed to acquire data needed
D. Quality assurance and quality control procedures to ensure the Plan is implemented as prescribed
E. Assessment procedures to determine if the data conform to the specified criteria and will satisfy the program objectives, and the analysis and format for presentation of the results

Large tables that are for frequent reference during the life of the monitoring program are located in a Tables section following the text, noted with a "T" prefix.

Section A. Goals and Objectives of the Program

This section covers basic program management, including history and objectives, delegation of responsibilities, and other details to ensure that the program is well defined and understood by all participants. The following elements are included:

1. Background
2. Program description
3. Organization and schedule

1. Background

Stormwater treatment and hydrologic best management practice (BMP) evaluation monitoring is required to be conducted by Clark County according to Section S8.F of the Phase I Permit as modified by the Final Settlement Agreement between the Washington Department of Ecology and Phase I Permittees. To address this monitoring requirement, full-scale field monitoring will be conducted at three BMP sites to evaluate the effectiveness and operation/maintenance requirements of the selected stormwater treatment and hydrologic management BMPs applied under Clark County jurisdiction.

1.1 Permit overview and monitoring requirements

The Washington State Department of Ecology (Ecology) issued the current NPDES and Phase I Permit on January 17, 2007 with modifications on June 17, 2009. The Phase I Permit applies to all entities in Washington State that are required to have stormwater permit coverage under current (Phase I) U.S. Environmental Protection Agency (EPA) stormwater regulations. This includes unincorporated portions of counties whose populations exceed 100,000 in the 1990 census, specifically Clark County.

In accordance with the Phase I Permit, each permittee is required to develop and implement a comprehensive long-term monitoring program consistent with Special Condition S8 of the Permit. In general, the required monitoring program shall include the following components:

- Stormwater characterization monitoring (S8.D)
- Targeted stormwater management program effectiveness monitoring (S8.E)

- Stormwater treatment and hydrologic management best management practices evaluation monitoring (S8.F).

A separate Plan is developed for each component of the monitoring program; this Plan provides details on the stormwater treatment BMP effectiveness monitoring program only. Ecology intends to combine the BMP effectiveness monitoring data from all Phase I Permitees into a single data set to conduct evaluation of the effectiveness of treatment BMPs on a regional scale.

1.2 Stormwater treatment Best Management Practice evaluation

BMP technologies are designed to control stormwater in one of three ways: preventing contaminants from coming into contact with stormwater by source control, reducing contaminant loads by treatment of stormwater discharged to surface or ground waters, or controlling the flow rate of stormwater by flow control. The focus for this monitoring program is evaluation of treatment BMPs, which have not been well studied and may be quite variable in their effectiveness. Treatment BMP facilities include wetlands, ponds, swales, and filters of various kinds that provide treatment by simple gravity settling of particulate pollutants, filtration, biological uptake, and soil adsorption.

In accordance with Section S8.F of the Permit, Clark County is required to monitor at least two treatment BMPs that are standard technologies within their facilities, with no less than two sites per BMP. Clark County has submitted a “Monitoring Approach Proposal” to Ecology for approval to monitor a total of three BMP sites: two treatment wetland sites and one treatment train site with combined biofilatration swale/media filter vault system.

The statistical goal for monitoring is to determine mean effluent concentrations and mean percent removals by each BMP treatment with 90-95% confidence and 75-80% power. Because of differences in retention time among the target BMP sites, it is necessary to define different sampling strategies among these sites to meet this goal. For the treatment train site, which has a short retention time (i.e. comparable to the storm duration period with little or no storage), the sampling strategy will be focused on monitoring targeted storm events with paired inflow and outflow samples. Evaluation of treatment efficiency will be done by comparing inflow concentrations and loads directly with outflow concentrations and loads. For the treatment wetland sites where retention times are

relatively long (relative to the duration of storm events), it cannot be assumed that the sampled parcel of water flowing into the facility during a storm is the same parcel flowing out. Treatment efficiency for these sites will be characterized by aggregate characterization of inflow and outflow concentrations by random samples collected over the length of the program. Detailed descriptions of the proposed sampling strategies for all sites are presented in the Sampling Process Design Section.

1.3 Study area

The study area includes urban and rural land in unincorporated Clark County (Figure 1). Much of Clark County is within the northern-most portion of the Willamette Valley Ecoregion. Land use can be described as suburban within the developed areas and rural residential outside of the developed parts of the Urban Growth Area. Urbanization during the late 20th Century and early 21st Century has converted much of the farmland near Vancouver into residential subdivisions and small commercial areas along existing arterials and highways. Generally, the study area is comprised of gently rolling hills, about 200 to 300 feet above sea level, which are cut by small stream systems draining to Salmon Creek or Lake River. Late Ice Age Cataclysmic Flood Deposits underlay the study area and provide a source for fine-grained sediment.

Study sites were selected based on the list of possible BMP types described in the Permit (S8.F.2), as well as their technical feasibility for monitoring. Each of the selected treatment wetland BMPs provides basic treatment; the treatment train provides enhanced treatment to remove higher levels of dissolved metals.

Wetland site No.1 The first treatment wetland site is approximately 1,750 feet west of the intersection of NE 117th Street and Bassel Road, northwest of the city of Vancouver, Washington. It consists of a two cell configuration, sedimentation and wetland cells (combined area=0.58 acres) (Figure 2) that receive predominantly road runoff from approximately 14.3 acres and drains to Suds Creek, which drains to Salmon Creek. Design data are provided in Table 1. This site is defined as having a relatively long detention time on the basis of the plug-flow detention times, which range between about 11 and 14.5 hours (Table 1).

Table 1. Design data for 24-hour rainfall events for treatment wetland no. 1.

Parameter	2-year rainfall	10-year rainfall	100-year rainfall
Rainfall amount	2 inches	3 inches	4 inches
Inflow depth	0.8 inches	1.6 inches	2.4 inches
Inflow magnitude	2.0 cfs	4.4 cfs	7.1 cfs
Outflow magnitude	0.3 cfs	0.6 cfs	1.6 cfs
Plug-flow detention time	871 minutes	890 minutes	659 minutes

Inflow to treatment wetland no. 1 will be monitored from a new concrete vault (6 feet long x 4 feet wide x 7 feet deep) placed in line with and adjacent to the inflow for the sedimentation cell of the facility (Figure 2). Outflow will be monitored from the second manhole in the system draining the second wetland cell, which is 10 feet in depth (Figure 2).

Wetland site No.2 The second treatment wetland site is located adjacent to the Salmon Creek Sports Complex which is near the first site, but approximately 850 feet east of the Bassel Road intersection and 300 feet north of NE 117th Street.. It also consists of a two cell configuration, sedimentation and wetland cells, plus a high water storage area on the inflow side (combined area=0.38 acres) (Figure 3) and receives runoff from approximately 23.8 acres, draining directly to Salmon Creek. Design criteria are presented in Table 2. This site is designated as having a long detention time on the basis of the plug-flow detention times, which range between 13.5 – 17.6 hours (Table 2).

Table 2. Design data for 24-hour rainfall events for treatment wetland no. 2.

Parameter	2-year rainfall	10-year rainfall	100-year rainfall
Rainfall amount	2 inches	3 inches	4 inches
Inflow depth	0.8 inches	1.6 inches	2.4 inches
Inflow magnitude	3.2 cfs	6.7 cfs	8.2 cfs
Outflow magnitude	0.3 cfs	0.7 cfs	2.2 cfs
Plug-flow detention time	1,057 minutes	1,078 minutes	810 minutes

Inflow to treatment wetland no. 2 will be monitored from an access cut-out in the top of the upper end of a new 18 inch smooth interior-walled plastic pipe that conveys inflow across the storage portion of the facility before it enters the sedimentation cell. (Figure 3). Outflow will be monitored from the first 3 foot deep manhole outside the fenced facility and is located between the parking lot and the adjacent baseball field (Figure 3).

Treatment train This facility is located near the Klineline Bridge over Salmon Creek on Highway 99 (Figure 4 and Figure 5). It is less than one mile east of the two treatment wetland sites, approximately 500 feet downstream of the Klineline bridge and adjacent to Salmon Creek. The facility was recently constructed and only became functional in the late fall of 2008.

Water quality treatment for this site will be provided by means of a two-facility treatment train, designed in accordance with the enhanced treatment provisions of the Western Washington Manual (Chapters 3 and 4, Volume V). The first basic treatment facility will be a biofiltration swale, 120 feet long and 16 feet wide. The second treatment unit will be a proprietary (StormFilter) media filter vault system, equipped with 18 media filter cartridges. Water quantity control will be provided by means of a combination detention/infiltration pond. The facility was designed to meet two different sets of design criteria because the measured infiltration rate of the soils underlying the proposed pond does not meet the county's minimum rate of 8 inches per hour. The proposed facility has a detention volume of more than 63,600 cubic feet (1.46 acre-feet).

Highway 99 is a high-volume urban road (annual average daily traffic count > 7,500) whose runoff discharges to a fish-bearing stream. In order to comply with the requirements specified in Chapter 3, Volume V of the Western Washington Manual, enhanced treatment is required to provide a higher rate of removal of dissolved metals. Pretreatment of sediment-laden flows will be provided by a sedimentation manhole upstream of the facility. A flow-splitter manhole has been installed to by-pass portions of high flows directly to the detention / infiltration pond while also directing flows to the biofiltration swale ranging from 1.17 cfs for the water quality event up to 2.25 cfs for the 100-year event.

Basic water quality treatment will be provided by means of a Biofiltration Swale (BMP T9.10), designed in accordance with Clark County Detail D11.2. The proposed swale

design properties are described in Table 3. This facility is designated as having a short detention time on the basis of the minimum residence time of 9.7 minutes (Table 3).

Table 3. Design data for biofiltration swale.

Target inflow magnitude	1.17 cfs
Longitudinal slope	0.6%
Design velocity	0.22 ft/s
Length	120 feet
design flow residence time	9.7 minutes
Width	16 feet
Maximum water depth	4 inches
Manning coefficient	0.20

The second facility in the enhanced treatment train is the Media Filter, which must have the capability to remove dissolved metals. Ecology has approved the StormFilter™ leaf compost and zeolite-perlite-granular activated carbon (ZPG) media cartridges for this application. In accordance with Ecology's approval, the cartridges were sized for a flow rate of 7.5 gallons per minute. The peak stage of the water-quality event was determined to ensure that the treatment train does not become submerged and facilities maintain a free discharge (CCC 40.380.040(B)(4)(e) of the current county code). The biofiltration swale was designed to provide basic water quality treatment for a water-quality event inflow of 1.17 cfs and the filter unit was designed for additional enhanced treatment of swale exit flows less than 0.29 cfs, equivalent to the water quality event per WWHM3, with flows above this bypassing the filter cartridges via an overflow.

Inflow to the treatment train facility will be monitored from a 4.2-foot manhole located just upstream of the weir at the entrance to the bioswale. The outflow from the swale/inflow to the filtration vault will be monitored, in this closed system for flow, from both the vault inflow and outflow (for pacing). Sampling will be from the nearest upstream 3-foot deep manhole located just downstream from the exit from the bioswale. The outflow from the filtration vault, the treatment train's second facility, will be monitored for flow at the vault

outflow pipe and sampled for water quality on the upstream side of this pipe in the vault outlet bay.

County personnel will periodically observe the functioning of the facilities during storm events for signs of any deviations from the intended design function or any malfunctioning component of the system. Field notes will be made to record observations on the operation of the facilities and follow-up actions taken as needed.

1.4 Parameters of concern

The parameters of concern for this monitoring program are based on the treatment performance goals that have been defined by Ecology for basic treatment facilities. They include conventional parameters, nutrients, and a few metals for both stormwater (Table T 4) and sediment (Table T5).

1.5 Monitoring challenges

Evaluating the effectiveness of treatment BMPs that are designed to treat stormwater runoff is complicated by several features of stormwater that distinguish it from water transported in streams or stored in lakes. The primary issue is the large range of potential contaminants that are contained in stormwater because of land use and other local conditions. Concentrations of these contaminants can be highly variable under different types of storm events throughout the year. This variability is especially problematic when dealing with BMP facilities with long detention times, where inflows and outflows are characterized by long-term aggregate or mean concentrations. When variability in concentrations is high, more samples are required to estimate the mean within the target statistical limits of confidence and power. Additionally, for those sites with short detention times that are sampled during targeted storm events, sampling logistics is complicated by the unpredictability of storm events and the seasonal and sporadic nature of surface runoff.

2. Program Description

This section presents the goals and objectives of the program, including the information requirements, specific target constituents to be monitored, and the data required to meet the program objectives. Study area boundaries and practical constraints that will need to be addressed are also discussed.

2.1 Goal and objectives

The goal of this program is to collect data to evaluate the effectiveness of the selected treatment BMP facilities, in order to comply with Section S8.F of the Phase I Permit.

Flow, water-quality, and sediment monitoring will be conducted at each treatment BMP to meet the following specific objectives of the program—

1. Quantify the treatment performance for reducing pollutant concentrations and loads
2. Quantify sediment accumulation rates within each component of the BMP to determine maintenance requirements
3. Evaluate grain size distribution of accumulated sediment for each component of the BMP to assess overall performance
4. Evaluate pollutant concentrations in accumulated sediment within each component of the BMP

2.2 Information requirements and data collection

As previously mentioned, this program requires a sampling program that is adequate to evaluate the effectiveness of BMP facilities with both long and short residence time (relative to the duration of storm events). Because these strategies differ significantly, they will be described separately. Specific elements of each sampling design are described in the Sampling Process Design section.

Sites with long-residence time For the treatment wetland BMPs, where residence times are longer than storm events, sampling will be oriented toward calculation of average conditions for inflow and outflow sites. The sampling strategy calls for decoupling of inflow and outflow samples, which are collected randomly and independently from one another. The information required to develop the sampling design that will meet the study objectives for these sites includes the following—

- A preliminary estimate of the number of samples required to meet the statistical goals of the program
- A further refinement of the number of random sampling dates required to successfully collect the required number of samples
- A random process for scheduling the sampling days in advance of the sampling season

Sites with short-residence time For the enhanced treatment train BMP, where residence times are shorter than a typical storm event, paired storm samples from inflow and outflow monitoring stations will be collected together. For these stations, sampling will target specific storm events that meet qualifying criteria, based on continuous record of rainfall at one of the nearby wetland sites and discharge data at the site. The sampling design will be focused on describing the treatment efficiency of each separate component of the treatment train, as well as the total efficiency of the combined treatment facility.

All sites The following information will be required to meet the study objectives for all sites—

- Continuous record of rainfall data, especially prior to and during sampled events, including antecedent dry period and total rainfall during each event
- Continuous record of flow data (storm and base flow, where appropriate), especially flow data during sampled events
- Concentrations of constituents of concern in samples from the relevant inflow and outflow points

All data collected by this program must also meet information requirements specified by the National Stormwater BMP Data Base (S8.F.4), as follows—

- For all BMPs (Table T 1)
- Structural BMPs (Table T 2)
- Individual structural BMPs (Table T 3)

To meet these data needs, inflow and outflow monitoring stations will be established for each of the two treatment wetland BMPs (Figure 2 and Figure 3). Monitoring stations will be established at three sites within the treatment train: inflow to the bioswale, outflow from the swale/inflow to the media filter, and outflow from the media filter (Figure 4 and Figure 5). Three primary activities will be conducted at each monitoring site: hydrologic monitoring, water-quality (WQ) sampling, and sediment sampling.

Hydrologic monitoring. Hydrologic monitoring will be associated with all WQ samples, and will consist of measurements of discharge, water level (for estimating discharge), and precipitation depth. Continuous discharge data will be used to characterize the peak discharge rate, runoff volume, and flow duration at each station. Precipitation data will be used to characterize total rainfall distribution throughout the year.

Water-quality sampling. Automatic flow-weighted composite sampling methods will be used to collect WQ samples at the specified number of randomly selected dates or targeted storm events throughout the year. Each sample will be analyzed for the suite of constituents that is required by the Phase I Permit for evaluating basic or enhanced treatment performance (Table T 4).

Sediment sampling. Accumulated sediment samples will be collected and analyzed for the suite of parameters required by the Phase I Permit for evaluating basic or enhanced treatment performance (Table T5).

2.3 Target population

Sampling is designed to describe the target populations, i.e. mean influent and outflow concentrations and loads, for the selected treatment BMPs with acceptable confidence and power.

2.4 Study area boundary

The spatial boundary of the program is defined as the physical area to be studied and where samples will be taken. The three treatment BMPs are located within northwestern Clark County, within the jurisdiction of the Phase I permittee (Figure 1). The temporal boundary defines the timeframe when data will be collected. The life of the program assumes a 2-year sample collection cycle.

Each monitoring station will be equipped with equipment to facilitate continuous monitoring of precipitation (or from a nearby precipitation gage) and flow, and the collection of flow-weighted composite samples during targeted conditions over the duration of the program. The collection of flow-weighted composite samples is targeted for the site-specific number of samples per year to achieve the goal of obtaining adequate measures of effectiveness for each BMP by the end of the second year of the study period.

2.5 Practical constraints

Monitoring will be constrained by the assumptions and requirements of the sampling design, especially the expected concentrations of target constituents. If concentrations fall in the low end, with high variability between samples, it may be necessary to collect

additional samples in order to satisfy the power criteria for acceptable mean concentrations and loads. Additional constraints may arise due to specific equipment installation issues.

3. Organization and Schedule

This section describes the components of the program team and schedule, including any special training that will be required as well as the process of revising this Plan document when appropriate.

3.1 Roles and responsibilities

Below is a table that defines the major aspects of the program and the corresponding responsible personnel.

Table 4. Program roles and responsibilities.

Position	Role and responsibility
Department of Ecology Permit Coordinator	Review and approval of Plan and program deliverables from Clark County to Ecology
Program representative for Clark County	Overall management of the County's NPDES Phase I compliance activities. Monitor and assess the quality of work. Comply with corrective action requirements.
Project Manager (PM)	Develop, implement, ensure approval of, and maintain the Plan. Verify the Plan is followed and the program is producing data of known and acceptable quality. Ensure adequate training and supervision of all monitoring and data collection activities. Validate and verify data collected, and initiate corrective action as appropriate. Prepare reports. Manage all project contracts and consultant work. Acquire, verify, and transfer data from field and lab. Manage and oversee monitoring activities, including sampling decisions for targeted storm events, and data management.
Field Staff	Site preparation, equipment set-up, maintenance, sampler set-up and calibration, sample retrieval, sample transfer to laboratory.
Laboratory managers	Supervise laboratory personnel involved in generating analytical data for program. Ensure all QA/QC procedures are completed as required and analytical documentation is accurate and complete. Enforce corrective action as required.
Laboratory quality assurance managers	Supervise and verify all aspects of QA/QC in the laboratory. Validate and verify data before released from the laboratory.

3.2 Schedule

Table 5 describes the original estimated implementation schedule, assuming a 2-year length of the data-collection component of the program. It is now anticipated that monitoring will continue into water year 2012 in order to be able to reach the program's monitoring goals.

Table 5. Original anticipated program schedule.

Calendar Year 2009				
Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Deliverable Due Date
Program startup	March 2009	Ongoing	Planning; equipment procurement, installation, and testing; staff training	Not reported to Ecology
Continuous flow recording	May 2009	Ongoing	Develop baseline rainfall/runoff relationship	Not reported to Ecology
Event and random sampling	August 2009	September 2009	Stormwater Monitoring Report	March 2010
Calendar Years 2010 - 2011				
Event and random sampling	October 2009 October 2010	September 2010 September 2011	Stormwater Monitoring Report	March 2011 March 2012
Sediment sampling	October 2009 October 2010	September 2010 September 2011		
Data validation	As samples are collected	January 2010 January 2011		

3.3 Special training needs

Program staff will require the following training and certification:

- Any field personnel involved with monitoring equipment installation or equipment maintenance requiring confined space entry will complete confined space entry training.
- All field personnel will receive training in sampling equipment operation, maintenance, and calibration procedures.
- All field personnel will receive training in all necessary sample collection, sample handling, and chain of custody procedures for sediment and stormwater composite sampling.

In addition to technical training, field personnel will receive guidance that addresses specific monitoring issues that may impact their health and safety. Stormwater sampling conditions are often wet, cold, and poorly lit. Additionally, field crews may be exposed to biological hazards (e.g. medical waste or fecal matter), disease vectors (e.g. snakes or rats), fall hazards, other hazardous materials, and slippery conditions. All field activities will need to keep safety the top priority.

The laboratories selected for physical and chemical analyses will be fully accredited under the Washington Department of Ecology Laboratory Accreditation Program for the parameters to be analyzed.

3.4 Revisions

Changes to the Plan that are substantial enough to require the Plan to be revised and resubmitted to Ecology for approval are considered external revisions. Smaller changes do not require Ecology approval and are considered internal revisions. Necessary internal revisions will be documented in a Plan Addendum that will be distributed to all program personnel. If multiple Addendums are prepared, they will be compiled and distributed.

Section B. Type, Quality, and Quantity of Data Needed

This section defines the quality of data required to meet the study goals and objectives, and the sampling process design, which determines the type and quantity of data to be collected.

4. Quality objectives

This section defines the data quality indicators (DQIs) for the monitoring program, as well as the measurement quality objectives that will be utilized to evaluate the quality and usability of stormwater and sediment data. These DQIs will be achieved through attention to the prescribed sampling, measurement, and QA/QC procedures presented in this Plan.

4.1 Data quality indicators

DQIs may be either qualitative or quantitative, and describe the type, quality, and quantity of data that are required to fulfill the program objectives. DQIs utilized to evaluate meeting the objectives for this program include:

- Precision, bias, and accuracy will be evaluated
- Bias will be minimized by using controlled procedures for field sampling, sample handling and processing, laboratory analysis, and record keeping
- Data sensitivity will be upheld by using reporting limits low enough to support stormwater management targets
- Data collected will be of sufficient quality and quantity to enable calculation of sample or event mean concentrations, and seasonal and total annual constituent loads for all influent and outflow sites with required confidence and statistical power
- Data and samples collected will meet the program-specific requirements for representativeness

4.2 Measurement quality objectives

Measurement quality objectives (MQOs) describe measures of performance and criteria for acceptance, based primarily on DQIs, which provide the basis for evaluating data quality and usability. They are defined separately for hydrologic data and chemical data. They can indicate the minimum threshold levels for measures of bias, precision, accuracy, sensitivity, completeness, and representativenesss associated with the data (Table T 6). For chemical data, MQOs often are based upon specific types of quality control (QC) samples that are collected in the field and/or analyzed in the laboratory (Table T 7).

Bias Bias represents a difference from the "true" concentration, and may be either high or low. Potential sources of bias include sampling and analytical procedures that introduce contamination, instability of samples during transportation and storage, interference from other constituents in the sample matrix, inability of the analytical method to measure all forms of the constituent of interest, and faulty calibration of the measurement process. Errors of bias are minimized through use of standardized procedures by properly trained staff. Blank samples and laboratory control samples provide indications of bias from field and lab procedures. If bias is detected in these QC samples, required actions will be taken as defined in Table T 6.

Precision Precision is a measure of the repeatability of a set of replicated results, and is considered to represent random error in the measurement process. Poor precision is due to difficulties in obtaining samples under identical conditions (e.g. contamination, sub-sampling issues, or variability of field conditions during the time the replicate samples are collected) or poor sensitivity of laboratory procedures. Precision of field samples will be

evaluated by either field replicates or splits. Field replicate samples will be collected by near simultaneous grab samples (for fecal coliform and total petroleum hydrocarbons) while splits of flow weighted composite samples will be made under controlled conditions at the analytical laboratory. The two values (sample and replicate or split) will be compared to provide a measure of the relative percent difference between them (RPD). [RPD = $\frac{R_1 - R_2}{[R_1 + R_2]/2}\ x100$]. It is important to consider the magnitude of replicate error in context of the ambient concentration, e.g. where concentrations are low, the percent difference between replicates may be large even when the absolute magnitude of the difference is small. Sampling procedures will be carefully evaluated if field replicate results exceed the defined MQO criteria (Table T 6).

Accuracy Accuracy is a measure of the agreement between a measured result and the true value of the parameter, i.e. it represents a combination of both bias and precision. Laboratory analytical accuracy is measured by analyzing known reference samples or by analyzing samples spiked with known concentrations of the constituents of interest.. Factors that influence accuracy include those that cause bias (contamination, sample degradation, matrix interference, laboratory calibration) and those that influence precision (random error in the sampling and analytical process). Accuracy of discharge measurements is related to limitations of the equipment, specifically to the limits of discharge that the sensors are calibrated to operate within. Accuracy of discharge measurements will be assessed by comparing the instantaneous flow or stage measurements at installed controls with the concurrent flow meter readings during several different flow conditions. Maximizing accuracy of discharge is achieved by appropriate selection of measurement technology for the discharge conditions that will occur. Accuracy of tipping bucket rain gages is measured using a burrette to meter water into the funnel. Once the bucket tips the volume is recorded. The measurement is repeated 10 times on each side, then averaged and compared to the rain gage specification's tip volume. Specific actions that are required when MQOs are exceeded are defined in Table T 6.

Sensitivity Sensitivity is the measure of concentration that is sufficient for the analytical method to positively identify and quantify analytical results. For a given method, the

sensitivity is referred to as the detection limit, which can be defined with different levels of precision. The method detection limit is the minimum concentration that can be statistically determined with 99 percent confidence to be greater than zero. Lab reported concentrations less than the method detection limit are reported by the lab as "ND" along with the specific method reporting limit and annotated with a "U". The method reporting limit is the concentration that the laboratory can report with documented precision and accuracy under routine operating conditions, and is higher than the method detection limit. Concentrations greater than the method detection limit but less than the method reporting limit will be qualified by the laboratory with "J" for estimated. Section 12 contains further discussion of reporting limits.

Completeness Completeness is defined as the proportion of samples collected relative to the total number planned to be collected. It also depends upon the completion of analytical work by the laboratory. Combined, it represents an assessment of how field and laboratory problems affected the success of the data collection effort. Completeness depends upon the proportion of designated sample days or target storms that are sampled successfully, as well as adequate packing of samples for transport and timely processing at the laboratory.

Data that are qualified but still usable will be counted as valid data for assessing completeness, although data that are rejected for use will not be considered. During the data validation process, an assessment will be made whether enough valid data exist to meet the statistical requirements of the Permit. If not enough valid data are obtained, additional samples or corrective actions may be taken as determined by the Project Manager or his/her designee.

Representativeness Representativeness is a measure of the extent to which the sample data accurately and precisely represent site conditions. It is a qualitative measure, although it depends upon meeting quantitative criteria such as the method and timing of the sampling process and required confidence and statistical power of the seasonal and annual mean estimates for concentrations and loads. Additionally, representativeness includes the requirements that samples are collected during a targeted storm event or period and laboratory analysis be conducted within the method-required holding times. Data will be rejected if the samples are deemed non-representative.

5. Sampling process design

This section describes the sampling process design for the BMP effectiveness monitoring program, which was developed based on recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Stormwater Treatment Technologies* and the draft *Modification: Evaluating Stormwater Treatment Technologies with Long Detention Times—Technology Assessment Protocol (TAPE).*

As previously described, the specific objectives of this monitoring program are:

- Quantify the treatment performance for reducing pollutant concentrations and loads
- Quantify sediment accumulation rates within each component of the BMP to determine maintenance requirements
- Evaluate grain size distribution of accumulated sediment for each component of the BMP to assess overall performance
- Evaluate pollutant concentrations in accumulated sediment within each component of the BMP

Separate sampling strategies will be necessary for the two groups of BMPs, depending on their relative detention times. Detailed site visits have been conducted to determine the site-specific requirements for permanent installation and operation of flow monitoring and automatic sampling equipment. A short discussion of the general monitoring strategy for all sites is followed by the detailed sampling design for each BMP type, including selection of equipment for flow and WQ monitoring.

5.1 General monitoring strategy

Flow-weighted composite samples will be collected at each monitoring station, based on the site-specific sampling design developed for each BMP, as described below. Accumulated sediment samples will also be collected at each facility. Each monitoring station will be equipped with continuous flow monitoring gages and cellular telemetry to allow for remote data acquisition. Field staff will rely on real-time precipitation data from on-site or nearby precipitation gages and discharge data from each monitoring station to alert them when precipitation and flow conditions have been met for a qualifying sampling event. Additionally, the continuous rainfall and discharge record will be used to determine the rainfall/runoff relationship for each station so that the automatic samplers can be programmed appropriately to capture flow-weighted samples.

Flow rate at each monitoring site will be continuously measured and recorded for the first year, and during each targeted storm or sample event for subsequent years. Flow rate will be determined using the appropriate flow monitoring technology for the specific site. Because a key factor to collecting accurate stream gage information is the hydraulic control for the site, an artificial structure may be required to control the water level at some sites. Appropriate artificial controls will be built in the channel or selected pipe conveyances where needed to simplify the procedure of obtaining accurate discharge records. Ensuring the correct design and installation of artificial controls for this study, as necessary, will be the responsibility of the Project Manager or designee.

5.2 Treatment sites with short detention time

This section describes the sample process design for sampling the treatment train sites, which have been characterized as having a relatively short detention time compared to the typical storm event duration (i.e. defined in minutes instead of hours). For these sites, flow-weighted composite samples will be collected during targeted storm events and the inflow and outflow concentrations will be compared explicitly since they are assumed to represent the same parcel of water. Samples will be collected throughout the year, based on meeting the storm event guidelines which are expected to produce runoff containing pollutant concentrations within the targeted range. Thus, sampling design is focused on targeting qualifying storm events for sampling based on storm criteria defined by Ecology.

Qualifying storm events Qualifying criteria for sampling storms are described in Table 6.

Table 6. Criteria for targeting storms for sampling.

Criteria	Explanation	Minimum Values
Minimum amount of rainfall	Total rainfall amount during the sampling event	0.15 inches
Minimum storm duration	Shortest acceptable runoff duration	1 hour
Antecedent precipitation conditions	Minimum time interval without significant rainfall	6 hours with < 0.04 inches
Minimum storm intensity	Lowest intensity that qualifies as a rainfall event	None *
* Mean intensities should > 0.03 inches/hour for at least half of sampled storms		

Sampling strategy Automatic flow-weighted composite samples will be collected over the duration of a qualifying storm event (or a maximum of the first 24 hours of the event). The sample that results from this method is considered to represent the Event Mean Concentration (EMC). The objective is to collect a sufficient number of separate storm samples to meet the program's statistical goals, at least twelve (12) and no more than thirty-five (35) samples over the life of the program (assumed to be 2 years). The first full year of sampling will target 12 samples, after which the number of samples will be revised depending upon the observed variability in concentrations and loads in order to meet the statistical goals. Each site will be sampled according to the prescribed frequency unless good faith and good professional practice do not result in collecting a successful sample for the full number of storms. At least 10 aliquots will be composited for each sample, covering at least 75% of total runoff volume of the targeted storm.

5.3 Treatment sites with long detention time

The basic approach for treatment sites with relatively long detention times (i.e. measured in hours rather than minutes) will be to collect inflow and outflow samples as random and separate samples, not as pairs, in such a way that inflow and outflow parameters can be considered to be representative over time. With a large enough sample size, the aggregate inflow and outflow data can then be compared in order to quantify BMP effectiveness over the length of the sampling program, even though the samples were collected independently.

Determining the necessary sample size The first task in developing the sampling design is to determine a preliminary estimate of the number of samples necessary to meet the statistical goals of the program. This number will be modified as appropriate for each monitoring site as sampling proceeds, based on observed concentration data. A variety of programs are available to make this estimation, based on estimated (or observed) mean concentrations and standard deviations and the target confidence levels (90 – 95%) and statistical power (75 – 80%). To achieve these targets, results from the power procedure in SAS indicate that at least twelve (12) samples are required to detect significant differences at two locations where the coefficient of variation (COV) is 0.5 (α=.05, β=.20). Ecology has not determined an upper limit for the number of samples necessary to meet the statistical goals. For planning purposes, it is estimated that 17-18 samples should suffice as

a target for the first year of sampling. Evaluation of COV for these samples will demonstrate whether a larger or smaller number of samples are needed to meet the statistical criteria, resulting in the second year samples target being modified accordingly.

Determining the number of sampling days The second task is to estimate the number of sampling days that will be necessary to successfully collect the required number of samples. The number of sample days depends on the number of days where it is expected that inflow and outflow will be present to sample. Since base flow is not a focus for monitoring, samples should be collected only during times that are obviously associated with a rain event. As a result, the number of potential sampling days depends on the expected precipitation pattern, although the flow periods for outflow sites may be longer than rainfall periods because of storage in the BMP facility. Table 7 provides a summary of the mean number of days during each month where precipitation exceeded 0.15 inches at a representative precipitation station (Vancouver, station #458773) (data obtained from Washington State Climatologist http://www.wrcc.dri.edu/cgi-bin/sod_xtrmts2x.pl).

Table 7. Monthly means (1898-2007) for number of days with rainfall > 0.15 inches.

Month	Mean # days with rain > 0.15 inches	Total # days in month
October	6.24	31
November	11.01	30
December	11.34	31
January	10.5	31
February	8.52	28
March	7.98	31
April	5.75	30
Sub-total	61.34	212
May	4.59	31
June	3.51	30
July	1.13	31
August	1.54	31
September	3.54	30
Sub-total	14.31	153
Total	75.65	365

The TAPE guidance from Ecology recommends that the sample collection time period be split into sub-periods or seasons that have different rainfall frequencies. If we assume the wet season to occur from October through April, the total number of days with precipitation greater than 0.15 inches for the wet season is 61 days, or 81% of the number of days with greater than 0.15 inches of total precipitation during the year. Accordingly, 81% of the samples (i.e. 15 of the total of 18 samples) will be collected during these months. Since precipitation to meet the target criteria (at least 0.15 inches) falls an average of 61 days within the 212 day wet season sampling period, there is approximately a 0.29 (61 / 212) chance that a random sampling day will actually provide the opportunity to collect a sample. Since 15 samples are required, 52 (15 / 0.29) potential sampling days must be identified during the wet season. Similarly, during the dry season from May through September there is a 0.092 (14 / 153) chance that a random day will provide the opportunity to collect a sample. As a result, 33 (3 / 0.092) potential dry season sampling days must be identified during that 153 day period.

Scheduling the sampling days Based on the required number of randomly selected sampling days that has been determined, a random selection of sampling days will be generated for each season at each monitoring site. Sampling will be conducted on the predetermined dates unless there is no discharge on that day. To generate the randomly selected sampling days, the days of each sampling season will be consecutively numbered from first to last. A random number generator (e.g. in Microsoft Excel^{R}) will be utilized to generate separate lists for inflow versus and outflow sites for both treatment wetland BMP sites. Note that inflow and outflow sites will be sampled independently, each with its own separate set of proposed sampling days.

Sampling strategy For the long-detention time sampling approach, the collection period will be limited to a maximum of 24 hours. Flow-weighted composite samples will be collected, and the flow-weighted concentration is termed the “Sample Mean Concentration” (SMC). Where inflow or outflow stop before 24 hours of sampling can be completed, the sampling time can be as short as 6 hours. Storms occurring after several days or more of no precipitation may also be specifically targeted for sampling in order to include important first-flush events at the end of the dry season.

5.4 Site-specific sampling designs

This section describes the deployment and installation of monitoring equipment: rain gages, flow meters, automatic samplers, and data loggers. A fully integrated sampler system will be selected instead of multiple components from a variety of manufacturers. The appropriate selection of sampler characteristics is critical to efficient collection of water-quality data. The programming needs for data collection will be carefully considered, as well as the use of integrated sensors and data loggers.

ISCO™ samplers, Series 6712, will be installed at each monitoring station. Each unit will be configured with one 5.5 gallon high density polyethylene (HDPE) carboy with PTFE lined caps. Continuous precipitation data will be provided via telemetry from a new precipitation gage located at one of the Wetland sites near the treatment train facility. Since all BMP monitoring sites are located in close geographic proximity (Figure 1), data from this precipitation gage will be used to describe conditions at all three BMP sites. Continuous flow monitoring will be provided by Campbell Scientific CS450/460-L pressure transducers or a CS471 bubbler sensor / Ott Bubbler in conjunction, as needed, with artifical controls depending on the site-specific hydraulic conditions and ratings. Precipitation gages, flow sensors, and autosamplers will be integrated with Campbell Scientific CR800 or CR1000 data loggers that are also connected to cellular telemetry. Sediment samples for each facility will be composites from multiple sample collecting units deployed at various locations within each facility.

To the extent practicable, all equipment will be installed in a durable instrument shelter located on the surface, which will provide easy access to the samplers and avoid the need for routine confined space entry during storm events. Each site will be equipped with cell phone telemetry to allow the data to be viewed in real time and facilitate storm tracking. In addition, real-time data make it possible to efficiently identify erroneous data so that corrective actions can be taken in a timely manner. All equipment in the shelter will be powered with batteries that are continuously charged, either with solar panels or local AC power.

Section C. Sampling and Measurement Procedures

6. Sampling (field) procedures

The quality of field sampling activity is critical to ensure that sample collection is consistent, the samples adequately represent the target storm or sample conditions, and the data will be comparable to data collected by other monitoring programs. To this end, field operations and sample collection will be carefully planned and implemented, and will follow specific Clark County Standard Operating Procedures (SOPs) that have been or will be developed and SOPs developed by other Permittees(Table T 8). This section provides an overview of the field procedures that will be implemented. Specific details are provided in the Clark County SOPs.

All field activities must be documented in detail in field sheets that are assembled into a three-ring binder or field notebooks. Corrections are made by drawing a single line through the error so it remains legible, writing the corrections adjacent to the errors, and initialing the correction so that the data are legally defensible. Notes on the collection and handling of samples should be sufficiently detailed to allow a reviewer's understanding and evaluation of the process.

Required field log entries include the following—

- Name of program, and location of field work
- Identity of field crew
- Sequence of events
- Any changes to the sampling plan
- Site and climatic conditions
- Date, time, location, identification, and description of each sample collected
- Instrument calibration procedures
- Field measurement results
- Description of QC samples collected, if appropriate
- Unusual circumstances that may affect interpretation of data, if appropriate

6.1 Precipitation and Flow monitoring

The schedule for maintenance of precipitation and discharge monitoring equipment may vary depending on the specific instrumentation at each site, but will follow the general pattern described in Table 8.

Table 8. Precipitation and flow monitoring maintenance schedule.

Monitoring station	Timeframe	Frequency	Activities
Precipitation	First year of operation	At least monthly and during all site visits	Inspect and service equipment
	After first year	Every other month, once telemetry is functioning	Inspect and service equipment
Discharge	First year of operation	At least monthly	Inspect and check sensor
	After first year	Every other month, once telemetry is functioning	Inspect and service sensor

Data from the rain gage and flow meters will be automatically downloaded daily just after midnight and as needed during and following sampled events. Rain gages and flow sensors will be inspected monthly and serviced as needed during the first year of operation, and every other month after the first year. Calibration of stage sensors will be conducted at least monthly to establish accurate rainfall/runoff relationships. Stage calibration will be conducted less frequently, as appropriate, in subsequent years.

6.2 Sample collection procedures

This section describes the procedures for identifying an event for sampling, setting up the monitoring equipment prior to collecting the sample, monitoring sample collection and retrieving the sample, validating the sample collected, and maintaining equipment between sample events.

Each sample site will have a checklist of the samples to be collected, the required equipment and supplies, instructions for retrieving the bottles and processing the samples, and detailed servicing instructions for setting and programming the sampler for the next series of sample collection.

Event targeting Prior to selected random sampling days (treatment wetland sites) or during the period when potential storms are suspected to qualify for sampling (treatment train sites), the Project Manager (or designee) will consult precipitation forecasts for Clark County to identify storms during the next 3-7 day period that may meet the minimum target criteria. If forecasts indicate that a target storm may be approaching, the Project Manager or designee will decide whether to consider sampling. Once a decision is made to sample the event, as appropriate, County staff will continue reviewing the forecasts daily. Internet forecasts will be archived to document the decision process.

Ideally, the Project Manager (or designee) will make the decision about targeting the storm for sampling no less than twenty-four hours prior to the designated sampling day or the onset of the storm. The Project Manager, or designee,, will be responsible for assembling the field team to conduct pre-sample site setup activities and managing all field and sampling decisions until the samples are delivered to the laboratories.

Pre-sample setup activities If feasible, within 24 hours of the onset of a target sample event, the field team will visit each site to prepare for sampling. Based on the forecasted precipitation quantity, storm duration, and estimated runoff volume, the Project Manager or designee will have already determined the appropriate sampler pacing rate. During the setup visit, the field team will conduct any necessary maintenance, place the clean sample bottles into the autosampler, and program the sampler. All setup activities will be recorded on a field sheet. The following tasks will be performed—

- Inspect status of precipitation gage and stage / flow sensor and clean as appropriate
- Check status of sampler pump tubing, rinse with lab-grade deionized water and calibrate sampler pump as appropriate
- Stock sampler with clean sample bottles and ice
- Confirm sampler and flow meter programs and settings
- Run sampler diagnostics to ensure correct operation of distributor arm
- Start sampler program and ensure program is active and disabled, waiting for signal from flow meter to begin collecting the sample
- Ensure batteries are charged

Mid-sample event visit (as appropriate) During the course of the sample event, the Project Manager or designee will closely track the cumulative precipitation and discharge in order

to ascertain if sampler bottles will fill before the end of the storm or designated sampling period. This judgment will be based upon the expected runoff from observed rainfall, the sampler pacing rate, and the amount of precipitation that is forecast. If it is determined that the sampler bottles may fill too soon, the Project Manager or designee will send the field crew out to check the sampler and exchange sample bottles if needed. The following activities will be conducted—

- Check the status of the autosampler and decide if sampler bottles should be exchanged or if additional ice is needed
- If bottles are exchanged—
  - Review sampler report and record data
  - Cap and label bottles and store on ice for transport and storage
  - Deploy new clean bottles into the sampler
  - Restart the sampler program
- Check batteries and replace if necessary

All activities and observations should be recorded on the same field sheet used to document pre-sample setup activities.

Composite sample retrieval Throughout the sample event, the Project Manager or designee will monitor weather conditions and forecasts to identify when the event has ended. Once the sample event is over, the field team will be mobilized as soon as feasible to retrieve the composite sample. The following tasks will be conducted—

- Review the sampler report and record data
- Cap and label bottles and store on ice for transport
- Collect equipment blank sample, if scheduled
- Power down the autosampler or place in stand-by mode

All activities and observations should be recorded on the same field sheet used to document pre-sample setup activities.

Composite sample splitting and processing In order to minimize potential contamination and holding times, all sample splitting and processing will be done at a nearby contracted accredited commercial analytical lab. As soon as feasible after sampling is completed, the bottles of flow-weighted composite samples will be quickly placed within ice-filled

coolers, to minimize sample's exposure to light, and transported to the laboratory for splitting, processing, and analyses. Composite sample splitting and processing procedures are described in detail in the USGS National Field Manual for the Collection of Water-Quality Data (NFM, 2002, Chapter 5). Sample-specific requirements for volume, containers, and hold times are described in Table T 9. This section provides a brief overview of sample bottles as well as splitting and processing procedures.

Polyethylene (HDPE) bottles (5.5 gallon) for samples to be analyzed for both inorganic and metal constituents should be ordered pre-cleaned, acid rinsed, and should arrive capped from the laboratory. Before deploying in the field, all bottles (including acid-rinsed bottles) should be pre-rinsed three times with deionized water and stored in plastic coolers.

At the accredited laboratory, samples may be divided through a Teflon™ cone splitter (Figure 6) or, depending on volume, just a churn splitter (for set-up instructions, see NFM, Chapter 2). Composite samples exceeding 22 liters (for example if composite bottles are replaced mid-storm) are first split using a Teflon cone splitter in order to get a homogenous and representative smaller sample that is then further split using a 22 liter polyethylene / polypropylene churn splitter into required laboratory sample analyses containers. All tubes exiting the cone splitter must be the same length, as short as possible, and pre-cleaned. The entire composite sample volume must be poured or pumped into the splitter from the large automatic sampler bottles for thorough distribution, taking care not to spill any sample or overfill analytical sample bottles.

All field sample bottles must be clearly labeled with the following information—

- Station number
- Date and time

Bottle labels may be written directly on each bottle with permanent, waterproof marker or preprinted labels that will remain securely attached to the bottles, even if they become wet.

Document on field forms pertinent sampling information including the types of samples collected, last sample time, number of aliquots, estimated total sample volume, and sampler screen readings...

Equipment cleaning Cleaning of all sample splitting and processing equipment will be done at the contracted accredited analytical lab. Equipment should be cleaned periodically in the workplace laboratory, where complete disassembly is more practical and more thorough procedures are possible (NFM, Chapter 3). Equipment blank and field blank data should be examined regularly to determine whether adjustments to the cleaning protocol are needed.

Transport of samples to lab and chain of custody Samples should be packaged and transported to the laboratory for analysis as soon as possible, preferably on the day of collection (assuming that the laboratory will be open to receive the samples on the appropriate day). Samples designated for chilling will be packed with ice in insulated ice chests. The amount of ice will depend upon the length of time in transit and the ambient air temperature.

Before transporting samples, check that sample bottles are labeled correctly and that a chain-of-custody form has been completed. Samples should be packed carefully in the ice cooler to prevent bottle breakage, container leakage, and sample degradation. Check that bottle caps have been securely fastened.

In order to provide continuous documentation of each time the sample changes hands, a chain-of-custody form will be completed by the person sending the samples. These forms must describe the location, date, sample number, nature of sampling program, and name of individuals who collected the samples, as well as their signature. Chain-of-custody forms will follow the samples through the analytical process in the laboratory, with personnel sign-offs each time the samples change hands.

6.3 Field sample validation

The Project Manager or designee will validate the treatment train samples using the qualifying storm criteria to determine that they were collected during qualified storm events. Additionally, the storm hydrographs and timing of sample aliquot collection will be reviewed to confirm that each sample represents at least 75 percent of the hydrograph during the first 24 hours of the storm. For the wetland sites, validate that sampling occurred during the targeted random sampling date or for repeated dates on alternate date.

All samples will be validated as follows—

- Review field forms for missed aliquots or bottles overfilling or other conditions that would disqualify the composite sample
- Confirm that the composite sample contains at least 10 aliquots
- Check that sufficient volume was collected to complete laboratory analysis

6.4 Preventive maintenance

Periodically, preventative maintenance will be conducted between sampling events at all sites so that equipment can be properly operated. All maintenance issues, including any sign of vandalism, will be comprehensively documented in field notebooks associated with each site. Approximately every six months, the sampler suction lines will be replaced for cleaning. Typically before each sampler set-up, the sampler will be manually checked and calibrated as needed to verify that the sampler is pumping the desired volume and working correctly.

6.5 Sediment sample collection

The bottle will be placed on ice for transport to the analytical laboratory for further processing. In order to preserve the grain size distribution, the sediment sample should never be frozen prior to analysis.

7. Measurement (laboratory) procedures

This section describes the analytical laboratories that will conduct analyses for this program, as well as the analytical methods that will be used.

7.1 Analytical laboratory for chemical analysis of stormwater and sediment

Columbia Analytical Services (CAS) laboratories are currently certified to perform environmental analysis of stormwater by the Washington State Department of Ecology through the Environmental Laboratory Accreditation Program (ELAP) (#C1203 / C544, expires July 8, 2011). Most parameters in water and sediment will be measured by CAS. Columbia Analytical Services main laboratory is in Kelso, Washington but the firm also has a large network of different laboratory facilities located throughout the United States. The CAS laboratory located in nearby Kelso is one of the largest CAS laboratory facilities,

offering a wide variety of environmental analyses and analytical methods. A full list of parameters that CAS laboratory is accredited to perform is found at

http://www.ecy.wa.gov/apps/eap/acclabs/lab.asp?id=1203

The CAS Kelso Laboratory is located at the following address:

Columbia Analytical Services
1317 S. 13th Ave
Kelso, WA 98626
360-577-7222
www.caslab.com

Particle size distribution analysis, for water samples, will be performed for CAS by the subcontracted lab Microlab Northwest at the following address:

Microlab Northwest
7609 140th PL NE
Redmond, WA 98052
(425) 885-9419
www.microlabnw.com

7.2 Chemical analysis procedures

This section describes the analytical methods that will be utilized for analysis of stormwater and sediment samples collected as part of this program.

Analytical instruments All analytical instruments used for analyses for this program will be maintained and calibrated regularly according to specifications in the internal laboratory Quality Assurance Plan (QAP), including all appropriate standard operating procedures (SOPs), instrument manufacturer's specifications, and specific method requirements.

Analytical methods and reporting limits Target constituents and corresponding analytical or Ecology approved alternative methods, method detection limits, method reporting limits, and reporting limit targets for stormwater and sediments are described in Table T 10 and Table T 11. Note that no guidance was provided by Ecology for the approved method or target reporting limit for total phosphorus in sediment.

All analyses will be conducted according to the laboratory standard procedures and analyte-specific procedures.

Section D. Quality Assurance and Quality Control Procedures

8. Quality control

This section describes the quality control (QC) requirements for all field and laboratory activities conducted by this program. Data quality will be evaluated according to the measurement quality objectives (MQOs) described in the Quality Objectives Section (see Table T 6 for specific criteria and corresponding actions).

8.1 Field quality control

Field QC requirements include procedures for field measurement and documentation, sample collection, field QC samples, and corrective action for identified issues for field activities.

Field quality control procedures All preventative maintenance and calibration, as appropriate, of field and sampling equipment, including rain gages, flow sensors, automatic samplers, and other field instrumentation will be conducted according to the schedule defined in the Sampling (Field) Procedures Section.

Designated binders will be maintained for original field records for all monitoring and field activities. Program-specific forms will include storm data field sheets and maintenance inspection/activity sheets. Documentation will also include details surrounding sediment collection deployment, work permits for confined spaces, and chain-of-custody forms. All entries in field documentation must be clearly written; errors will be corrected by crossing a line through the error and entering the correct information (dated and initialed).

All sampling and processing procedures will be conducted according to the specifications detailed in this Plan, in order to ensure consistent and representative samples and reduce contamination.

Usually field QC samples will be collected during sampling events as described below, with the exact schedule to be determined by the Project Manager. QC samples must be

clearly identified and labeled with unique sample identification codes so that the results can be clearly tracked. QC sample data will provide the basis for necessary corrective action to be taken to correct problems that may occur, as determined by the Project Manager. The process of corrective action will include the identification of a problem, action to correct the problem, monitoring to evaluate the corrective action, verification that the problem has been appropriately solved, and documentation of the chain of events. Corrective actions may deal with issues in chain-of-custody, sampling collection and/or transport to the laboratory, field record keeping, or additional training that may be required. Field procedures may be revised as appropriate to deal with problems that are identified.

Field quality control samples Field QC samples are used to evaluate sample collection procedures and other conditions that could potentially impact the integrity of the samples before they reach the laboratory (Table T 12). These could include ambient site conditions during sample collection, the processes of storage and transport, and the adequacy of equipment cleaning. The target ratio of QC samples to ambient samples will be at least 1:20. distributed across all S8E and S8F sampling sites. Specific types of QC samples include—

- Field Split samples
- Field Blank samples
    - Transport blanks
    - Transfer blanks
    - Equipment (rinsate) blanks
    - Temperature blanks

Field Splits Split samples provide a measure of the variability of the analytical process. Split samples will be prepared at the laboratory by reserving a second carboy of sample water immediately following processing the large initial volume through the cone splitter. The second carboy will be processed through the churn splitter and analyzed in the same manner as the sample. Up to 10 split samples will be analyzed per year as follows: at least two splits (to include the first split collected each year) will be analyzed for the entire suite of chemical constituents. Based on available sample volume, up to eight additional splits will be run for only one group of analytes selected from among: conventionals, nutrients,

metals, and organics. Results from split samples will not be utilized to accept or reject data, but as a qualitative assessment of sampling precision.

Results from split samples will not be utilized to accept or reject data, but as a qualitative assessment of sampling precision. If the relative percent difference between replicate samples exceeds 25 percent (except for samples with ambient concentrations near the detection limit, which are inherently more variable), the field crew will be notified to identify and correct the source of sampling variability as appropriate.

Transport blanks Transport blanks provide a measure of possible contamination from a variety of sources associated with transporting samples. Prior to sample collection on a particular date, blank water that has been certified for the suite of constituents to be analyzed will be used to fill a randomly selected set of sample containers in the office prior to leaving for the field and submitted to the lab for analysis. Transport blank samples will be clearly identified by a unique sample identification code associated with a specific site. A single transport blank will be prepared once per year.

Transfer blanks Transfer blanks are prepared in the field by transferring certified blank water to a laboratory- supplied sample bottle. The transfer blank detects contamination due to handling, the designated sampling area, or contamination present in a laboratory-supplied bottle. A transfer blank will be collected at least once per year at a representative field site.

Field equipment (rinsate) blanks Field equipment blanks are collected to specifically identify the potential for contamination of the sampling equipment, and evaluate the effectiveness of cleaning procedures. An equipment blank will be collected at least once per year from an automatic sampler within a representative configuration of equipment used by this program. The equipment blank sample will be collected in-situ by pumping the appropriate certified blank water through the cleaned sampler into a randomly selected set of bottles, labeling them as appropriate, and submitting the bottles to the laboratory for analysis. Equipment blank results will be evaluated in the same manner as field blanks, and similar corresponding actions will be taken as appropriate (Table T 6).

Temperature blanks Temperature blanks provide a measure of the temperature conditions during transport to the laboratory, and thereby the potential for sample degradation prior to analysis. Temperature blanks will be prepared with deionized water and submitted in the coolers for all environmental samples delivered to the laboratory for this program. The laboratory will be responsible to check the temperature of the temperature blanks upon receipt. If the temperature is greater then 6°C, the field crew will be notified so that appropriate corrective actions (i.e. additional ice packed in the coolers) can be taken prior to the next sample.

Field blanks (including transport, transfer, field equipment rinsate, and temperature blanks) will be evaluated and appropriate corrective actions taken as needed (Table T 6). If the results for field blank samples exceed twice the method reporting limit for any constituent, the data for those analytes will be flagged as appropriate based on the ambient concentrations observed (Table T 6 and Table T 6). Additional corrective action will include notification of the field crew and evaluation of sampling procedures in order to identify the source of the contamination. Additionally, if laboratory blank results indicate that the significant source is from the field, not the lab, field blanks may be collected for subsequent samples to help identify and minimize possible sources of contamination.

8.2 Laboratory quality control

The analytical laboratories will conduct all chemical and physical analyses as requested, meeting holding time requirements and target reporting limits to the extent possible. Columbia Analytical Services analyses are performed according to the laboratory's NELAP – approved quality assurance program. Test results meet requirements of the current NELAP standards (under the NELAC Institute) except when noted otherwise in individual laboratory result case narratives

Data acquired from laboratory QC samples will be utilized to evaluate the quality of analytical data, to determine the need for appropriate corrective action, and to interpret the effectiveness of corrective actions after they are implemented. Each method SOP includes a QC section that describes the minimum QC requirements for that procedure. Internal QC checks may differ but all procedures include both negative and positive controls (e.g. blank

samples or standard reference samples, respectively), as described in the following sections.

Method blanks Method blanks are defined as certified blank water that is carried through the entire sample preparation and analysis procedure. All reagents are added in the exact manner as in analyzing environmental samples. At least one method blank is required for each batch of samples for each method. The purpose of the method blank is to evaluate the potential for contamination during preparation, processing, and analysis for each batch.

The method blank is processed along with, and under the same conditions, as the associated samples including all steps of the analytical procedure. The goal is no detectable contaminants. If contamination is observed, the source must be investigated and measures taken to eliminate or minimize the problem. Samples that are associated with a contaminated method blank are evaluated to determine the best corrective action (i.e. reprocessing or flagging with appropriate qualifying codes).

Laboratory control samples Laboratory control samples (LCS) include standard reference samples, reagent spikes, surrogate spikes, and continuing calibration verification standards. The LCSs are utilized to assess the performance of the total analytical system, including all preparation and analysis steps. The number of LCS samples varies for each method, and is specified by the SOP. Analyte concentrations in the LCS must be within the calibration range of the methods where possible.

Data from these samples are compared to established criteria by the use of control charts, and indicate that the analytical system is out of specification if they exceed these criteria. Criteria for determining the need for corrective action are based upon guidance from the National Environmental Laboratory Accreditation Conference (http://www.epa.gov/nelac/standard/2003nelacstandard.pdf). Data from any samples associated with LCS results that exceed these criteria are reanalyzed or qualified as appropriate.

Reagent spike samples consist of water that is known to be free of analytes of interest, and subsequently spiked with known and verified concentrations of target constituents. Generally, due to concern of analyte cross-reactions or interferences, reagent spike samples

are made from a subset of the entire method list. This subset is selected to represent the method performance characteristics for all the analytes measured by the method.

Surrogates are frequently used in organic chromatography analyses and are selected to represent the variety of chemistries for the selected analytes of the method. They are added prior to sample preparation and extraction, and provide a measure of recovery for each sample matrix. They are deliberately chosen because they are unlikely to be present already as an environmental contaminant in the sample. Frequently surrogates are compounds that are isotopically labeled, fluorinated, or brominated.

Generally, the number of surrogates varies with each method. When used, surrogate compounds are added to all samples in the set, including standards and blanks.

Certified reference materials are commercially purchased and contain verified concentrations of analytes, used to measure analyte recoveries for applicable methods.

Continuing calibration verification standards are used to check instrument response to the analytes in relation to the calibration curve. They are prepared similarly to calibration standards at a concentration typically in the midrange of the calibration curve.

9. Data management procedures

Data from this monitoring program will consist of the following—

- field activity data, including sampling and equipment maintenance documentation
- field monitoring data, including flow, precipitation, and field probe data
- laboratory data, including water quality and sediment data

All records of monitoring information must be retained for at least five (5) years, including all calibration and maintenance records, all original recordings for continuous monitoring instrumentation, copies of all required reports, and records of all data.

9.1 Field activity data

Field notebooks and 3 ring-binders will contain all field activity data, as follows—

- completed storm data field sheets
- chain of custody forms
- maintenance inspection and activity logs

Field staff is responsible for updating this information and storing it in appropriate binders securely located and available to the Project Manager.

9.2 Field monitoring data

Field data will be downloaded remotely every day automatically via cell phone telemetry onto a project computer in backed up data files. The files are then appended and converted for storage, analyses, and editing utilizing commercially available ISCO Flowlink or Aquaticinformatics Aquarius software, and an industry-standard Microsoft Access database. Rainfall and discharge data can also be downloaded on demand remotely, as needed, and imported into a project database. The Project Manager is responsible for acquiring the data in a timely manner and maintaining the project database, which will be backed up regularly.

9.3 Laboratory data

All laboratory data will be transmitted electronically from the laboratory to the County's Project Manager or designee. The Project Manager is responsible for acquiring the data and conducting preliminary quality checks. The Project Manager also is responsible for conducting final review, verification, and validation of data.

Section E. Assessment Procedures

10. Audits and reports

This section describes the processes that will ensure that the quality assurance procedures specified by this Plan are being implemented correctly, that the quality of the data is acceptable, and that corrective actions are conducted in a timely manner.

10.1 Audits

Audits are an important tool to verify that the quality assurance procedures described in this Plan are being adequately implemented as necessary. During an audit, the reviewer will check for the following—

- Sufficient documentation of all required activity
- Compliance with site-specific plans
- Correction of any problems that have been identified

Audits may be scheduled by request from the Project Manager at Clark County, or the Department of Ecology.

Laboratory audits The Department of Ecology Laboratory Accredation Unit conducts external audits of the Columbia Analytical Services Kelso Laboratory facility to verify that all laboratory operations comply with established requirements. The audits are conducted with about a month's notice every 2-3 years. The audit is implemented by trained and qualified personnel who are independent of the audited activity. The audits verify that laboratory procedures follow published methods, approved SOPs, and the overall quality management requirements of the laboratory. A major function of these audits is to ensure that established policies are documented in unit SOPs, are well understood by personnel, and are fully integrated into the workflow. Any nonconformances to documented procedures that are identified are reported in the audit report and necessitate corrective action by appropriate personnel.

Field audits The Project Manager or a designated representative may conduct audits of the field activities, if deemed appropriate. This audit will address the following questions—

- Are field operations performed as specified?
- Are documentation records complete?
- Are problems identified and resolved appropriately?
- Are data management procedures adequate?

Any nonconformance to established protocols will result in appropriate corrective action. The Project Manager has ultimate responsibility for ensuring that the corrective action response is appropriate, complete, and documented.

10.2 Reports

Reports that will be generated for this program include sample files, status reports, and the Annual Stormwater Monitoring Report.

Sample files Sample files are not required by the Phase I Permit, but will be maintained to track the details of each sampling event. They will include all supporting information and documentation of the sample, including the rainfall and runoff flow rate, the stormwater hydrograph showing when samples were collected, and documentation of weather tracking

and forecasts for targeted storm samples (treatment train sites only). Other supporting documentation may include notes regarding sampling anomalies or other issues that may impact data analysis and reporting. The Project Manager, in collaboration with the field staff, is responsible for maintaining these files.

Status reports Status reports will be prepared and submitted to the Program Representative for Clark County as requested. These will include a summary of the successful and valid samples to date, a summary of the quality control results for analytical data, and a discussion of any issues that may need to be addressed. The Project Manager is responsible for preparing these reports.

Annual stormwater monitoring report The Stormwater Monitoring Report is required to be submitted with the annual report every year (S8.H). Each report will contain all monitoring data collected during the previous water year (October 1 through September 30). As appropriate, the reports will integrate data from earlier years into the analysis of results.

Reports will be submitted in both paper and electronic form and will include:

- A summary description of each BMP monitoring site, describing location, land use, drainage area, and hydrology
- The status of implementing the BMP effectiveness monitoring program
- A comprehensive data report, including QA/QC, with an explanation and discussion of the results
- Performance data, reported consistent with guidelines from "Evaluation of Emerging Stormwater Treatment Technologies (Ecology)
- useage of "*Urban Stormwater BMP Performance Monitoring"* (EPA 821-B-02-001), including information pertinent to fulfilling the "National Stormwater BMP Data Base Requirements" (section 3.4.3)
- Recommended future actions based on the findings

If the Permittee monitors any pollutant more frequently, or conducts any other stormwater monitoring in addition to that required by the Permit, the results from this monitoring must be included in the report.

The data report will explain the program results, present the data, document the overall quality of the data (i.e. completeness, representativeness, and usability), and discuss any data anomalies. The QA/QC section will include a summary and discussion of the field

and laboratory QC procedures and results, and whether the measurement quality objectives were met. This section will include any planned changes to the current Plan that may be appropriate to address QA issues that have been observed.

11. Data verification and validation

This section describes the data review, verification and validation procedures that determine whether the data conform to the criteria required by the program objectives.

11.1 Summary of procedures

Data review is the process of examining the data for errors or omissions. Data verification is based on the QC results, and determines whether the data meet acceptance criteria. Data validation includes the complete sampling process to assess whether the appropriate procedures were followed in sample collection.

All data generated by this program will be reviewed and verified for conformance to the requirements of the program. Data will then be validated according to the data quality objectives described in the Quality Objectives Section. Once data are found to be supported by acceptable QC data and to meet the specified measurement quality objectives, they will be considered acceptable and usable for the program.

Procedures for verification and validation will be conducted according to the guidance provided by EPA, 2002 (*Guidance on Environmental Data Verification and Data Validation*, EPA QA/G-8). The Project Manager, in collaboration with the support staff, is responsible for ensuring that field data are reviewed and verified. After each successful sampling event, the Project Manager or designee will review rainfall and flow data for gross error (e.g. spikes or data gaps) to verify the completeness of the data. The field staff will also check to see that stormwater samples were collected in accordance with required criteria.

The personnel and management of the analytical laboratories are responsible for the validation and verification of the data generated by each lab. The Project Manager is responsible for ensuring that all analytical data are reviewed once they are transmitted from the laboratory prior to being imported into the County's water quality database. The Project Manager is responsible for verifying that all data meet the QA criteria, and also for

validating that all data conform to the objectives of the program and are suitable for reporting.

11.2 Methods of verification and validation

This section presents a brief overview of the methods that may be used for verifying and validating data, including the input that will be necessary, the specific methods to be used, and the output from the verification process.

Data input A variety of records will be necessary for data verification and validation. These could include, but are not limited to, the following—

- Field logs
- Chain-of-custody forms
- Laboratory temperature logs
- Analytical service requests
- QC results

Data verification methods Data verification methods will be documented throughout the course of the process, and may be revised as appropriate to the situation. These methods will include—

- Identification of data gaps or missing data
- Identification of data anomalies or spikes outside the limits of reality
- Cross checks with field sheets and calibration records
- Evaluation of expected patterns versus observed
- Evaluation of QC results (within acceptable criteria)

Data verification products Outputs from the data verification process include both the verified data and the verification documentation. Verified data will be submitted to the final quality or usability assessment described in the next section. Verification documentation may be included in status reports and/or the QA/QC section of the Annual Stormwater Monitoring Report. Data verification documentation should also include a discussion of any technical issues or other shortcomings of the data.

12. Data Quality Assessment

Once data have been verified and validated, the final data quality assessment is conducted. The data quality objectives defined in this Plan must be satisfied in order for the data to be considered usable for meeting program objectives. The main goals of this assessment are to determine if the data meet the quantity of samples required, are representative of the target inflows and outflows to treatment facilities, and are sufficient to calculate treatment efficiencies.

12.1 Data usability assessment

Usability assessment is a qualitative process where data are evaluated relative to the specified measurement quality objectives. Three levels of data quality will be defined—

- Accepted: data meet all requirements for sample collection and analysis, quality control criteria, and documentation
- Qualified: data meet most requirements with only minor deviations from specified methods, critical QC criteria and documentation are met
- Rejected: data do not meet critical QC criteria and documentation is missing

The usability assessment includes examination of outliers, verification that the data are complete, representative, and comparable to other data collected in similar programs.

Data processing guidelines Data processing guidelines will be developed, depending upon the specific data issues that occur. All laboratory results less than the method detection limit (MDL) will be reported as ND and qualified with a “U” flag. For data analyses purposes, ND results will be replaced with one-half of the method reporting limit (MRL) value. Results that are greater than the MDL but less than the MRL will be qualified with a “J” flag.

12.2 Data reduction methods

Data will be used to calculate treatment efficiencies (both concentrations and loads) for each measured constituent.

Sites with short detention times For the treatment train sites, characterized by short detention times, efficiencies will be based upon event mean comparisons as follows:

Individual storm reduction in pollutant concentration = $\frac{100[A-B]}{A}$

where A = flow-weighted inflow concentration and B = flow-weighted outflow concentration.

Individual storm reduction in pollutant loading = $\frac{100[A-B]}{A}$

where A = inflow concentration * storm volume and B = outflow concentration * storm volume.

Aggregate reduction in pollutant loading = $\frac{100[A-B]}{A}$

where A = (Storm 1 inflow concentration * Storm 1 inflow volume) + (Storm 2 inflow concentration * Storm 2 inflow volume) + … (Storm N inflow concentration * Storm N inflow volume) and

B = (Storm 1 outflow concentration * Storm 1 outflow volume) + (Storm 2 outflow concentration * Storm 2 outflow volume) + … (Storm N outflow concentration * Storm N outflow volume).

<u>Sites with long detention times</u> For the treatment wetland sites, characterized by long detention times, efficiencies will be based upon aggregate concentration reduction as follows:

Aggregate reduction in pollutant concentration = $\frac{100[A-B]}{A}$

where A = mean inflow concentration and B = mean outflow concentration.

Aggregate reduction in pollutant loading = $\frac{100[A-B]}{A}$

where A = (Storm 1 inflow concentration * Storm 1 inflow volume) + (Storm 2 inflow concentration * Storm 2 inflow volume) + … (Storm N inflow concentration * Storm N inflow volume) and

B = (Storm 1 outflow concentration * Storm 1 outflow volume* outflow correction factor) + (Storm 2 outflow concentration * Storm 2 outflow volume* outflow correction factor) + … (Storm N outflow concentration * Storm N outflow volume* outflow correction factor).

The outflow correction factor is determined as follows—

Sum of flow volumes for inflow samples / sum of flow volumes for outflow samples.

The basis for this correction factor is the assumption that the sum of the outflow volume sampled should be set equal to the sum of the inflow volume sampled to provide an estimate of mass removal (Ecology, 2008 *Modification: evaluating stormwater treatment technologies with long detention times*).

13. Data analysis and presentation

This section describes the content of the Annual Stormwater Monitoring Report that presents the BMP effectiveness monitoring component and includes data collected during the previous water year. The following four elements are required to be included—

- Site summary
- Status of implementation
- Data and QA/QC report
- Treatment efficiencies for each site

13.1 Site summary

Each site summary will describe the location, land use, drainage basin area, and hydrology for the BMP facility. Additionally, a detailed description of the technologies employed by each treatment BMP will be provided, including physical details, expected treatment capabilities, and bypass processes as appropriate. Finally, the report will document all land use changes in the drainage basin for each site that could potentially impact either the hydrology or pollutant loading to the treatment facilities.

13.2 Status of implementation

The status of implementation will include an assessment of the samples collected to date and the observed variability in target concentrations, focused on evaluating the likelihood

that the current sampling program will be sufficient to achieve the statistical goals for reporting the final performance data.

13.3 Data summary

The data summary will describe procedures for obtaining data, including equipment used as well as the statistical goals for monitoring. Summary tables will describe all samples, including the storm conditions and duration, number of aliquots collected, inflow and outflow flow volumes, and comparisons to storm event or targeted random sample criteria. Removal efficiencies for each constituent will be provided for each storm or in aggregate, as appropriate (i.e. based on detention time).

13.4 QA/QC summary

This section will include the following elements—

- Data validation information for each sample that describes any field and/or laboratory QC issues and corrective actions, as appropriate
- Summary QA report, including
  - Overview narrative summarizing all data validation information
  - General assessment of usability and representativeness of data
  - Description of any proposed changes to the existing QAPP to deal with observed QA/QC problems

Table T 1. National Stormwater BMP Database requirements for all BMPs.

Data element	Description
General site information	
BMP test site name	Local name for site
City	City closest to site
State	State where site is located
Zip code	Zip code of the site
Country	Country where the site is located
Altitude	Altitude of site, to nearest 100ft or 30 m
Sponsoring and monitoring agencies	
Address	Monitoring and sponsoring agency name and contact information
Watershed information	
Watershed name	Local name for watershed
Total watershed area	Topographically-defined area drained by system
Percent (%) impervious area	Total percent of impervious surface in watershed
Regional climate station	Regional climate station that is most relevant to site
Land use information	Description of land use (for non-structural BMP only)
Monitoring stations	
Station name	User-defined name for monitoring station
Upstream BMP	BMP upstream of monitoring station (if any)
Relationship to upstream BMP	Relationship to monitoring station (i.e. inflow, outflow, not applicable)
Downstream BMP	BMP downstream of monitoring station (if any)
Relationship to downstream BMP	Relationship to monitoring station (i.e. inflow, outflow, not applicable)
Monitoring instrumentation	
Monitoring station name	Identify monitoring station where instrument is located
Precipitation data	
Monitoring station name	Identify monitoring station where precipitation data are collected

Storm runoff and base flow data	
Monitoring station name	Identify monitoring station where flow data are collected
Type of flow	Base flow or stormwater runoff
Flow start date	Month, day, and 4-digit year
Total bypass volume (if any)	Total runoff volume minus runoff volume influent to BMP
Total storm flow volume (into or out of BMP)	Total runoff volume minus bypass volume
Dry-weather base flow rate	Flow rate during dry-weather conditions
Water-quality (WQ) sampling event	
Monitoring station name	Identify monitoring station where samples were collected
Related flow event	Identify flow data corresponding to WQ data
Date WQ sample collected	Month, day, and 4-digit year
Medium monitored by instrument	Groundwater or surface runoff
WQ parameters	STORET WQ parameters analyzed
Value	Value of measured constituent
Unit	Units of measurement
Qualifier	STORET qualifier code

Table T 2. National Stormwater BMP Database requirements for structural BMPs.

Data element	Description
Structural BMP name	Common name for BMP
Structural BMP type	Select type of BMP (drop-down list)
Date facility was put into service	Month, day, and 4-digit year
Number of separate inflows	Number of inflows into the facility
Type and design of each BMP outlet	Description of the outlet configuration
Is BMP designed to bypass when full?	Select “Overflow” or “Bypass” characteristics of BMP
BMP drawing	Plan view and profile of BMP (in bitmap format for database)

Table T 3. National Stormwater BMP Database requirements for individual structural BMPs.

Data element	Description
Wetland channel and swale design data	
Length of channel or swale	Length of channel or swale from stormwater inflow to outflow point
Longitudinal slope	Measured slope between grade control structures
Bottom width	Average width between side slopes
Side slope	Average slope of sides
2-year flow design depth	Average depth of water during 2-year flow
2-year peak design flow velocity	Design velocity for 2-year flow
Type of plant species in wetland zone	List and description of plant species, percent of cover, and densities

Table T 4. Parameters to be measured in water.

Analyte group	**Parameter**
Conventional	Hardness (alkalinity)
	pH
	Particle size distribution
	Total suspended solids
Metals (dissolved and total recoverable)	Copper
	Zinc
Nutrients	Orthophosphate
	Total phosphorus

Table T 5. Parameters to be measured in sediment.

Analyte group	Parameter
Solids	Grain size
	Percent total solids
	Total volatile solids
Metals, total recoverable	Cadmium
	Copper
	Lead
	Zinc
Nutrients	Total phosphorus
Total petroleum hydrocarbons	Diesel range organics (DRO)

Table T 6. Criteria for measurement quality objectives (MQO) and required actions when not met.

Data Quality Indicator	Evaluation	MQO (criterion)	Action
Bias	Field Blank samples: Transport, Transfer, Equipment (Rinsate)	< 2x method reporting limit (Table T 10 and T 11)	If MQO not met, flag sample result U for any sample < 5x field blank value. Notify field crew for evaluation of sampling procedures.
	Laboratory control samples ,Matrix spikes, Surrogates	% recovery[1] Table T 7	If MQO not met, flag associated sample results J
Precision	Field replicate samples	RPD[2] Table T 7	If MQO not met, flag associated sample results J
	Field split sample	RPD[2] Table T 7	
	Laboratory replicate samples	RPD[2] Table T 7	
Accuracy	Precipitation depth	Within 5% tipping bucket volume	Utilize data from nearest alternative precipitation gage
	Discharge	Within 20% of actual flow for flows in 10%-90% of equip. operating range; within 35% for flows outside this range	Flag event J if Q does not meet MQO
Sensitivity	Reporting limits	Tables T 10 and T 11	Results < MDL reported as ND and qualified with a "U" flag; Results > MDL but < MRL qualified with a "J" flag
Complete-ness	Chemical data	90% of intended samples	Criterion not met if successfully-collected data < MQO based on amount intended, document performance and significant issues
	Hydrologic data	90% of data record	
Representa-tiveness	Methodology	Analytical and field methods defined	Deviations must be approved by Project Manager
	Holding time (stormwater only)	Table T 9	Flag sample J if MQO exceeded by < 2x holding time; Flag sample R if MQO exceeded by 2x or greater
	Storm event criteria	Table 6	Discard sample if storm does not meet MQO
	Sampler performance	At least 10 aliquots, collected for at least 75% of Treatment Train storm hydrograph (or 75% of first 24 hrs of storm hydrograph) or over 6-24 hours on wetlands' targeted random date	Discard sample if performance does not meet MQO. Deviations must be approved by Project Manager.

[1] Percent recovery = $\frac{SSR - SR}{SA} x100$ where SSR=spiked sample result, SR=sample result, SA=spiked concentration added to spiked sample. [2] Relative Percent Difference (RPD) = ($\frac{R_1 - R_2}{[R_1 + R_2]/2} \; x100$)

Table T 7. MQOs for analytical bias, precision, and accuracy.

	Bias			Precision	
Quality Control Sample Type (Limits Used)	**Lab control sample (Percent recovery limits)**	**Matrix spikes (Percent recovery limits)**	**Surrogate standards (Percent recovery limits)**	**Lab replicate samples or duplicate lab control samples (Relative percent difference)**	**Field replicate and split samples (Relative percent difference)**
Parameter					
Conventionals					
TSS	80-115	NA	NA	20%	25%
Hardness	90-116				
pH	85-115				
Nutrients					
Total phosphorus	85-115	50-144	NA	20%	25%
Orthophosphate	89-118	81-119			
Metals					
Total recoverable (Cu, Zn, Pb, Cd)	85 -115	70-130	NA	20%	25%
Dissolved (Cu, Zn, Pb, Cd)					
Total Petroleum Hydrocarbons					
Diesel					
NWTPH-Dx	46-140		50-150	30%	25%

Table T 8. Standard Operating Procedures list

Category	Title	Author
Sampler Setup and Gauge Calibration / Maintenance	Sampler Setup Procedures for S8D Land use / Stormwater Characterization Sites	Clark County Clean Water Program
	Sampler Setup Procedures for S8F BMP / Stormwater Treatment Effectiveness Sites	Clark County Clean Water Program
	Pressure Sensor Calibration SOP Memorandum	Herrera Environmental Consultants, Inc
	Continuous Gauge Maintenance SOP Memorandum	Herrera Environmental Consultants, Inc
Storm Analyses and Sampler Pacing	S8 Storm Analyses and Sampler Pacing Procedures	Clark County Clean Water Program
	S8 Wetland#1 and Wetland#2 Independent Inflow and Outflow Seasonal Random Sample Dates	Clark County Clean Water Program
Data Retrieval and Data Logger Programs	Data Retrieval SOP Memorandum	Herrera Environmental Consultants, Inc
	Clark County NPDES Monitoring Data Logger Program Description	Herrera Environmental Consultants, Inc
Sediment Sampling	SOP for Collection of Stormwater Sediments Using In-Line Sediment Traps	City of Tacoma and Washington State Department of Ecology

Table T 9. Sample information for chemical analyses for water.

Parameters analyzed in stormwater	Volume (mL)	Container	Holding Time
TSS	1000	polyethylene (20L hdpe) Composite Carboy	7 Days
Hardness (alkalinity)	50	polyethylene (20L hdpe) Composite Carboy	14 Days
Total phosphorus	100	polyethylene (20L hdpe) Composite Carboy	28 Days
Orthophosphate	5	polyethylene (20L hdpe) Composite Carboy	48 Hours
Total recoverable (Cu, Zn)	500	Polyethylene, acid rinsed (20L hdpe) Composite Carboy	6 Months
Dissolved (Cu, Zn)	500	Polyethylene, acid rinsed (20L hdpe) Composite Carboy	6 Months
Particle size distribution	1000	Polyethylene, acid rinsed (20L hdpe) Composite Carboy	2-3 Days
pH	20	Polyethylene, acid rinsed (20L hdpe) Composite Carboy	NA

Table T 10. Information on analytical methods and reporting limits for target constituents in water.

Parameter	Laboratory Method	Method Detection Limit	Method Reporting Limit	Target Reporting Limit
Total suspended solids (TSS)	SM 2540D	1 mg/L	1 to 10 mg/L, Depends on degree that sample clogs filter	1 mg/L
Hardness (alkalinity)	SM2340C	0.08 mg/L	2 mg/L	1 mg/L
Total phosphorus	EPA 365.3	0.004 mg/L	0.010 mg/L	0.01 mg P/L
Orthophosphate	EPA 365.3	0.004 mg/L	0.010 mg/L	0.01 mg P/L
Total recoverable copper	EPA 200.8	0.02 ug/L	0.10 ug/L	0.1 ug/L
Dissolved copper		0.02 ug/L	0.10 ug/L	0.1 ug/L
Total recoverable zinc		0.2 ug/L	0.5 ug/L	5 ug/L
Dissolved zinc		0.2 ug/L	0.5 ug/L	1 ug/L
Particle size distribution	Coulter Counter	NA	NA	NA
pH	SM 4500-H+B	NA	NA	0.2

Table T 11. Information on analytical methods and reporting limits for target constituents in sediment.

Parameter	Laboratory Method	Method Detection Limit	Method Reporting Limit	Target Reporting Limit
Percent total solids	SM 2540B	NA	NA	NA
Total volatile solids	EPA 160.4	NA	NA	0.1%
Grain size	ASTMD422M	NA	NA	NA
Total recoverable copper	EPA 200.8 (ICP/MS)	0.08 mg/kg	0.1 mg/kg	0.1 mg/Kg
Total recoverable zinc		0.2 mg/kg	0.5 mg/kg	5.0 mg/Kg
Total recoverable lead		0.009 mg/kg	0.05 mg/kg	0.1 mg/Kg
Total recoverable cadmium		0.004 mg/kg	0.02 mg/kg	0.1 mg/Kg
Total phosphorus	EPA 365.3M	Based on % solid result	0.1 mg/kg	0.01 mg/kg
Total petroleum hydrocarbons (Diesel)	WDOE NWTPH-Dx	0.79 mg/kg	25 mg/kg	25 – 100 mg/Kg

Table T 12 Field Quality Control Samples

Field QC Sample Type	Frequency and Method
Field Replicate	One or two replicate samples per year will be collected concurrently with early storm grab samples and analyzed for fecal coliform and total petroleum hydrocarbons. Field replicates will be collected for grab samples by filling a second set of bottles in rapid succession to the first.
Field Splits	Split samples will be prepared at the laboratory by reserving a second carboy of sample water immediately following processing through the cone splitter. The second carboy will be processed through the churn splitter and analyzed in the same manner as the original carboy. Up to 10 split samples will be analyzed per year as follows: two splits (to include the first split collected each year) will be analyzed for the entire suite of chemical constituents. Up to eight additional splits will be run for only one group of analytes selected from among: conventionals, nutrients, metals, and organics.
Transport Blanks	One transport blank will be collected each year at a representative site by filling a random set of sample containers (labeled for a specific site) in the office with lab deionized water then carried unopened to the field and back on a sample retrieval run and submitted with them to the lab for analysis.
Field Equipment (rinsate) Blanks	An equipment (rinsate) blank will be collected at least once per year from the automatic sampler within a representative configuration of equipment used by this program. The equipment blank sample will be collected in-situ by pumping lab deionized water through the cleaned sampler into a randomly selected set of bottles, labeling them as appropriate, and submitting the bottles to the laboratory for analyses.
Transfer Blanks	A transfer blank will be collected at least once per year at a representative field site. Transfer blanks are prepared in the field by transferring lab deionized water to a laboratory-supplied sample bottle, labeling them as appropriate, and submitting the bottle to the laboratory for analyses.
Temperature Blanks	Temperature blanks, provided by the contracted lab, will be submitted with all samples to the lab to check that temperature conditions within coolers are properly maintained during transport.

Figure 1. Clark County Washington, with locations of treatment BMP facilities.

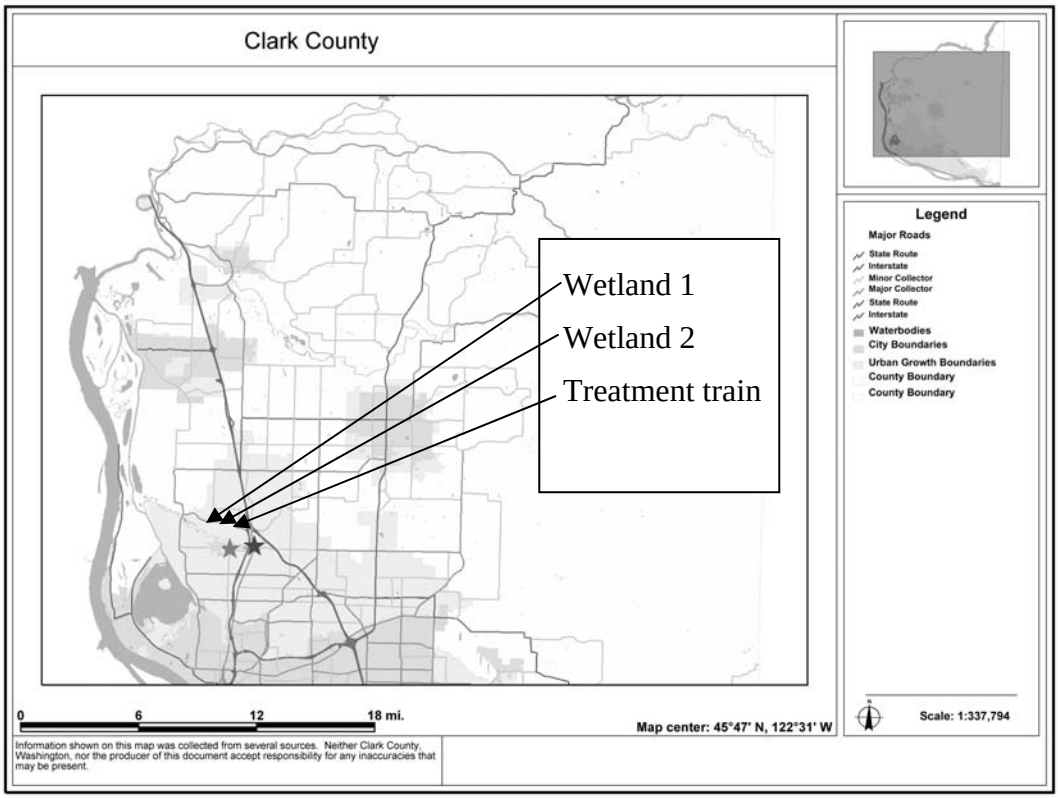


Figure 2. Design drawings for wetland treatment site # 1.

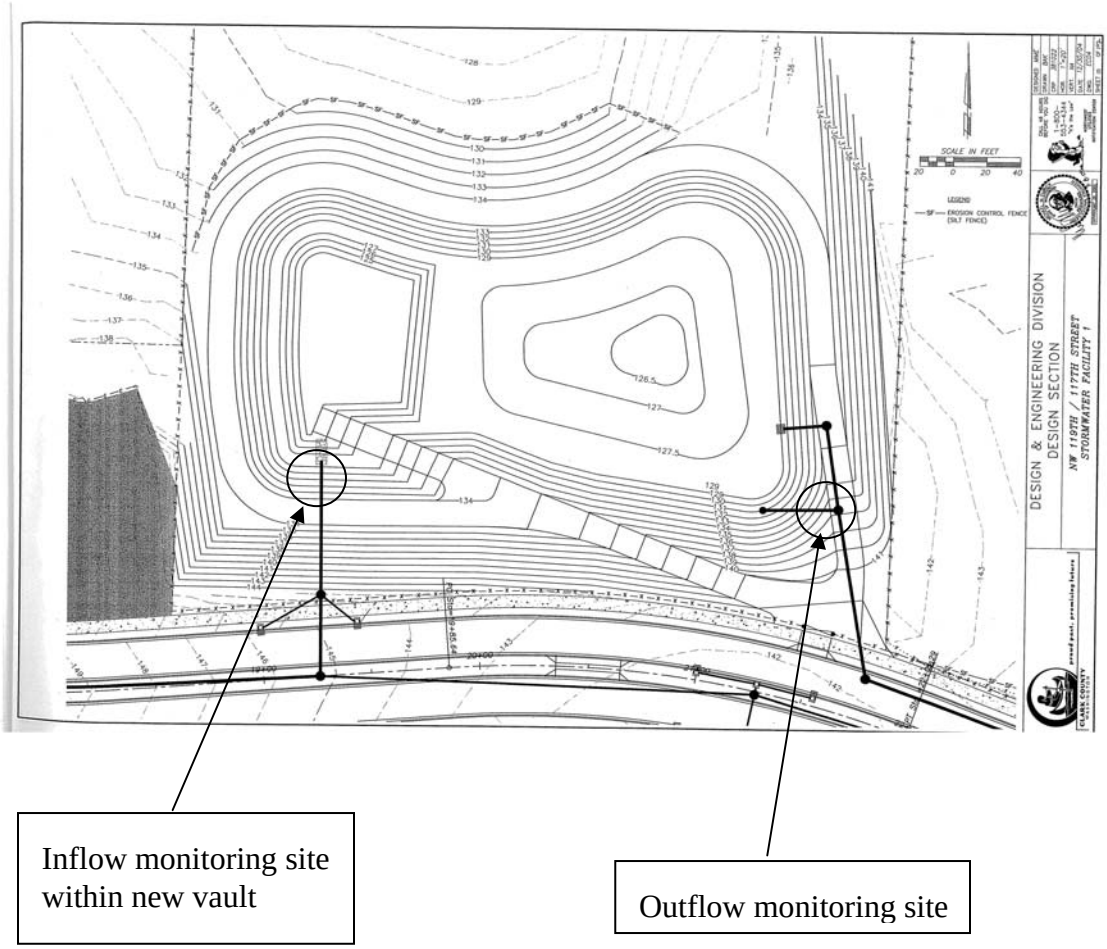
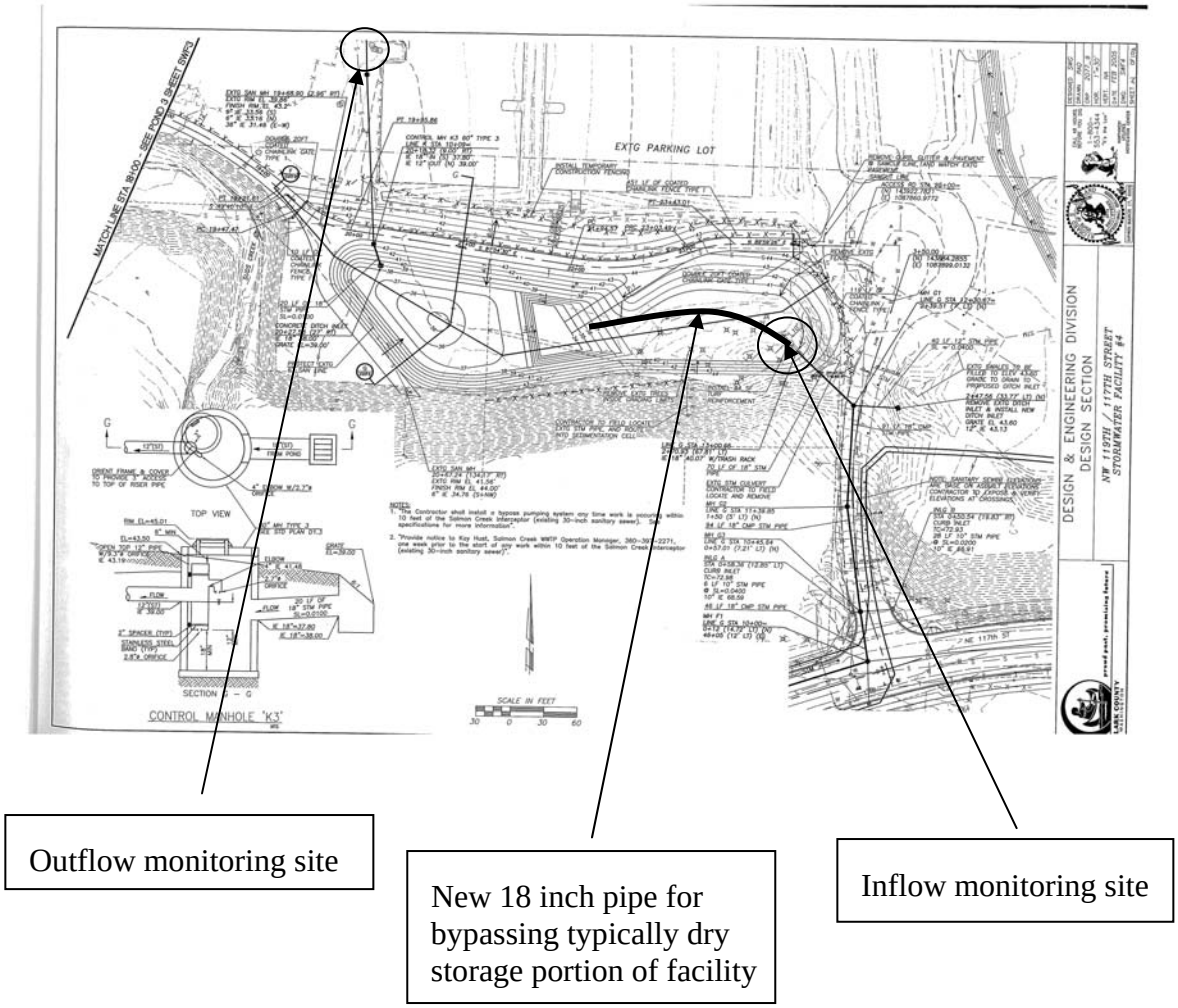


Figure 3. Design drawings for wetland treatment site #2.



Outflow monitoring site

New 18 inch pipe for bypassing typically dry storage portion of facility

Inflow monitoring site

Figure 4. Orthophotography for treatment train site.

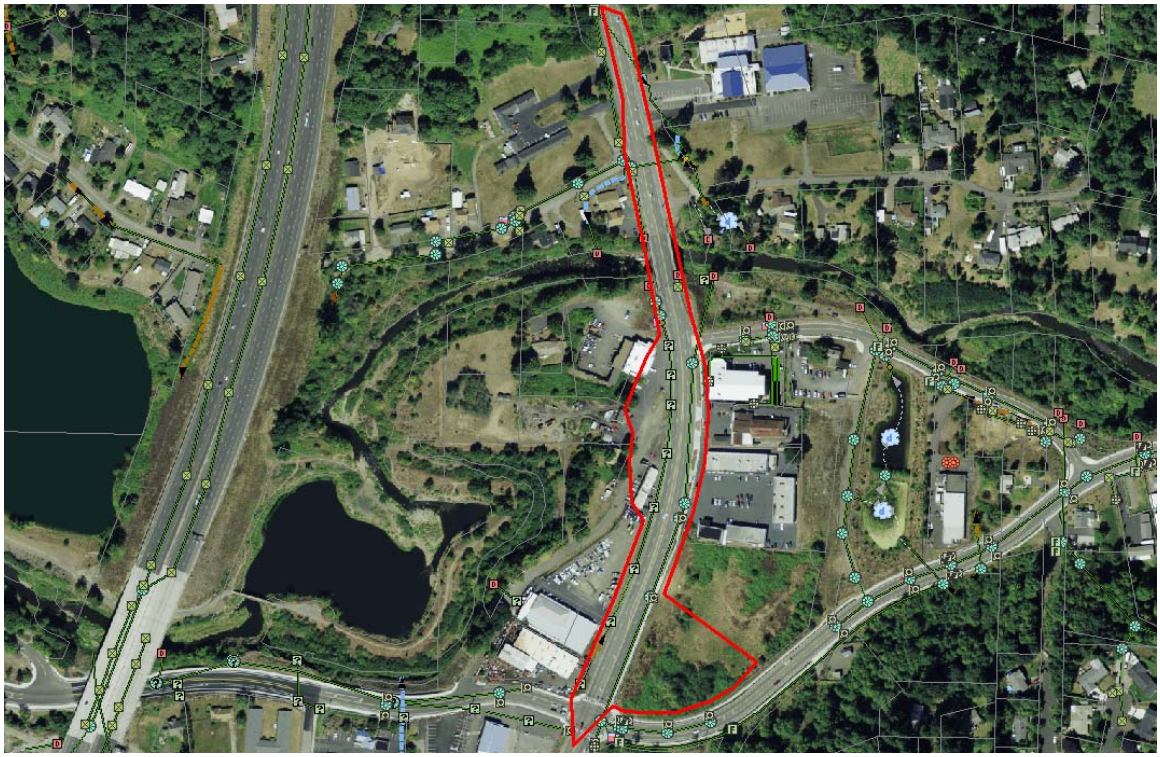


Figure 5 Design drawing for Treatment Train showing basic biofiltration swale and enhanced treatment filter vault locations and monitoring sites.

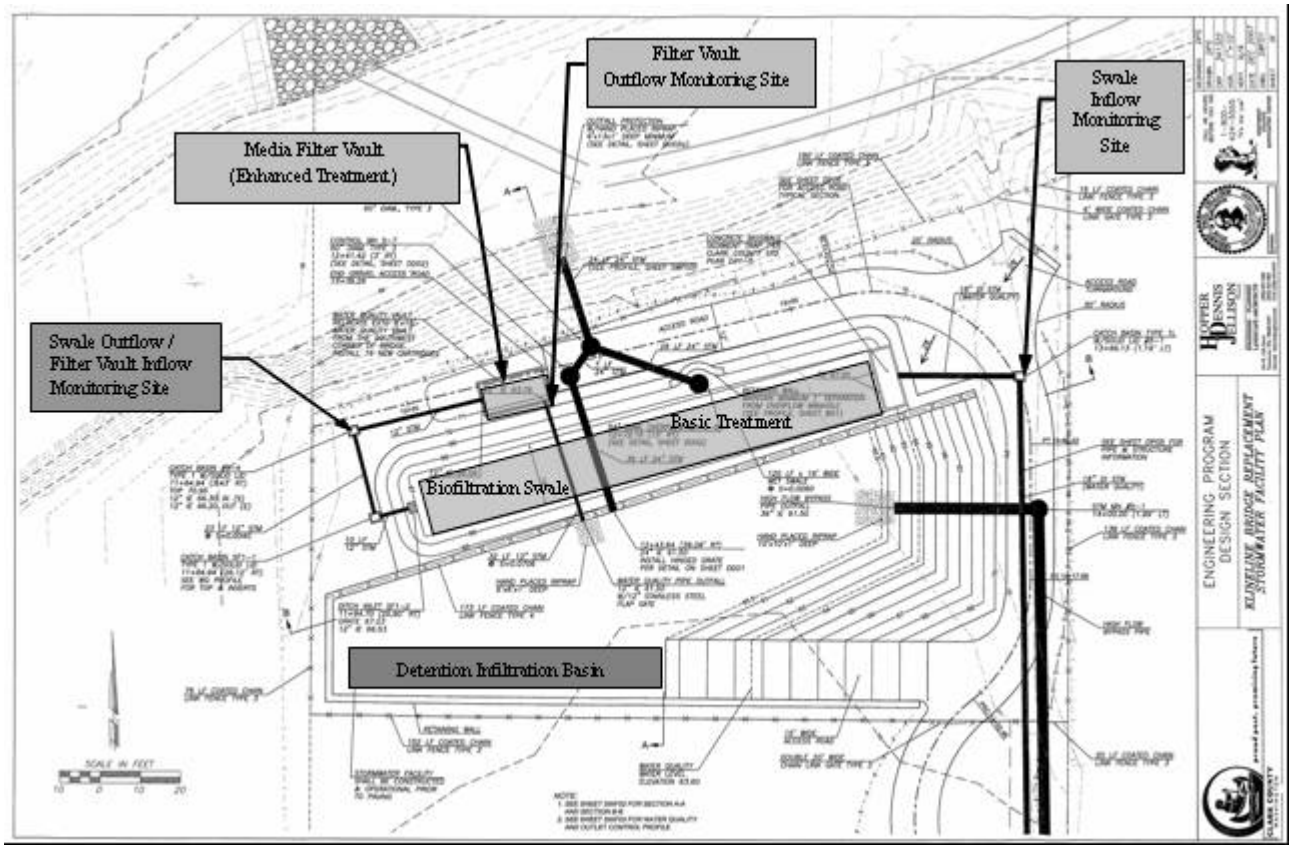
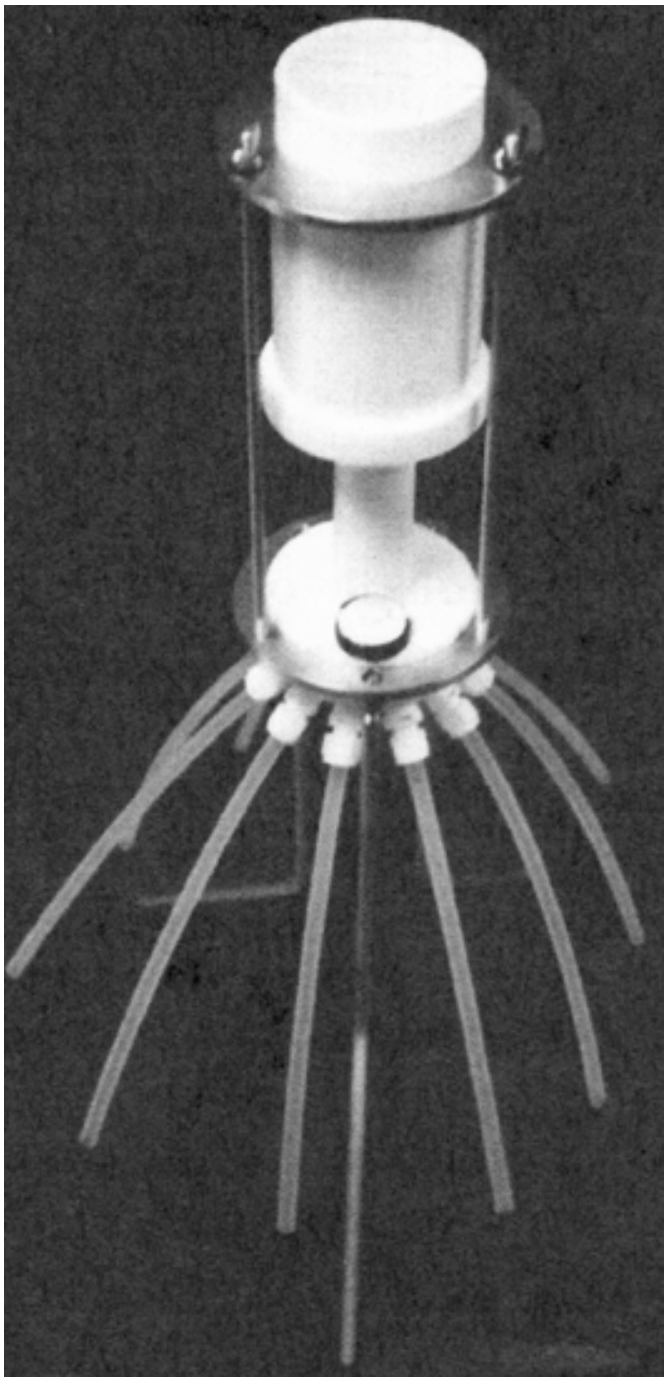



Figure 6 Cone splitter.