Quality Assurance Project Plan for WSDOT Roadway Stormwater Treatment Evaluation: Best Management Practices

September 2011

Prepared by

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September 2011

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WSDOT – Washington State Department of Transportation

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1 Abstract

The Washington State Department of Ecology's (Ecology) Environmental Assessment Program (EAP) was contracted by the Washington State Department of Transportation's (WSDOT) Stormwater and Watersheds Program to prepare a Quality Assurance Project Plan (QAPP) for stormwater monitoring under the 2009 WSDOT National Pollutant Discharge and Elimination System (NPDES) and State Waste Discharge Permit for Municipal Stormwater (hereinafter "permit") (Ecology, 2009a).

A QAPP describes the objectives of the study and the procedures to be followed to ensure the quality and integrity of collected data and ensure the results are representative, accurate, and complete.

This QAPP is specifically written for monitoring activities required under S7.C and S7.E of the permit, which require WSDOT to conduct seasonal first flush toxicity testing, effectiveness monitoring of stormwater treatment, and hydrologic management of best management practices (BMPs). The QAPP has been created to implement a monitoring program that will meet the requirements of the permit.

2 Background

WSDOT is responsible for more than 7,000 miles of highway across the state. The stormwater generated by these impervious surfaces is regulated by the U.S. Environmental Protection Agency's (EPA) NPDES program. EPA has delegated the NPDES permit development and issuance authority to Ecology, which oversees implementation at the state level.

Three QAPPs were prepared by Ecology's Environmental Assessment Program (EAP) for WSDOT to meet permit monitoring requirements. This QAPP describes a plan to conduct toxicity and effectiveness monitoring of stormwater treatment and hydrologic management best management practices (BMPs) that will meet the permit requirements. The other QAPPs describe stormwater monitoring from WSDOT facilities and highways.

Stormwater monitoring conducted under the NPDES permit will provide information for WSDOT to include in the *Highway Runoff Manual* (HRM) (WSDOT, 2010a). WSDOT's stormwater program utilizes BMPs to help meet the permit requirement to "reduce pollutants in discharges to the maximum extent practicable" (Ecology, 2009a). The BMPs assessed under this QAPP include:

- Vegetative filter strips (VFS)
- Modified VFS
- Compost-amended VFS (CAVFS)

This QAPP is designed to ensure the quality and integrity of the collected samples and to describe monitoring stations, field sampling procedures, and the quality assurance and quality control (QA/QC) procedures used to ensure the results are representative, accurate, and complete. Additional information is provided in the appendices:

- Appendix A provides a glossary of terms and acronyms used herein.
- Appendix B provides a copy of the NPDES stormwater permit S7. A–E.
- Appendix C provides a copy of the toxicity guidance from Appendix 6 of the permit.

2-1 WSDOT NPDES Permit History

Stormwater discharges are regulated through the NPDES program, which was established by the federal government in Section 402 of the Clean Water Act (CWA). In the state of Washington, EPA has delegated authority to Ecology to implement all provisions of the CWA, including the NPDES program. Municipal stormwater permits are one component of the NPDES program. Phase I of the NPDES stormwater permitting program was promulgated in 1990 and applies to all municipalities with populations greater than 100,000. Phase I permittees in Washington are required to conduct monitoring under their NPDES permits. In 1999, federal Phase II stormwater requirements were published, which expanded coverage of NPDES permits to smaller urbanized areas.

In 1995 Ecology issued an NPDES municipal separate stormwater permit, which requires WSDOT to prepare and implement a stormwater program to treat highway runoff before it is released into receiving water bodies. The following water quality management areas in Washington State were designated as Phase I areas and covered by the 1995 permit: Cedar/ Green, Island/Snohomish, and South Puget Sound. In those permits, WSDOT was identified

as a co-permittee with other Phase I jurisdictions (King, Pierce, and Snohomish Counties and the cities of Seattle and Tacoma). In 1999 Ecology issued a Phase I stormwater permit covering Clark County. Those permits were originally scheduled to expire on July 5, 2000. However, Ecology granted the permittees, including WSDOT, an administrative extension until the permits were updated and reissued.

In January 2007 Ecology reissued the Phase I municipal stormwater permit, with the Port of Seattle and Port of Tacoma identified as Phase I secondary permittees. Concurrently, Ecology issued the Phase II municipal stormwater permits, which apply to more than 100 cities statewide and parts of 13 counties, covering areas that generally have a population density of more than 1,000 people per square mile.

WSDOT's permit coverage continued under the original 1995 permit, until it was issued its own municipal stormwater permit (number WAR043000A) on February 4, 2009. WSDOT's current permit covers discharges from municipal separate storm sewer systems (MS4s) owned or operated by the department. MS4s are conveyances or a system of conveyances, including roads with drainage systems, municipal streets, curbs, gutters catch basins, ditches, constructed channels, and storm drains. Discharges covered in the WSDOT permit include stormwater runoff from state highways, rest areas, park and ride lots, ferry terminals, and maintenance facilities. The geographic area of coverage includes Phase I and Phase II permitted areas, as shown in Figure 1.

The permit was most recently modified on May 5, 2010, in response to a settlement agreement with Puget Soundkeeper Alliance, an environmental advocacy organization. WSDOT's permit is effective through March 6, 2014.

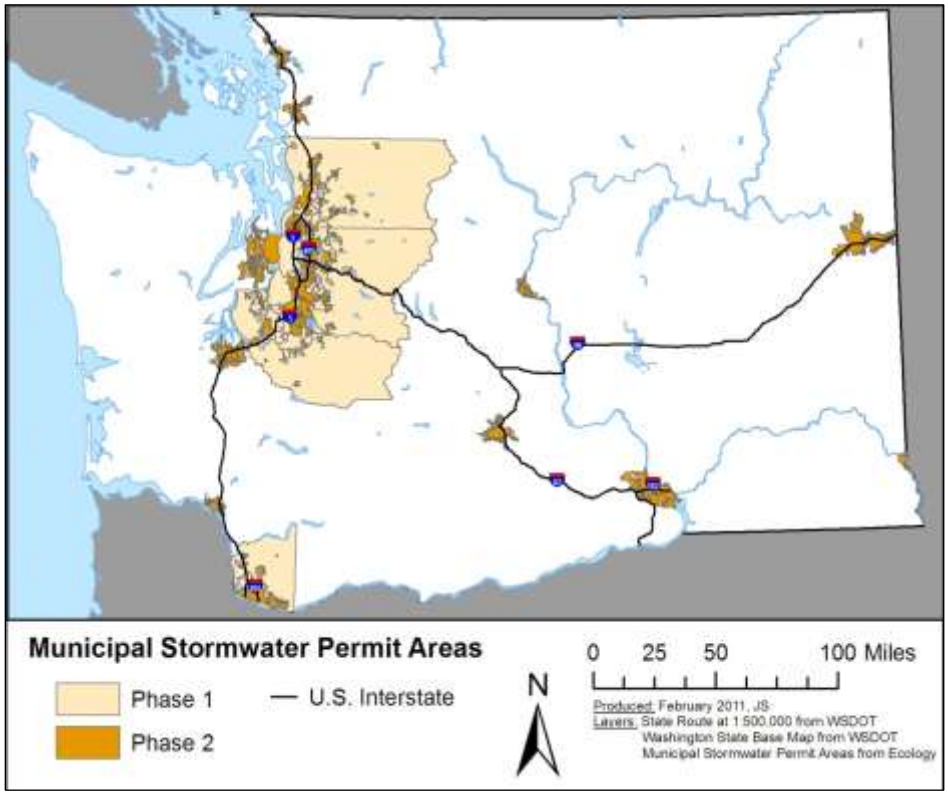


Figure 1 WSDOT municipal stormwater permit area.

2-1.1 Permit Monitoring Requirements

S7 of the permit (see Appendix B) requires WSDOT to develop and implement a stormwater monitoring program. The permit identifies three WSDOT land uses, each with specific monitoring requirements:

- Highways: Baseline stormwater characterization monitoring (S7.B) and seasonal first flush toxicity testing (S7.C).
- Rest areas, maintenance facilities, and ferry terminals: Baseline stormwater characterization (S7.D).
- Best management practices (BMPs): Stormwater treatment and hydrologic management evaluation monitoring (S7.E) and seasonal first flush toxicity testing (S7.C).

A separate QAPP was submitted to Ecology's Water Quality Program for each land use, to meet the S7 monitoring requirements in the permit. Each QAPP addresses the specific monitoring requirements for the land use designated in the permit. This QAPP addresses the requirements in S7.E and S7.C of the permit related to BMP effectiveness evaluation and seasonal first flush toxicity testing. This QAPP describes how monitoring will be conducted to gather water quality and quantity data from the influent and effluent of each BMP. BMP monitoring will include collecting year-round stormwater samples with hand grabs, composite autosamplers, and annual sampling for seasonal first flush toxicity.

This QAPP describes the process to:

- Target storm events
- Monitor rainfall and runoff
- Collect samples
- Analyze results to ensure quality data
- Locate sampling points
- Set up monitoring stations
- Verify and summarize data

This sampling program is designed to monitor real time continuous rainfall, temperature, and stormwater hydrology at each of the sites year round. Grab samples, composite samples for storm runoff, and annual seasonal first flush toxicity samples will be collected to complement the continuous monitoring.

2-2 BMP Types

WSDOT has been managing stormwater from new impervious surfaces statewide since the late 1990s. WSDOT uses BMPs for controlling and managing stormwater. These are the structural devices, maintenance procedures, management practices, and activities used to prevent or reduce the harmful effects of stormwater runoff, such as pollution, erosion, and flooding (WSDOT, 2010a). WSDOT continues to develop and monitor BMPs to improve the efficacy of road shoulder flow control and treatment of runoff in a cost-effective manner.

The HRM recommends using low-impact development (LID) techniques that use the site's terrain, vegetation, and soil features to promote infiltration so the landscape retains more of its natural hydrologic function. This is in contrast to techniques that concentrate the flow of

stormwater through pipes, drains, and other conveyance channels. The most common LID method utilized by WSDOT to preserve and employ the benefits of terrain, vegetation, and soil features for stormwater sheet flow are vegetated filter strips.

2-2.1 Vegetated Filter Strips (VFS)

Following is a description of a VFS from the HRM (WSDOT, 2010a):

> *A vegetated filter strip provides a very efficient and cost-effective runoff treatment option. Vegetated filter strips function by slowing runoff velocities and filtering out sediment and other pollutants and by providing some infiltration into underlying soils. Vegetated filter strips consist of gradually sloping areas that run adjacent to the roadway. As highway runoff sheets off the roadway surface, it flows through the grass filter. The flow can then be intercepted by a ditch or other conveyance system and routed to a flow control BMP or outfall.*

Figure 2 shows an example VFS. WSDOT uses VFS BMPs frequently because often they can be placed on existing road embankments without acquiring additional right of way.VFS can be used for pretreatment as well as primary treatment. Additionally, a VFS does not create habitat for mosquitoes like other BMP options. A VFS fulfills one of the four runoff treatment targets in the HRM: *basic treatment*, which is focused on the removal of total suspended solids from runoff (WSDOT, 2010a).

VFS provide other functionality besides total suspended solids removal. The National Cooperative Highway Research Program describes filter strips as "highly effective at controlling water quality from stormwater runoff by reducing pollutant concentrations of total suspended solids, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and phosphorus (TRB, 2006)." Several studies support the mass retention capabilities of VFS for heavy metals by observing an 18 to 114 percent reduction in zinc and an 8.9 to 15.6 percent reduction in copper (Dorman et al., 1996; Kaighn and Yu, 1996; Ebihara et al., 2009).

2-2.2 Amended Vegetated Filter Strips

Adding soil amendments to a VFS can increase its functionality, particularly compost. Compost is an excellent filtration medium, which provides treatment for highway runoff. Compost has a high cation exchange capacity (CEC) that chemically traps dissolved heavy metals and binds them to the compost material. Oils, grease, and floatables are also removed from stormwater as it is filtered through the compost (WSDOT, 2010a). This extra functionality addresses an additional treatment: *enhanced treatment* (removal of dissolved metals). Therefore, in addition to a VFS, WSDOT will also monitor an experimental modified VFS- and HRM-approved compost-amended vegetated filter strip (CAVFS). The CAVFS will be used for comparison to the experimental modified VFS.

The modified VFS and CAVFS have compost amendments that improve soil quality and texture, and thus improve infiltration. The compost amendments bind to dissolved metals, while biota in organic soil break down and neutralize the surface runoff pollutants. Soil amendments also have a very high capacity to hold moisture (up to 1½ times their weight) and can significantly reduce off-site flows (WSDOT, 2010a). In a modified VFS, the compost amendment is a 3-inch layer of compost applied to the top of the soil. A CAVFS is a VFS with a layer of compost tilled into the top layer of the soil, producing a final organic content of 10 percent.

Figure 2 VFS on the shoulder embankment of State Route 9 near Marysville, WA.

Preliminary data from an unpublished WSDOT study suggest that CAVFS may be effective in mitigating the impacts of stormwater runoff by reducing runoff volumes (87 percent reduction), peak discharge rates (88 percent reduction), and flow durations (78 percent reduction) (WSDOT, on file, 2010b). However, the study's authors suggest further investigation into the performance of CAVFS and VFS to verify these conclusions. Additional studies support WSDOT's findings that VFS treated with compost prior to vegetation growth have significantly lower erosion and runoff rates compared to untreated or unvegetated areas (Persyn et al., 2002).

A modified VFS is an experimental BMP consisting of a standard VFS with a 3-inch-thick layer of compost/hydroseed blend applied evenly on top to enhance treatment capabilities. The potential advantages of a modified VFS include reduced costs to construct versus a CAVFS, because the compost requires minimal ground disturbance and can be applied on a steeper slope. Additionally, a compost blanket may be applied to a broader area and be applied early in the construction process as erosion control. However, this is an experimental BMP type; therefore, WSDOT does not know the water quality improvement potential. Gathering data as a part of permit compliance will contribute knowledge about the functionality of modified VFS BMPs.

WSDOT's interests in monitoring these two compost-amended BMPs are as follows:

1. Compost amendments are thought to provide *enhanced treatment*, which:
    - May have a higher rate of dissolved metals removal when compared to other treatment options.
    - Generally has improved vegetation growth and infiltration of stormwater.
    - Increases the moisture-holding ability of the BMP to reduce flows.
2. Compost amendments can be applied at relatively low cost, broadening the statewide applicability for this treatment option.
3. Studies about compost-amended BMPs serve a dual purpose: combining the stormwater research interests of the agency with monitoring required for permit compliance.
4. The effectiveness of modified VFS in comparison to CAVFS and VFS can be investigated.

3 Project Description

3-1 Project Goals

The goal of this QAPP is to describe a monitoring program intended to collect high-quality data that characterizes BMP effectiveness in reducing stormwater runoff pollutants and flows. The monitoring program will be implemented in accordance with requirements of:

- S7.E of the permit: Monitoring the Effectiveness of Stormwater Treatment and Hydrologic Management Best Management Practices (BMPs)
- S7.C of the permit: Seasonal First Flush Toxicity Testing
- Appendix C: Toxicity Guidance from the Permit
- Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE) (Ecology, 2008a)

Specifically, this QAPP addresses hydrological monitoring at the edge of pavement (EOP) and the seasonal first flush toxicity testing from treated highway runoff. This information, along with other data, will be used to address the following permit goals:

1. Produce scientifically credible data that represent discharges from WSDOT's various land uses.
2. Provide information that can be used by WSDOT for designing and implementing effective stormwater management strategies for Washington's highways.
3. Provide data that can be used to inform WSDOT's *Highway Runoff Manual* (HRM) (WSDOT, 2010).

The BMPs selected for monitoring will improve understanding of the characteristics of compost amendments to a set of BMPs already utilized by WSDOT. This information will be incorporated into future versions of the HRM for both retrofit and new construction projects if approved for use by Ecology.

3-2 S7.E and S7.C Monitoring Requirements

S7.E of the permit requires WSDOT to conduct a full-scale monitoring program to evaluate the effectiveness, operation, and maintenance requirements of stormwater treatment and hydrologic management BMPs. The permit specifies that WSDOT select BMPs according to the type, location, treatment level, and design standards in the HRM.

S7.C of the permit requires WSDOT to test the chemistry and toxicity of stormwater runoff on the biological endpoint *Hyalella azteca*, a small aquatic crustacean. Permit-required monitoring is summarized in Table 1.

Table 1 Permit requirements for stormwater monitoring data (Ecology, 2009a).

Category	Description
BMP Type	S7.E.2.c states that WSDOT may select between the following BMP treatment types for monitoring: • Basic (removal of suspended solids) • Enhanced (removal of metals) • Metals/Phosphorus (removal of metals and phosphorus) • Oil Control (removal of oil) S7.C.3.b states that one BMP site shall be an enhanced treatment BMP for metals removal. The CAVFS is considered enhanced metal treatment and oil control BMPs. S7.E.2.d states, "WSDOT shall also select one flow reduction strategy BMP (such as LID) that is in use or planned for installation." The BMPs selected fulfill the flow reduction requirement in the permit and will be monitored in a paired study design.
BMP Quantity	S7.E.2 requires WSDOT to monitor at least two treatment BMPs, at no less than two sites per BMP. The BMP monitoring on I-5 northbound in the Everett area and I-5 southbound at Pilchuck satisfy this requirement.
BMP Location	S7.C.3.b requires the BMPs to be located at the following AADTs: • One highly urbanized site (≥100,000 AADT) • One urbanized site (≤100,000 and ≥30,000 AADT) • One rural site (≤30,000 AADT) BMP studies on I-5 and SR 9 satisfy these requirements.
Sampling Method	Monitoring guidelines in TAPE call for sampling using automatic samplers, except for chemical constituents that require manual grab samples. The automatic flow-weighted composite sampling scheme described in TAPE (pg 17) will consist of at least 75% of the storm event hydrograph, a minimum of 10 aliquots, and the storm must be at least 1 hour in duration. In accordance with S7.C.5, annual seasonal first flush toxicity samples will be collected either by flow-weighted or time-weighted programmed automatic composite samplers. If toxicity is collected by time-weighted composite, then these data cannot be used to meet TAPE criteria.
Sample Timing and Frequency	WSDOT will conduct sampling as early in the runoff event as feasible. At least 12 influent and 12 effluent samples will be monitored each year. Sampling will continue until the permit-required statistical goals of 90-95% confidence and 75-80% power are met for the parameters for which the BMP is approved in the HRM. If permit-required statistical goals are not achieved within the term of this permit, Ecology will consider continuing the monitoring effort in the next permit cycle. Additionally, WSDOT will collect a sample that represents the seasonal first flush event no earlier than August 1. If the first sampling attempt is unsuccessful despite good faith efforts or due to invalid or anomalous test results, a second attempt to collect a toxicity sample will be made if storm event criteria can be met. If the second attempt is unsuccessful, further sampling will not be required.
Storm Event Criteria (BMP Effectiveness Monitoring)	Storm event criteria are specified by TAPE for BMP effectiveness monitoring. TAPE storm event guidelines are: • Minimum storm depth for the total rainfall should be ≥ 0.15 inches. • Storm start/end (antecedent dry period) should be 6 hours minimum with less than 0.04 inches of rain. • Minimum storm duration should be ≥ 1 hour. • Minimum storm intensity to qualify as a rain event is specified as "none," given that the average intensities should exceed 0.03 inches per hour for at least half the sampled storms.
Storm Event Criteria (Seasonal First Flush Toxicity Testing)	Seasonal first flush toxicity shall be collected annually with at least a one-week antecedent dry period in August or September. If attempts in August or September are unsuccessful, an additional attempt should be made in October irrespective of the antecedent dry period.
Parameters	Permit-required sampling parameters for BMP characterization and seasonal first flush toxicity testing are listed in Table 13.

3-3 Data Collection

The permit monitoring implementation will begin on September 6, 2011; however, the 2013 Annual Monitoring Report is only required to cover monitored events that occur after October 1, 2011. During the three-week interim period, the following apply:

1. Sampling for dry season storms from September 6 to September 30 will not be conducted because the entire dry season will not be captured.
2. Because only one seasonal first flush toxicity storm event is required after August 1, this sample will still be attempted and reported regardless of whether the sampling occurs before or after October 1, 2011.
3. Missed storms will be documented.

To characterize site hydrology, data collection at some locations will begin before September. Monitoring will continue through the three-year permit cycle. Information to meet the permit objectives includes:

- Identification of highway pollutant-generating activity areas and drainage area maps of the selected characterization locations.
- Continuous annual records of rainfall data and site runoff flow data, not just sampled events, for at least one year.
- Concentrations of constituents of concern in samples collected.

To accomplish monitoring at all field sites as early in the runoff event as feasible, a data collection platform (DCP) consisting of composite autosamplers, a data logger, and associated equipment will be installed at each BMP effectiveness monitoring site.

Rainfall data will be collected continuously to characterize the antecedent dry period, total rainfall distribution during the sampled events, inter-event dry period, and rainfall intensity during the sampled storm events.

Data loggers at each site will record measurement data from the autosampler and all other associated monitoring equipment, such as the rain gage, stage measuring device, and temperature meter. Data from the logger will be manually downloaded as well as telemetered to WSDOT. Telemetered data will be restricted to the information most valuable to help with timing deployment of the sampling teams. More sampling and data collection information is presented in Section 7, Sampling Process Design.

3-3.1 Target Population and Sampling Frequency

For the stormwater monitoring effort under this permit, target stormwater populations are characterized by the following:

- Wet and dry season storm criteria
- Continuous rainfall and flow monitoring throughout all sampled storm events
- Composite sampling for chemical and biological analyses
- Grab sampling for chemical and biological analyses
- Seasonal first flush toxicity monitoring (at three sites)

The BMP effectiveness monitoring program is designed to collect stormwater data from at least 12 influent and 12 effluent samples, with a maximum of 35 events each year, based on guidance in S7.E.4.b of the permit and TAPE (Ecology, 2008a).

The statistical goal is to calculate the mean and median effluent concentrations and determine percent removals for each BMP type based on a 90–95 percent confidence and 75–80 percent power for the parameters for which the facility is approved in the HRM. To satisfy permit requirements, a seasonal first flush toxicity sample is also required to be collected annually.

3-3.2 Qualifying Sample Criteria

The TAPE protocol (Ecology, 2008a) defines "representative" storms that must be monitored when determining performance of treatment BMPs. Storm event criteria are established to: ensure adequate flow will be discharged, allow some build-up of pollutants during dry weather intervals, and ensure the storm will be representative (that is, typical for the area in terms of intensity, depth, and duration).

Ensuring a representative sample requires two considerations: the storm event must be representative, and the sample collected must represent the storm event. Table 1 lists the qualifying criteria to ensure the storm event sampled is representative. Samples will be collected from at least 75 percent of the runoff volume and will consist of a minimum of ten aliquots. These wet and dry storm event mobilization criteria are consistent with sampling criteria for highway characterization monitoring sites (S7.B.6).

3-3.3 Sampling Locations

To conserve resources, BMP effectiveness monitoring sites are co-located with highway runoff characterization sites to satisfy multiple permit monitoring requirements. However, there are several differences between the requirements for BMP and highway characterization, including:

1. Storm event criteria:
    - Highway characterization rainfall depth of 0.20-inch minimum.
    - BMP rainfall depth of 0.15-inch minimum.
2. Highway characterization requires several additional parameters to be measured.
3. Antecedent dry period:
    - BMPs: 6 hours, with less than 0.04 inches of rain.
    - Highway characterization: 24 hours in the wet season and 72 hours in the dry season, with less than 0.02 inches of rain.
4. Storm Duration:
    - Highway characterization: For storms lasting longer than 24 hours, at least 75 percent of the hydrograph of the first 24 hours must be sampled.
    - BMPs: 75 percent of the storm's total runoff volume must be sampled regardless of storm length.

Given these differences in criteria, the most stringent criteria will be followed for combined sites to allow data to be used for both BMP and highway characterization permit requirements. Storm

events where only one set of criteria (BMP or highway characterization) are met may still be sampled, but the data will only be used for the applicable purpose.

3-4 Practical Constraints for BMP Monitoring

Practical constraints for a successful permit monitoring program include:

- Study boundaries.
- Geographic limitations and climatic challenges.
- Study design requirements.
- Physical challenges of the study design.
- Logistical challenges regarding weather forecasting, verification of storm quality, and synchronization of sampling.

WSDOT will put forth good faith efforts to collect and meet this permit requirement. The phrase "good faith efforts" was used in the permits for the other Phase I permittees and is believed to apply to WSDOT as well, although it may have been inadvertently deleted. The following text is from the Phase I Municipal Stormwater NPDES and State Waste Discharge General Permit S8.D.2.a, page 45 (Ecology, 2010a):

> *Each stormwater monitoring site shall be sampled according to the following frequency unless good faith efforts with good professional practice by the Permittee do not result in collecting a successful sample for the full number of storms*.

3-4.1 Study Boundaries

BMP monitoring sites were selected based on WSDOT ownership of the BMP, representative drainage areas, safety of sampling, and permit-required average annual daily traffic (AADT) levels.

3-4.2 Geographic Limitations and Climatic Challenges

During the winter, western Washington storms are typically long in duration (multiple days) and frequent. An additional challenge is the ambiguity of forecasting rain, particularly in western Washington.

Large stormwater volumes are required to analyze for seasonal first flush toxicity samples. Adequate stormwater volumes may or may not be available for the first two qualifying storms of the fall season.

3-4.3 Study Design Requirements

The selection of BMPs to monitor under the permit were governed by several factors:

- BMPs meet "current" HRM standards; the 2008 HRM was the current version at the time of permit issuance.
- Most of WSDOT's existing BMPs were built before the 2008 HRM; therefore, finding newer BMPs for monitoring has been a priority.

- Finding suitable BMPs within specific traffic levels to match the toxicity requirements proved to be more difficult than expected for the rural AADT requirements.

In all, more than 20 BMP locations were considered for monitoring. Most of the BMPs were ruled out because they were located in areas that would pose complications for monitoring (such as lack of a safe area for sample collection) or they did not meet permit criteria; for example, the media filter drain represents a BMP of importance to WSDOT, but suitable locations meeting the AADT criteria were not found, or for other BMP types, monitoring pairs could not be established.

The solution to a shortage of BMPs that met both the permit monitoring requirements and WSDOT's interests for monitoring was found by coordinating two programs' interests. These programs at WSDOT are the:

- Highway Runoff Program, which conducts research to inform future guidelines and design specifications in the HRM.
- Stormwater and Watersheds Program, which is in charge of stormwater monitoring for permit compliance.

WSDOT prioritized monitoring certain BMPs to gather information on effectiveness that met the needs of both programs. Current research interests and permit monitoring priorities for BMPs are: media filter drains, compost-amended biofiltration swales, and compost-amended vegetated filter strips.

These two programs will work together to monitor stormwater BMPs for permit compliance and to inform the HRM.

3-4.4 Physical Challenges of the Study Design

The BMPs selected for monitoring include VFS, CAVFS, and the modified VFS. All three BMPs are infiltration-type BMPs that are designed to treat sheet flow runoff by infiltration. By incorporating the runoff into a soil or compost matrix, water quantity is reduced and water quality is improved. These BMPs are discussed in greater detail in Section 2-2.

Practical Constraints for Biofiltration BMPs

TAPE requires stormwater sediment samples to be collected from the BMPs to assess accumulation of sediment or sediment treatment. However, collecting sediment from infiltration-type BMPs such as VFS and CAVFS that use grass and soil or compost, grass, and soil as filtration media poses a challenge, because these BMPs are not designed to collect sediment. Sampling representative stormwater sediment is not feasible since there is no technique to ensure the collected sediment represents only stormwater-carried sediment and not components of the BMP's soil or compost. Therefore, sediment samples from BMPs will not be collected.

A further constraint that may affect sampling success is related to how well the chosen BMP types function to slow runoff velocities, trapping sediment and other pollutants, and providing some infiltration and biological uptake. Depending on the size of the storm and environmental conditions, effluent may or may not be discharged.

3-4.5 Logistical Challenges

Some of the logistical challenges associated with this project include:

- Monitoring small, flashy drainage areas that contribute to the BMPs
- The complexity and variability of stormwater discharge
- Requirements to sample the whole runoff event
- The large geographic scale of the monitoring site locations
- Unpredictable environmental conditions at sites
- Limitations due to laboratory personnel
- Sampling equipment programming limitations

Drainage Area Logistical Challenges

The drainage areas for the selected monitoring locations are small. This is unavoidable due to the goal of capturing runoff from the road surface. Stormwater rapidly runs off the road surface instead of being slowed by soil or vegetation to the edge of pavement (EOP).

Stormwater Discharge Logistical Challenges

The EOP influent collectors are anticipated to receive adequate amounts of runoff for sampling. However, since one of the purposes of the three BMP types selected is flow reduction and infiltration, reduced volumes will be available for sampling in the 2-meter and 4-meter effluent monitoring sites. This reduced sample volume may make it difficult to collect enough sample for analysis, particularly for toxicity sampling, which requires large sample volumes.

Storm Duration Logistical Challenges

To meet the requirements under TAPE, the permit sampling must be collected to represent 75 percent of the hydrograph for each storm event. This presents a challenge for storms that last many days, which is typical in western Washington. Sampling crews will have to closely monitor the samplers to make sure that the sample bottles are replaced before overflowing occurs and that the samples are cooled for the duration of the sampling until the entire sample can be composited.

Several bottles may be required in order to collect the entire storm event. The resulting large quantity of stormwater must be kept cooled and be available throughout the storm so samples can be filtered and preserved when the storm ends (filtration must occur within 15 minutes of the last aliquot). Compositing samples from multiple bottles may prove difficult due to time constraints for filtering, handling multiple bottles, and organizing the compositing process. The compositing process may include filling sample bottles individually with aliquots from each composite or creating a large composite sample that is then allocated to the sample bottles.

Geographic and Climatic Logistical Challenges

Logistical complications are anticipated to reduce sampling success. Three BMP monitoring sites are located at least 90 miles or more from where the WSDOT sampling team will be based in Tumwater. Samples could be missed due to the amount of driving time necessary to reach the BMPs, even if the field sampling teams stay in hotels near the sites. The geographic scope of the monitoring locations requires advanced warning of qualifying storm events to allow travel time. However, the variability of Washington's precipitation patterns increases the difficulty of predicting storms.

Successful sampling and monitoring will require a well-developed, automated field data collection system and supporting monitoring team. WSDOT will train staff and maintain a field crew that will likely deploy to the field location or a local hotel when a promising forecast occurs during the work week. Telemetered data reporting and automated sample collection will be utilized to accomplish the monitoring goals by improving the successful rate of storm event sampling. Nonetheless, travel times and storm dynamics will likely be major factors contributing to missing some of the holding times for filtration of dissolved metals and orthophosphate.

Automatic samplers will be programmed to collect composite samples for water quality monitoring as soon as the sampling thresholds programmed in the logger are met. Grab samples may be missed due to the flashy nature of storms and the potential for limited availability of representative runoff. Timing of the sampling will be difficult because the samples must be collected by hand and require staff to be on-site within the first hour of runoff.

Environmental Logistical Challenges

Damage from storm events (e.g., washouts or flooding) or the immediate environment (e.g., trees falling or traffic accidents) may present limitations for stormwater monitoring. Site equipment design and implementation will identify, remove, or prevent equipment damage or safety hazards. By utilizing telemetry, WSDOT will be able to identify malfunctions, errors, and damaged equipment via the hourly transmission from each station. Field staff will be dispatched as soon as feasible to repair or replace damaged equipment.

Laboratory Logistical Challenges

Several of the sample parameters have short holding times that will require laboratories to process samples possibly within 8 hours of receiving them. Many laboratories, including Manchester Environmental Laboratory in Port Orchard, do not maintain 24-hour and 7-day-a-week staffing levels. Some labs have limited working hours on weekends. As a result, the days and times of the sampling program may be limited to the following proposed schedule:

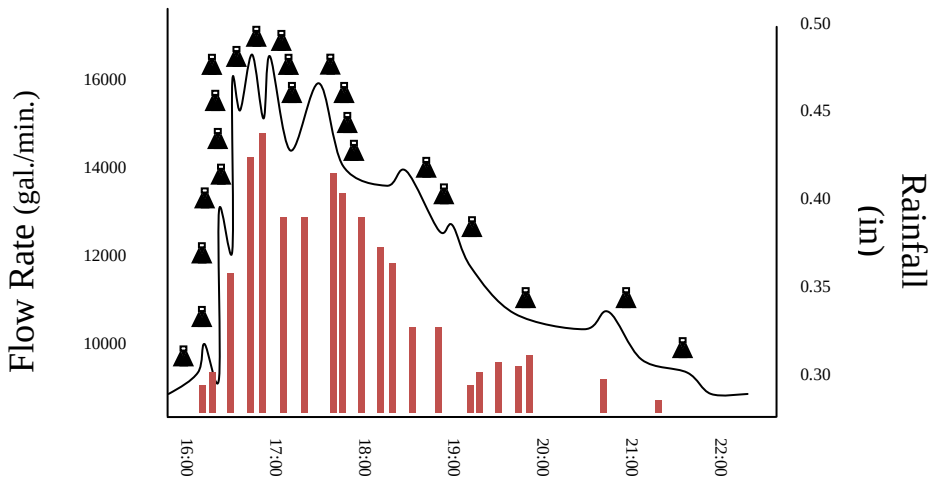
- Sample during weekdays until noon on Fridays.
- Do not sample on Saturdays or on Sunday mornings.
- Sampling late (after 3:00 pm) Sundays is a possibility.

Instrumentation and Programming Logistical Challenges

Automatic samplers will be programmed to collect flow-weighted composite samples for water quality monitoring and flow or time-weighted composite samples for toxicity parameters. Figure 3 shows how samples of equal volume are collected at equal increments of flow volume in a flow-weighted compositing scheme. Figure 4 shows how samples of equal volume are collected at equal increments of time in a time-weighted compositing scheme from the Standard Operating Procedure for Automated Sampling for Stormwater (Ecology, 2009b).

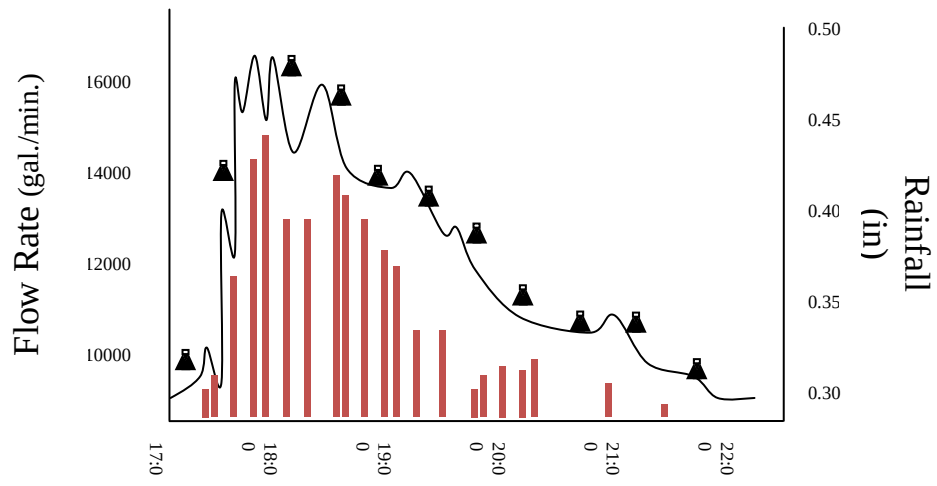
The potential for human programming errors is a possibility when operating any monitoring equipment. While some testing will be conducted prior to sampling, there will likely be a continuous need to monitor and adjust programming to meet permit requirements given site conditions. Care will be taken to follow standard operating procedures (SOPs) in an effort to minimize human programming errors. Field staff will be prompted to notify the Field Lead or check the NOAA Emergency Data Distribution Network website to verify station transmissions after any alterations to programming.

A loss of power to any of these stations may inhibit monitoring by turning the data logger and automatic sampler off. To avoid power loss, field staff will visit each station on a six-week rotational maintenance schedule or earlier for storm event sampling. During scheduled maintenance trips, batteries and solar panels will be maintained according to standard operating procedures.



Constant Volume/Constant Flow Volume Increment: Samples of equal volume are taken at equal increments of flow volume and composited (Ecology 2009b).

Figure 3 Flow-weighted compositing schemes.



Constant Time/Constant Volume: Samples of equal volume are taken at equal increments of time and composited to make an average sample (Ecology 2009b).

Figure 4 Time-weighted compositing schemes.

4 Organization and Schedule

The following section describes the roles and responsibilities of the key participants, including WSDOT's Stormwater and Watersheds Program and staff from Ecology. The organizational structure was designed to provide project control and proper quality assurance and quality control (QA/QC) for the field investigations.

4-1 Organization

The roles of key individuals involved in the study are presented in Table 2. A detailed description of the lines of authority and reporting between these individuals and organizations is provided. WSDOT staff may delegate their responsibilities to other staff when they are not present or are busy with other tasks. This allows for adaptive management of the monitoring program responsibilities and may be necessary to meet permit requirements. If responsibilities are delegated, staff will still be responsible for ensuring their responsibilities were carried out properly in their absence.

4-1.1 Training

Field personnel will receive training in proper sampling and field analysis for each SOP they will be using. They will demonstrate to the Field Lead their ability to properly operate the automatic samplers and retrieve the samples. The Field Lead will verify that each field staff member is adequately prepared to operate equipment and collect samples.

A field audit will be performed at least annually to verify proper methods and techniques. In addition, a follow-up meeting at the end of the water year will be organized to discuss methods and procedures. Stormwater monitoring crews will receive training for working in wet, cold, and poor-visibility conditions. Monitoring personnel and workers who install or maintain equipment may be exposed to traffic hazards, confined spaces, and slippery conditions. They may need confined space entry training.

Monitoring crews will be trained on the traffic control plan for sites that expose them to traffic hazards. A traffic safety plan and safety guidelines for use while conducting monitoring or maintenance activities at field sites are presented in Appendix D. These traffic controls were adapted from WSDOT's *Work Zone Traffic Control Guidelines* (WSDOT, 2009b). The safety plans specify personal protective gear and include a Pre-Activity Safety Plan for Stormwater Field Work form, which is to be filled out on each site visit.

Table 2 Organization of project staff and responsibilities.

Name	Roles	Responsibilities
WSDOT Stormwater and Watersheds Program Staff		
Fred Bergdolt	NPDES Stormwater Monitoring Project Manager	Manages overall WSDOT compliance activities; verifies whether or not the QAPP is followed and the project is producing data of known and acceptable quality; ensures adequate field training and supervision of all monitoring staff; complies with corrective action requirements.
Sarah Burdick	Quality Assurance Officer	Develops a quality management system for stormwater monitoring; oversees all operations, identifying whether QA/QC goals are met; validates and aids in verifying data collected; assists with the monitoring reports to Ecology.
Janice Sloan	Data Steward	Acquires data from telemetered systems and contract laboratories; verifies and transfers data collected into databases; manages laboratory contracts; analyzes and interprets data; assists with reports to Ecology.
Zackary Holt	Field Lead	Manages and oversees stormwater monitoring activities, sampling decisions, and equipment maintenance; manages internal and external field teams. Served as co-author during QAPP development and site design.
Brad Archbold	Logistics Lead	Coordinates with laboratories and field staff to ensure sampling equipment and bottles are tracked and distributed; cleans, calibrates, and organizes monitoring equipment.
Field Crew x 2	Field Sampling	Assist in collecting and processing of field composite and grab samples.
WSDOT staff	Field Sampling / Project Reporting	WSDOT region staff assist in collecting and processing field composite and grab samples. WSDOT HQ staff assist with storm forecasting activities and in writing the draft and final reports.
ECOLOGY Staff		
Foroozan Labib, Water Quality Program	Permit Coordinator	Reviews and approves QAPPs and project deliverables from WSDOT to Ecology for NPDES Municipal Stormwater Permit implementation.
Julie Lowe, Water Quality Program	Permit Monitoring Coordinator	Reviewed monitoring elements and provided advice/comments for QAPP development during the period of Feb. 2009 to June 2011.
Brandi Lubliner, Toxic Studies Unit, EAP	Project Manager (WSDOT Contractor)	Lead author for QAPP development and site design; assisted in site set up; coordinated technical lead duties and analytical contracts during the period of Aug. 2009 to April 2011.

EAP = Environmental Assessment Program, within Ecology

QAPP = Quality Assurance Project Plan

4-2 Schedule

Table 3 lists key deadlines for WSDOT under the permit. This schedule reflects the extension in time due to the exceedance of the 90-day review time frame by Ecology's Water Quality Program's (WQP).

Table 3 Key deadlines for QAPPs and reports.

Date Due	Description
September 6, 2010	Draft QAPPs due from WSDOT to Ecology's WQP (submitted September 2, 2010).
October 31, 2010	SWMP Progress Report and First Stormwater Monitoring Report on status of preparations to meet permit conditions S7.A through S7.E.
November 30, 2010	Ecology's WQP reviews the QAPPs within 90 days and responds with comments to WSDOT. Since Ecology's WQP did not meet the 90-day review period (returned QAPPs to WSDOT on 1/3/2011), the QAPP approval deadline is extended by the equivalent number of days per permit condition S7.G.
April 16, 2011	The deadline for revised QAPPs submittal to Ecology's WQP for approval is extended from March 6 to **April 16, 2011**. The WQP has recommended WSDOT submit the QAPP three weeks prior to the approval deadline to allow time for the WQP to approve the QAPP by the approval deadline.
September 6, 2011	Final QAPPs due to Ecology's WQP, with all revisions complete.
September 6, 2011	Full implementation of the monitoring program begins. Collection of toxicity monitoring data for reporting begins.
October 1, 2011	Collection of monitoring data for reporting begins.
October 31, 2011	Second Stormwater Monitoring Report on status of preparations to meet permit conditions S7.A through S7.E.
October 31, 2012	Third Stormwater Monitoring Report on status of preparations to meet permit conditions S7.A through S7.E.
October 31, 2013	Fourth Stormwater Monitoring Report will be prepared and submitted with the Annual SWMP Progress Report, covering data collected from October 1, 2011–September 30, 2012, described in S8.F of the permit. This will be the first time a monitoring report will be submitted with the annual report. BMP effectiveness interim results will not be included. Only toxicity results from BMP monitoring will be discussed.
February 6, 2014	A Final Water Quality Monitoring Report for each program outlined in S7 is due to Ecology's WQP. BMP effectiveness interim results will not be included. Only toxicity results from BMP monitoring will be discussed.
Date to be determined	A final report on each BMP monitored will be submitted once the monitoring statistical goals are met. This may or may not occur after the Final Water Quality Monitoring Report is due.

5 Quality Objectives

A primary purpose of this QAPP is to ensure data collected for the WSDOT stormwater permit are scientifically and legally defensible and meet the requirements of WSDOT's permit. This section primarily discusses the chemical quality assurance (QA) topics for stormwater. Biological and chemical toxicity guidance (see Appendix C) and quality assurance criteria are also discussed.

The permit requires that some data quality objectives from Ecology's Technology Assessment Protocol (TAPE) process (Ecology, 2008a) or 40 CFR 136 are followed. All data quality objectives are discussed.

5-1 Data Quality Objectives (DQOs)

DQOs are qualitative and quantitative statements developed using the data quality objectives process. This process clarifies study objectives and defines the appropriate type of data and tolerable levels of potential errors. The DQOs for WSDOT's stormwater monitoring projects are as follows:

1. The data will be generated according to set criteria and procedures for field sampling, sample handling and processing, laboratory analysis, and record keeping.
2. The data will be representative of the monitoring site and be of known precision, bias, and accuracy.
3. Data reporting and analytical sensitivity will be clearly established and adequate for stormwater management program decisions and endpoints.

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

5-2 Measurement Quality Objectives (MQOs)

MQOs are the acceptance thresholds for data, based on the data quality indicators, and are specifically used to address instrument and analytical performance.

Quality control (QC) is often confused with the term quality assurance (QA). Quality control (discussed further in Section 10) refers to a set of standard operating procedures for the field and laboratory that are used to evaluate and control the accuracy of measurement data. Quality assurance is a decision-making process, based on all available information, that determines whether the data are usable for all intended purposes (Ecology, 2004).

The QA decision-making process relies on measurable values, such as MQOs, that specify how good the data must be in order to meet the objectives of the study. MQOs established for WSDOT stormwater permit monitoring are based on guidance from multiple sources, which include EPA, Ecology, laboratory experience, and best professional judgment. The hierarchy of guidelines to be followed in descending order is:

1. Permit (Ecology, 2009a) (and TAPE [Ecology, 2008a] for BMP stations)
2. 40 CFR 136
3. Guidance documents referred to in the permit
4. Other guidance documents from:
    - Ecology, such as standard operating procedures (SOPs), and
    - EPA, such as *Methods and Functional Guidelines* (USEPA, 2008 and 2010), and 2002 EPA guidance on Environmental Data Verification and Data Validation (USEPA, 2002a)
5. Best professional judgment

MQOs are the performance or acceptance thresholds or goals for the study's data, based primarily on the data quality indicators (DQIs). DQI performance measures are expressed in terms of:

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

Measurements to address these DQIs are shown in Tables 4, 5, and 6, and further descriptions are provided in the following sections. Tables 4, 5, and 6 represent how the data will be verified by WSDOT to assess sensitivity, accuracy, precision, and comparability. Failure to meet the MQOs may result in data being qualified or rejected.

Refer to Section 9, Measurement Procedures, for a thorough discussion of laboratory-specific MQOs.

Table 4 Measurement quality objectives for chemical analysis of stormwater (Ecology, 2009a and 2011; USEPA, 2010 and 2008).

Parameter	Reason for Monitoring[1]	Lowest Conc. of Interest (Reporting Limit)	Lab Duplicate[2] (RPD)	Matrix Spike[3] (% Rec*)	Matrix Spike Duplicate (RPD)	Control Standard (LCS)/ Surrogate Standard[6] (% Rec*)
MQO		**Sensitivity**	**Bias and Precision**	**Bias and Accuracy**	**Bias and Precision**	**Bias and Accuracy**
Conventionals						
TSS	BMP, Tox, Hwy	1 mg/L	≤20%	n/a	n/a	80–120
Chloride	Tox, Hwy	0.2 mg/L	≤20%	75–125	≤20%	90–110
Hardness as $CaCO_3$[5]	BMP, Tox, Hwy	1 mg/L	≤20%	75–125	≤20%	70–130
Particle size distribution	BMP	n/a	≤20%	n/a	n/a	n/a
pH	BMP, Tox, Hwy	0.2 units	≤5%	n/a	n/a	n/a
Nutrients						
Total phosphorus (TP)	BMP, Hwy	0.01 mg/L	≤20%	75–125	≤20%	80–120
Orthophosphate (OP)	BMP, Hwy	0.01 mg/L	≤20%	75–125	≤20%	80–120
Metals						
Total recoverable (Cu, Zn)[5]	BMP	(0.1, 5.0) µg/L	≤20%	75–125	20%	70–130
Dissolved(Cu, Zn)[5]	BMP	(0.1, 1.0) µg/L	≤20%	75–125	20%	70–130
Total recoverable (Cu, Pb, Cd, Zn)[5]	Tox, Hwy	(0.1, 0.1, 0.2, 5.0) µg/L	≤20%	75–125	20%	70–130
Dissolved (Cu, Pb, Cd, Zn)[5]	Tox, Hwy	(0.1, 0.1, 0.1, 1) µg/L	≤20%	75–125	20%	70–130
Organics						
PAH Compounds:	Tox, Hwy					
Acenaphthene		0.1 µg/L	≤40%	55–97	≤40%	40–112
Acenaphthylene		0.1 µg/L	≤40%	48–103	≤40%	10–126
Anthracene		0.1 µg/L	≤40%	51–113	≤40%	24–127
benzo[a]anthracene		0.1 µg/L	≤40%	59–137	≤40%	38–147
benzo[b]fluoranthene		0.1 µg/L	≤40%	53–99	≤40%	42–116
benzo[k]fluoranthene		0.1 µg/L	≤40%	33–122	≤40%	38–131
benzo[ghi]perylene		0.1 µg/L	≤40%	38–110	≤40%	12–122
benzo[a]pyrene		0.1 µg/L	≤40%	42–110	≤40%	14–129
chrysene		0.1 µg/L	≤40%	51–116	≤40%	37–128
dibenzo[a,h]anthracene		0.1 µg/L	≤40%	27–129	≤40%	10–134
fluoranthene		0.1 µg/L	≤40%	60–107	≤40%	42–123
fluorene		0.1 µg/L	≤40%	50–134	≤40%	50–134
indeno[1,2,3-cd]pyrene		0.1 µg/L	≤40%	37–135	≤40%	29–129
naphthalene		0.1 µg/L	≤40%	41–97	≤40%	41–105
phenanthrene		0.1 µg/L	≤40%	18–105	≤40%	18–105
pyrene		0.1 µg/L	≤40%	61–118	≤40%	43–131
PAH Surrogates:	Tox, Hwy					
Terphenyl-D_{14}		n/a	n/a	n/a	n/a	34–148
2-Fluorobiphenyl		n/a	n/a	n/a	n/a	28–136
Acenaphthylene-D_8		n/a	n/a	n/a	n/a	50–150
Fluorene-D_{10}		n/a	n/a	n/a	n/a	50–150
Anthracene-D_{10}		n/a	n/a	n/a	n/a	50–150
Pyrene-D_{10}		n/a	n/a	n/a	n/a	48–143
Benzo(a)pyrene-D_{12}		n/a	n/a	n/a	n/a	50–150
Phthalates:	Tox, Hwy					
bis(2-Ethylhexyl)phthalate		1.0 µg/L	≤40%	61–131	≤40%	80–128
Butyl benzyl phthalate		1.0 µg/L	≤40%	80–150	≤40%	23–183

Table 4 (continued) Measurement quality objectives for chemical analysis of stormwater (Ecology, 2009a and 2011; USEPA, 2010 and 2008).

Parameter	Reason for Monitoring[1]	Lowest Conc. of Interest (Reporting Limit)	Lab Duplicate[2] (RPD)	Matrix Spike[3] (% Rec*)	Matrix Spike Duplicate (RPD)	Control Standard (LCS)/ Surrogate Standard[6] (% Rec*)
MQO		**Sensitivity**	**Bias and Precision**	**Bias and Accuracy**	**Bias and Precision**	**Bias and Accuracy**
Di-n-butyl phthalate		1.0 µg/L	≤40%	73–148	≤40%	70–156
Diethyl phthalate		1.0 µg/L	≤40%	79–117	≤40%	77–123
Dimethyl phthalate		1.0 µg/L	≤40%	73–126	≤40%	74–122
Di-n-octyl phthalate		1.0 µg/L	≤40%	61–148	≤40%	75–135
Phthalate Surrogates:	Tox, Hwy					
Dimethylphthalate-D_6		n/a	n/a	n/a	n/a	50–150
Herbicides:[4]	Tox, Hwy					
Dichlobenil		0.033 µg/L	≤40%	50–150	≤40%	50–140
Diuron		0.05 µg/L	≤40%	50–150	≤40%	50–140
2, 4-D		0.0625 µg/L	≤40%	20–150	≤40%	25–140
Clopyralid		0.0625 µg/L	≤40%	20–150	≤40%	21–140
Picloram		0.0625 µg/L	≤40%	10–100	≤40%	10–100
Triclopyr		0.0625 µg/L	≤40%	50–150	≤40%	50–140
Glyphosate		25 µg/L[8]	≤40%	50–150	≤40%	50–140
Herbicide Surrogates:						
2,4,6-Tribromophenol		n/a	n/a	n/a	n/a	33–99
2,4-Dichlorophenylacetic acid		n/a	n/a	n/a	n/a	37–91
1,3-Dimethyl-2-nitrobenzene		n/a	n/a	n/a	n/a	41–135
Surfactants:	Tox					
Methylene blue active substances (MBAS)		0.025 mg/L	Meet all performance criteria in lab method relative to sample replication and reference toxicant.			
TPH:	Tox, Hwy					
TPH-Diesel (NWTPH-Dx)		0.25-0.5 mg/L[7]	≤40%	70-130	≤40%	70-130
TPH-Gas (NWTPH-Gx)		0.25 mg/L	≤40%	70-130	≤40%	70-130
TPH Surrogates:	Tox, Hwy, BMP					
Pentacosane		n/a	n/a	n/a	n/a	50-150
1,4-Difluorobenzne		n/a	n/a	n/a	n/a	70-130
Benzene, 1,4-dibromo-2-methyl-		n/a	n/a	n/a	n/a	70-130

[1] Parameter required by permit under S7.E BMP effectiveness (BMP), S7.B highway monitoring (Hwy), or S7.C seasonal first flush toxicity testing (Tox).

[2] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit. RPD must be ± 2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.

[3] For inorganics, the *Contract Laboratory Program Functional Guidelines* state that spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of four or more (USEPA, 2010).

[4] Limited to the herbicides as listed in the permit and used within the drainage area by WSDOT. This list may decrease based on usage records from WSDOT. This list will be updated annually.

[5] Method Quality Objectives (matrix spike & LCS values) are based on *Contract Laboratory Program Functional Guidelines* for inorganic data review (USEPA, 2010) and organic data review (USEPA, 2008). All other values were obtained from Manchester Environmental Laboratory performance criteria (Ecology, 2011).

[6] For PAHs and phthalates, both deuterated and nondeuterated monitoring compounds are the surrogate standards.

[7] The reporting limit depends on the hydrocarbons detected. The lighter the hydrocarbons, the lower the limit; therefore, a range is used for the acceptable reporting limit.

[8] Results for glyphosate analysis between the RL of 25 ug/L and MDL of 2.5 ug/L will be reported. These results will be qualified as estimates.

* Recovery

Table 5 Measurement quality objectives for biological analysis of stormwater (Ecology, 2009a; USEPA, 2010 and 2008).

Test	Temp	Animal Age	Acclimation Period	Aeration	Water[1] and Substrate	Control of Performance
	(°C)	(Days)	(Days)	(mg/l)	n/a	(Survival)
Hyalella azteca (controlled and tested organisms) 24-hr acute toxicity test	23±1	7–14, 1–2 day range in age	Feed ground cereal leaf prior to testing; no feeding during testing	If D.O. is below 4.0	Moderately hard synthetic water on square of nitex screen	≥90% survival in negative control and reference (if provided)

[1] Stormwater sample hardness may be adjusted to match receiving water hardness.

Table 6 Measurement quality objectives for chemical analysis of sediments (Ecology, 2009a and 2011; USEPA, 2010 and 2008).

Parameter	Lowest Concentration of Interest (Reporting Limit)	Lab Duplicate[1] (RPD)	Matrix Spike[2] (% Rec*)	Matrix Spike Duplicate (RPD)[3]	Control Standard (LCS)/ Surrogate Standard (% Rec*)[4]
MQO	**Sensitivity**	**Bias and Precision**	**Bias and Accuracy**	**Bias and Precision**	**Bias and Accuracy**
Conventionals					
Particle size (grain size)	n/a	≤20% RSD[7]	n/a	n/a	n/a
Total volatile solids	0.1%	≤20%	n/a	n/a	n/a
Total solids	n/a	≤20%	n/a	n/a	n/a
Nutrients					
Total phosphorus (TP)	10.0 mg/Kg dry	≤20%	75–125	≤20%	70–130
Metals					
Total recoverable (Cu, Pb, Cd, Zn)[5]	(0.1, 0.1, 0.1, 5.0) mg/Kg dry	≤20%	75–125	≤20%	80–120
TPH and Surrogate					
TPH-Diesel (NWTPH-Dx)	25.0–100.0 mg/Kg dry[8]	n/a	n/a	n/a	70–130
Pentacosane	n/a	n/a	n/a	n/a	50–150

[1] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit. RPD must be ±2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.

[2] For inorganics, the *Contract Laboratory Program Functional Guidelines* states that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (USEPA, 2010).

[3] The matrix spike duplicate RPD is applied when the analyte concentration is greater than the practical quantitation limit (PQL).

[4] Surrogates are used only for some analyses.

[5] Method Quality Objectives (matrix spike & LCS values) are based on *Contract Laboratory Program Functional Guidelines* for inorganic data review (USEPA, 2010) and organic data review (USEPA, 2008). All other values were obtained from Manchester Environmental Laboratory performance criteria (Ecology, 2011).

[6] Grain size requires a triplicate analysis; therefore, a relative standard deviation (RSD) is calculated.

[7] The reporting limit depends on the hydrocarbons detected. The lighter the hydrocarbons, the lower the limit; therefore, a range is used for the acceptable reporting limit.

* Recovery

5-2.1 Sensitivity

Sensitivity is the measure of the concentration at which an analytical method can positively identify and report analytical results. The sensitivity of a method is commonly called the "detection limit." In fact, there are multiple and different limits in analytical analyses and reporting.

- Instrument detection limit (IDL)
- Method detection limit (MDL)
- Practical quantitation limit = reporting limit (RL)

The "reporting limit" expressed in the permit refers to the practical quantification limit established by the laboratory, not the method detection limit. Refer to Section 9, Measurement Procedures, for more information.

Ecology specified the reporting limits and analytical methods in the permit's Appendix 5, and they are restated in Tables 4 and 6. MQOs that were not stated in the permit's Appendix 5 were based on other sources, such as the Manchester Environmental Laboratory's *Laboratory Users Manual*, 9th Edition (MEL, 2008), and the EPA's published guidelines for the Contract Laboratory Protocols (CLP) for inorganic and organic data (USEPA, 2008 and 2010).

5-2.2 Bias and Blanks

Bias represents systematic error and can be used to describe a tendency or preference in one direction. Bias in water quality samples will be assessed based on the analyses of method blanks, field blanks, transport blanks, matrix spikes, and laboratory control samples (LCS).

A hydrologic example of bias can be described as: the difference between instrument readings and an independently measured "true" value.

- Bias in rain gage measurements will be assessed by comparing known volumes of water to the rain gage's measurements.
- Bias in stage measurements will be assessed by comparing field observations of stage (at the weir or flume) with collected stage data in the data logger during a rain event.
- Hydrological biases from temperature can be checked by observing temperature readings to check for frozen water.
- Bias from sediment accumulation behind weirs will be managed with regular cleaning and removal of debris that has settled behind the weirs.

Field Sample Bias and Blanks

Field blank results greater than the reporting limit (RL) will be flagged as blank contamination (*B*). The associated project samples collected with that blank sample will be scrutinized by the Quality Assurance Officer upon receipt of the laboratory report. Depending on the type of blank collected (trip, transfer, or equipment), the Field Lead should be notified as soon as possible to re-run the blank and reclean the equipment that may have contaminated the field blank. Typically, associated project samples within five times the blank concentration will be qualified as an estimate (*J*). Data flagged with a *B* and qualified as *J* due to blank contamination will not be considered valid for TAPE compliance.

Laboratory Bias and Blanks

The following sections describe the differences between method blanks and matrix spikes, both of which are used to identify potential biases affecting results.

Blanks

Laboratory method blanks should not exceed the reporting limit. If this occurs, the associated blank concentration is defined as the new reporting limit. For all samples with identified contaminants, the sample concentration must be at least five times the method blank concentration for the result to be considered valid, per TAPE guidelines (Ecology, 2008a). Sample concentrations within this five times de facto reporting limit will be flagged by the laboratory as *B*, associated project data reviewed and qualified as *U* or *J*, and the WSDOT Data Steward will be alerted to the contamination. Common laboratory contaminants within ten times the de facto reporting limit will be flagged as *B*, per CLP guidance. WSDOT will determine how many samples are affected and if corrective actions are necessary.

Matrix spikes (Bias)
The targeted range for percent recovery of matrix spikes and matrix spike duplicates (ms/msd) varies according to the parameter, as shown in Table 4 and 6. Percent recovery for matrix spikes will be calculated using Equation 1 (Ecology, 2004).

Equation 1: Percent recovery for MS/MSD

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

Where:

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

Laboratory Control Sample (LCS) (Bias)

The laboratory control sample (LCS) serves as a monitor of the overall performance of each step during the analysis, including the sample preparation (USEPA, 2010). The goals for percent recovery of LCS vary for each parameter. Percent recovery for LCS will be calculated using Equation 2 (USEPA, 2010).

Equation 2: Percent recovery for LCS

$$\%\mathrm{R} = \frac{M}{T} \times 100\%$$

Where:

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

5-2.3 Representativeness

Representativeness is a qualitative measure of the degree to which sample data represent characteristic environmental conditions or, more specifically, site conditions. Representativeness of the hydrologic data will be ensured by proper site selection and proper selection, installation, and maintenance of all associated monitoring equipment. Rainfall patterns, stormwater conveyance features, and surrounding land uses are the elements that were considered in the identification of monitoring locations and sampling frequencies. Hydrologic monitoring will be conducted over a sufficient length of time to ensure data are collected during representative climatic conditions for the region. "Target events" will be triggered by rainfall amounts, so that the runoff will be representative of the specified storm criteria.

Representativeness of the water quality data from WSDOT BMP sites will be ensured by targeting criteria set forth in S7.B, S7.C, and S7.E of the permit and listed in Table 1. It is understood that these data will systematically not include very low-volume storms or the long intermittent storms typical of the Northwest.

Representativeness of the samples can also be evaluated by analysis of field replicates. Field variability found using composite techniques may be different from the field variability found between replicate grab samples. Any sample data may be deemed "nonrepresentative" and rejected by the Quality Assurance Officer or Data Steward if any of these criteria are not met.

The representativeness of the seasonal first flush toxicity data will be ensured by employing consistent and standard sampling procedures. If sampling requirements cannot be met in the first two qualified seasonal first flush storm events, the representativeness of seasonal first flush characteristics will be considered unmet and this type of sampling will be discontinued.

5-2.4 Precision

Precision is the measure of nearness of repeated measurements to the same value over time. Precision of samples and data collected will be evaluated using field replicate and laboratory duplicate sample analyses. Poor precision of field replicates may be due to heterogeneity of the stormwater and entrained sediments, which has been a fairly common problem in stormwater characterization studies. Field replicates may be evaluated at the targeted relative percent difference (RPD) or relative standard deviation (RSD) as listed in Tables 4 and 6. Other reasons for poor precision may include problems with sampling, contamination, or poor sensitivity of the analytical methods. Bias and blanks will assist with determining a reason for poor precision.

Analytical precision is measured using laboratory duplicate (split) samples for inorganic analyses and matrix spike/matrix spike duplicate (ms/msd) samples for organic analyses. Poor laboratory precision may indicate:

- Poor sample homogenization
- High sample heterogeneity
- Matrix interferences
- Poor sample handling in the laboratory
- Contamination of laboratory chemicals or equipment
- Poor sensitivity of the analytical methods

Laboratory duplicates are generally performed by splitting one sample into two and performing the analysis separately on each split. Matrix spikes and matrix spike duplicates (ms/msd) are prepared by adding a known concentration of a compound to the sample and determining the concentration of that spike in the sample matrix. The matrix spike and matrix spike duplicate are compared to provide an estimate of the precision of the laboratory method.

Often in stormwater samples, the poor recovery of the ms/msd data will help quantify the interferences that may be part of the original (native) sample.

Precision of a duplicate pair is calculated as the relative percent difference (RPD), which is usually expressed as a percentage (shown in Equation 3) (Ecology, 2004).

Equation 3: Relative percent difference

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

Where:

RPD = relative percent difference
C_1 = concentration of original sample
C_2 = concentration of duplicate
$\bar{x}$ = mean of samples

Precision of more than three samples is calculated as the relative standard deviation (RSD), which is expressed as a percentage (shown in Equation 4) (Ecology, 2004).

Equation 4: Relative standard deviation

$$\text{RSD} = \frac{\text{S}}{\bar{x}} \times 100\%$$

Where:

RSD = percent relative standard deviation
S = standard deviation
$\bar{x}$ = mean of samples

5-2.5 Accuracy

Accuracy is the measure of agreement between a measurement's result and the true or known value. Analytical accuracy can be found by analyzing known reference materials or known standards (LCS, ms/msd, and/or surrogates). A common metric is the percent recovery of a spike. Factors that influence analytical accuracy include laboratory calibration procedures, sample (field and laboratory) preparation procedures, and laboratory equipment or deionized water contamination.

Accuracy is calculated as the percent recovery, which is usually expressed as a percentage (see Equation 1).

5-2.6 Completeness

Completeness is the percentage of measurements judged to be valid over the total number of measurements compared to the amount of data deemed necessary to meet monitoring objectives. Completeness goals in terms of number of storm events sampled are set to the number of storm events required by TAPE. Completeness of data gathered will be maximized in the field by telemetry, composite autosamplers, refrigerated samples, packaging samples for transport to avoid breakage, and timely sample processing.

One of the goals is to determine whether monitoring over the permit cycle will reach the critical number of storms to be statistically relevant for each site. If the critical number of events to reach statistical relevance are not reached during the permit cycle, then monitoring may continue.

Laboratories can improve completeness by processing samples within their holding times. Completeness for telemetered data is anticipated to be high; however, the grab sample data completeness is expected to be much lower. For data analysis, valid sample data may include all unflagged data and *J* flagged data reviewed by the Data Steward.

If sampling requirements cannot be met in the first two qualified seasonal first flush storm events for toxicity sampling, the conditions will be considered unmet and sampling will be discontinued. This lack of data will not be considered incomplete if the conditions in the permit for attempts are met and WSDOT made the attempts in good faith.

5-2.7 Comparability

Comparability is a qualitative measure designed to express the confidence with which one data set may be compared to another. Standard sampling procedures, analytical methods, units of measurement, reporting rules, and reporting limits will be applied to meet the goal of data comparability. Comparability is limited by other MQOs because data sets can be compared with confidence only when precision and accuracy are known.

6 Site Descriptions

This section addresses the experimental design, monitoring methods, site descriptions and site development for data collection. A monitoring site refers to the physical locality and the monitoring station refers to the sample collection location. Detailed drawings and runoff calculations are provided in Appendix E. Tables containing technical and design information are provided in Appendix F.

6-1 BMP Types and Locations

WSDOT has combined permit-required monitoring for BMP effectiveness with permit-required highway runoff monitoring to reduce travel time and the number of sampling sites. The Interstate 5 (I-5) monitoring sites and the State Route (SR) 9 site are located in western Washington, and they serve a dual purpose for BMP effectiveness and highway characterization monitoring.

The following biofiltration BMPs were selected for monitoring:

- Vegetated filter strips (VFS)
- Modified VFS
- Compost-amended VFS (CAVFS)

6-1.1 BMP Locations

Five of the six BMPs that will be monitored under this QAPP are located at the two I-5 monitoring sites. Sites located on I-5 are along the highway shoulders at milepost (MP) 197 northbound (north of Everett) and MP 210 southbound (near Pilchuck Creek). Existing monitoring infrastructure and history make these sites well suited to monitor. Plans for the I-5 Modified Vegetated Filter Strip Study were developed based on conceptual approval from Ecology's WQP (May, 2010) for permit monitoring.

The rural VFS is located north of Lake Stevens, near Marysville, on SR 9. Table 7 lists the BMPs that will be tested, and Figure 5 shows their locations. Site-specific BMP design supporting materials are available in Appendix F.

Monitoring sites to fulfill the BMP and highway characterization portions of the permit were combined to conserve monitoring efforts and costs, and to reduce the hazards of putting crews on the side of the road at additional locations. Monitoring will be conducted at the edge of pavement (EOP) to characterize highway runoff and "influent" to BMP treatment. BMP "effluent" will be captured at two locations down the shoulder of the embankment: at 2-meter and 4-meter distances from the edge of the shoulder pavement.

6-1.2 BMP Set

A BMP set is the combination of the EOP, 2-meter, and 4-meter interceptors. The difference in treatment (both runoff flows and pollutant concentrations) from the EOP station to the 2-meter or 4-meter stations will be calculated.

- The 2-meter station is part of the study design because many highways in highly urbanized areas have only 2 meters of shoulder, and much of the pollutant load reduction is expected to be achieved in this segment.
- The 4-meter station is part of the study design to evaluate additional treatment of the BMP if available room exists on the road shoulder embankment.

6-1.3 Road and BMP Slopes

Current design guidelines limit VFS to embankments with lateral slopes between 2 and 15 percent (WSDOT, 2010a). These shallow slopes ensure sheet flow runoff from adjacent impervious surfaces is maintained, and sedimentation and infiltration rates are maximized. In some cases, concentrated flows from steeper gradients can cause erosion and reduce VFS potential to treat stormwater.

In western Washington, however, vegetated embankments with slopes to 25 percent are common. These steeper slopes are often used directly or indirectly for stormwater management. Although a 25 percent slope exceeds current VFS design guidelines, recent studies suggest even steep vegetated embankments with slopes exceeding 30 percent can provide effective runoff treatment and flow control (Yonge and Reister, 2005; Ebihara et al., 2009).

Modification of WSDOT guidelines to allow slopes up to 25 percent for VFS could reduce the cost of acquiring additional right of way and permit use of VFS for stormwater treatment on more highway embankments. In steep slope areas where physical constraints make it is impossible to install CAVFS, a modified VFS with a compost blanket applied may provide a practicable alternative.

More research is needed before slope limits in current VFS guidelines are modified. BMP effectiveness monitoring on I-5 and SR 9 will provide data to inform the HRM and stormwater managers at WSDOT.

Table 7 BMP effectiveness monitoring sites.

BMP Study	Permit Traffic Designation[1]	AADT	BMP Type	Location	Average Slope (H:V)*	Average % Grade
I-5 Modified VFS Study	Urban	78,500	VFS[2]	I-5, Pilchuck, MP 210.71	4H:1V	25
	Highly Urban	120,500		I-5, Everett, MP 197.27	3.7H:1V	27
	Highly Urban	120,500	CAVFS[2][3]	I-5, Pilchuck, MP 210.78	3.85H:1V[5]	26
	Urban	78,500	Modified VFS[2] (compost blanket)	I-5, Pilchuck, MP 210.85[4]	3.7H:1V	27
	Highly Urban	120,500		I-5, Everett, MP 197.35[4]	3.85H:1V	26
SR 9 Rural VFS Study	Rural	6,700	VFS	SR 9, Marysville, MP 17.92[4]	4H:1V	25

[1] These traffic designations come from S7.B.3 of the permit.
[2] Provides a paired study design for LID comparison.
[3] Location is Pilchuck, based on best professional judgment, until infiltration rates are determined.
[4] Toxicity samples will be taken at these BMP effluents.
[5] Estimated slope.
* Horizontal:Vertical

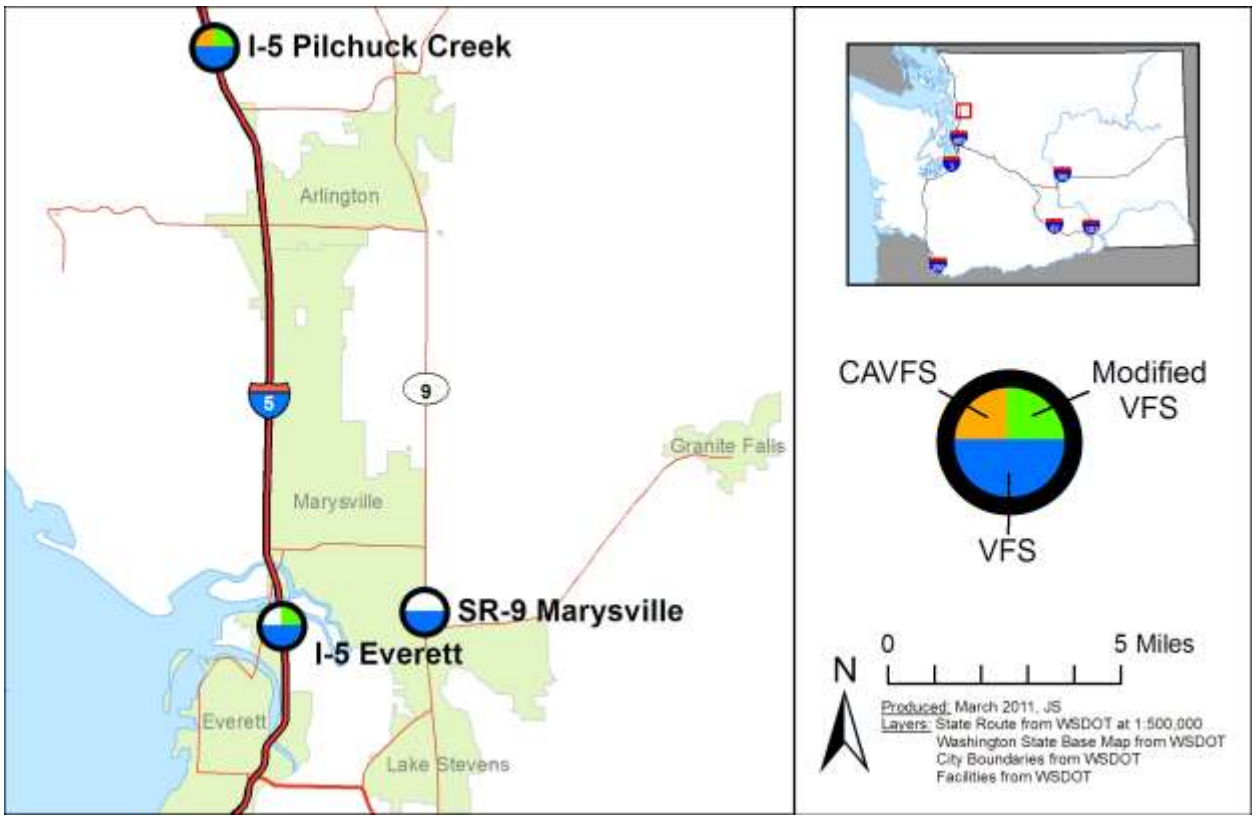


Figure 5 BMP locations and types for WSDOT stormwater monitoring.

6-2 I-5 BMP Study Site Descriptions

The attributes of the I-5 Modified Vegetated Filter Strip Study include the following:

1. Support of WSDOT stormwater research priorities.
2. CAVFS qualifies for use as an *enhanced treatment* BMP; modified VFS will be tested for the same parameters under the permit's classification of *enhanced treatment* BMP.
3. I-5 at Everett meets the "highly urban" AADT highway monitoring requirement.
4. I-5 near Pilchuck meets the "urban" AADT highway monitoring requirement.
5. Provides a paired study for comparison of a LID treatment approach.
6. WSDOT research funds will help pay for the project, and the timeline fits well within the permit monitoring schedule.

6-2.1 I-5 Everett

Two study sites are on I-5 northbound near Everett on the eastern shoulder of the freeway in Snohomish County, just north of the Snohomish River. The AADT of I-5 (northbound only) at these monitoring sites is listed as 120,500. This monitoring site can only be accessed from the shoulder of the highway. The slope of the highway is 60H:1V from the farthest point at the median to the EOP interceptor. The size of the drainage area, time of concentration, and peak flow are listed in Table 8.

- **VFS:** The VFS BMP is the southernmost of two on this section of I-5. The center of the EOP interceptor is located at MP 197.27. The 2-meter and 4-meter runoff collectors for the standard VFS are located at MP 197.26 and MP 197.28, respectively. The embankment slope was measured to be 3.7H:1V.
- **Modified VFS:** The modified VFS BMP is the more northern BMP on this section of I-5, with the center of the EOP located at MP 197.35. The 2-meter and 4-meter runoff collectors will be located at MP 197.34 and MP 197.36, respectively. The embankment slope ranges from 3.8H:1V to 3.9H:1V, with an average embankment slope of 3.85H:1V.

Each EOP interceptor pipe is 12 meters in length and receives sheet flow from three traffic lanes and two paved shoulders. The width of the pavement that drains to the embankment is approximately 18.3 meters.

Figure 6 shows two BMP monitoring sets. The first BMP set is in the lower half of the figure, which consists of the EOP, 2-meter, and 4-meter stations for the VFS at MP 197.27. The modified VFS BMP set (EOP, 2-meter, and 4-meter) is located at MP 197.35, at the top of the figure.

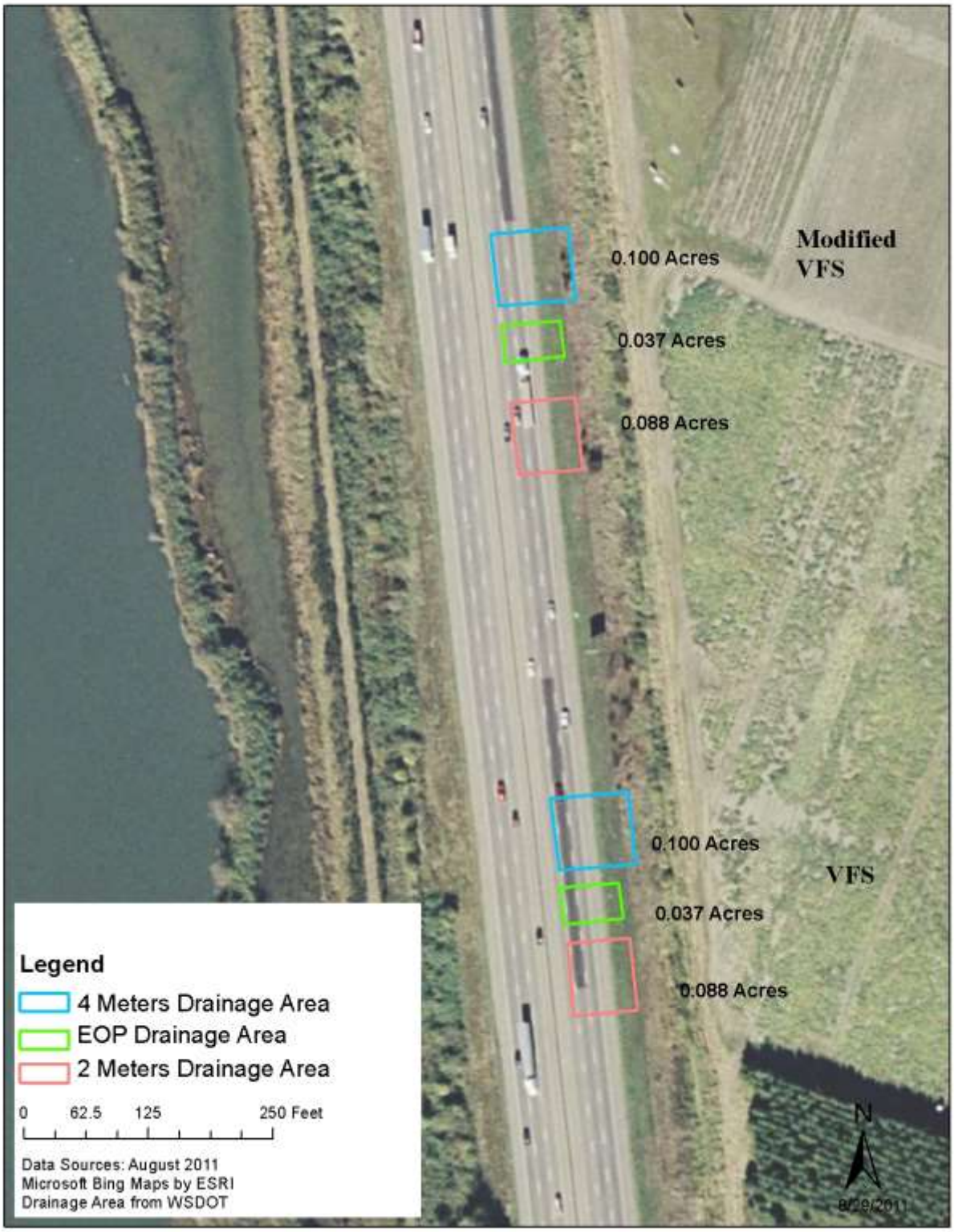


Figure 6 I-5 Everett BMP monitoring site.

6-2.2 I-5 Pilchuck

The southbound I-5 Pilchuck study site is located just north of the Stillaguamish River and Pilchuck Creek. The AADT at this location is 78,500 (southbound only). The monitoring site can be accessed from the shoulder of the highway or from Old Highway 99, which runs parallel to I-5. This monitoring location will feature three different BMP types: VFS, modified VFS, and CAVFS.

The embankment receives sheet flow from two of the three southbound lanes and one shoulder. The third lane is crowned and drains along with the far shoulder to the median. The width of the contributing pavement is approximately 36 feet and the vertical loss is 1 foot (36H:1V). The longitudinal slope of the roadway is 3.94 percent. The size of the drainage area, time of concentration, and peak flow are listed in Table 8.

- **VFS:** The VFS BMP is the southernmost of the three BMPs on this section of I-5. The center of the EOP is located at MP 210.71. The 2-meter and 4-meter runoff collectors for the VFS are at MP 210.70 and MP 210.72, respectively. The embankment slope was measured to be 4H:1V.
- **Modified VFS:** The modified VFS BMP is the more northern BMP on this section of I-5, with the center of the EOP located at MP 210.85. The 2-meter and 4-meter runoff collectors will be located at MP 210.84 and MP 210.86, respectively. The embankment slope ranges from 3.4H:1V to 4.1H:1V, with an average embankment slope of 3.7H:1V.
- **CAVFS:** The CAVFS BMP will be built between the VFS and modified VFS, with the center of the 2-meter and 4-meter runoff collector located at MP 210.77 and MP 210.79, respectively. The EOP interceptor station or BMP "influent" information can be gathered from averaging the other two EOPs at the Pilchuck site. This was agreed to by Ecology's WQP and WSDOT in January 2011. The embankment slope is estimated to have slopes similar to the other two BMPs at this site.

Figure 7 shows the three BMP monitoring sets. The first set is in the lower half of the figure, which consists of the EOP, 2-meter, and 4-meter stations for the VFS at MP 210.71. The Modified VFS set (EOP, 2-meter, and 4-meter) is located at MP 197.35, at the top of the figure. In the middle of the figure is the CAVFS, which consists of only the 2-meter and 4-meter monitoring stations. The CAVFS was added to the monitoring to aid in determining the effectiveness of the modified VFS. There is no EOP station at this BMP since it is located between two EOP stations (<1,000 feet apart); therefore, adding an additional EOP station is redundant. In addition the purpose of the CAVFS BMP is to compare the results from the effluent to the modified VFS effluent to evaluate pollutant loads between these two types of BMPs.

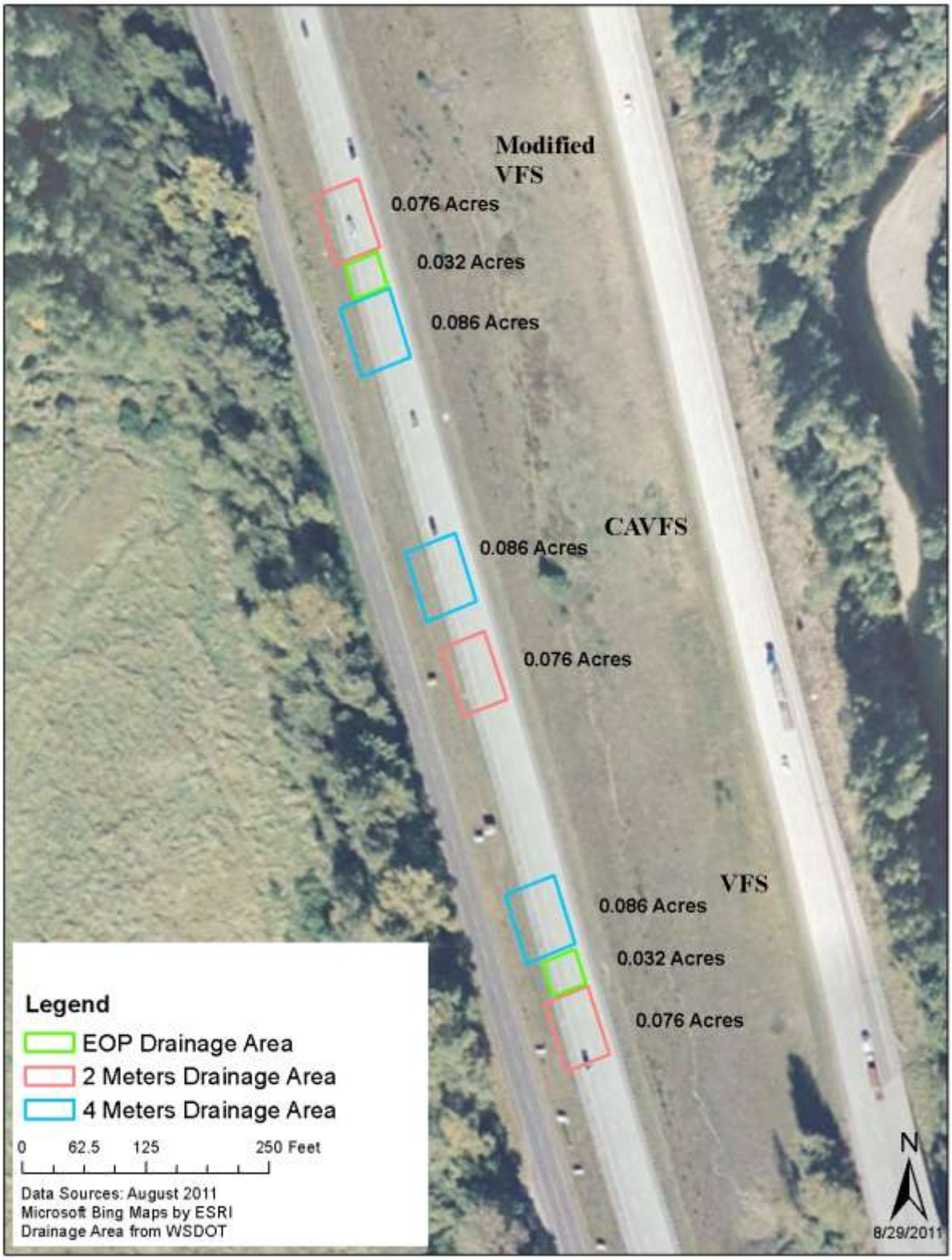


Figure 7 I-5 Pilchuck BMP monitoring site.

6-3 SR 9 Rural VFS Study

Attributes of the SR 9 Rural VFS Study include:

1. It fulfills the "rural" AADT BMP permit requirements for toxicity monitoring.
2. It fulfills the "rural" AADT highway characterization monitoring requirements.

6-3.1 Site Description

Recent work to improve the intersection of SR 9 with E. Sunnyside Rd., near Marysville, included installation of several stormwater treatment BMPs. This monitoring location meets the "rural" traffic-level designation with an AADT of 16,500. Just south of the intersection along the west side of the highway, a VFS receives runoff from SR 9. This VFS was built in 2001 and meets the current HRM design criteria. Sheet flow runoff from one and a half lanes of SR 9 enters the VFS and sheet flows across the width (18 feet) to a continuous flow biofiltration swale, where it collects and continues to a detention pond. Only the embankment VFS will be studied as part of the permit monitoring effort. The embankment slope is 4H:1V.

Figure 8 shows the BMP monitoring set, which consists of the EOP and 4-meter stations for the VFS at MP 17.92. The 4-meter station at SR 9 will be used for toxicity testing only. BMP effluent characterization monitoring will not take place at this site.

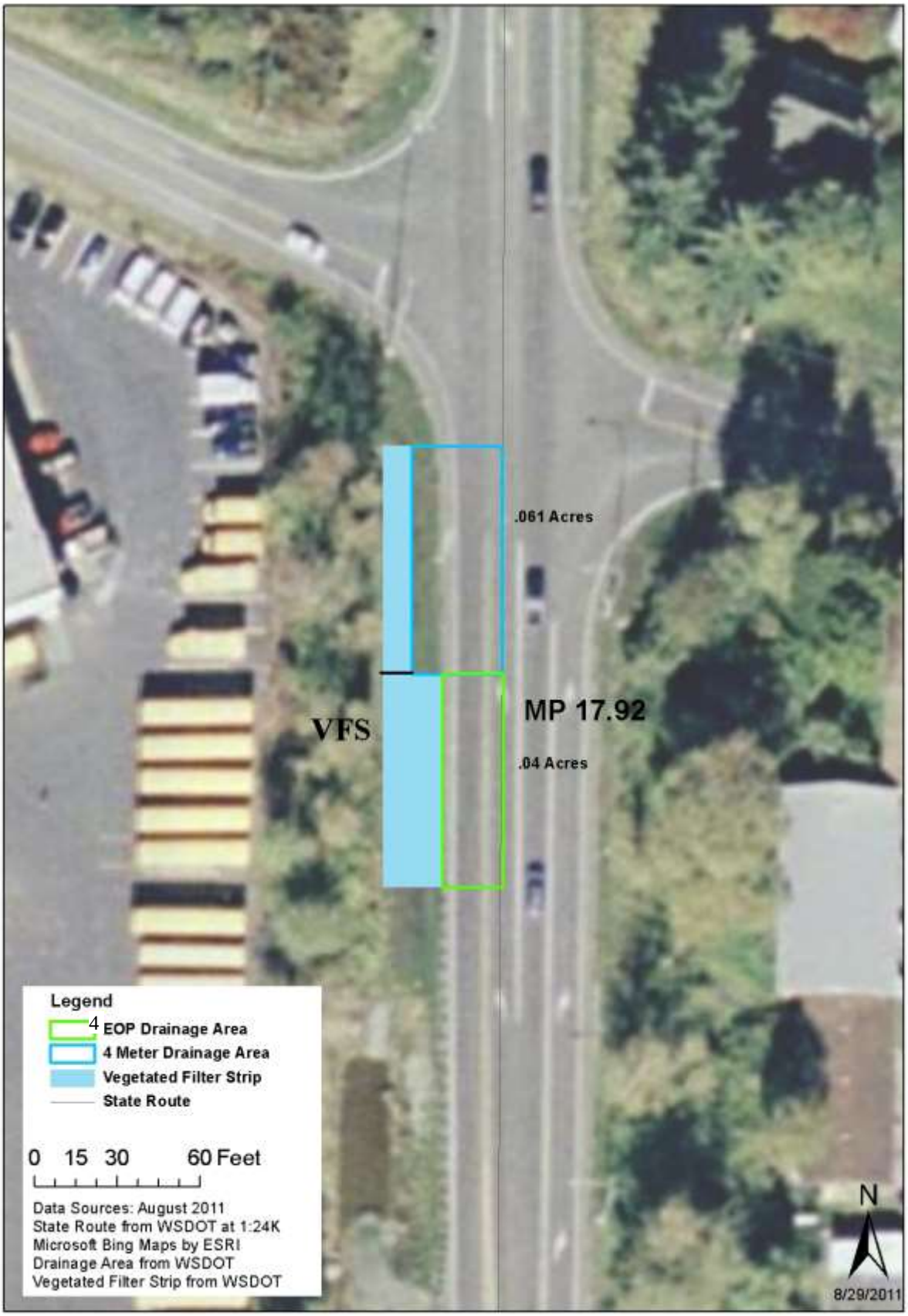


Figure 8 SR 9 Marysville BMP monitoring site.

6-4 BMP Design Details

6-4.1 Drainage Area Characteristics

Drainage areas conveying water to the BMPs were defined using WSDOT's Geographic Information System (GIS) Workbench (WSDOT, 2011) or the Design Office's Computer Aided Design (CAD) files. Mapping and documenting conveyance systems is an ongoing effort at WSDOT. Using as-built and design drawings in combination with field survey verification with global position systems (GPS) allows staff to verify the exact collection system information. This information was used to calculate the drainage area for each station. The estimated drainage area was then used in determining runoff time of concentration for each station.

The time of concentration is the time necessary for surface runoff to reach the outlet of a subbasin from the most remote point in the drainage area (WSDOT, 2010a). This was calculated using the TR 55 methodology (SCS, 1986) to meet permit requirements for highway runoff monitoring (S7.B.3 and S7.B.6). Flow lengths and slopes of the lanes of the freeways were measured from as-builts (see Appendix E) and were confirmed by field measurements or from previous reports (WSDOT, on file, 2010b; AASHTO, 2004). The slopes of the shoulders and lanes of the freeway were measured together to calculate an average slope.

Peak flow was calculated using the Rational Method for each BMP influent station (EOP) to estimate the peak flow of water under two rainfall conditions: 0.15 inch (minimum rainfall TAPE criteria) and 2 inches. The Rational Method is shown in Equation 5.

Equation 5: Peak Flow by the Rational Method

$$Q_p = C \times I \times A$$

Where:

Q_p = Peak Flow (ft^3/sec)
C = Rational Method C-Coefficient
I = Precipitation Intensity (inch/hr)
A = Drainage Area (ac)

The Rational Method C coefficient is an estimate of roughness. Asphalt and pavement are given a range of values (0.8–0.95) (Lindeburg, 2003). The lower end of the range was used to account for the age of the concrete and roughness of the asphalt shoulders at the I-5 sites.

Precipitation intensity values were estimated as either 0.15-inch/24 hr or 2-inch/24 hr. The drainage area was calculated using the width of the lanes and shoulder at 15 feet each by the length of the interceptor. The interceptor lengths at Pilchuck and Everett are 12 meters (~40 feet) for the EOPs and 24 meters (~80 feet) for the 2-meter and 4-meter sections. At SR-9 Marysville, the EOP and 2-meter interceptors are both 24 meters (~80 feet). The EOP was lengthened at SR-9 from 12 to 24 meters to increase sample volumes.

Table 8 lists each BMP's influent drainage area characteristics, time of concentration, and peak flow based on a range of rainfall depths that are typical to western Washington.

Table 8 BMP EOP site runoff characteristics and time of concentration for typical seasonal storms.

Site Location	Milepost	BMP Types	Flow Length of Longest Path[1] (ft)	Drainage Area[2] (ft^2)	Rainfall at 0.15"		Rainfall at 2"	
					Tc (min)[3]	Qp (L/min)[4]	Tc (min)[3]	Qp (L/min)[4]
I-5 Everett	197.27	VFS	136	2,400	5.78	0.46	2.42	6.17
I-5 Everett	197.35	Modified VFS	136	2,400	5.78	0.46	2.42	6.17
I-5 Pilchuck	210.71	VFS	93	1,360	1.97	0.26	1.32	3.50
I-5 Pilchuck	210.85	Modified VFS	93	1,360	1.97	0.26	1.32	3.50
SR 9 Marysville	17.92	VFS	81	1,786	3.98	0.16	1.59	2.16

[1] Lane and shoulder widths are measured from as-builts (see Appendix E).

[2] Drainage area is the flow length multiplied by the width of the EOP (40 ft).

[3] Tc: Time of concentration (minutes)

[4] Qp (L/min): Peak flow (liters/minute)

Table 8 provides an estimate of the time of concentration for BMP EOP monitoring sites. The following were used to calculate these estimates:

- The first assumption is that the plane of the roadway is constantly sloped toward the EOP interceptor for the length assumed above at the percentage shown. Slopes are derived from as-builts (see Appendix E).
- The second assumption is that the volume of water droplets and spray carried into the drainage area by vehicular traffic is also carried out of the drainage area.

6-4.2 MGS Flood Design Flow Rates

Per TAPE guidance, BMP sizing must be based on an Ecology-approved continuous simulation model with the goal of treating at least 91 percent of the runoff volume. MGS Flood is an Ecology-approved model and was used for this purpose.

MGS Flood Model Output

Flow rates shown in Table 9 represent larger storm events that occur periodically and may cause flooding. These flow rates were calculated in MGS Flood v4.09 using 15-minute time steps. The following information was used to populate the model:

- Water collector pipes at the EOP are 12 meters (~40 feet) for Everett and Pilchuck and 24 meters at SR 9 Marysville.
- Water collector pipes at all sites, for the 2-meter mark and the 4-meter mark, are both 24 meters long (~80 feet)

Table 9 Example of highway runoff calculations for design storms.

Site Location	Drainage Area (Impervious)		Drainage Area (Pervious – toe grass)		Flow Rates (cfs) (Calculated by MGS Flood V4.09 with 15-Minute Time Steps)					
	L (ft)	W (ft)	L (ft)	W (ft)	2 YR Flood	10 YR Flood	25 YR Flood	50 YR Flood	100 YR Flood	200 YR Flood
I-5 MP 197 (Everett)										
EOP	40	60	–	–	0.020	0.029	0.037	0.047	0.054	0.056
2-Meter Collector	79	60	79	7	0.041	0.061	0.079	0.097	0.115	0.119
4-Meter Collector	79	60	79	13	0.041	0.062	0.083	0.097	0.121	0.123
I-5 MP 210.71 (Pilchuck)										
EOP	40	34	–	–	0.012	0.019	0.023	0.028	0.034	0.035
2-Meter Collector	79	34	79	7	0.026	0.041	0.051	0.061	0.075	0.077
4-Meter Collector	79	34	79	13	0.026	0.040	0.051	0.063	0.078	0.080
SR 9 MP 17.92 (SR 9)										
EOP	79	21	–	–	0.015	0.022	0.027	0.033	0.040	0.042

Note: Complete information for all BMP effectiveness monitoring sites are contained in Appendix E.

6-4.3 Compost Properties

Description of the Compost

Both the modified VFS and CAVFS BMPs call for compost amendment. Compost will likely be purchased from a local vendor to minimize hauling costs. The organic content of the compost and site soils varies. The HRM states that, when built, the CAVFS BMP should have a final organic content of 10 percent.

Specifications for compost soil amendments in Section 5-4.3.2 of the HRM state that compost material should be aged and cured according to Section 9-14.4 (8) in the *Standard Specifications*. Mature high-quality compost should be stable and derived from organic waste materials. Desirable compost qualities include:

- Earthy smell that is not sour, sweet, nor ammonia-like
- Brown to black in color
- Mixed particle sizes
- Stable temperature and does not get hot when rewetted
- Crumbly texture

The HRM states that compost materials must meet the definition for "composted materials" in Section 9-14 of the *Standard Specifications* (WSDOT, 2010c) and WAC 173-350-220.

Compost for *enhanced treatment* BMPs must not contain biosolids or any street or highway sweepings.

Organic Matter Content

The minimum organic matter content of the final soil mixture may be achieved by amending soils using the preapproved Presumptive Method or the Custom Method. The Presumptive Method simplifies planning and implementation; however, the organic matter content of the disturbed on-site soils may be relatively good and not require as extensive an application of amendment material. The Custom Method would require the BMP designer to calculate a custom amendment rate for the existing site soil conditions. The Custom Method has the potential to save in materials and application costs if site soils are already high in organic matter.

The Presumptive Method for Determining Soil Organic Content

Soil amendments can be placed on top of the soil or incorporated into it. To encourage grass growth for CAVFS, 3 inches of coarse compost are incorporated into the top 9 inches of soil. Vegetation is established on top of the compost-incorporated soil.

The Custom Method for Determining Soil Organic Content

Calculating a custom rate requires collecting soil samples from both the area to be amended and from the compost material. The soil and compost are then tested for percent organic matter. Compost and topsoil producers can often supply the required information for the amendment material. A quick way to determine the approximate organic matter content of a soil mix would be to use the following rules of thumb:

- Compost is typically 40–50% organic matter (use 45% as an average).
- Compost weighs approximately 50% as much as loam.
- A mix that is 40% compost measured by volume is roughly 20% organic matter by volume.
- Compost is only 50% as dense as the soil, so the mix is approximately 10% organic matter by weight (the organic matter content in soil is determined by weighing the organic material before combustion and then weighing the ash after combustion).

Compost that is applied as a land cover must have a minimum blanket depth of 2 to 3 inches, depending on slope and soil types. Slopes steeper than 4H:1V should receive 3 inches of compost as a cover. Likewise, more erodible soils must be at the higher end of the compost application range.

Soil Design

The design of the final soil composition is critical to the success of the BMP. The following guidelines for design are summarized from the HRM and should be followed:

- The texture of the soil for a LID BMP should be loamy sand.
- The final soil mix should have a minimum long-term hydraulic conductivity of 1.0inch/hour per ASTM Designation D 2434 at 80% compaction per ASTM Designation D 1557. Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil.
- The final soil mixture should have a minimum organic content of 10% by dry weight per ASTM Designation D 2974.

- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60–65% loamy sand mixed with 25–30% compost or 30% sandy loam, 30% coarse sand, and 30% compost.
- The final soil mixture should be tested by the WSDOT Materials Lab prior to installation for fertility, micronutrient analysis, and organic material content.
- Clay content should be less than 5%.
- The pH for the soil mix should be between 5.5 and 7.0.
- Soil depth should follow the design criteria in the *Roadside Manual* (WSDOT, 2003), to provide acceptable minimum pollutant attenuation and good growing conditions for selected plants.
- Soil mix should be free from material (stones, stumps, roots, etc.) larger than 2 inches.
- When placing topsoil, it is important that the first lift of topsoil is mixed into the top of the existing soil. This allows the roots to penetrate the underlying soil easier and helps prevent the formation of a slip plane between the two soil layers.

6-4.4 Soil Properties

Site-specific BMP soil properties and water quality model information are anticipated to be gathered according to the schedule in Table 10. Additional details on site characteristics are in Appendix F.

Table 10 Soil characterization schedule.

Date	Activity
April 2011	Soil borings of each BMP will be drilled. A decision to use the Presumptive Approach or Custom Approach to determine soil organic content will be decided by WSDOT.
May 2011	Laboratory analysis complete for K_{sat},[1] CEC,[2] and soil gradation of all BMP native site soils, analysis will be conducted by WSDOT.
May 2011	If the Custom Approach is to be used to design the compost-amended BMPs, then a sample of the compost organic matter needs to be analyzed.
September 2011	Final construction of all BMPs is complete and ready for monitoring.

[1] K_{sat}: saturated hydraulic conductivity

[2] CEC: cation exchange capacity

7 Sampling Process Design

7-1 BMP Effectiveness

The sampling process design was developed based on the monitoring requirements identified in the permit and the recommended procedures from TAPE. Further guidance was provided by EPA's *Urban Stormwater BMP Performance Monitoring* (publication #821-B-02-001) (USEPA, 2002b). This section addresses sampling experimental design to ensure the data collection and monitoring methodologies satisfy the requirements of the permit and data of known quality are generated from this monitoring effort.

As previously described, the specific objectives of this monitoring study are as follows:

- Quantify the treatment performance of each BMP for reducing both runoff pollutant concentrations and loads.
- Determine the effectiveness of each BMP at treating the applicable water quality design flow.
- Determine whether the treatment performance of each BMP varies in relation to storm event characteristics and/or other operational considerations.

The VFS BMPs have the ability to infiltrate some water to underlying soils. The modified VFS and CAVFS BMPs have the additional advantages of reduced flows and pollutant concentrations due to higher surface roughness; greater retention and infiltration; sorption of contaminants; improved vegetation health; and reduction of invasive weeds (WSDOT, 2010a).

7-1.1 Modified VFS and CAVFS Study Goals

Two variations of the VFS BMP are proposed for monitoring: a VFS with 3 inches of compost applied as a blanket to the surface of the soil, and a typical CAVFS (3 inches of compost mix tilled into the top 9 inches of soil). For both BMPs, hydroseeding takes place after compost amendments have been applied. Compared to the CAVFS installation, a compost blanket application reduces costs for stormwater retrofit and can be applied to many more situations where equipment to till the soil could not be previously used.

The I-5 Modified Vegetated Filter Strip Study will evaluate the benefits of a compost blanket for improving the water quality and quantity treatment performance of a VFS. As part of this study, WSDOT will apply a 3-inch compost blanket to a VFS at two locations along I-5 north of Everett. At each location, an existing VFS will be used for data comparison and as a control.

WSDOT will also install a CAVFS at one of the locations for comparison purposes. This will be a typical CAVFS installation with compost tilled into the top layer of the soil. The final location for this CAVFS will be determined after soil infiltration rates are evaluated during geotechnical site assessment. To serve as a "worst case" research scenario, the CAVFS will be installed at the location with the least permeable soils. This site is currently believed to be the Pilchuck location due to difficulty digging with hand shovels. The CAVFS will not be used to meet permit requirements for toxicity monitoring. Results from monitoring the CAVFS will be used to inform the HRM.

Influent to the BMP will be representative of highway runoff, which is the drainage area to this kind of BMP. Comparisons between influent and effluent will indicate the BMP's performance and effectiveness at reducing pollutant concentrations and loads.

The proposed study design compares the pollutant-removal effectiveness and flow-reduction potential of a VFS, CAVFS, and modified VFS with compost blankets. Results from these side-by-side comparisons will be used to update the HRM, inform the agency's highway stormwater management programs, and satisfy the flow reduction strategy monitoring requirements contained in S7.E.2.d of the permit. There are several BMP effectiveness questions this monitoring effort intends to answer:

- How effective is each BMP at attenuating stormwater flows and reducing stormwater pollutant concentrations?
- How do performance data compare for each BMP?
- What is the runoff attenuation or water quality benefit of the 4-meter station versus the 2-meter station for each BMP?

Table 11 lists the BMP design elements, attributes of the BMPs, and anticipated outcomes. This table is representative of the types of questions that will be asked between the BMPs for the 2-meter and 4-meter stations.

Table 11 BMP design elements and monitoring outcomes.

VFS	Modified VFS (compost blanket)	CAVFS	Questions
Storm Event Runoff Volume Differences from EOP and 4m[1] *(flow control effect)*			
Storm Event Runoff Volume (V1)	Storm Event Runoff Volume (V2)	Storm Event Runoff Volume (V3)	V1 < V2 V1 < V3
Water Quality Difference from EOP and 4m *(water quality effect)*			
Water quality improvement (WQI1)	Water quality improvement (WQI2)	Water quality improvement (WQI3)	WQI1 < WQI2 WQI1< WQI3
Alternative Outcomes			
No absorption and infiltration improvements due to compost amendment.			V1 = V2 V1 = V3
The compost-amended BMP removes more surface water flow than the unamended VFS, due to absorption and/or a greater hydraulic conductivity, and may hold rain and spray water.			V1 < V2 V1 < V3
The two methods of compost amendment behave differently for flow volume reduction.			V2 ≠ V3
The compost-amended BMPs remove more pollutants than VFS.			WQI1 < WQI2 WQI1 < WQI3
The two methods of compost amendment behave differently for water quality improvement.			WQI2 ≠ WQI3

[1] The information contained in this table fulfills the flow reduction strategy requirement in S7.E.2.d of the permit (Ecology 2009a).

The data from these studies will provide evidence to determine whether a modified VFS with compost applied as a blanket is a practical use of WSDOT stormwater treatment BMP planning and resources. In addition, the findings will add information to the "feedback loop" that Ecology hopes will improve BMP application, design criteria, and performance. Since the compost blanket is a slight variation from HRM specifications, information gathered as part of this effort may be used to meet TAPE requirements for approval as an effective BMP.

7-1.2 Monitoring Set-Up for BMPs

The interceptor pipe design borrowed from a previous study (WSDOT, 2010b) is the mechanism that will be used to capture runoff from the highway pavement and effluent from the BMP soil matrix. This interceptor is a high-density polyethylene (HDPE) pipe with a one-quarter section removed; the pipe is then buried and mortared to the EOP at a level that water can freely enter. Figure 9 shows a cross-sectional view of the interceptor pipe at the EOP. The interceptor itself will be sloped downhill slightly toward the pipe weirs and sampling equipment.

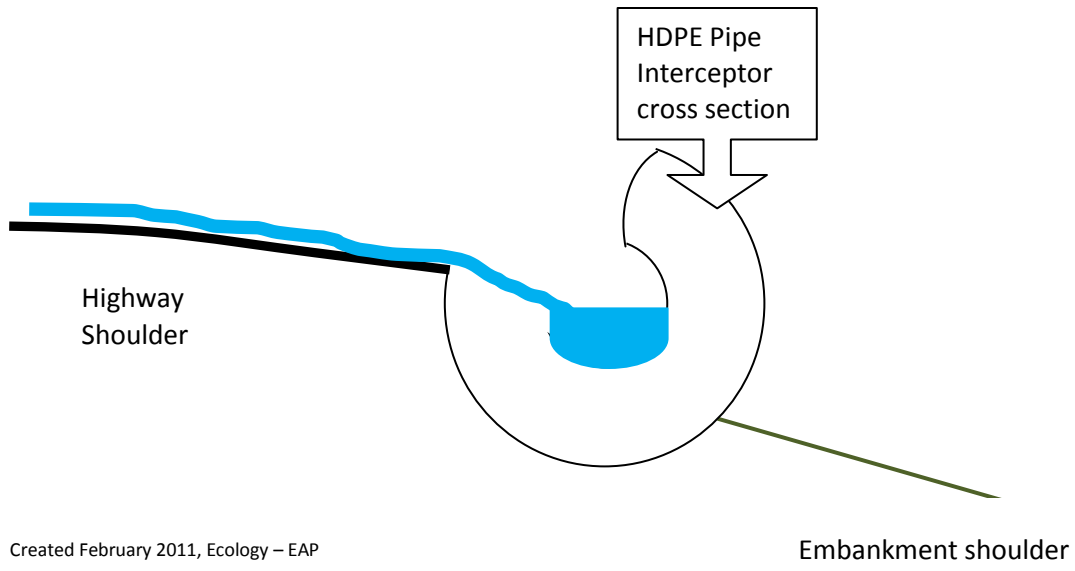


Figure 9 Cross section of the EOP Interceptor.

The 2-meter and 4-meter interceptors will be recessed into the BMP, below the surface level, and oriented to collect the surface runoff flowing through the BMP at 2 meters and 4 meters from the edge of pavement, as shown in Figure 10. Stormwater at both 2 meters and 4 meters will be collected from the treated layer or BMP, not from the soil column below. Although stormwater treatment is occurring in the native soil or embankment soils, this BMP effectiveness monitoring is aimed at quantifying only the treatment from the BMP itself. Similar to the EOP interceptor, the 2-meter and 4-meter interceptors will be sloped downhill slightly toward the pipe weirs and sampling equipment to promote directional flow for measurement.

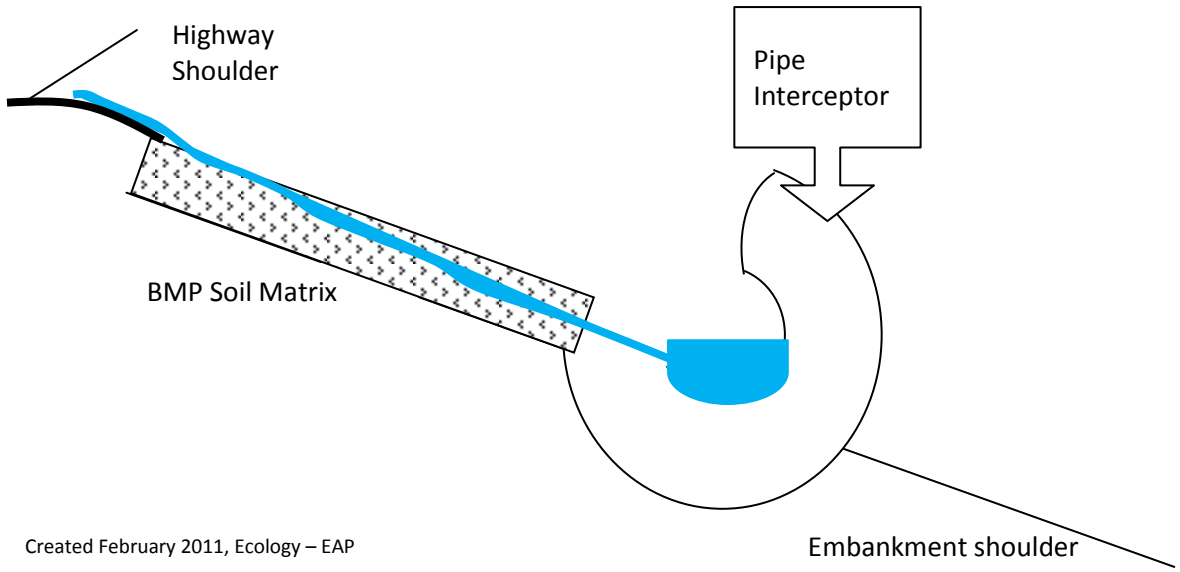


Figure 10 Cross section of the BMP interceptor.

Figure 11 shows an example sampling layout of the interceptors at the combined highway runoff and BMP effectiveness sites (Pilchuck and Everett). This diagram illustrates how the interceptor collects sheet flow runoff from the highway and throughout the BMP and transports the stormwater downslope through an HDPE pipe to the weir for flow measurement.

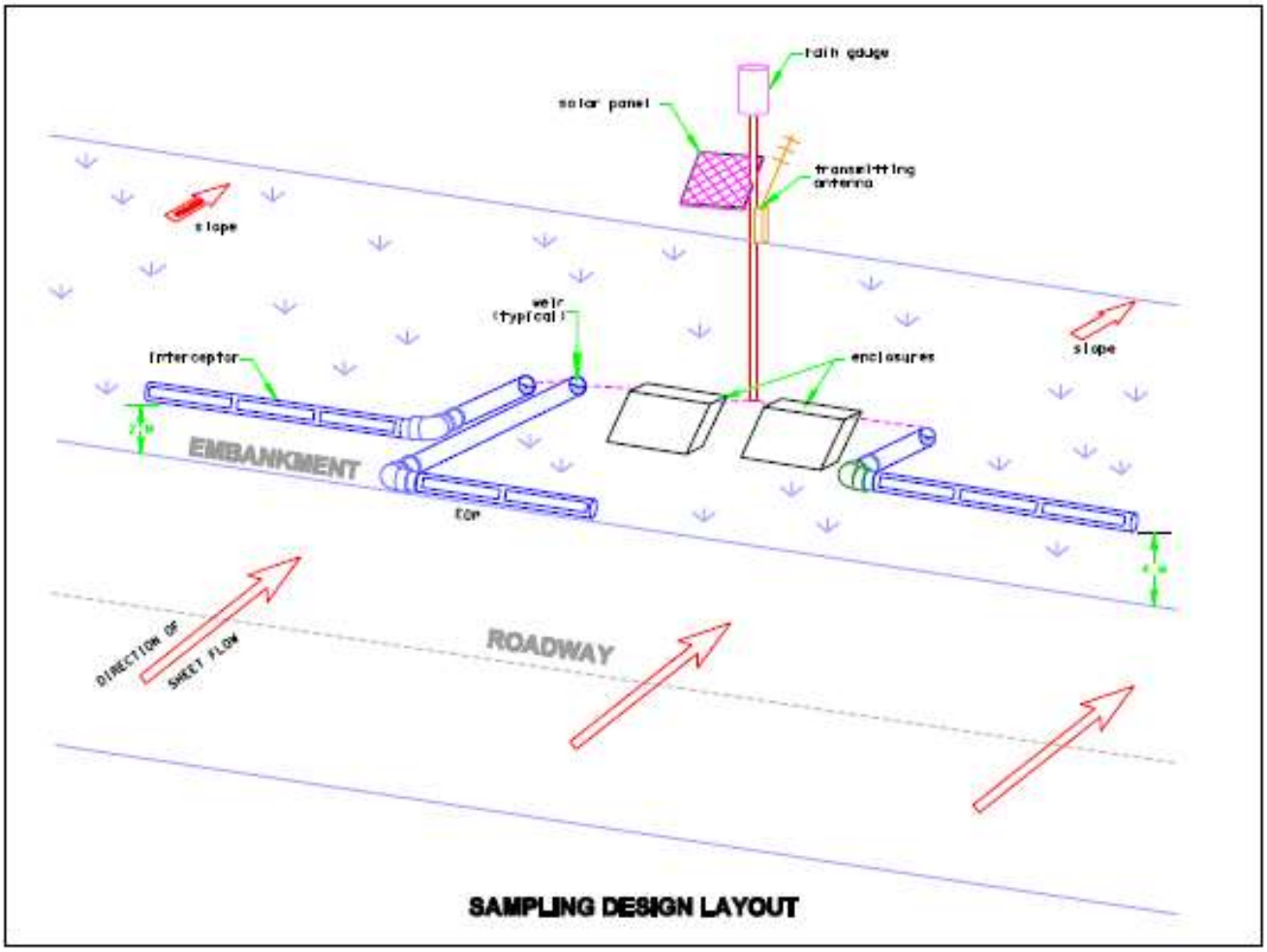


Figure 11 Example sampling design layout with EOP interceptor and sampling equipment.

A more detailed example of a data collection platform, including the pipes, weirs, and concrete pads, is shown in Figure 12.

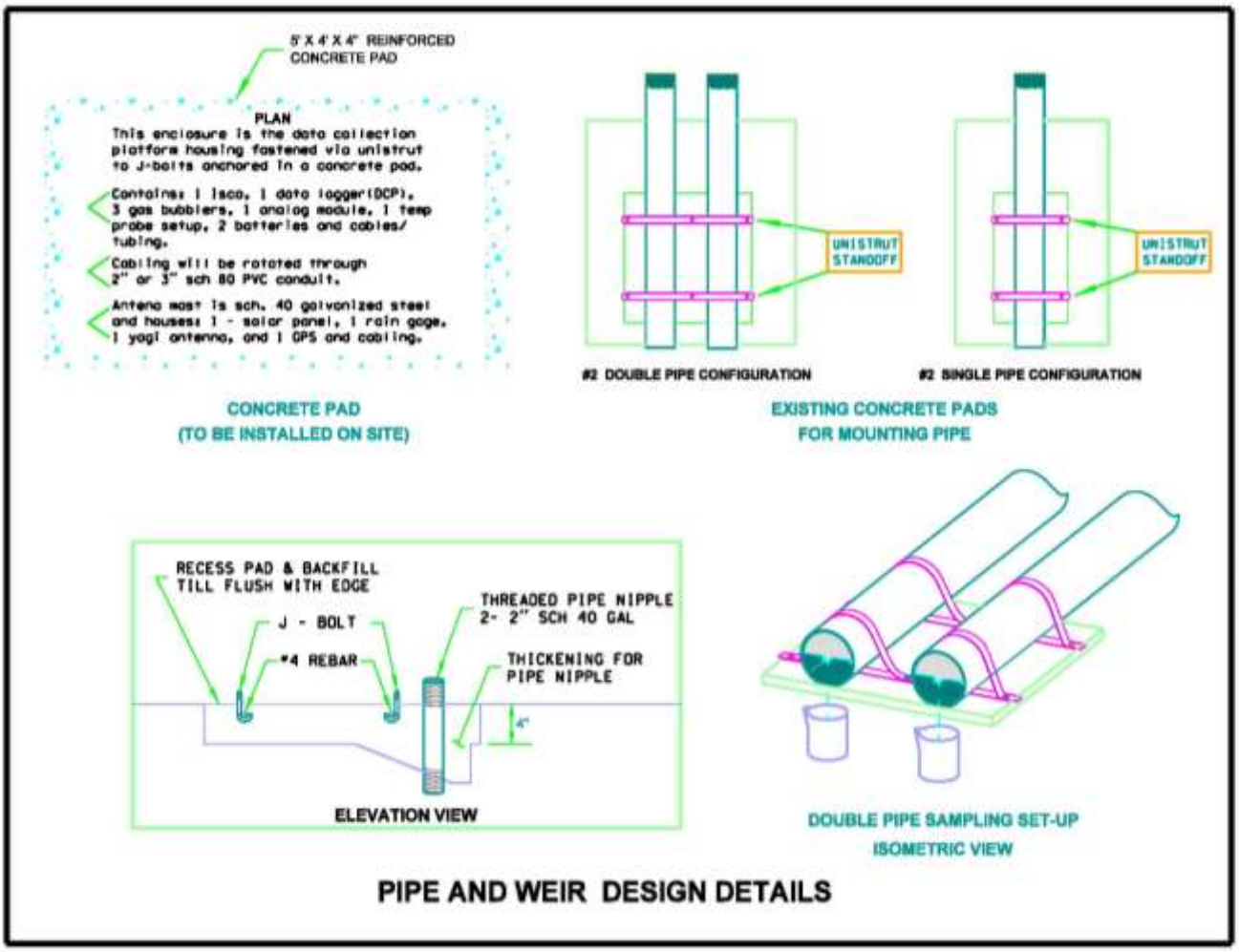


Figure 12 Example pipe and weir details.

Figures 13, 14, and 15 are line drawings of the Everett, Pilchuck, and SR 9 monitoring sites, respectively. The Everett and Pilchuck VFS and modified VFS BMPs will be monitored by a set of three monitoring stations: an EOP station, a 2-meter station (2 meters downslope), and a 4-meter station (4 meters downslope), as shown in Figures 13 and 14. An interceptor will be placed at each station to capture flow. At the Pilchuck monitoring site, the CAVFS BMP will have a similar set of runoff collection stations, except that there will not be an EOP station (see Figure 14).

At the SR 9 rural VFS monitoring site, the VFS will have a similar set of runoff collection stations, except that there will not be a 2-meter (mid-BMP) monitoring station (see Figure 15). The 4-meter station at SR 9 will be used for toxicity testing only. BMP effluent characterization monitoring will not take place at this site.

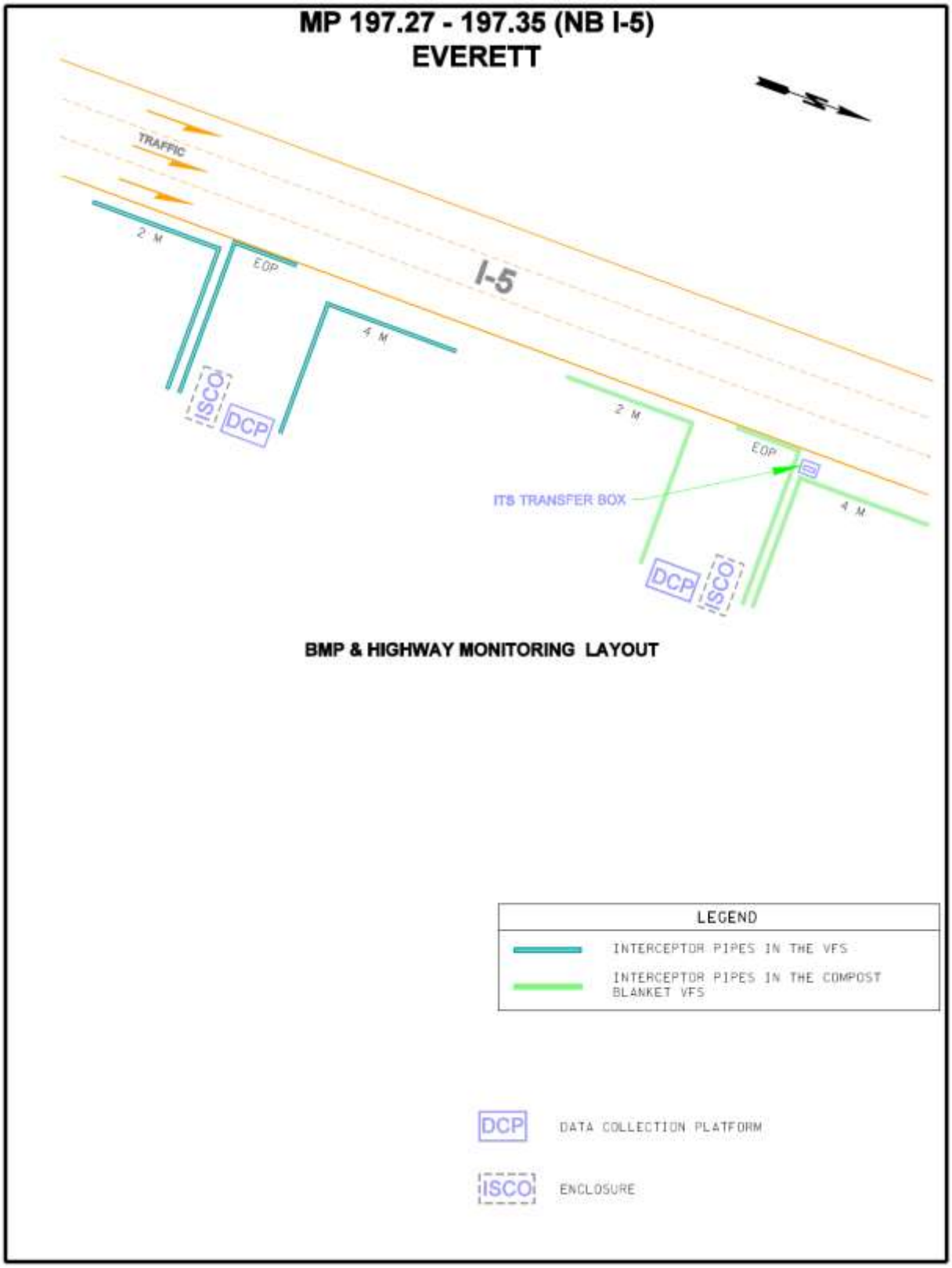


Figure 13 I-5 Everett BMP site line drawing.

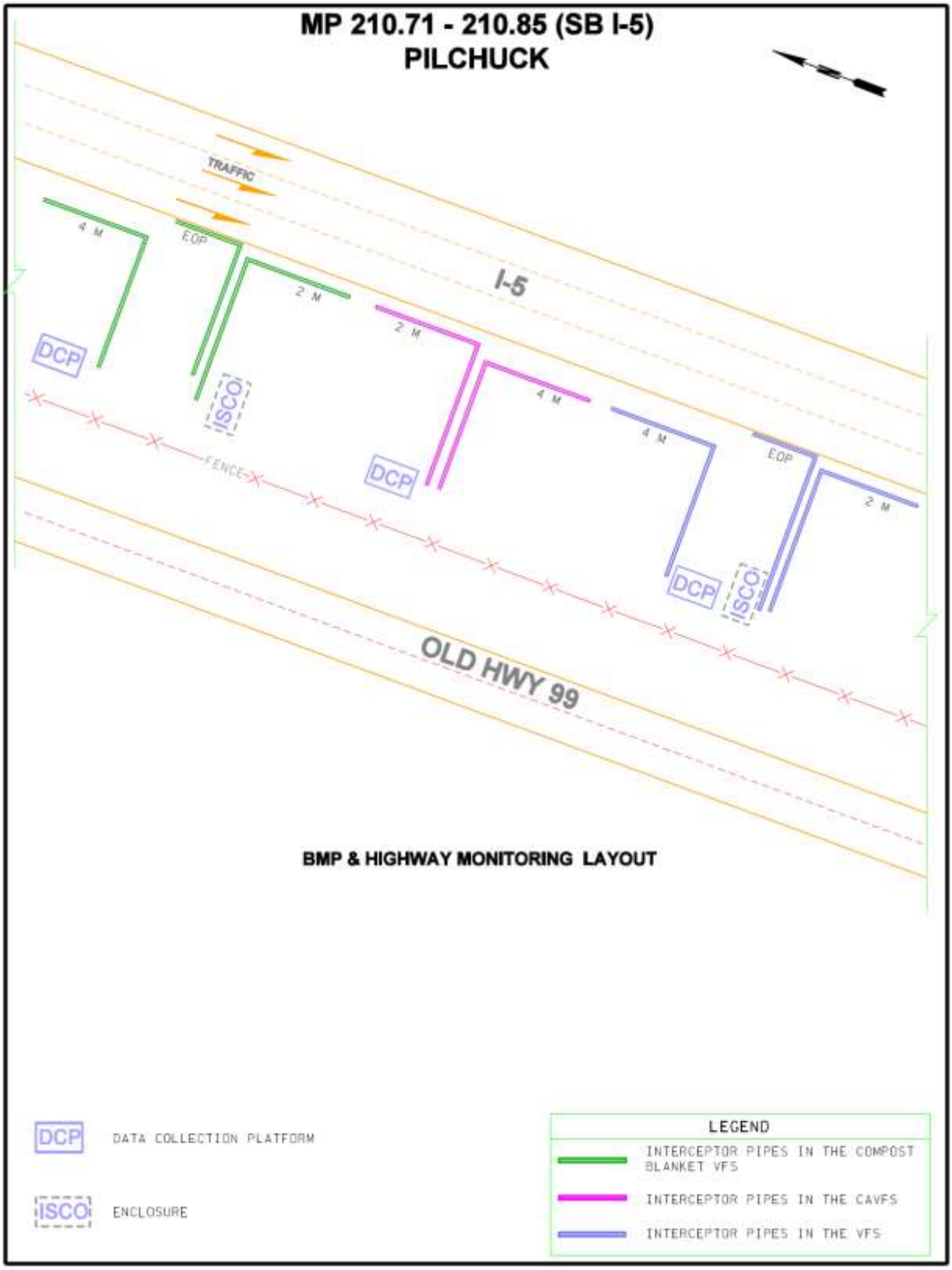


Figure 14 I-5 SB Pilchuck BMP site line drawing.

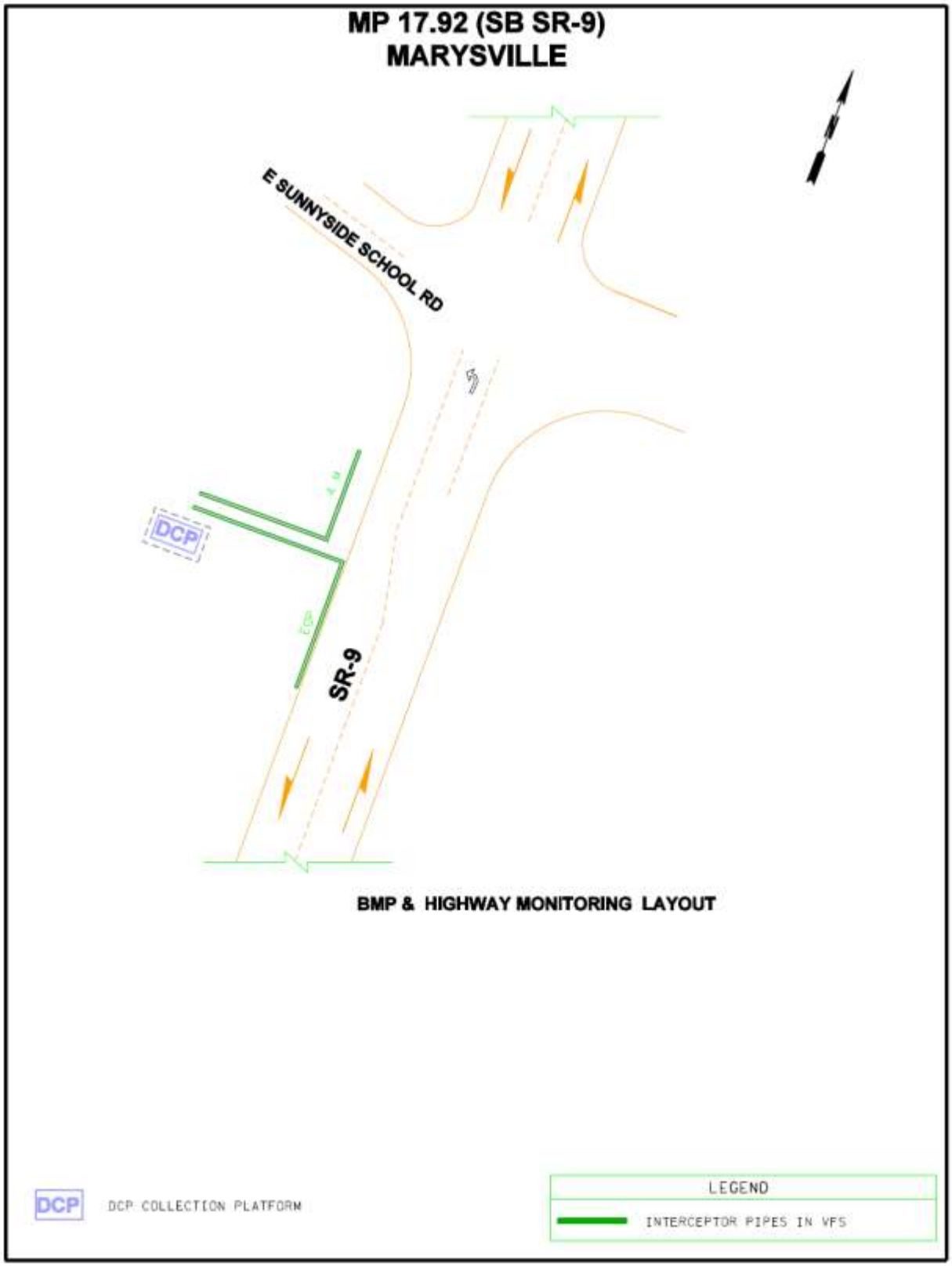


Figure 15 SR 9 SB Marysville BMP site line drawing.

7-2 Monitoring Strategy Overview

An overview of the preliminary site monitoring assessment will include:

- Geotechnical investigations to determine infiltration rates, soil horizons and layers, and soil type.
- Early TSS and particle size distribution (PSD) samples, per TAPE guidance.

A broad overview of the BMP effectiveness monitoring is further described in this section. Influent and effluent monitoring stations will be established to measure stormwater quantity and quality at the selected BMPs. Table 12 lists the parameter categories, sampling frequency, and methods. Actual parameters are discussed below.

Table 12 Overview of monitoring at WSDOT BMP sites.

Parameter Category	Sampling Frequency	Sampling Method	Telemetered Data
Rainfall	Continuous, year round	Rain gage	Yes
Stage (Flow)	Continuous, year round	Stage measuring device	Yes
Temperature	Continuous, year round	In situ probe	Yes
Chemical, except TPH	Discrete storm events	Autosampler	No
TPH	Annually	Grab sample	No
Toxicity	Annually	Autosampler	No

7-2.1 Method of Sampling

Continuous Samples

Rainfall, temperature, and stormwater flow rates will be continuously monitored at all highway station locations. A data collection platform (DCP) will be located at each monitoring location. The DCP will consist of the data logger, autosampler, and attached peripheral probes for water temperature, rain gage, and stage at the weir or flume. Data loggers will be programmed to record measurements every 15 minutes, in accordance with TAPE guidance (Ecology, 2008a). Each data logger will be equipped with a satellite antenna to telemeter flow data. These 15-minute data blocks will be saved to the internal logger memory and will also be transmitted at one-hour intervals year round to establish a site-specific characterization. Field crews will also manually download data from the data loggers. Hydrographs and hyetographs will be created from the collected rain gage and discharge data to accurately compare and relate the two parameters.

Grab Samples

Grab samples are typically those collected manually in jars or measured in situ by a hand-held meter. Grab samples are required for temperature, TPH-Dx, and TPH-Gx. Temperature will be continuously monitored at each site using a probe, while TPH will be collected by hand. Grab samples will be collected following Ecology's Standard Operating Procedure for Collecting Grab Samples from Stormwater Discharges (Ecology, 2009c) or Using Portable Meters (WSDOT, in draft 2011). Using portable meters will be described in an SOP to encourage consistent technique and training. This SOP discusses calibration, cleaning, data collection, and proper maintenance of portable meters.

Ecology and WSDOT have agreed that an annual sediment grab samples will not be collected to meet permit requirements (S7.E.6). This type of sampling is not deemed applicable for LID-type BMPs by Ecology and WSDOT. Sediment data will not be collected or used for TAPE due to the inherent difficulty of separating stormwater sediments from the soils or compost at a location mid-BMP. Therefore, sediment grab samples cannot be used for mass balance calculations.

Composited Samples

The permit specifies that stormwater runoff must be collected by flow-weighted compositing. Refrigerated autosamplers such as ISCO's Avalanche or a similar product will be used at each of the monitoring stations to collect stormwater samples during a qualifying storm event. The data logger will be preprogrammed to control the flow-weighted runoff compositing to comply with TAPE specifications identified in Table 1. Autosamplers will be programmed to begin sampling at the predetermined rates required for analysis. Sample collection into autosampler bottles will be triggered by a three-step threshold system. The three thresholds are:

- Rainfall to ensure a storm event is occurring.
- Presence of runoff to ensure water is flowing through the conveyance system.
- Water temperature to prevent sampling during freezing conditions.

Water temperature, rainfall, and stage will be measured using external probes connected to the data logger. If these three thresholds do not meet the programming criteria, samples will not be collected. Each monitoring station will be equipped with a refrigerated compositor and a pre-cleaned glass bottle for sample containment. Each monitoring location will support different bottle configurations, depending on sample volume requirements, planned replicates, or anticipated storm size. Ecology's SOP for Automatic Sampling for Stormwater Monitoring will be followed (Ecology, 2009b; WSDOT, in draft 2011).

7-2.2 Monitoring Timeline

A general timeline for the BMP monitoring program is presented in Table 13.

Table 13 Timeline for BMP monitoring.

Timeline	Event	Purpose
September/October 2010–ongoing	I-5 VFS EOP stations built with HDPE pipe, and hydrology monitoring equipment installed	Beta testing for highway runoff hydrological monitoring to understand the rainfall runoff relationship
Spring 2011	Runoff concentrations for TSS and PSD measured at each BMP influent station	Required testing by TAPE to better understand the potential success of the BMP to treat the runoff
Spring 2011	Receiving water samples may be collected for each BMP site	Suggested for toxicity
Spring 2011	Geotechnical assessment	Site soils characterization
Summer 2011	Final equipment purchased and installed	Beta testing at each site for full-scale monitoring
September 2011	Permit monitoring begins	Permit-required monitoring
May 2012	Field audit	Permit compliance
May 2013	Field audit	Permit compliance
May 2014	Field audit	Permit compliance

TAPE specifically requires TSS and PSD monitoring of the influent runoff to be conducted prior to BMP construction to gauge the treatability of the runoff. If the runoff contains relatively low levels of pollutants, such as TSS, then it is presumed the BMP may not be found to be effective. This early sampling requirement in TAPE is intended to help the BMP builders improve their study design. TSS and PSD values will be sampled at each BMP site to inform WSDOT and Ecology of the usefulness of the BMPs for suspended sediment removal. The results will help both entities gain an understanding of the number of samples needed to show BMP removal effectiveness.

7-2.3 Parameters

S7.C.4, S7.E.5, and S7.E.6 of the permit specify the parameters to be monitored at each BMP monitoring site for effectiveness and toxicity monitoring. The parameters for effectiveness and toxicity monitoring are listed in Table 14.

Stormwater samples will be collected by either grab or composited techniques, as required by the permit. If an insufficient sample quantity is collected, WSDOT is advised to process the sample for the next-highest priority pollutants in accordance with the volume requirement shown in Table 16. Sampling for toxicity is the exception to this advice and is further discussed in Section 7-3, Annual Seasonal First Flush Toxicity Monitoring.

Table 14 Water quality parameters to be monitored (Ecology, 2009a).

Effectiveness Monitoring	Seasonal First Flush Toxicity Testing (BMP effluent)[2]
Total recoverable and dissolved metals (copper, zinc)	*Hyalella azteca* 24-hr acute toxicity test
TSS	Total recoverable and dissolved metals (copper, zinc, cadmium, and lead)
Hardness	Herbicides (if used in drainage area)[3]
pH	TSS
Nutrients: total phosphorus, orthophosphate	Chlorides
Particle size distribution (PSD)	Hardness
	Methylene blue active substances (MBAS)
	Polycyclic aromatic hydrocarbons (PAHs)
	Phthalates
	Total petroleum hydrocarbon: NWTPH-Dx and NWTPH-Gx[1]

[1] Grab samples.

[2] Hardness, conductivity, dissolved oxygen, and pH will be measured on seasonal first flush toxicity samples by the toxicity laboratory at a minimum.

[3] Limited to the herbicides listed in the permit and used by WSDOT in the drainage area.

Herbicides

The permit requires herbicide monitoring at BMP sites only for toxicity monitoring. In addition, the permit requires herbicide monitoring "only if applied in the monitoring site drainage area." The drainage area for the BMP sites is assumed to mean only the area contributing runoff to the edge of the highway.

Based on WSDOT's current and historical records of usage from 2008 to the present, the herbicides listed in the permit that were used at the selected highway sites are:

- Everett I-5 MP 197.27: Glyphosate (nonaquatic formula)
- Everett I-5 MP 197.35: Glyphosate (nonaquatic formula)
- Pilchuck I-5 MP 210.71: Glyphosate (nonaquatic formula)
- Pilchuck I-5 MP 210.78: Glyphosate (nonaquatic formula)
- Pilchuck I-5 MP 210.85: Glyphosate (nonaquatic formula)
- Marysville SR 9 MP 17.92: Glyphosate (nonaquatic formula)

WSDOT will communicate with staff at least annually to stay up to date on the application of herbicides near the monitoring locations to adaptively manage sampling to meet permit requirements. These yearly reviews will be used to update the list of herbicides to be monitored at each site. Modifications to the list of herbicides and fertilizers to be monitored will be made using an addendum to this QAPP.

S7.B.4 of the permit provides the list of herbicides that WSDOT would need to monitor:

- Triclopyr (ester formula only)
- 2,4-D
- Clopyralid
- Diuron
- Dichlobenil
- Picloram
- Glyphosate (nonaquatic formula only)

From this list, anytime the herbicide triclopyr is mentioned later in the permit, it is assumed that triclopyr (ester formula only) is implied.

7-3 Annual Seasonal First Flush Toxicity Monitoring

This section describes the toxicity study design for required seasonal first flush toxicity sampling from three highway and three BMP effluent samples. The sampling process design was developed based on the monitoring requirements identified in the permit and recommended procedures from Ecology (ASTM E1192-97).

7-3.1 Toxicity Target Population

S7.C.1 of the permit requires that WSDOT collect six toxicity screening samples, three from EOP stations and three from BMP effluent stations, and associated chemical analysis at least once per monitoring year in August or September. Samples will be collected with at least a one-week antecedent dry period (or October, irrespective of antecedent dry period, if unsuccessful in August or September). The permit's toxicity guidance (see Appendix C) states that "WSDOT shall not be required to make more than two sample attempts for toxicity testing described in S8.C." Presumably, this reference to S8.C actually meant to refer to S7.C, because S8.C refers to records retention. WSDOT will only make two attempts annually (August through October) to collect seasonal first flush toxicity testing samples from the BMP effluents.

The seasonal toxicity will be tested for screening purposes only. If a qualifying event is missed despite documented good faith efforts, or if the sample is invalid or has an anomalous test result, a second sample collection will be attempted if sufficient time remains to meet the toxicity storm

event criteria. If the second attempt is unsuccessful, then no additional attempts will be made that calendar year.

7-3.2 Toxicity Monitoring Requirements

Annually, one seasonal first flush toxicity sample will be collected from each of the influent and effluent BMP monitoring stations listed in Table 15. The EOP interceptor will be sampled for the influent and the 4-meter interceptor will be sampled for the effluent.

Table 15 Toxicity monitoring stations for BMP effluents.

BMP Type	Location of BMP
Modified VFS	Northbound I-5 at Everett (MP 197.35)
Modified VFS	Southbound I-5 at Pilchuck (MP 210.85)
VFS	Southbound SR 9 near Marysville (MP 17.92)

It may prove difficult to collect sufficient volume for toxicity sampling from the relatively small areas contributing to the runoff at these highway monitoring sites. The total volume required for toxicity testing and associated chemical analyses is in the range of 9.9 liters, without any extra volume for chemical duplicates. If a minimum volume of 2.0 liters (1.2 liters for toxicity at 4 replicates at 4 concentrations and 100 mL per replicate and 0.8 liters for metals and chloride) is not collected, then the sample will not be analyzed. Table 16 lists the parameters to be tested when the volume collected is between 2.0 and 9.9 liters, as well as the parameter priority, in descending order, when the volume collected is less than 9.9 liters. The irregular intervals of sample volume for toxicity and chemistry combined are due to variations in sample quantity needs for different parameters. Any excess sample volume that is not used for toxicity testing or chemistry will be reserved for use during the follow-up actions outlined in Appendix F.

The toxicity lab will measure conductivity, dissolved oxygen, and pH for each site once the samples reach the laboratory.

To improve the chances of collecting enough volume, an additional autosampler will be placed at each toxicity BMP effluent sampling location. Toxicity autosamplers will be preset and deployed by field staff just before the first qualifying seasonal storm in order to collect a composited toxicity sample.

A decision will be made by the Field Lead and Project Manager on whether to program the autosampler for time-weighted (equally time-spaced subsamples) or flow-weighted compositing programs. S7.C.5 of the permit allows flexibility in the sampling method between time- or flow-weighted compositing programs when collecting seasonal first flush toxicity samples only. Time-weighted sampling would likely provide larger volumes for the average storm; however, the chemistry data will not qualify for BMP monitoring if not collected by the flow-weighted sampling program. Seasonal first flush toxicity samples will be collected in a sterilized glass carboy and capped with Parafilm® to prevent contamination. Use of a modified clean hands/dirty hands technique to prevent field contamination of samples is not required but will serve as a guideline for clean field practices.

Grab samples for TPH for toxicity testing will be collected into an appropriate container and sent to a laboratory for measurement. The method of grab collection may vary due to access to the discharged stormwater: a container may be held by hand or fixed to a pole sampler. Refer to the SOP for Collecting Grab Samples from Stormwater (Ecology, 2009c) for further details on this method.

Table 16 Toxicity order of priority for sampling (Ecology, 2009a).

Volume (L) Obtained[1]	Sample Volume (L) Toxicity and Chemistry	Sample Volume (L) for Toxicity	Toxicity Test Details[1]	Sample Volume (L) for Chemistry	Chemistry Analyses Performed
2.0–2.4	2.0	1.12	4 reps., 4 concentrations, 100 mL per replicate	0.8	Metals, Chloride
	2.1			0.9	Metals, Chloride, Hardness
2.4–3.0	2.5	1.15	4 reps., 5 concentrations, 100 mL per replicate	1.3	Metals, Chloride, Hardness, MBAS
	2.9			1.7	Metals, TSS
	3.0			1.8	Metals, TSS, Chlorides
3.0–6.0	3.1	1.4	4 reps., 5 concentrations, 125 mL per replicate	1.7	Metals, TSS
	3.2			1.8	Metals, TSS, Chlorides
	3.3			1.9	Metals, TSS, Chlorides, Hardness
	3.7			2.3	Metals, TSS, Chlorides, Hardness, MBAS
	4.7			3.3	Metals, TSS, Chlorides, Hardness, MBAS, PAH
	5.2			3.8	Metals, Herbicides[2]
	5.3			3.9	Metals, Herbicides,[2] Chloride
	5.4			4.0	Metals, Herbicides,[2] Chloride, Hardness
	5.8			4.4	Metals, Herbicides,[2] Chloride, Hardness, MBAS
>6.0	7.3	2.5	4 reps., 5 concentrations, 250 mL per replicate	4.8	Metals, Herbicides,[2] TSS
	7.4			4.9	Metals, Herbicides,[2] TSS, Chlorides
	7.5			5.0	Metals, Herbicides,[2] TSS, Chlorides, Hardness
	7.9			5.4	Metals, Herbicides,[2] TSS, Chlorides, Hardness, MBAS
	6.4			8.9	Metals, Herbicides,[2] TSS, Chlorides, Hardness, MBAS, PAHs
	7.4			9.9	Metals, Herbicides,[2] TSS, Chlorides, Hardness, MBAS, PAHs, Phthalates

[1] Laboratory guidance for *H. azteca* is discussed in detail in Appendix C. Replicate totals and volumes needed are listed.

[2] Limited to the herbicides listed in the permit and used within the drainage area by WSDOT.

WSDOT must notify the toxicity laboratory two days prior to the date of the forecasted storm event, and they must be notified upon sample collection that the field trip was successful.

The toxicity sample must be cooled and sent to the laboratory immediately. If the sample temperature exceeds 6°C by its receipt at the laboratory, the Ecology WET coordinator must be contacted for conditional acceptance for a sample temperature deviation. Acceptance of a temperature deviation will be based upon Ecology's "Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria" (Ecology, 2008b). Temperature deviations will not be granted for samples warmer than 14°C unless the sample is received within one hour of collection.

The toxicity guidance (see Appendix C) suggests that WSDOT collect additional samples of the stormwater and receiving waters. The purpose of these additional samples would be to improve the understanding of the toxicant in the stormwater and to gather enough information for use in the Biotic Ligand Model. WSDOT may collect a grab sample for hardness from the receiving water, which will be collected and sent to the laboratory for hardness correction of the stormwater samples. Other parameters suggested for receiving water monitoring, permit-suggested toxicant identification testing, and required follow-up actions are discussed in Appendix G.

7-3.3 Toxicity Data Management and Follow-Up Requirements

The permit allows for adaptive management in analyzing for toxicity parameters. S7.C.4 of the permit states "Chemicals below reporting limits after two years of data analysis may be dropped from the list of parameters." This pertains only to the toxicity parameters in Table 14.
The permit's toxicity guidance (see Appendix C) encourages preparation of a toxicity identification plan for identifying a toxicant if the list of chemical analytical results did not point to a likely toxicant. A plan for interpretation of toxicity test results and permit-required follow-up actions is discussed in detail in Appendix G. These follow-up actions include suggested monitoring for indentifying the toxicant if still unknown. An additional parameter, cobalt thiocyanate activating substances (CTAS), may be analyzed if the toxicant identity is unknown and nonionic surfactants may be present.

8 Sampling Procedures

The following sections describe the methods and procedures for identifying, organizing, collecting, maintaining, and processing samples, equipment, and data in the field. Any field sampling for this project will follow these guidelines.

8-1 Storm Event Targeting Procedures

Satellite imagery and model predictions will be used as a basis for weather information provided by the National Oceanic and Atmospheric Administration, the National Weather Service, and/or private forecasters. These predictions will be evaluated by the Field Lead to determine potential qualifying storm events. As candidate storms approach, radar observations and hourly reports from land-based weather stations will be used to track and evaluate storm progress. Land-based weather stations include universities, news programs, or state and national agencies, and they will be observed via the Internet.

The minimum rainfall criterion is a rainfall depth of 0.15 inch. This means that for a storm event to qualify for permit compliance, this minimum rainfall criterion must be met. Autosamplers and WSDOT field crews may initiate sampling before the minimum rainfall has accumulated so that the entire hydrograph is sampled for highway and BMP monitoring sites.

Establishment of the rainfall/runoff relationship will help guide sampling and minimize the sampling of storms that do not qualify. Establishment of this relationship has begun at two I-5 sites. Based on preliminary data, runoff at the EOP stations has been determined to begin at less than 0.10 inch of rainfall. This information can be used to program equipment to better capture the beginning of the storm hydrograph.

Snowmelt alone will not be considered a qualifying event. Snowmelt accompanied by rainfall (typically called sleet) and a rain-on-snow event are considered qualifying events that will be monitored. Once a storm is determined to be a candidate for measurement, the Field Lead will notify the appropriate personnel (and appropriate laboratories) and initiate mobilization for stormwater sampling as soon as feasible.

These decisions and further explanations regarding staff training are documented in the SOP for Decision Matrix for Targeting Storm Events (WSDOT, in draft 2011). This SOP will also inform staff on the decision-making process to mobilize for criteria versus a non-criteria storm event. The estimated duration and estimated rainfall used in the decision (the "*Go*" decision) to initiate sampling procedures will be logged on storm-tracking forms (see an example form in Appendix H) and stored in WSDOT central files, along with a printed copy of the forecast. A diagram of the series of decisions and events for sampling is shown in Figure 16.

The Field Lead will notify the sampling field crew to begin pre-event preparation for stormwater sampling. Given the logistical difficulties in getting to the sampling sites, the Field Lead may make the decision based on storm size (for example, if the storm is predicted to be small) not to deploy the sampling team for a grab sample.

8-2 Pre-Event Preparation Procedures

Figure 16 is a simplified flow diagram of the decisions and actions needed for successful sampling.

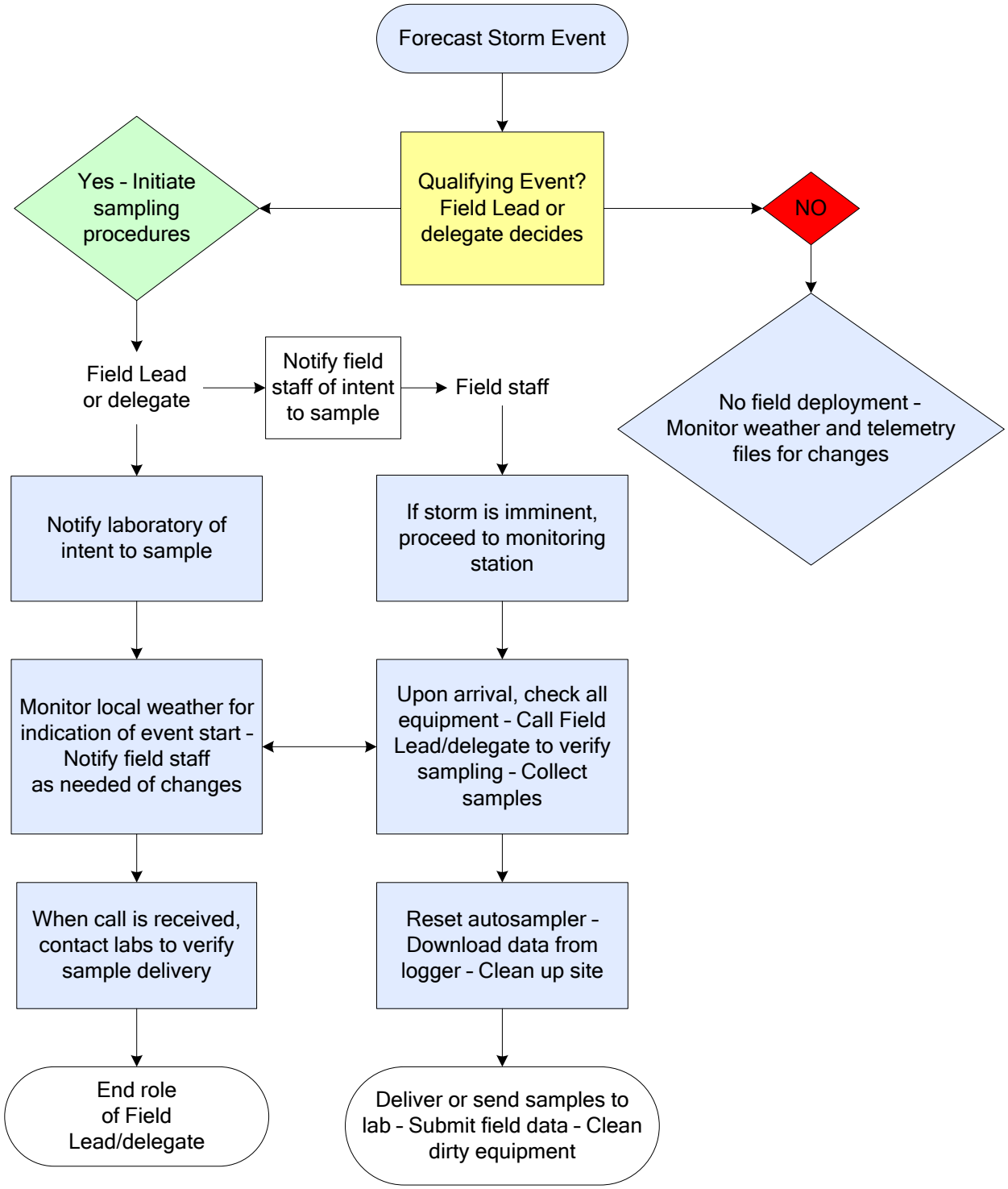


Figure 16 WSDOT sampling procedures flow diagram.

8-2.1 Trip Preparation

When a storm has been categorized as "qualified" by the Field Lead, it may be necessary to be on-site before the rainfall begins in order to be ready for early event grab sampling. In certain areas, this may require time allocations for commutes or for hotel arrangements prior to the storm events. Draft packing lists and trip checklists, with detailed instructions, will be used; example lists are included in Appendix H. Prior to deployment, field technicians are responsible for packing all necessary equipment for site maintenance, sampling, and sending the samples to the lab. Due to the potential for short notices for storm events, the travel vehicles should be staged and ready.

Monitoring the telemetered data from a mobile Internet-capable device will assist in the timing of field deployment. Deployment timing will depend on when the level of rainfall predicted to generate runoff begins. After each sampling event, autosamplers will be reset for the next sampling event; therefore, crews will be prepared to clean the sampler and exchange bottles and equipment as necessary.

8-2.2 Laboratory Notification

Once samples are collected, the field technicians must notify the laboratories whether sampling was successful and whether they need to prepare for the reception of samples. If the sampling trip is to collect the seasonal first flush toxicity samples, the field technician is responsible for notifying the appropriate laboratories 48 hours in advance of the storm event for toxicity testing.

8-2.3 Site Preparation

Upon arrival at the monitoring site, field technicians will visually inspect sampling equipment activity in progress. Any necessary alterations will be catalogued and reset to ensure sampling precision. If field crews arrive before sampling begins, they will:

- Check the data logger program to verify sampling will take place when the step triggers have been satisfied.
- Inspect autosamplers to verify bottles are appropriately set and tubing is attached properly at the sampling point.
- Check the leveling of flow-measuring devices (weirs, flumes, etc.) and remove any obstructions and sediment that could impede the flow of stormwater.
- Prepare for grab sampling.

8-3 Monitoring and Maintenance Procedures

8-3.1 Precipitation Measurement

At each monitoring site, pole-mounted tipping bucket rain gages will be deployed to accurately represent on-site rainfall characteristics. Rain gages must be installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage. Rain gage placement will, to the best of WSDOT's ability, follow the National Weather Service specifications (http://www.weather.gov/om/coop/standard.htm).

Rain gages will be calibrated prior to the onset of permit monitoring and maintained in accordance with the manufacturers' specifications.

Rain gage data are collected every 15 minutes and stored in the data logger's memory. In addition, the rain gage data are broadcast hourly via telemetry to a WSDOT database in order to remotely identify on-site weather characteristics. During each station visit, the rain gages will be inspected, cleared of debris, and maintained in accordance with the manufacturers' specifications. Rain gage data will be downloaded from the logger for each storm event or during the maintenance checks.

8-3.2 Discharge Measurement

Discharge will be calculated by the data logger using stage values combined with equations specific to the gaging device (weir or flume). Discharge data will be plotted with the rainfall data in a site-specific rating curve. Pipe weirs (Thel-Mar type) tend to be preferred over Parshall flumes in lower-flow "flashy" systems in order to more accurately characterize small-scale hydrological features (Rantz et al., 1982; USEPA, 2002b).

- Equations for v-notch pipe weirs are derived specifically for each weir and will be provided by the manufacturer.
- Discharge equations for Parshall flumes are provided by the specific manufacturer and will vary based on throat size.

Refer to the USGS *Water Supply Paper 2175* (Rantz et al., 1982), the weir manufacturer's specified calibration/conversion sheets (Thel-Mar type weirs, etc.), and EPA's *Urban Stormwater BMP Performance Monitoring* guidance manual (EPA-821-B-02-001) (USEPA, 2002b) for standard flume and weir equations and descriptions of flume and weir applications. Reduction of flow by BMP treatment will be calculated by measuring the difference in volume between the influent flow and effluent flow.

Flow Monitoring Equipment

Pipes will be fitted with Thel-Mar-type removable weirs or Parshall flumes (as shown in Figure 17). Thel-Mar-type v-notch weirs may be installed to improve the accuracy of stage height readings for lower flows.

Water quality samples collected by the autosampler or manually will be gathered from a collection device that is mounted at the outlet beyond the weir and flume. Peripheral sensors will be fitted to a pipe extension.

A stage measuring device (such as a gas bubbler or pressure transducer) will be installed behind the weirs or in the flume stilling wells. These instruments will be connected to data loggers to record water level measurements. DC power from solar panels and batteries will be used if access to AC power is not possible. Monitoring equipment will be housed in protective enclosures. Enclosures will be installed on concrete pads or anchored securely to the ground via driven anchors near the sampling location. Tubing and sensor cables will be routed to the enclosures in protective conduit. Routine maintenance and calibration training will be captured by the SOP for Equipment Calibration and Cleaning (WSDOT, in draft 2011).

Figure 17 Photos of Thel-Mar-type v-notch weir and 1-inch throated Parshall flume.

8-3.3 Grab Sampling

Water grab samples will be collected throughout the year when storm events occur. Manual collection of grab samples for TPH will begin as early in the runoff event as feasible. If the drainage area is very small, field staff may need to be on-site before the storm begins to prepare for grab sampling. Grab samples will be collected either by using an appropriate pole sampler with a bucket or claw for holding the sample jar or by hand into the sample jars, following the guidance in the SOP for Collecting Grab Samples from Stormwater Discharges (Ecology, 2009c).

Hand-held portable meters may be used to measure pH or to enhance stormwater characterization by measuring water quality parameters not required for permit compliance. Care must be taken not to interfere with the autosampler during composite sample collection. Methods for mid-event sample collection are discussed in the SOP for Automatic Sampling for Stormwater Monitoring (Ecology, 2009b). Mid-event measurements made using portable meters will be recorded on field forms, in accordance with the Using Portable Meters SOP (WSDOT, in draft 2011), and filed in the central files when they are returned to WSDOT.

8-3.4 Composited Sample Retrieval

Upon completion of sampling, the data logger and autosampler will return to normal operating modes. The autosampler will be ready for the field technicians to recover the sample bottles. Field personnel will wear nitrile gloves at all times during sample collection and follow standard health and safety procedures. Preservation and filtration of samples (if needed) will occur immediately after composited samples have been collected.

Upon completion of sampling, prefabricated labels will be verified and samples will be placed in coolers with bubble wrap and blue ice packs for transport. Chain of custody (COC) forms will be filled out completely and sent with the coolers (see Appendix K for an example COC form from Ecology's Manchester Environmental Laboratory).

Collection of blanks will occur as scheduled and be included in the transport coolers.

The autosampler will then be inspected, cleaned, and restocked according to a Field Sampling with Autosamplers SOP specific to WSDOT's program for field crew training (WSDOT, in draft 2011). Ecology's SOP for Automatic Sampling for Stormwater Monitoring (Ecology, 2009b) will serve as a guide. An important aspect of cleaning and restocking the autosampler will be switching the bottles on an as-needed basis.

8-3.5 Field Filtration

Prefiltration Holding Time

Orthophosphate and dissolved metals will be filtered in the field within 15 minutes of final aliquot collection. If filtering occurs between 15 minutes and 24 hours, the sample will be *J* qualified. If field filtering occurs after 24 hours for both orthophosphate and dissolved metals, then the sample will be rejected and labeled with an *R* on the field forms. Field sampling efforts, including filtration and other activities, will be documented on a field sampling form (see example in Appendix J).

Metals Sample Collection/Handling

A modified version of the EPA's "clean hands/dirty hands" protocol for low-level detection of metals (USEPA, 1996) will be used as a guideline during sample collection. A modified version of the protocol will allow sampling to be performed by one field technician as opposed to two. Accordingly, the laboratory will preclean laboratory bottles for metals, as required for the analytical method. The laboratory will then place the metals bottles into two separate Ziploc® (or comparable) sealed plastic bags for transport to the site. Prior to sample collection, the field technician will wear a new set of gloves (i.e., clean and powder free) for each sequence of clean or dirty hands sampling that is required for proper implementation of the protocol. The sequence of clean and dirty hands operations to be used during sampling is described in detail as follows:

Dirty Hands (two sets of new gloves):

- Open the cooler with sample bottles
- Remove double-bagged sample bottle from cooler
- Unseal outer bag

Clean Hands (remove outer set of gloves):

- Unseal inner bag containing sample bottle
- Remove bottle and unscrew cap
- Rinse bottle three times in water to be sampled (if sample contains no preservative)
- Fill sample bottle
- Return sample bottle to inner bag
- Reseal inner bag
- Reseal outer bag
- Return double-bagged sample to cooler

8-3.6 Field Sample Verification

Before sending the coolers to the laboratory, field staff must fill out field sampling forms. Draft versions of a sampling form are presented in Appendix J. Additionally, field staff may need to verify that the storm event met the permit requirements for storm sampling (antecedent dry period and rainfall quantity) before sending the coolers to the laboratory (see Section 9-2.2 for post-event processing). However, if in doubt, technicians should always send the cooler as soon as possible. They should follow up with a call to the laboratory to cancel the analysis if the Field Lead or Project Manager determines that the storm event did not meet permit criteria or if the samples should be used as one of the three nonqualifying events. Communication between the field crew and Field Lead or Project Manager is critical and will require cellular phones.

The field technician will be able to determine the final volume of the sample captured and aliquot samples to their respective sample jars. If insufficient sample volume was collected for analysis of all parameters, parameters will be analyzed in order of priority according to the list (see Table 16). After shipping the samples to the laboratory, field technicians will return to headquarters (or the field station) and submit their field notes and copies of COC forms to the Field Lead for review.

The Field Lead will review the collected storm reports, hydrographs, field notes, COC forms, and maintenance forms to determine whether any data quality errors were made. If errors are found, notice will be given to the laboratory regarding the type of error, which sample was collected erroneously, and whether the sample should be disqualified for analysis based on the error.

If hydrograph errors are found, a ratings shift may be applied to the hydrograph. These errors must be validated by field observation of stage during storm events. A shift may be applied at any time to a rating to better fit the hydrograph to actual measurements and account for drift.

8-3.7 Telemetered Data Collection

Each station's telemetered data logger will be preprogrammed to continuously collect temperature, stage, and rainfall data, as well as composite samples when conditional requirements are met. The data loggers are programmed with a step-triggering system designed to minimize falsely triggered sampling. The step-triggering system utilizes environmental data (such as rainfall, water temperature, and stage) collected by the data logger to determine whether a storm event is qualified and whether or not to initiate sample collection. Upon qualification, the

logger will wake up the autosampler and initiate its sample collection program. The autosampler will collect preprogrammed amounts in accordance with the permit requirements and analytical needs.

Temperature, rainfall, and stage data will be collected and logged every 15 minutes and transmitted every hour to the WSDOT database throughout the duration of the storm event.

Upon receipt of transmission in the central database, data will be qualified, tabulated, and stored, until the data are able to be reviewed and finalized by the Data Steward.

Field technicians must download the internal memory of the data logger to a specified storage drive (thumb drive) after final stormwater samples have been collected. These data will supplement the telemetered data and be used to fill the transmission or data gaps that may have occurred.

8-3.8 Equipment Maintenance and Cleaning

Servicing of scientific instrumentation will follow manufacturers' methods or will be conducted as needed by trained technicians in a controlled environment. Routine site visits will occur every six weeks or after a sampled storm event. Refer to the Equipment Maintenance and Cleaning SOP for the specifics on instrument cleaning, station visit, and maintenance (WSDOT, in draft 2011). For specific equipment maintenance, refer to operators' manuals.

Generally, maintenance will consist of equipment inventories, inspections, testing, and replacement of worn or missing components.

Equipment Decontamination

All sampling equipment and containers will be prepared prior to the sampling event. Any portion of the autosampler (including intake screen, intake tubing, pump tubing, and sampler containers), filters, or other materials coming into contact with the sampled stormwater will be decontaminated prior to use or will be certified as precleaned from the equipment source.

Plastic or tubing will be washed or rinsed with nonphosphate soap, rinsed three times with deionized water, and air dried. Clean implements will be stored in aluminum foil or polyethylene bags for transport to the field station. Stainless steel sampling implements, including the spoons, bowls, and stirrers, will be cleaned by sequentially:

1. Washing in nonphosphate detergent and hot tap water
2. Rinsing with hot tap water
3. Rinsing with 10% nitric acid (if sampling for metals)
4. Rinsing with deionized water three times
5. Air drying in clean area free of contaminants
6. Rinsing with pesticide-grade acetone (if sampling for organics)
7. Air drying in clean area free of contaminants
8. Rinsing with pesticide-grade hexane (if sampling for organics)
9. Air drying in clean area free of contaminants

After drying, equipment will be wrapped in aluminum foil and stored in polyethylene bags until used in the field. Sampling equipment will be dedicated to the station and will only be used at subsequent stations after cleaning in accordance with the above procedures, which are based on EPA guidelines (USEPA, 1992).

8-3.9 Adaptive Management

Once experience is gained with monitoring, a process called "adaptive management" will be employed for minor or major changes. Relatively small changes to the monitoring program will not incur authoritative signature approval.

Examples of small changes include, but are not limited to:

- Sizes of bottles used in the automatic sampler
- The equipment used for field filtration
- Using a different brand of equipment but retaining functional equivalency
- Adjustments to the programming of the automatic samplers

Major changes to the sampling program are required by the permit to get signatory approval from WSDOT and Ecology prior to the changes.

Major changes may include:

- Changing the sampling location at a site
- Changes in analytical methods

9 Measurement Procedures

This section describes the laboratory selection process, sample processing procedures, sample labeling and chain of custody, laboratory methods, and reporting limits.

9-1 Laboratory Selection

Laboratories will be selected based on their current accreditation status with Ecology (http://www.ecy.wa.gov/programs/eap/labs/search.html) and their ability to achieve acceptable limits of detection for the parameters measured as part of this project. Due to the scale of sampling under this permit, multiple laboratories will be selected to ensure sample completeness.

The laboratory will report the analytical results to WSDOT in a timely manner. The laboratory will provide all sample and quality control data in standardized laboratory reports suitable for evaluating the project data. Laboratory reporting of reviewed and qualified data, will include, but not be limited to:

- Case narratives and data summaries discussing laboratory QA/QC.
- Reported result values, including those between the method detection limit and the laboratory reporting limit.
- The method detection limits and laboratory reporting limits for all analytes for each batch.
- QA/QC results such as field replicates, laboratory duplicates, surrogates, method blanks, and matrix spikes.
- A PDF or equivalent copy of the case narrative and data.
- An electronic deliverable datum developed by WSDOT specifying the format in which laboratories are to report data.

The laboratory reports will also include any problems encountered in the analyses. Raw data will be kept at the laboratory for a minimum of five years.

9-1.1 List of Laboratories

Laboratories selected by WSDOT are accredited and capable of meeting reporting limits and holding times set forth by the method or permit, unless noted in this QAPP. Table 17 lists the selected laboratories for sample processing. A complete list of accredited laboratories and parameters analyzed can be found at: http://www.ecy.wa.gov/programs/eap/labs/search.html

Table 17 Selected laboratories for sample processing.

Laboratory Name	Analytical Purpose	Address	Phone
Manchester Environmental Laboratory	All parameters in Table 19, except glyphosate, MBAS, pH, toxicity, and particle size distribution.	Washington State Dept of Ecology Manchester Environmental Laboratory 7411 Beach Drive East Port Orchard, WA 98366 Work Hours 8:00 to 4:30 Weekdays	Stuart Magoon 360-871-8800
TestAmerica Laboratories, Inc.	Glyphosate, orthophosphate,[1] total Kjeldahl nitrogen	Labs nationally – GA contract: TestAmerica: Seattle, Tacoma, Spokane, Portland	Katie Downie 253-922-2310
Analytical Resources, Inc.	Particle size distribution	4611 South 134th Pl., Suite 100 Tukwila, WA 98168	Mark Harris 206-695-6210
Anatek Labs, Inc.	Fecal coliforms[1]	504 E. Sprague Suite D Spokane, WA 99202	Kathy Sattler 509-838-3999
AmTest Laboratory	Fecal coliforms,[1] MBAS	13600 NE 126th Pl., Suite C Kirkland, WA 98034	Aaron Young 425-885-1664
NewFields Northwest, LLC	Toxicity	PO Box 216 Port Gamble, WA 98364	Brian Hester 360-297-6070
WSDOT	pH	pH analysis will be conducted using a meter in the field or at WSDOT facilities by WSDOT staff	Fred Bergdolt 360-570-6648

[1] Additional laboratories beyond Manchester Environmental Laboratory are needed to meet holding times for this analysis.

9-2 Sample Processing Procedure

This section presents the post-storm event sample processing procedures for stormwater samples. At the end of a successful sampling event, a final composite sample may be required at sites where more than one bottle was filled. Post-storm event sample processing for routine samples will take place after the storm event is completed and all runoff samples are taken.

9-2.1 Sample Amounts and Containers

The collected samples will be analyzed for the parameters required by the permit. Table 18 lists the sample volumes, holding times, containers, and preservation requirements for BMP effectiveness monitoring and toxicity testing parameters. Table 18 was created from the *Laboratory Users Manual* (MEL, 2008), Table II of 40 CFR 136.3, and specified methods within the permit. Seasonal first flush toxicity sample parameters are listed in Appendix C. If toxicity is found in stormwater samples, testing for additional parameters will be conducted. Appendix C provides details for this testing.

Table 18 Sample containers, amounts, preservation, and holding times for stormwater samples (MEL, 2008; 40 CFR 136.3; Ecology, 2009a).

Analysis	Quantity Needed for Analysis	Quantity Needed for QC Samples	Container	Holding Time	Preservative[1]
BMP Effectiveness Monitoring					
Hardness as $CaCO_3$	100 mL	Dup = 100 mL	125 mL w/m poly bottle	6 months	H_2SO_4 to pH<2; cool to ≤6°C
Metals – dissolved (Cu, Zn)	100 mL	MS, MSD, and Dup = 100 mL each	500 mL HDPE bottle[4] with Teflon® lid	6 months	Filter within 15 minutes of collection[4]; then add HNO_3 to pH <2[5]; cool to ≤6°C
Metals – total recoverable (Cu, Zn)	100 mL	MS, MSD, and Dup = 100 mL each	500 mL HDPE bottle[4] with Teflon® lid	6 months	HNO_3 to pH <2
Orthophosphate (OP)	30 mL	MS, MSD, and Dup = 125 mL each	125 mL amber w/m poly bottle	48 hours	Filter within 15 minutes of collection[4]; cool to ≤6°C
pH	500 mL; no head space in bottle	N/A	500 mL w/m poly bottle	24 hours	Cool to ≤6°C
Particle size distribution	2 liters	2 liters	HDPE, glass, or Teflon® ®container	7 days	Cool to 4°C
Total phosphorus (TP)	50 mL	MS, MSD, & Dup = 50mL	60 mL clear w/m poly bottle	28 days	HCl to pH<2; cool to 4°C±2°C
TSS	1 liter	Dup = 1 liter for clear water, less to none if dirty	1 liter w/m poly bottle	7 days	Cool to ≤6°C
Toxicity (collected once per year)					
H. azteca 24-hour acute toxicity test	6 liters	none	Glass bottle	36 hours	Cool to ≤6°C
Chloride	100 mL	MS, MSD, and Dup = 100 mL each	125 mL w/m poly bottle	28 days	Cool to ≤6°C
Hardness as $CaCO_3$	100 mL	Dup = 100 mL	125 mL w/m poly bottle	6 months	H_2SO_4 to pH<2; cool to ≤6°C
pH	500 mL; no head space in bottle	N/A	500 mL w/m poly bottle	24 hours	Cool to ≤6°C
Herbicides – Diuron	1 liter	MS & MSD= 1 liter each	1 liter amber glass bottle with Teflon® lid	7 days to extraction; 40 days after extraction	Cool to ≤6°C
Herbicides – Picloram, triclopyr (ester formula)	1 liter	MS & MSD = 1 liter each	1 liter amber glass bottle with Teflon® lid	7 days to extraction; 40 days after extraction	Cool to ≤6°C
Herbicides – Glyphosate* (nonaquatic formula)	60 mL	60 mL	60 mL screw cap bottles with a Teflon® faced silicone septa	14 days	Cool to ≤4°C[2]

Table 18 (continued) Sample containers, amounts, preservation, and holding times for stormwater samples (MEL, 2008; 40 CFR 136.3; Ecology, 2009a).

Analysis	Quantity Needed for Analysis	Quantity Needed for QC Samples	Container	Holding Time	Preservative[1]
Metals – dissolved (Cu, Cd, Zn, Pb)	100 mL	MS, MSD, and Dup = 100 mL each	500 mL HDPE bottle[4] with Teflon® lid	6 months	Filter within 15 minutes of collection[4]; then add HNO_3 to pH <2[5]; cool to ≤6°C
Metals – total recoverable (Cu, Cd, Zn, Pb)	100 mL	MS, MSD, and Dup = 100 mL each	500 mL HDPE bottle[4] with Teflon® lid	6 months	HNO_3 to pH <2
Methylene blue active substances (MBAS)	400 mL	400 mL	1 liter amber glass bottle	48 hours	Cool to 4°C
PAH compounds	1 liter	MS and MSD = 1 liter each	1 liter amber glass bottle with Teflon® lid	7 days to extraction; 40 days after extraction	Store in dark; cool to ≤6°C[2]
Phthalates	1 liter	MS and MSD = 1 liter each	1 liter amber glass bottle with Teflon® lid	7 days to extraction; 40 days after extraction	Store in dark; cool to ≤6°C[2]
TSS	1 liter	Dup = 1 liter for clear water, less to none if dirty	1 liter w/m poly bottle	7 days	Cool to ≤6°C
TPH-Diesel (NWTPH-Dx) (grab)	1 liter	Dup = 1 liter	1 liter n/m glass jar, organic free with Teflon® lined lids	7 days for unpreserved; 14 days for preserved**	HCl to pH<2; cool to 4°C ±2°C
TPH-Gas (NWTPH-Gx) (grab)	120 mL (fill vial full)	Dup = 120 mL	(3) 40 mL glass VOA vials with Teflon® coated septum-lined screw tops	7 days for unpreserved; 14 days for preserved	HCl to pH<2; cool to 4°C ±2°C

w/m = wide mouth
n/m = narrow mouth
MS = Matrix spike
MSD = Matrix spike duplicate
Dup = Laboratory Duplicate

[1] Preservation needs to be done in the field, unless otherwise noted. Ice will be used in cool samples to approximately 4°C.

[2] At the lab a reducing agent may be added as a preservative if an oxidant such as chlorine is present.

[3] Containers cleaned in accordance with OSWER Cleaning Protocol #9240.0-05 (MEL 2008).

[4] 0.45 micron pore size filters.

[5] Preserved in lab within 24 hours of arrival.

* EPA Method 547

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Sample Volumes

For the purpose of ensuring the highest possible quality of data and to ensure fulfillment of permit-required parameter sampling, an excess amount of sample will be collected (if available) for each composited sample. Each autosampler will hold glass carboys to collect composited stormwater for highway runoff samples, unless otherwise specified. Sample amounts listed in Table 18 are based on the needed quantity for a single laboratory analysis for each analyte and the excess volume for lab QC samples. This volume has been determined by the laboratory to be satisfactory for its minimum requirements. Field replicates will be collected according to the established schedule. For toxicity samples, a glass carboy will be set up for autosampler collection. Refer to Appendix C for specific permit requirements related to toxicity sampling.

Sample Containers

For all samples, commercially available precleaned sample containers will be used, and the laboratory will maintain a record of certification from the suppliers. The sample container shipment documentation will record batch numbers for the containers. With this documentation, containers can be traced to the supplier and container wash analysis results can be reviewed.

Laboratories are able to clean and reuse many containers. Containers will be cleaned to EPA QA/QC specifications (USEPA, 1992). Precleaned sample containers (bottles and carboys) will be used for sampling.

A glass carboy (volume dependent upon parameters required per site) will be used primarily to collect composited samples directly from the autosampler in the field. Tubing lined with fluorinated ethylene propylene (FEP) or a similar product will be inserted into the opening of the carboy and sealed with an appropriate stopper, or it will be wrapped in Parafilm® to form a seal. Several parameters can be analyzed from the same composite sample; therefore, sample splitting is required. Sample splitting will take place in the field unless contamination is a concern; then it will be done at the laboratory. Unpredicted conditions or circumstances may require the use of rosettes containing individual bottles, instead of one large bottle.

Sample Splitting

Parameters that require preservatives or field filtration from the master composite and/or grab samples will be processed in the field. Processing in the field for automatically composited samples will consist of homogenizing the bottle's contents and placing aliquots of the composite into appropriate precleaned laboratory containers for subsequent analysis. Sample splitting will be performed using the automatic sampler head and tubing used to collect the sample. This process will involve replacing the inlet tubing with a precleaned shorter section of tubing and reversing the autosampler pump to fill lab bottles. The tubing and top of the carboy will be wrapped with Parafilm® to prevent sample contamination. The carboy will be agitated during the reverse pumping timeframe. Agitation will be done by placing the carboy on a prefabricated stool with only one central leg that can be held by a field crew member and swirled back and forth and side to side. Vortex swirling will be avoided to prevent entrapment of heavier particles in the middle of the carboy. If this method of sample splitting is inadequate in practice, the widely available churn splitter will be employed.

Post-storm event sample handling is described below and will be developed into training for field crews. Contents of this training will be based on the following section.

9-2.2 Post-Event Processing, Preservation, and Holding Times

After the storm event, data collected during the storm will be assessed to determine whether the storm qualified according to the permit specifications. If the storm event did not qualify, the samples may be discarded and the associated bottles sent to the laboratory for cleaning in preparation for the next storm event. If the criteria have been met, field crews will remove the chilled carboys and bottles for sample splitting, filtration (if necessary), and preservation. The Field Lead and Data Steward will decide whether a nonqualifying storm event will be sampled to meet permit requirements.

Sample Preservation

Some of the parameters to be analyzed (TP, TPH, metals, and hardness) will require chemical preservation to maintain the integrity of the samples and prevent them from degrading prior to laboratory analysis. Filtration is required as well for orthophosphate and dissolved metals and will be conducted immediately after composited sample collection is completed.

Samples for orthophosphate and dissolved metals will be filtered using a filtering set-up that pulls the sample through a filter using vacuum pressure created by a peristaltic (or hand) pump. Prior to filtering the sample, an aliquot of deionized water will be passed through the filter to rinse the filter and container. After rinsing, the filtered sample will be collected and distributed into the laboratory sample bottles. Disposable filter set-ups will be used for each sample.

Sample cooling to 4º – 6ºC or less, but not freezing, is necessary for the preservation of most of the parameters to be analyzed. Collected samples must be transferred from the field station to the lab in an ice-filled or blue ice-filled cooler to maintain temperature requirements.

Sample Holding Times

Holding times can be described as the maximum allowable length of time between sample collection and laboratory manipulation. The holding time for parameters collected by the autosampler will be calculated from the time the autosampler's final aliquot is collected. Holding times are different for each analyte and are in place to maximize analytical accuracy and representativeness. Each sample collected will be packaged in a container and labeled accordingly. Refer to Appendix C for toxicity sample holding times. If holding times cannot be met, the Field Lead will process and label the sample for the next appropriate parameter.

If necessary, the Field Lead will coordinate with the analytical laboratory to ensure samples can be transported, received, and processed during nonbusiness hours. Sample containers will be transported or sent by the field team to the analytical laboratory, following established sample handling and chain of custody procedures. At the laboratory, samples may be further divided for analysis or storage.

9-3 Sample Labeling and Chain of Custody

9-3.1 Labeling

Labeling is used to identify where and when a sample was collected and the analyte(s) in that sample to be analyzed. Laboratory-prepared bottles will be labeled to identify the cleanliness

and/or preservative contents for each bottle. Labels will be premade. Bottles will be either numbered or prelabeled to ensure proper handling. Labels will be filled out in pencil or permanent pen, placed on sample containers, and taped with packing tape to reduce water damage to the label. Sample labels will contain the following information:

1. Station name/identification
2. Analysis to be performed
3. Date and time of sampling
4. Sample ID or coding information
5. Sample numbers (1 of 3, 2 of 3, and so on)
6. Name/initials of field tech performing the sampling

This labeling information will be written in the chain of custody forms, discussed below.

9-3.2 Chain of Custody (COC)

Chain of custody can be defined as a systematic procedure for tracking a sample or datum from its origin to its final use. Chain of custody procedures are necessary to ensure thorough documentation of handling for each sample, from field collection to laboratory analysis. The purpose of this procedure is to minimize errors, maintain sample integrity, and protect the quality of data collected. A COC form will accompany each cooler of samples. After completing the form and packaging the samples for shipping, the sampler should retain a copy of the form for the records. Individuals who manipulate or handle these samples are required to log their activities on the form. Definitions of custody from the Manchester Environmental Laboratory's *Laboratory Users Manual* (MEL, 2008) are described below:

A sample is considered to be under a person's custody if it is:
In the individual's physical possession
In the individual's sight
Secured in a tamper-proof way by that person, or
Secured by the person in an area that is restricted to authorized personnel

Elements of chain-of-custody include:
Sample identification
Security seals and locks
Security procedures
Chain-of-custody record
Field log book

When the laboratory receives a cooler of samples, it will assume responsibility for samples and maintenance of the COC forms. The laboratory will then conduct its procedures for sample log-ins, storage, holding times, tracking, and submittal of final data to the responsible parties.

9-4 Laboratory Methods, Instruments, and Reporting Limits

9-4.1 Laboratory Methods and Analytical Reporting Limits

The selected analytical methods and reporting limits are shown in Table 19.

9-4.2 Laboratory Instrumentation

Maintenance of laboratory equipment will be conducted in a manner specified by the manufacturer or by the quality assurance guidelines established by the chosen laboratory. The instrumentation in service records will either meet or exceed manufacturers' specifications for use.

Table 19 Methods and reporting limits for water samples.

Parameter	Reason for Monitoring[1]	Method in Water* (SM=Standard Method, EPA=EPA Method, ASTM= American Society of Testing and Materials Method)	Reporting Limit
H. azteca 24-hr acute toxicity test	Tox	ASTM E1192-97	50% mortality
Chloride	Tox, Hwy	EPA 300.0	0.2 mg/L
Dissolved (Cd, Cu, Pb)	BMP, Tox, Hwy	EPA 200.8 (ICP/MS)	0.1 ug/L
Dissolved (Zn)	BMP, Tox, Hwy	EPA 200.8 (ICP/MS)	1.0 ug/L
Hardness as $CaCO_3$	BMP, Tox, Hwy	SM 2340B (ICP)	1.0 mg/L
Herbicides – Picloram, triclopyr (ester formula only)	Tox, Hwy	EPA 8270D GC/MS	0.01 – 1.0 ug/L
Herbicides – Diuron	Tox, Hwy	EPA 8270/8321 LC/MS	
Herbicides – Glyphosate[4] (nonaquatic formula)	Tox, Hwy	EPA 547	25 ug/L
Methylene blue active substances (MBAS)	Tox	SM 5540C	0.025 mg/L
Orthophosphate (OP)	BMP, Hwy	SM 4500-P G	0.01 mg/L
PAH compounds[2]	Hwy, Tox	EPA 8270D	0.1 ug/L
Particle size distribution (PSD)	BMP	Laser diffraction	NA
pH	BMP, Tox, Hwy	SM 4500H$^+$	0.2 units
Phthalates[3]	Tox, Hwy	EPA 8270D GC/MS	1.0 ug/L
Total phosphorus (TP)	BMP, Hwy	SM 4500-P F	0.01 mg/L
Total recoverable (Cd)	Hwy, Tox	EPA 200.8 (ICP/MS)	0.2 ug/L
Total recoverable (Cu)	BMP, Tox, Hwy	EPA 200.8 (ICP/MS)	0.1 ug/L
Total recoverable (Pb)	Tox, Hwy	EPA 200.8 (ICP/MS)	0.1 ug/L
Total recoverable (Zn)	BMP, Tox, Hwy	EPA 200.8 (ICP/MS)	5.0 ug/L
TSS	BMP, Tox, Hwy	SM 2540D (TAPE requires TSS samples not to exceed 500 microns – A US Standard sieve [#35] or equivalent device may be used for sieving at the lab)	1.0 mg/L
TPH-Diesel (NWTPH-Dx)	Tox, Hwy	NWTPH-Dx – Ecology, 1997 (Publication No. 97-602)	0.25 – 0.50 mg/L
TPH-Gas (NWTPH-Gx)	Tox, Hwy	NWTPH-Gx – Ecology, 1997 (Publication No. 97-602)	0.25 mg/L

[1] Parameter required by permit under S7.E BMP effectiveness (BMP), S7.B highway monitoring (Hwy), or S7.C seasonal first flush toxicity testing (Tox).

[2] PAH's of interest: acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene fluorine, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, and pyrene.

[3] Phthalates of interest: bis(2-Ethylhexyl)phthalate, Butyl benzyl phthalate, Di-n-butyl phthalate, Diethyl phthalate, Dimethyl phthalate, and Di-n-octyl phthalate.

[4] Results for glyphosate analysis between the RL of 25 ug/L and MDL of 2.5 ug/L will be reported. These results will be qualified as estimates.

* SM: http://www.standardmethods.org/, http://water.epa.gov/scitech/methods/cwa/methods_index.cfm,
EPA: http://www.epa.gov/osw/hazard/testmethods/sw846/online/index.htm, http://www.astm.org/SITEMAP/index.html
ASTM: http://www.ecy.wa.gov/biblio/97602.html

** Tox: Seasonal first flush toxicity testing

10 Quality Control Procedures

This section discusses the quality control (QC) procedures that will be implemented in order to provide high-quality data that meet the requirements of the WSDOT permit. Quality control procedures will encompass field collection and laboratory processing of all samples, and it will be monitored throughout the duration of the study. The quality of raw, unprocessed, and processed data is subject to review according to the established protocols in Section 5-2, Measurement Quality Objectives.

10-1 Field Quality Control Procedures

10-1.1 Standard Operating Procedures (SOPs)

Quality control in the field will refer to SOPs (listed in Table 20) for field sampling; maintaining field equipment; field documentation; sample collection; blank or replicate sample collection; and appropriate action for correcting and documenting potential field errors. The field quality control schedule for monitoring efforts is shown in Table 21. To ensure the quality and consistency of sample collections, equipment maintenance and sample collection SOPs will be followed.

Table 20 Standard Operating Procedures.

SOPs Published by Ecology[1]
ECY001 – Collecting Grab Samples from Stormwater Discharges
ECY002 – Automatic Sampling for Stormwater Monitoring
ECY004 – Calculating Pollutant Loads for Stormwater Discharges
EAP029 – Metals Sampling
EAP030 – Fecal Coliform Sampling
SOPs Developed by WSDOT (in draft)[2]
Equipment Calibration and Cleaning
Decision Matrix for Targeting Storm Events
Field Sampling with Autosamplers
Using Portable Meters

[1] Ecology 2006, 2007, 2009b, 2009c, 2009d, 2010b.

[2] WSDOT, in draft 2011a.

These SOPs will describe the following elements in detail:

- Regular maintenance of monitoring stations to ensure data relevance.
- Collection of continuous temperature, rainfall, and stage data for reference.
- Collection of automated, refrigerated, composited samples to characterize storm events.
- Use of certified, contaminant-free, or decontaminated sample containers.
- Storage of unused sampling bottles in clean, sealed containers prior to use.
- Implementation of modified “clean hands/dirty hands” techniques (for example, one person collects samples, while the other person opens the manhole covers and changes batteries) for sample collection and site maintenance.

- Replacement of sampler tubing with its surrogate tube (two tubes for each sampler, one always clean and stored away while the other is in use; switch when dirty, clean, and repeat as needed).
- Storage of collected samples on ice in a labeled cooler designated for transport.
- Delivery of samples to the laboratory, with completed COC forms and within proper holding times.

10-1.2 Field Instrument Quality Control

In order to maintain the highest degree of data quality, field equipment will undergo routine cleaning, calibrations, and maintenance at the recommended frequency specified by each manufacturer. Battery maintenance and data downloads from the data loggers will occur for each storm event or every six weeks, whichever comes first.

10-1.3 Documentation

Field data sheets will be printed on Rite-in-the-Rain® water-resistant forms or waterproofed tablet PCs to allow ease of use during storm events. When completed, these field sheets will be submitted to the Data Steward and stored in an organized central filing location. Forms and documentation will include the station visit/maintenance sheet, COC forms, and weather qualification report. (See Appendices G, H, I, and J for examples of field forms.) All entries on field documents will be made in pencil or permanent pen, and will list the field technician's name(s). Any errors or typos will be crossed out and rewritten by the technician who recorded the data. All corrections will be initialed and dated when made.

If field sampling or procedural errors are discovered, action will be taken to manage and correct those errors. Corrections may occur with corrective editing, relabeling, or, if warranted, flagging, discarding, and resampling. If a consistent error persists, an amendment to the sampling procedures may be required. Refer to Appendices C and G for guidance on corrective and follow-up actions for seasonal toxicity sampling.

10-1.4 Composite/Grab Field Replicate Samples

Composited field replicate samples will be collected at a rate of 10 percent of the total samples collected for monitoring under the permit. Field replicates will be collected by splitting composited samples or by setting up an additional autosampler to collect additional sample volume as equipment is available. Excess volume will be programmed into loggers to provide enough sample volume for field replicates collected by splitting composite samples (if the storm event is large enough). A schedule will be maintained by site to facilitate field crews knowing when to collect field replicate samples at each site. Parameters measured in the field sample will also be measured in the replicate sample for a particular storm event.

Grab field replicates will be collected following a similar schedule to the composited field replicates, but they may not be collected during the same storm event at the same site. Staggering the grab samples and composite samples may be necessary to increase the volume of sample available for collection. Grab field replicates will also be collected at a rate of 10 percent of the total samples.

All field replicates will be labeled the same as other samples, so that the sample has its own unique number. These replicate samples will be submitted blind to the laboratory with all other field samples.

The sampling schedule may be adjusted to meet the field replicate frequencies early in the fall/winter sampling season to prepare for a dry spring/summer season. The Field Lead and Data Steward should continuously manage the field replicate collections to achieve the 10 percent goal and communicate with the field crews so they know what samples, which storms, and to which monitoring sites field replicates should be taken for the monitoring program.

10-1.5 Field Blanks

The term "field blanks" includes equipment rinsate blanks, transport blanks, transfer blanks, and specific equipment blanks such as tubing. For BMP sites, an initial effort to collect equipment rinsate blanks at each site will be conducted two times early in the monitoring program but after the first sampling event. After this initial effort, equipment rinsate blanks will be collected at the remaining monitoring sites within the first year of monitoring. Equipment rinsate blanks will be collected at least once a year at each site (see Table 21).

The equipment rinsate blanks will consist of laboratory-supplied contaminant-free water that is run through the decontaminated autosampler system into a clean sample bottle. The goal is to mimic the sampling process to determine whether contamination is present from any part of sampling such as equipment, sample filtration, sample handling, or transport.

Additional field blanks will be collected if sample procedures or site conditions change. They may also be used as part of field audits to ensure procedures to reduce contamination are being followed. All field blank samples will be labeled with unique numbers and will accompany field samples sent to the laboratory.

If field blank contamination is discovered, additional field blank samples will be used to determine the source of the contamination. Field blank samples collected to determine the contamination source may include:

- A tubing equipment blank collected after an autosampler's Teflon® tubing is replaced, to determine whether contamination is from the tubing.
- A field equipment blank collected from the filtration apparatus used to filter metals and orthophosphate.
- A field transfer blank collected by pouring lab-provided deionized water into a clean sample bottle to determine whether field contamination is present, unrelated to the equipment.
- A field transport blank collected by transporting unopened bottles containing organic and metal-free certified clean water from the laboratory into the field, and then returning it to the laboratory (bottles are not opened in the field). Transport blanks are used to determine whether any contamination occurs while traveling from field to laboratory.

Any field blank contamination will be reviewed by the QA Officer or Data Steward to determine whether samples associated with the field blanks should be qualified based on the contamination. Sample results will be flagged with a *J* if they are less than or equal to 5 times the field blank concentration.

A schedule of storm events with planned field replicate, blank, or other QC samples will be maintained and followed as part of the stormwater sampling program.

Table 21 Field quality control schedule.*

Field Sample Collected	Frequency [2]	Control Limit	Corrective Action
Composited field replicate	10% of total samples or 1 per batch[1]	Qualitative control – Assess representativeness, comparability, and field variability	Review procedures; alter if needed
Grab field replicate	10% of total samples or 1 per batch[1]		Review procedures; alter if needed
Equipment rinsate blank	At least once a year at each site (the first year; BMP sites will be sampled twice early in the program, per TAPE guidance)	Blank analyte concentration should be below the reporting limit	Compare blanks for analyte to determine whether the sampling process is the source of contamination; re-evaluate decontamination procedures; evaluate results greater than 5x blank concentrations
Blank samples for determining a contamination source	As needed	Blank analyte concentration should be below the reporting limit	Compare results from separated blanks to isolate the source of contamination; evaluate results greater than 5x blank concentrations

[1] Total samples are for the entire monitoring program under S7 of the permit.

[2] Frequencies will be maintained for the monitoring program in its entirety.

* The table is based in part on an EPA QA and SOP website (Appendix B-3: Field QC and Laboratory QC Sample Collection and Documentation Requirements) accessed January 2011: http://www.epa.gov/earth1r6/6pd/qa/qadevtools/mod5_sops/sample_handling_preservation/appendix_b3.pdf

10-2 Laboratory Quality Control Procedures

This section discusses the quality control (QC) procedures that will be implemented by the contracted analytical laboratory in order to provide high-quality chemical and physical analyses that meet the requirements of the WSDOT permit. Contract laboratories will make every effort to meet sample holding times and target reporting limits for all parameters. Laboratory QC procedures and results will be closely monitored throughout the duration of the permit-mandated sampling. For guidance on seasonal first flush toxicity quality control procedures, refer to Appendices B and G.

The quality of laboratory data is subject to review via the established protocols in Section 5-2, Measurement Quality Objectives. A typical schedule for laboratory QC samples is shown in Table 22 and, at a minimum, includes:

- Laboratory duplicates
- Matrix spikes
- Matrix spike duplicates
- Method/instrument blanks
- References (lab standards/surrogate standards/internal standards)

10-2.1 Laboratory Instrument Calibration

The instrumentation utilized by the chosen laboratories will meet or exceed manufacturers' specifications for use and maintenance. Maintenance of this equipment will be conducted in a manner specified by the manufacturer or by the quality assurance guidelines established by the chosen laboratory. Use of this equipment will follow the chosen laboratory's standard operating procedures or the methods established by the manufacturer.

10-2.2 Laboratory Duplicate/Split

Laboratory duplicate samples will be analyzed regularly to verify that the laboratory's analytical methods are maintaining their precision. The contracted laboratory should perform "random" duplicate selection on submitted samples that meet volume requirements. After a sample is randomly selected, the laboratory should homogenize the sample and divide it into two identical "split" samples. To verify method precision, identical analyses of these lab splits should be performed and reported. Some parameters may require a double volume for the parameter to be analyzed as the laboratory duplicate. Matrix spike duplicates may be used to satisfy frequencies for laboratory duplicates.

10-2.3 Laboratory Matrix Spikes and Matrix Spike Duplicates

Matrix spike samples are triple-volume field samples (per parameter tested) to which method-specific target analytes are added or spiked into two of the field samples, and then analyzed under the same conditions as the field sample. A matrix spike provides a measure of the recovery efficiency and accuracy for the analytical methods being used. Matrix spikes are typically analyzed in duplicate (matrix spike/matrix spike duplicate [ms/msd]) to determine method accuracy and precision. Matrix spikes will be prepared and analyzed at a rate of 1 pair/20 (five percent) samples collected or one pair for each analytical batch, whichever is most frequent. In addition, metals must have at least two ms/msd samples per year per TAPE guidance. (Batch matrix spikes may be performed on other samples not related to this monitoring effort.) The ms/msd samples should be collected in the first shipment of organics samples.

Use of ms/msd at the frequency of five percent of the total number of samples is common practice. For the purposes of permit monitoring, these frequencies meet the expectations. However, WSDOT may consider a more frequent use of ms/msd samples early in the monitoring program, then taper off to five percent or one pair for each analytical batch later in the program. Laboratory duplicates may be used to satisfy frequencies for matrix spike duplicates.

10-2.4 Laboratory Blanks and Standards

Laboratory blanks are useful for instrument calibrations and method verifications as well as to determine whether any contamination is present in laboratory handling and processing of samples.

Laboratory Standards

Laboratory standards (reference standards) are objects or substances that can be used as a measurement base for similar objects or substances. In many instances, laboratories using digital or optical equipment will purchase from an outside accredited source a solid, powdered, or liquid standard to determine high- or low-level quantities of a specific analyte. These standards are accompanied with acceptance criteria and are used to test the accuracy of the laboratory's methods. Laboratory standards are typically used after calibration of an instrument and prior to sample analysis.

Surrogate and Internal Standards

Surrogate standards are used for processing and analysis of extractable organic compounds (TPH, PAHs, phthalates, and herbicides). A surrogate standard is added before extraction, and it monitors the efficiency of the extraction methods. Internal standards are added to organic compounds and metal digestates to verify instrument operation when using inductively coupled plasma mass spectrometry (ICP-MS) analysis.

Method Blanks

Method blanks are designed to determine whether contamination sources may be associated with laboratory processing and analysis. Method blanks are prepared in the laboratory using the same reagents, solvents, glassware, and equipment as the field samples, and they will accompany the field samples through analysis.

Instrument Blank

An instrument blank is used to "zero" analytical equipment used in the laboratory's procedures. Instrument blanks usually consist of laboratory-pure water and any other method-appropriate reagents, and they are used to zero instrumentation.

Table 22 Example of laboratory quality control schedule for monitoring effort.

Quality Control Sample[1]	Analysis Type	Frequency[2]	Control Limit	Corrective Action
Laboratory Duplicates[3]	inorganic	5% of total samples or 1 per batch (method-specific)	RPD[4] >20%	Evaluate procedure; ID contaminant source; reanalyze or qualify affected data
	conventional		Analyte/matrix-specific: usually RPD >20%	
	organics		RPD >40%	
Matrix Spikes	inorganic	For metals at least 2 samples per year; otherwise, 5% of total samples or 1 per batch[1]	Analyte/matrix-specific: usually Recovery <75% or >125%	Evaluate procedure and assess potential matrix effects; reanalyze or qualify data
	conventional	5% of total samples or 1 per batch[1]	Analyte/matrix-specific: usually Recovery <75% or >125%	
	organics	5% of total samples or 1 per batch[1]	Analyte/matrix-specific: ranges from Recovery <10% or >150%	Evaluate lab duplicates/standards recoveries and assess matrix effects; evaluate or qualify affected data
Matrix Spike Duplicates[3]	inorganic	For metals at least 2 samples per year; otherwise, 5% of total samples or 1 per batch	RPD >20%	Evaluate procedure and assess potential matrix effects; reanalyze or qualify data
	conventional	5% of total samples or 1 per batch	Analyte/matrix-specific: usually RPD >20%	
	organics	5% of total samples or 1 per batch	Analyte/matrix-specific: usually RPD >40% (water); RPD >20% (soil)	
Method / Instrument Blanks	inorganic	5% of total samples or 1 per batch (method-specific)	Blank analyte/matrix concentration ≤ reporting limit	Blank concentration is defined as the new reporting limit – Evaluate procedure; ID contaminant source; reanalyze blanks or qualify sample data (<5-10x blank concentration). Sample concentrations must be ≥ 5x blank results to be considered valid by TAPE
	conventional			
	organics			
References (lab control standard, surrogate, and internal standards)	inorganic	5% of total samples or 1 per batch (method-specific)	Analyte/matrix-specific: ranges from Recovery <70% or >130	Evaluate lab duplicates and matrix spike recoveries, and assess efficiency of extraction method; evaluate or qualify affected data
	conventional		Analyte/matrix-specific: ranges from Recovery <70% or >130%	
	organics		Analyte/matrix-specific: ranges from Recovery <10% or >183%	

[1] Quality control samples may be from different projects for frequencies on a per batch basis.

[2] Frequencies may be maintained for the monitoring program in its entirety. BMP sites will hold to the frequencies in this table per TAPE guidance.

[3] Laboratory and matrix spike duplicates both measure precision and accuracy; a combination of these two quality control samples may be used to satisfy frequencies.

[4] RPD: relative percent difference.

11 Data Management Procedures

WSDOT's stormwater monitoring program will be collecting and managing data from three sources: telemetered field stations, field observations/measurements, and laboratory analysis of field samples. All data will be managed and stored by WSDOT. Post-processed data will be finalized and incorporated into annual reports and electronic reports. Reports and data will be submitted to Ecology in the format required by the permit.

11-1 Telemetered Data Management

Telemetered data will be transmitted from each station hourly throughout the year and will be managed by WSDOT and stored in a WSDOT database. Telemetered data will be augmented with data downloaded from the data logger to fill any potential data gaps. Hydrographs and hyetographs will be developed for report comparisons and to determine baseline rainfall/runoff relationships.

11-2 Field Data Management

Field checklists and forms will be completed in the field during sampling and maintenance visits. All field documentation will be reviewed by the field technicians for completeness and identification of potential errors while in the field. Documents will be organized and stored in the appropriate central storage, which will be determined by the WSDOT Data Steward.

Data downloaded from the field data loggers will be uploaded to a centralized dedicated location at WSDOT. After uploading data, field staff will send the responsible senior staff an e-mail notifying them that the data have been moved to the storage folder for processing. Senior staff will then import, verify, and process these data via WSDOT's database.

11-3 Laboratory Data

Finalized laboratory data will be sent to WSDOT from each laboratory following analysis. The laboratories will be allowed to batch samples based on holding times to provide cost savings. Therefore, reporting will vary depending on holding time but should not exceed 6 months of the documented sampling date. Data will be submitted as an electronic data deliverable and a hard copy or PDF report. Hard copies or PDFs will be mailed or e-mailed to the Data Steward at WSDOT. Laboratory reports will be reviewed by the Data Steward/Quality Assurance Officer. Any errors or missing data will be reported to the responsible laboratory for amendment or correction. Finalized electronic laboratory data will be incorporated into WSDOT's database, while hard copy data sheets will be filed in WSDOT's central data storage.

The toxicity data submitted to WSDOT by the labs will be formatted for Ecology's Comprehensive Environmental Toxicity Information System™ (CETIS) database.

11-4 Audits

Routine audits will be conducted by senior staff to ensure this QAPP is being implemented correctly and the quality of the data is acceptable. A review of field procedures will be conducted once annually for each crew. If QA issues are identified during an audit, assessment and response actions will be implemented as necessary. The sections below describe in detail the steps to be carried out in connection with each of these activities.

During an audit review, the auditor may check that:

- Sampling locations were correctly sampled.
- SOPs were followed.
- There is documentation of the visit, with chain of custody or maintenance forms.
- There is proper identification and resolution of nonconformances.
- Correction of identified deficiencies has been made.
- Assessment has been made and corrective action taken.

The need for an audit can be determined by any participating member in the stormwater monitoring program. An audit may include procedural reviews, field visits, technical oversight, inspection, data quality assessment, or management system review. Audits of the analytical laboratories are limited to the subcontract agreements made with those laboratories.

11-5 Deficiencies, Nonconformances, and Corrective Action

Deficiencies are defined as unauthorized deviations from those procedures documented in the QAPP or SOPs. Nonconformances are deficiencies that severely affect the data quality and render them unacceptable or indeterminate. Deficiencies related to field and laboratory measurement systems include, but are not limited to, missed field visit forms, instrument malfunctions, blanks contamination, and quality control sample failures.

Routine audits will be performed to detect potential deficiencies in the hydrologic and water quality data collected for this project. Audits for hydrologic data will occur on a weekly to biweekly basis, when data are remotely downloaded from the monitoring stations. The newly downloaded data will be compared with previously downloaded and audited data to identify potential QA issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies among the discharge, water level, and/or precipitation data from the various monitoring stations.

Any data generated from calibration checks that were performed at a particular monitoring station will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. If QA issues are identified on the basis of these audits, a site visit will be performed immediately to troubleshoot the problem and to implement corrective actions. For specific deficiencies, anomalous data, or corrective action relating to seasonal first flush toxicity sampling, refer to Appendix C for more details. Any quality assurance issues that are detected through these audits will be documented in the electronic data record.

Audits performed for water quality data will occur according to WSDOT's Stormwater Monitoring Quality Management Plan. This review will be performed to ensure all data are consistent, correct, and complete, and all required quality control information has been provided. Results from these audits will be documented in quality assurance worksheets that will be prepared for each batch of samples. If a potential QA issue is identified through these audits, the Quality Assurance Officer will review the data to determine whether any response actions are required. Response actions in this case might include the collection of additional samples or the reanalysis of existing samples. If reanalysis is not an option, corrective actions may include the qualification of the data as estimated (*J*) or rejected (*R*) values. All deficiencies, nonconformances, and corrective actions will be documented in annual data reports for the project.

Deficiencies detected through routine audits will be documented in accordance with the procedures identified above. The Quality Assurance Officer, in consultation with the Project Manager, will determine whether the deficiency constitutes a nonconformance. If it is determined that a nonconformance exists, the Quality Assurance Officer will decide the disposition of the nonconforming data and any necessary corrective action(s). Corrective actions may include the qualification of the data as estimated (*J*) or rejected (*R*) values. All deficiencies, nonconformances, and corrective actions will be documented in annual status reports for the project. Status reports may include:

- Graphical and tabular summaries of the collected data.
- Results from comparisons in hydrology and water quality between the monitoring sites.
- Conclusions.
- Appendices: quality assurance memoranda, raw data tables, field datasheets, and chain of custody documentation.

12 Data Verification, Validation, and Usability

12-1 Data Verification

Data verification refers to the process of data review that occurs at the end of a data collection effort, such as at the end of the wet season or year. Data verification is defined as:

> *Examination of a dataset for errors or omissions, and assessment of the Data Quality Indicators related to that dataset for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a dataset.* (Kammin, 2010)

The Quality Assurance Officer or the Data Steward will implement the data verification process. Field data inputs, the completed chain of custody (COC), and laboratory reports, bench sheets, laboratory certifications, and laboratory process documentation will be reviewed to see whether they met requirements. If poor data quality trends or significant problems are identified, corrective action(s) will be implemented to improve the data quality.

The data verification procedures are being developed by a consultant for WSDOT to complement the QAPPs. As a result, verification procedure documentation will provide WSDOT a data assessment toolbox and programmatic approach to ensure quality goals. The verification procedures will be a stand-alone document and will not be submitted along with the QAPPs. Initial data verification will focus on reviewing the data records, laboratory reports, field reports, and COCs. This review will look at previously qualified or flagged data and evaluate their impact on the overall data quality objectives. If the data do not meet the statistical data review criteria, then the data point will be removed from the overall data set. The preliminary review may incorporate the statistical review methods described in Section 12-1.1. Issues that could affect the usability of the data may include: apparent anomalies in recorded data, missing values, deviations from standard operating procedures, and the use of nonstandard data collection methods (USEPA, 2002a).

Any changes to the results as originally reported by the laboratory should either be accompanied by a note of explanation from the data verifier/laboratory or reflected in a revised laboratory data report.

Data verification records include certification statements, which certify the data have been verified and signed by appropriate personnel. Data verification records can also include a narrative that identifies technical noncompliance issues or shortcomings of the data produced during the field or laboratory activities.

12-1.1 Statistical Data Review

Data analysis will include calculating the permit-required (S.7.E.4.b) mean and median effluent concentrations and percent removals. BMP effectiveness goals are not to achieve the pollutant-removal goals listed in TAPE. The permit specifies that the statistical goals are to meet 75–80% power with 90–95% confidence for the parameters for which the BMP is approved in the HRM.

A statistical data review will be conducted to identify outliers and other abnormalities in the data. Statistical analyses will calculate the mean, median, mode, sample range, sample variance, standard deviation, standardized mean difference, and coefficient of variation. Outliers or data that are anomalous with the entire data set will be reviewed for the origin of the error in data collection, laboratory analysis, data input and recording, QA/QC, and data verification.

The data will be plotted (using scatter plots) to identify additional outliers or confirm outliers and abnormal data. Outlying data will be compared against the statistical and preliminary data review to confirm that the point is an outlier or anomaly.

If the data are unable to conform or do not meet the data quality objectives, or it is uncertain whether the data are able to conform to the project data set and goals, then the data will be removed.

Data analyses will be performed to evaluate the water quality treatment performance of each of the monitored BMPs following procedures identified by TAPE and the EPA in *Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements* (USEPA, 2002b). The specific procedures that will be used in these analyses are as follows:

- Statistical analyses to compare influent and effluent concentrations and loads.
- Calculations of pollutant-removal efficiency.
- Statistical analyses to determine the power and confidence of percent removals.
- Calculations of "achievable" and "relative" pollutant-removal efficiency.
- Calculations of pollutant-removal efficiency based on regression of influent and effluent pollutant loads.
- Comparisons of the cumulative probability distribution for influent and effluent pollutant concentrations and loads.

12-1.2 Nondetects

Nondetected data will be addressed through the use of statistical methods, commonly agreed upon by the group of Phase I permittees. An SOP for evaluating nondetects (currently in draft form) provides a summary and comparison of the following methods: Substitution Half-U, Maximum Likelihood Estimation, Regression on Order Statistics, Robust Regression on Order Statistics (RROS), or Kaplan Meier (Non-parametric).

12-2 Data Validation

Data validation goes beyond data verification to examine the data for usability. WSDOT may seek data validation on all or parts of the stormwater monitoring program for its own purposes; however, data validation is not required by the permit. Validation is defined as:

> *An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the dataset.* (Kammin, 2010)

Ecology considers the following three key criteria to determine whether data validation has actually occurred:

- Use of raw or instrument data for evaluation
- Use of third-party assessors
- Use of EPA *National Functional Guidelines* (USEPA, 2008 and 2010*)*, or the equivalent for review

12-3 Usability Statement

If the data verification process finds that the data quality objectives (DQOs) stated in this QAPP are met, then the data will be useable for project objectives. This statement of usability pertains to the data being acceptable for the purposes under which it was collected, but does not cover uses outside of the original intent. If the DQOs are not met, a determination will be made to either quantify and qualify the offending data and proceed with project goals or to consider elimination of the offending data completely. Anomalies in the data will be identified and their impacts on the data assessed in each annual Stormwater Monitoring Report.

Three main aspects of the Usability Statement are:

1. Determining whether the stormwater runoff samples are representative.
2. Ensuring sample results met the storm and sample criteria.
3. Ensuring the statistical goals are met to calculate wet and dry season loads.

13 Reports

In accordance with the schedule presented in Section 4, Organization and Schedule, six types of reports will be generated in relation to the Stormwater Monitoring Program's activities covered in this QAPP. These report types are:

1. Sample Field Notes
2. Sample Event Records
3. Data pertinent to fulfilling the National Stormwater BMP Database requirements
4. Stormwater Monitoring Report
5. Final Water Quality Monitoring Report
6. Final Study Report

13-1 Field Notes and Event Records

13-1.1 Field Notes

Notes recorded in the field will be kept in an organized filing system and may include the following (paper or electronic) information:

- Field sampler name, date, and time of sampling
- Filtration and preservation of samples
- Volume of water collected
- Measurements made by multi-meter probes
- Visual observations
- Rainfall and runoff observations
- Records of number of grab samples taken
- Maintenance activity logs
- Maintenance inspection field sheets

13-1.2 Event Records

Records of the storm event will be kept in an organized filing system and may include the following (paper or electronic) information or components:

- Website print-outs of predicted rainfall
- Storm event hydrograph
- Sampling time frame for the storm event
- Data quality analysis indicating how the sampled event met criteria
- Chain of custody forms
- Support documents such as calculations or problems encountered

13-1.3 National Stormwater BMP Database Requirements

S7.E.4.a of the permit requires collection of data pertinent to fulfilling the National Stormwater BMP database requirements outlined in Section 3.4.3 of EPA's manual *Urban Stormwater BMP Performance Monitoring* (#821-B-02-001) (USEPA, 2002b). Refer to Appendix L for specific data needs. The downloadable spreadsheet with all data fields can be found under Final Stormwater BMP Database Data Entry Spreadsheets at:
www.bmpdatabase.org/DataEntry.htm

13-1.4 Annual Stormwater Monitoring Report

The annual Stormwater Monitoring Report is required by S8.F of the permit to provide a summary of the previous water year's monitoring results. Detailed stormwater monitoring data reports are due to Ecology by October 31, beginning in 2013 and annually thereafter. The complete Annual Stormwater Monitoring Report will include, at a minimum, the information specified by the permit in S7 and S8.

For the reports submitted in 2010, 2011, and 2012, reporting requirements include the status of preparations to meet requirements in S7.A through S7.E of the permit and will be included in the annual Stormwater Management Plan (SWMP) Progress Report. In October 2013, a complete and separate Stormwater Monitoring Report is due, to accompany the annual SWMP Progress Report (Table 23).

Table 23 outlines the monitoring report requirements as stated in the permit for each report. Data sets required to be submitted to Ecology will be in Excel format and included in the reports as tables or data summaries. All required reports will be submitted to Ecology in both paper and electronic formats.

Table 23 Reporting requirements for the 3rd, 4th, and 5th Annual Stormwater Monitoring Reports beginning in 2013 (Ecology, 2008b; Ecology, 2009a).

Category	Source	Reporting Requirement
Each Sampling Event from Each Site	Permit Section S7.E.7	Sample event identification (date, time, and location).
		Tabular water quality data and summary results for each monitored parameter.
		Antecedent dry period, inter-event period, and total precipitation depth.
		A graphical representation of storm hyetograph and hydrograph for both the influent and effluent, with each aliquot collection point spatially located throughout the hydrograph; the sampled time period (% of hydrograph sampled), total runoff time period and total runoff volume.
Each Site	Permit Section S7.E.8	Status of implementing the monitoring program and a description of Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring programs still in progress at the end of the reporting year.
		WSDOT shall compute and report cumulative (including previous years) performance data for each treatment BMP test site, and for both sites of the same treatment BMP type, consistent with the guidelines in appropriate sections of Ecology's guidance for "Evaluation of Emerging Stormwater Treatment Technologies" and USEPA publication number 821-B-02-001, "Urban Stormwater BMP Performance Monitoring," including information pertinent to fulfilling the "National Stormwater BMP Data Base Requirements" in section 3.4.3. of that document.
		Status of cumulative (including previous years) performance data in terms of statistical goals for each test site and for both test sites of the same treatment BMP type.
		Status of performance data concerning flow reduction performance for the hydrologic reduction BMP.
		Any proposed changes to the monitoring program that could affect future data results.
First Flush Toxicity Sampling Event	Permit Section S7.C.8	WSDOT shall report an EC_{50} for each test. WSDOT shall submit all reports for toxicity testing in accordance with the most recent version of Department of Ecology Publication #WQ-R-95-80,[1] *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*.
		Reports shall contain bench sheets, and reference toxicant results if required for the protocol, for test methods.
		WSDOT shall submit toxicity test reports, bench sheets, and reference toxicity results in electronic format for entry into Ecology's database and shall submit a hardcopy.
		WSDOT shall calculate the EC_{50} by the trimmed Spearman-Karber procedure. WSDOT may apply Abbott's correction to the data before deriving this point estimate.

[1] Ecology, 2008b.

13-1.5 Final Water Quality Monitoring Report

A Final Water Quality Monitoring Report is due February 6, 2014. It will include a complete discussion of each monitoring program outlined in S7 and S8.F of the permit. The report must include the following items:

- An estimated cost for each monitoring program component.
- Stormwater management actions taken or planned to reduce pollutants from WSDOT land uses.
- A description of the monitoring programs still in progress.
- A cumulative water quality results summary for each site.
- An estimated water quality loading from highway runoff sites for each pollutant, based on precipitation and runoff volume.
- Evaluation of monitoring sites.
- A cumulative analysis of parameters of concern from each of WSDOT's land use monitoring sites.

Final Monitoring Report on BMPs

In addition to the Final Water Quality Monitoring Report, a final report on each BMP monitored shall be submitted once the monitoring statistical goals are met. The final report shall include an analysis of the performance data collected on the BMPs as described in the appropriate sections of Ecology's TAPE (available on Ecology's website).

14 References

AASHTO (American Association of State Highway and Transportation Officials). 2004. A Policy on Geometric Design of Highways and Streets (Green book), Fifth Edition. Washington, D.C.

ASTM E 1192-97: Standard guide for conducting acute toxicity tests on aqueous ambient samples and effluents with fishes, macroinvertebrates, and amphibians.

Dorman ME, Hartigan J, Steg RF, Quasebarth TF. 1996. Retention, detention, and overland flow for pollutant removal from highway stormwater runoff, volume I: Research report. Federal Highway Administration (FHA). Report No. FHWA-RD-96-095, Federal Highway Administration, McLean, VA.

Ebihara Tatsuji, Fricke LFR Levine, Young C. Bryan, Tiwari Vibhuti, Agee Lisa M. 2009. Treatment of contaminated roadway runoff using vegetated filter strips. Report No. K-TRAN: KU-03-5. University of Kansas, Lawrence, KS.

Ecology. 1997. Analytical Methods for Testing Petroleum Hydrocarbons. Washington State Department of Ecology, Olympia, WA. Publication Number ECY 97-602.

Ecology. 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. http://www.ecy.wa.gov/biblio/0403030.html

Ecology. 2006. Standard Operating Procedure for Manually Obtaining Surface Water Samples. (EAP015). Washington State Department of Ecology, Olympia, WA.

Ecology. 2007. Standard Operating Procedure for the Collection of Fecal Coliform Bacteria Samples. (EAP030). Washington State Department of Ecology, Olympia, WA.

Ecology. 2008a. Guidance for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol – Ecology (TAPE). January 2008 Revision. Washington State Department of Ecology, Olympia, WA. Publication no. 02-10-037.

Ecology. 2008b. Guidance and Whole Effluent Toxicity Test Review Criteria. December 2008 Revision. Washington State Department of Ecology, Olympia, WA. Publication no. WQ-R-95-80. http://www.ecy.wa.gov/biblio/9580.html

Ecology. 2009a. Washington State Department of Transportation Municipal Stormwater Permit, National Pollution Discharge Elimination System and State Waste Discharge Permit for Large and Medium Municipal Separate Storm Sewer Systems. Washington State Department of Ecology. Olympia, Washington. Permit No. WAR043000A. Issuance Date February 4, 2009.

Ecology. 2009b. Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring (ECY002). Washington State Department of Ecology, Olympia, WA.

Ecology. 2009c. Standard Operating Procedure for Collecting Grab Samples from Stormwater Discharges (ECY001). Washington State Department of Ecology, Olympia, WA.

Ecology. 2009d. Standard Operating Procedure for Calculating Pollutant Loads from Stormwater Discharges (ECY004). Washington State Department of Ecology, Olympia, WA.

Ecology. 2010a. Phase I Municipal Stormwater Permit, National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for Discharges from Large and Medium Municipal Separate Storm Sewers. Washington State Department of Ecology. Olympia, Washington. Issuance date: January 17, 2007; modification date: September 1, 2010.

Ecology. 2010b. Standard Operating Procedure for the Collection and Field Processing of Metals Samples. (EAP029). Washington State Department of Ecology, Olympia, WA.

Ecology. 2011. Manchester Environmental Laboratory Performance Criteria. Internal spreadsheet files. Washington State Department of Ecology, Olympia, WA. Accessed February 2011.

HydroQual, Inc. June 2007. Biotic Ligand Model, Windows Interface, Version 2.2.3., User's Guide and Reference Manual. 1200 MacArthur Blvd. Mahwah, NJ 07430. (201) 529-5151.

Kaighn Jr RJ, Yu SL. 1996. Testing of roadside vegetation for highway runoff pollutant removal. Transportation Research Record, 1523, 116.

Kammin. 2010. Ecology Quality Assurance Glossary. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

Lindeburg Michael. 2003. Environmental Engineering Reference Manual. 2nd ed. Belmont, CA: Professional Publications Inc. Print.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Persyn RA, Glanville TD, Richard TL. 2002. Evaluation of Soil Erosion and Soil Erodibility Factors for Composted Organics on Highway Right-of-Ways. Paper Number: 022081, Proc. American Society of Agricultural Engineers, Saint Joseph, MI.

Rantz SE et al. 1982. USGS Water Supply Paper 2175. Measurement and Computation of Streamflow: Volume 1. United States Government Printing Office, Washington D.C.

Soil Conservation Service (SCS). 1986. Technical Release 55, Urban Hydrology for Small Watersheds. Publication 210-VI-TR-555, Second Ed., June 1986.

Transportation Research Board (TRB). 2006. Evaluation of Best Management Practices for Highway Runoff Control. Report 565. National Cooperative Highway Research Program (NCHRP), Washington, D.C.

USEPA. 1992. Specifications and Guidance for Obtaining Contaminant-Free Sample Containers. US Environmental Protection Agency. Publication 9240.0-05A.

USEPA. 1996. Method 1669, Sampling Ambient Water for Trace Metals at EPA Water Quality Control Levels. US Environmental Protection Agency, Office of Water, Engineering and Analysis Division. July 1996.

USEPA. 1997. Glossary of Quality Assurance Terms and Related Acronyms. Quality Assurance Division, National Center for Environmental Research and Quality Assurance. December 10, 1997.

USEPA. 2002a. Guidance on Environmental Data Verification and Data Validation. EPA QA/G-8. EPA/240/R-02/004. November 2002.

USEPA. 2002b. Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements. EPA-821-B-02-001. April 2002.

USEPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. EPA/240/B-06/001. February 2006.

USEPA. 2008. USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Raw Data Review. USEPA-540-R-08-01. June 2008.

USEPA. 2010. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review. USEPA-540-R-10-011. January 2010.

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

WSDOT. 2003. *Roadside Manual*. July 2003.WSDOT Design Office, Engineering and Regional Operations Divisions. Olympia, WA. Publication Number M 25-30. www.wsdot.wa.gov/publications/manuals/m25-30.htm

WSDOT. 2009a. Pre-Activity Safety Plan. Washington State Department of Transportation, Olympia, WA.

WSDOT. 2009b. *Work Zone Traffic Control Guidelines* M 54-44.01 Washington State Department of Transportation, Olympia, WA.

WSDOT. 2010a. *Highway Runoff Manual*. Updated May 2010. Washington State Department of Transportation, Environmental and Engineering Programs Design Office. Olympia, WA. Publication Number M 31-16. www.wsdot.wa.gov/publications/manuals/m31-16.htm

WSDOT. 2010b. Compost Amended Vegetated Filter Strip Performance Monitoring Study. Unpublished report: 06-03427-005 Prepared by: Herrera Environmental Consultants, Seattle, WA. On file at WSDOT Environmental Services Office, Olympia, WA.

WSDOT. 2010c. *Standard Specifications for Road, Bridge, and Municipal Construction.* January 2010. Washington State Department of Transportation,. Construction Administration Office, Engineering and Regional Operations Division. Olympia, WA. Publication Number. M 41-10. www.wsdot.wa.gov/publications/manuals/m41-10.htm

WSDOT. 2011. GIS Workbench. Washington State Department of Transportation, Environmental Services Office, Olympia, WA.

WSDOT, in draft. 2011a. WSDOT SOPs required for stormwater monitoring. Under development by Taylor and Associates, estimated to be finalized in August, 2012.

WSDOT, in draft. 2011b. Geotechnical Evaluation Report for BMP Effectiveness Stormwater Monitoring Sites on I-5 and SR-9. Under development by WSDOT, estimated to be finalized in October, 2011.

Yonge DR, Reister MS. 2005. Application of a Simplified Analysis Method for Natural Dispersion of Highway Stormwater Runoff. Washington State University, Pullman, WA.

Laws, Regulations, Glossary Sources

"Composting facilities." Title 173, WAC 173-350-220. [accessed July 19, 2011]
http://apps.leg.wa.gov/wac/default.aspx?cite=173-350-220

"Definitions." Title 173, WAC 173-50-040. [accessed July 14, 2011]
http://apps.leg.wa.gov/wac/default.aspx?cite=173-50-040

"Definitions." Title 173, WAC 173-200-020. [accessed July 21, 2011]
http://apps.leg.wa.gov/wac/default.aspx?cite=173-200-020

"Definitions." Title 173, WAC 173-205-020. [accessed July 21, 2011]
http://apps.leg.wa.gov/wac/default.aspx?cite=173-205-020

"Environmental Measurement Glossary of Terms." [accessed August 4, 2011]
http://www.epa.gov/fem/pdfs/env_measurement_glossary_final_jan_2010.pdf

"Guidelines establishing test procedures for the analysis of pollutants." Title 40, CFR 136. [accessed July 14, 2011] http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr136_main_02.tpl

"NPDES Glossary." [accessed July 21, 2011]
http://cfpub.epa.gov/npdes/glossary.cfm?program_id=0

"Toxicity identification/reduction evaluations." Title 173, WAC 173-205-100. [accessed July 14, 2011] http://apps.leg.wa.gov/wac/default.aspx?cite=173-205-100

"Waste and Cleanup Risk Assessment Glossary." [accessed July 21, 2011]
http://www.epa.gov/oswer/riskassessment/glossary.htm

"Water Quality Standards for Surface Waters in the State of Washington." Title 173, Chapter 173-201A WAC. Washington State Department of Ecology, Olympia, WA.
www.ecy.wa.gov/laws-rules/ecywac.html

"Whole effluent toxicity testing and limits." Title 173, Chapter 173-205 WAC. [accessed July 14, 2011] http://apps.leg.wa.gov/wac/default.aspx?cite=173-205

15 Appendices

Appendix A Glossary, Acronyms, Abbreviations, and Units of Measurement

Glossary

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

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

analyte – An element, ion, compound, or chemical moiety (pH, alkalinity) that is to be determined. The definition can be expanded to include organisms, such as fecal coliform or Klebsiella (Kammin, 2010).

best management practices (BMPs) – The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices approved by Ecology that, when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State (Ecology, 2009a).

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

blank – A sample prepared to contain none (or as little as possible) of the analyte of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

calibration – The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. The most important aspect of any calibration method is its ability to obtain accurate results with a high degree of certainty and repeatability (Kammin, 2010; Ecology, 2004).

Clean Water Act (CWA) – A federal act passed in 1972, formerly referred to as the Federal Water Pollution Control Act, which contains provisions to restore and maintain the quality of the nation's waters. Major amendments to the CWA in 1987 addressed stormwater pollution by extending the National Pollutant Discharge Elimination System (NPDES) permit program to include stormwater discharges. Section 402 of the CWA governs the NPDES permit program. Section 303(d) of the CWA establishes the Total Maximum Daily Load (TMDL) program. Pub.L.92-500, as amended Pub. L.95-217, Pub. L.95-576, Pub. L. (6-483 and Pub.L.97-117, 33 USC 1251et.seq).

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

completeness – The amount of valid data obtained from a data collection project compared to the planned amount. Completeness is usually expressed as a percentage; a data quality indicator (USEPA, 1997).

control chart – A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology, 2004).

control limit – Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean—action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

data integrity – A qualitative DQI that evaluates the extent to which a data set contains data that are misrepresented, falsified, or deliberately misleading (Kammin, 2010).

data quality indicators (DQI) – Data quality indicators are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

data quality objectives (DQO) – Data quality objectives are qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

data set – A grouping of samples, usually organized by date, time, and/or analyte (Kammin, 2010).

data validation – An analyte- and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set (Ecology, 2004). Data validation criteria are based upon the measurement quality objectives developed in the QA Project Plan or similar planning document, or presented in the sampling or analytical method. Data validation includes a determination, where possible, of the reasons for any failure to meet method, procedural, or contractual requirements, and an evaluation of the impact of such failure on the overall data set. Data validation applies to activities in the field as well as in the analytical laboratory (USEPA, 2002a). Data validation follows data verification (USEPA, 2006). Ecology considers four key criteria to determine whether data validation has actually occurred. These are:

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

Examples of data types commonly validated would be:

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

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes
- *J*, data is estimated, may be usable, may be biased high or low
- *R*, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004)

data verification – The process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements. Again, the goal of data verification is to ensure and document that the data are what they purport to be, that is, that the reported results reflect what was actually done. When deficiencies in the data are identified, then those deficiencies should be documented for the data user's review and, where possible, resolved by corrective action. Data verification applies to activities in the field as well as in the laboratory (USEPA, 2002a). Data verification precedes data validation (USEPA, 2006).

data collection platform (DCP) – A collection of instruments or sensors that operate and report to a central data logger. A DCP is collectively housed in a central location or "platform" at the monitoring site.

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

duplicate samples – Two samples taken from and representative of the same population, and carried through the steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess the variability of all method activities, including sampling and analysis (USEPA, 1997).

EC_{50} (effective concentration, fifty percent) means the effluent concentration estimated to cause an adverse effect in fifty percent of the test organisms in a toxicity test involving a series of dilutions of effluent (WAC 173-205-020).

edge of pavement (EOP) interceptor – A 6-inch HDPE pipe or similar device that is set up to collect runoff from an impervious roadway. EOP interceptors also act as conveyance systems for stormwater from the road surface to pass through a flow measurement device and allow for composite sample collection.

fecal coliform – That portion of the coliform group which is present in the intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within twenty-four hours at 44.5 plus or minus 0.2 degrees Celsius (WAC 173-201A-020).

field blank – Blanks that are analyzed to determine whether there is contamination during sampling. For water sampling, these consist of pure (e.g., deionized, micro-filtered) water that is subjected to all aspects of sample collection, field processing, preservation, transportation, and laboratory handling as an environmental sample. The pure water must be obtained from the laboratory or other reliable supplier (Ecology, 2004). Field blanks include the following types:

> ***equipment rinsate blank*** – Pure (deionized, micro-filtered) water that is run through the sample pickup, tubing, and collection apparatus of the automated sampler, and is otherwise subjected to all subsequent aspects of sample collection, field processing, preservation, transportation, and laboratory handling as an environmental sample. If the equipment is not cleaned or rinsed with pure water before each environmental sample is drawn, then the equipment should not be cleaned or rinsed with pure water before collecting the rinsate blank.
>
> ***filter blank*** – A special case of a rinsate blank prepared by filtering pure water through the filtration apparatus after routine cleaning. The filter blank may detect contamination from the filter or other part of the filtration apparatus (Ecology, 2004). This is only applicable if filtration is done in the field.

transport blank – A container of pure water that is prepared at the lab and carried unopened to the field and back with the other sample containers to check for possible contamination in the containers or for cross-contamination during transportation, storage of the samples (Ecology, 2004).

transfer blank – Prepared by filling a sample container with pure water during routine sample collection to check for possible contamination from the surroundings. The transfer blank will also detect contamination from the containers or from cross-contamination during transportation and storage of the samples (Ecology, 2004).

laboratory control sample (LCS) – A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

matrix spike – A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

measurement quality objectives (MQOs) **–** A subset of data quality objectives (DQOs) that specify how good the data must be in order to meet the objectives of a project (Ecology, 2004). The acceptance thresholds or goals for a project's data, usually based on the individual data quality indicators (DQIs) for each matrix and analyte group or analyte. These include bias, precision, accuracy, representativeness, comparability, completeness, and sensitivity (USEPA, 2006).

measurement result – A value obtained by performing the procedure described in a method. (Ecology 2004).

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

method blank – A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Kammin, 2010; Ecology, 2004).

method detection limit (MDL) – The minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99 percent probability of being identified and reported to be greater than zero (40 CFR 136).

National Pollutant Discharge Elimination System (NPDES) – The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Federal Clean Water Act, for the discharge of pollutants to surface waters of the state from point sources. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology (Ecology, 2009a).

nonpoint source – The term nonpoint source is used to identify sources of pollution that are diffuse and do not have a point of origin or that are not introduced into a receiving stream from a specific outlet. Common non-point sources are rainwater and runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings (EPA Waste and Cleanup Risk Assessment Glossary).

nutrient – A substance such as carbon, nitrogen, or phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

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

pH – A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

point source – Any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock concentrated animal feeding operation (CAFO), landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff (NPDES Glossary).

pollution – Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life (WAC 173-200-020).

precision – The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998). Usually expressed as relative percent difference (RPD) or relative standard deviation (RSD) (Ecology, 2004).

quality assurance (QA) – A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

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

quality control (QC) – The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

replicate samples – Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

reporting limit – (1) The minimum value below which data are documented as nondetects. (2) The minimum value of the calibration range. Analyte detections between the detection limit and the reporting limit are reported as having estimated concentrations (EPA Environmental Measurement Glossary 2010).

representativeness – The state or quality of being accurately representative of something. Expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at the sampling point, or an environmental condition (USEPA, 2006).

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

sample (statistical) – A finite part or subset of a statistical population (USEPA, 1997).

sensitivity – In general, denotes the rate at which the analytical response (e.g., absorbance, volume, or meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

spiked blank – A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

spiked sample – A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 1997).

split sample – This term denotes when a discrete sample is further subdivided into portions, usually duplicates (Kammin, 2010).

stormwater – That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface water body or a constructed infiltration facility (WSDOT, 2010).

surrogate – For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

systematic planning – A step-wise process that develops a clear description of the goals and objectives of a project and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The data quality objectives (DQO) process is a specialized type of systematic planning (USEPA, 2006).

Technology Assessment Protocol – Ecology (TAPE) – A Washington State Department of Ecology process for reviewing and approving new stormwater treatment technologies (Ecology, 2008a).

Total Maximum Daily Load (TMDL) – TMDL means a water cleanup plan. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure the water body can be used for the purposes the state has designated. The calculation must also account for seasonable variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each water body, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs (Ecology, 2009a).

Acronyms and Abbreviations

40 CFR	Title 40 of the Code of Federal Regulations
AADT	average annual daily traffic
BMP	best management practice
CAD	computer aided design
CAVFS	compost-amended vegetated filter strips
CEC	cation exchange capacity
CFR	Code of Federal Regulations
CLP	contract laboratory protocols
COC	chain of custody
CTAS	cobalt thiocyanate activating substance
CWA	Clean Water Act
DCP	data collection platform
DQI	data quality indicator
DQO	data quality objective
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EOP	edge of pavement
EPA	U.S. Environmental Protection Agency
et al.	and others
FEP	fluorinated ethylene propylene
GIS	Geographic Information Systems
HDPE	high-density polyethylene
HRM	*Highway Runoff Manual*
ICP-MS	Inductively coupled plasma-mass spectrometry
IDL	instrument detection limit
LCS	laboratory control sample
LID	low-impact development
MBAS	methylene blue active substances
MDL	method detection limit
MEL	Manchester Environmental Laboratory
MP	milepost
MQO	measurement quality objective
MS4	municipal separate storm sewer system
MS/MSD	matrix spike/matrix spike duplicate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OP	orthophosphate
PAH	polycyclic aromatic hydrocarbons
PSD	particle size distribution
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RL	reporting limit

RPD	relative percent difference
RSD	relative standard deviation
SCS	Soil Conservation Service
SOP	standard operating procedure
SWMP	Stormwater Management Program
TAPE	Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol – Ecology (TAPE)
TEF	Technology Equipment Fund
TIE	toxicity identification evaluation
TI/RE	toxicity identification/reduction evaluation
TMDL	Total Maximum Daily Load
TP	total phosphorus
TPH	total petroleum hydrocarbon
TRE	toxicity reduction evaluation
TRM	Transportation Research Board
TSS	total suspended solids
USGS	United States Geological Survey
VFS	vegetated filter strip
WAC	Washington Administrative Code
WQP	Water Quality Program
WSDOT	Washington State Department of Transportation

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
ft	feet
g	gram, a unit of mass
in	inch
L/min	liters per minute
mg	milligram
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
ug/Kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µm	micrometer
oz	ounce

Appendix B Section 7 of 2009 WSDOT NPDES Municipal Stormwater Permit

S7. MONITORING

A. Monitoring Objectives

WSDOT shall develop and implement a monitoring program to establish baseline stormwater discharge information from its highway conveyances, rest areas, maintenance facilities, and ferry terminals and develop and implement a monitoring program to evaluate Best Management Practice (BMP) effectiveness. Annual monitoring report data requirements shall be submitted as described in S8.F Stormwater Monitoring Report. WSDOT shall design the monitoring strategy to:

1. Produce scientifically credible data that represents discharges from WSDOT's various land uses;
2. Provide information that can be used by WSDOT for designing and implementing effective stormwater management strategies for WSDOT facilities; and
3. Determine the long-term effectiveness of individual facility Stormwater Pollution Prevention Plans.

B. Baseline Monitoring of WSDOT Highways

1. WSDOT shall obtain stormwater discharge quality and quantity data from the edge of pavement at highway sites. WSDOT shall collect data to allow analysis of pollutant loads and prioritize parameters of concern. WSDOT shall collect samples at each site, at the frequencies and durations, and for the parameters specified in this section.

2. Continuous flow recording of all storm events (not just sampled storm events) is necessary for at least one year to establish a baseline rainfall/runoff relationship.

3. Baseline Monitoring Site Selection

   Baseline monitoring sites shall have the conveyance system and drainage area mapped, and be suitable for permanent installation and operation of flow-weighted composite sampling equipment. WSDOT shall document the time of concentration for each selected drainage area using rainfall durations for typical seasonal storms.

   WSDOT shall establish monitoring sites at locations with the following annual average daily traffic (AADT):

   a. Two highly urbanized Western Washington sites (≥100,000 AADT)
   b. One urbanized Western Washington site (≤100,000 and ≥30,000 AADT)
   c. One rural Western Washington site (≤30,000 AADT)
   d. One urbanized Eastern Washington site (≤100,000 and ≥30,000 AADT)

4. Parameters To Be Sampled and Analyzed

   a. WSDOT shall sample, analyze, and report the following parameters as indicated in order of priority if insufficient volume exists. Chemicals below method detection limits after two years of data analysis may be dropped from the list of parameters. Parameter details, analytical methods and reporting limits are included in Appendix 5.
      i. Total and dissolved metals: copper, zinc, cadmium and lead
      ii. Polycyclic Aromatic Hydrocarbons (PAHs)
      iii. Total suspended solids (TSS)

iv. Chlorides
v. Phthalates
vi. Herbicides: Triclopyr (Ester formula only), 2,4-D, Clopyralid, Diuron, Dichlobenil, Picloram , and Glyphosate (only if NON aquatic formula is used). Herbicides shall be sampled and analyzed only if applied near the monitoring site vicinity.
vii. Nutrients: Total phosphorus, orthophosphate

b. Grab samples shall be collected as early in the runoff event as practical. If grab samples are not collected during *qualifying* storm events, non-qualifying sized storm events may be sampled. Grab samples shall be collected, analyzed and reported for the parameters listed below. The total number of grab samples collected shall be equal to the total number of storm events collected to meet the conditions in S7.B.6.a. Parameter details, analytical methods and reporting limits are included in Appendix 5.
   i. Total Petroleum Hydrocarbons (TPH): NWTPH-Dx and NWTPH-Gx
   ii. Fecal coliform
   iii. Temperature (collected from runoff in-situ or as a grab sample)
   iv. Visible sheen observation

5. Sampling method

   WSDOT shall use flow-weighted composite samplers to sample qualifying storm events, except where this permit specifies grab samples or other sampling methods. The automated sampler shall be programmed to begin sampling as early in the runoff event as practical. Each composite sample must consist of at least 10 aliquots. Composite samples with 7 to 9 aliquots are acceptable if they meet the other sampling criteria and help achieve a representative balance of storm events and storm sizes. WSDOT shall obtain samples from the edge of the pavement or from a location within a pipe conveyance system as long as in the latter case, the stormwater has not passed through a treatment BMP, a vegetated area, or the soil column.

6. Sample timing and frequency

   WSDOT shall sample storm events as early in the storm event as practical and continue sampling past the longest estimated time of concentration for the contributing drainage area. For storm events lasting less than 24 hours, samples shall be collected for at least seventy-five percent of the storm event hydrograph. For storm events lasting longer than 24 hours, samples shall be collected for at least seventy-five percent of the hydrograph of the first 24 hours of the storm.

   a. WSDOT shall sample each stormwater monitoring site at the following frequency:
      i. Sixty-seven percent of the forecasted qualifying storms, which result in actual *qualifying* storm events up to a maximum of 14 storm events per water year. 11 of the 14 storm events must meet the qualifying storm event criteria defined in Section S7.B.6.b.
      ii. WSDOT may collect and report data from up to 3 storm events that were forecasted qualifying storms but which did not meet the qualifying storm event criteria for rainfall depth (0.2-inch minimum). These 3 non

qualifying storms events may be collected and counted as part of the 14 required storm events.

iii. WSDOT shall ensure that storm samples are distributed throughout the year and approximately reflecting the distribution of rainfall between the wet and dry seasons. The goal for western Washington sites is to collect 60-80% of the samples during the wet season and 20-40% during the dry season. For eastern Washington, the goal is to collect 80-90% of the samples in the wet season and 10-20% of the samples in the dry season.

b. Storm Event Criteria

i. A qualifying storm event during the wet season in Western Washington (October 1 through April 30) and in Eastern Washington (October 1 through June 30) shall meet the following conditions:

1) Rainfall depth: 0.20-inch minimum, no fixed maximum
2) Rainfall duration: No fixed minimum or maximum
3) Antecedent dry period: less than 0.02-inch rain or no surface runoff in the previous 24 hours
4) Inter-event dry period: 6 hours

ii. A qualifying storm event during the dry season in Western Washington (May 1 through September 30) and in Eastern Washington July 1 through September 30) shall meet the following conditions:

1) Rainfall depth: 0.20-inch minimum, no fixed maximum
2) Rainfall duration: No fixed minimum or maximum
3) Antecedent dry period: less than 0.02-inch rain in previous 72 hours
4) Inter-event dry period: 6 hours

7. Baseline Sediment Testing

WSDOT shall trap and analyze sediments at each highway sampling site or at the vicinity of each stormwater monitoring site at least annually. WSDOT shall collect sediment samples using in-line sediment traps. Similar methods or sampling of receiving water sediment deposits shall be approved by Ecology at the time of QAPP submittal.

a. WSDOT shall sample, analyze, and report the following parameters in sediments, as indicated in order of priority if insufficient volume exists. Chemicals below method detection limits after two years of data analysis may be dropped from the list of parameters. Parameter details, analytical methods and reporting limits are listed in Appendix 5.

i. Particle size (grain size)
ii. Total organic carbon
iii. Total metals: copper, zinc, cadmium and lead
iv. PAHs
v. TPH – NWTPH-Dx Phenolics
vi. Herbicides: Dichlobenil, Triclopyr, Pircloram, and Clopyralid. Herbicides shall be sampled and analyzed only if applied in the monitoring site drainage area.
vii. Phthalates
viii. Total solids

8. Reporting for Baseline Monitoring of Highways

a. The Annual Stormwater Monitoring Report shall include the following information for each sampled storm event:
   i. Sample event identification (date, time, location);
   ii. Tabular water quality data and summary results for each monitored parameter including sediments;
   iii. Antecedent dry period, inter-event period and total precipitation depth; and
   iv. A graphical representation of the storm's hyetograph and hydrograph, with aliquot collection points spatially located throughout the hydrograph; the sampled time period (% of hydrograph sampled), total runoff time period and total runoff volume.
b. WSDOT shall include in each Annual Stormwater Monitoring Report the following information for each site once sampling begins:
   i. Rainfall/runoff relationship established using continuous flow records and precipitation data;
   ii. For the 2013 Annual Stormwater Monitoring Report, submit the following for each parameter:
      1) Mean and median Event Mean Concentrations (EMCs) only from sampled storm events; and
      2) Total annual pollutant load and the seasonal pollutant load for the wet and dry seasons only from sampled storm events.
   iii. For all other Annual Stormwater Monitoring Reports, WSDOT shall submit the following for each parameter:
      3) Mean and median EMCs only from sampled storm events;
      4) Total annual pollutant load and the seasonal pollutant load for the wet and dry seasons for both sampled and estimated unsampled storm events.
      5) The method used to estimate loads for unsampled events shall be applied to previously submitted data and continue for remaining years of the permit cycle.
      6) Any proposed changes to the monitoring program that could affect future data results.
c. WSDOT shall express the loadings as total pounds and as pounds per acre.

C. Seasonal First Flush Toxicity Testing

WSDOT shall test the seasonal first flush for toxicity in accordance with the criteria and procedures described in this section. This toxicity testing is for screening purposes only and is not effluent characterization or compliance monitoring under WAC 173-205.

1. Toxicity Storm Event Criteria
   WSDOT shall collect six toxicity screening samples and associated chemical analysis at least once per monitoring year in August or September. Samples shall be collected with at least a one-week antecedent dry period (or October, irrespective of antecedent dry period, if unsuccessful in August or September).

2. Toxicity Sample Collection Criteria
   WSDOT shall collect adequate sample volume to perform both the toxicity test and the chemical analysis test described below. If sample volume for the toxicity test is equal to or less than 2 liters, do not attempt a toxicity test. Priority parameters are listed in S7.C.4 and volume requirements are listed in Appendix 6.

3. Toxicity Site Selection

   a. Once each year WSDOT shall test the seasonal first flush for toxicity from 3 untreated highway runoff monitoring locations. Samples shall be collected from the edge of the pavement or from a location within a pipe conveyance system as long as in the latter case the stormwater has not passed through a treatment BMP, a vegetated area, or the soil column. The following test sites shall be sampled:
      i. One highly urbanized site (≥100,000 AADT)
      ii. One urbanized site (≤100,000 and ≥30,000 AADT)
      iii. One rural site (≤30,000 AADT)
   b. Once each year WSDOT shall test the seasonal first flush for toxicity from 3 BMP effluent locations. BMPs shall be selected and designed in accordance with the HRM. One BMP site shall be categorized as an enhanced treatment BMP for metals removal. The BMPs shall be tested at the following sites:
      i. One highly urbanized site (≥100,000 AADT)
      ii. One urbanized site (≤100,000 and ≥30,000 AADT)
      iii. One rural site (≤30,000 AADT)

4. Parameters to be Sampled and Analyzed
   At each monitoring site, WSDOT shall collect a sample for chemical analysis and a sample for the toxicity test using the same sampling methods, at the same time and location. Parameter details, analytical methods and reporting limits are presented in Appendix 5. Chemicals below reporting limits after two years of data analysis may be dropped from the list of parameters. The following parameters shall be collected and analyzed, as indicated in order of priority if insufficient volume exists:
   a. Total and dissolved metals: copper, zinc, cadmium and lead
   b. Herbicides (listed in S7.B.4 and if only applied in the monitoring site drainage area).
   c. Total suspended solids
   d. Chlorides
   e. Hardness
   f. Methylene blue activated substances (MBAS)
   g. PAHs
   h. Phthalates
   i. TPH: NWTPH-Gx and NWTPH-Dx (collected as a grab sample)

5. Sampling Method

   WSDOT shall collect time or flow-weighted composite samples. If WSDOT is unsuccessful in completing a toxicity test despite documented, good faith efforts or due to an invalid or anomalous test result, WSDOT shall make a second sampling attempt if sufficient time remains to meet the toxicity storm event criteria. If the second attempt is also unsuccessful, WSDOT shall document its efforts in its annual stormwater monitoring report and shall not be required to conduct further sampling and analysis efforts under S7.C for that calendar year.

6. Laboratory Testing Procedures

   WSDOT shall follow toxicity testing procedures for *Hyalella azteca* 24-hour test per ASTM E1192-97. Toxicity tests must meet quality assurance criteria in the most recent versions of ASTM E1192-97 and the Department of Ecology Publication #WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria. The laboratory must conduct water quality measurements on all samples and test solutions for toxicity testing as specified in the most recent version of Department of Ecology publication #WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.* Sample volume, replicates, control and concentrations and required test conditions for the 24-hour survival test (ASTM E1192-97) are included in Appendix 6.

7. Follow up Actions

   If the EC_{50} from any valid and non-anomalous test is 100% stormwater or less, WSDOT shall conduct follow-up actions. WSDOT shall prepare a study design to further refine the knowledge of toxicant concentrations in stormwater discharged to receiving waters from WSDOT's roads and highways. WSDOT shall use the findings from this study to determine which highway site(s) warrant further investigation. The study design shall include a mapping of site-specific MS4s, any installed or planned structural BMPs, proposed sampling and analysis and a description of the toxicity pathways to receiving water. If necessary to produce knowledge from the study useful in source control or BMP improvement, WSDOT shall include a toxicity identification/reduction evaluation (TI/RE) in the study design. The TI/RE shall be based upon instructions in WAC 173-205-100.

8. Reporting for Annual First Flush Toxicity Testing

   WSDOT shall submit the following information for each sampling event at each site:

   a. WSDOT shall report an EC_{50} for each test. WSDOT shall submit all reports for toxicity testing in accordance with the most recent version of Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.* Toxicity reports shall be included in each Annual Stormwater Monitoring Report beginning in 2013 with the following information:
      i. Reports shall contain bench sheets, and reference toxicant results if required for the protocol, for test methods.

ii. WSDOT shall submit toxicity test reports, bench sheets, and reference toxicity results in electronic format for entry into Ecology's database and shall submit a hardcopy.

iii. WSDOT shall calculate the EC_{50} by the trimmed Spearman-Karber procedure. WSDOT may apply Abbott's correction to the data before deriving this point estimate.

D. Baseline Monitoring of Rest Areas, Maintenance Facilities and Ferry Terminals

1. Monitoring Site Selection

WSDOT shall conduct stormwater discharge monitoring to collect baseline water quality data. Monitoring locations shall be located to capture runoff from most of the site and down gradient of the major pollutant generating activities for each facility. WSDOT shall sample the following land uses:

a. Two High-Use Rest Areas
b. Six Maintenance Facilities, one in each WSDOT region;
c. One High-Use Ferry Terminal

2. Parameters Sampled and Analyzed in Stormwater

The following parameters shall be sampled, analyzed and reported in untreated water. Chemicals below method detection limits after two years of data analysis may be dropped from the list of parameters. Parameter details, analytical methods and reporting limits are presented in Appendix 5.

a. Rest areas (as indicated in order of priority if insufficient volume exists):
   i. TPH: NWTPH-Dx and NWTPH-Gx (grab)
   ii. Total and dissolved metals: copper, zinc, cadmium and lead
   iii. PAHs
   iv. TSS
   v. Herbicides (listed in S7.B.4 only for those that WSDOT applies on-site, stores on-site, or applies by vehicles parked on-site)
   vi. Nutrients: Total phosphorus, nitrate/nitrite, ortho-phosphorus, and total Kjeldahl nitrogen
   vii. Chlorides
   viii. Phthalates
   ix. Fecal coliform (grab)
   x. Temperature (collected from runoff in-situ or as a grab sample)
b. Maintenance facilities (as indicated in order of priority if insufficient volume exists):
   i. Total suspended solids
   ii. TPH: NWTPH-Dx and NWTPH-Gx (grab)
   iii. PAHs
   iv. Herbicides (listed in S7.B.4 only for those that WSDOT applies on-site, stores on-site, or applies by vehicles parked on-site)
   v. Nutrients: Total phosphorus, ortho-phosphorus, nitrate/nitrite and total Kjedahl nitrogen (where fertilizers are applied on-site, stored on-site or applied by vehicles parked on-site)
   vi. Total and dissolved metals: copper, zinc, cadmium and lead
   vii. Methylene blue activated substances (MBAS)

viii. Chlorides

c. Ferry Terminal (as indicated in order of priority if insufficient volume exists):
   i. PAHs
   ii. TPH: NWTPH-Dx and NWTPH-Gx (collected as a grab sample)
   iii. Total and dissolved metals: copper, zinc, cadmium and lead
   iv. MBAS
   v. Total suspended solids
   vi. Fecal coliform (grab)
   vii. Temperature (collected from runoff in-situ)

3. Sampling Method

   WSDOT shall collect samples using composite samplers or by manual compositing grab samples. A composite sample shall consist of a minimum of five individual stormwater grab samples equally spaced in time and collected within the first hour of runoff.

4. Sample Timing and Frequency

   WSDOT shall conduct sampling as early in the runoff event as practical but not later than 20 minutes after the onset of runoff at the monitoring location.

   a. WSDOT shall collect samples from a minimum of seven storm events throughout the calendar year.
      i. WSDOT shall sample at least five qualifying storm events during the wet season. Wet season samples shall be collected over a time frame exceeding 28 consecutive days.
      ii. WSDOT shall sample at least one qualifying storm event during the dry season
      iii. Additionally, WSDOT shall collect a sample that represents the seasonal first-flush event no earlier than August 1. The seasonal first-flush sample must have a one-week antecedent dry period.
   b. Storm Event Criteria

      A qualifying storm event during the wet season in Western Washington (October 1 through April 30) and wet season in Eastern Washington (October 1 through June 30) shall meet the following conditions:
      i. Rainfall depth: 0.20-inch minimum, no fixed maximum
      ii. Rainfall duration: No fixed minimum or maximum
      iii. Antecedent dry period: less than 0.02-inch rain or no surface runoff in the previous 24 hours
      iv. Inter-event dry period: 6 hours

      A qualifying storm event during the <u>dry</u> season in Western Washington (May 1 through September 30) and dry season in Eastern Washington (July 1 through September 30) shall meet the following conditions:

      v. Rainfall depth: 0.20-inch minimum, no fixed maximum
      vi. Rainfall duration: No fixed minimum or maximum
      vii. Antecedent dry period: less than 0.02-inch rain in previous 72 hours
      viii. Inter-event dry period: 6 hours

5. Reporting requirements for Baseline Monitoring of Rest Areas, Maintenance Facilities and Ferry Terminals

   a. WSDOT shall submit an Annual Stormwater Monitoring Report with the following information for each sampled storm event beginning in 2013:
      i. Sample event identification (date, time, location)
      ii. Tabular water quality data and summary results for each monitored parameter;
      iii. Antecedent dry period, inter-event period and total precipitation depth; and
      iv. The time period of sample collection.
   b. WSDOT shall include in each Annual Stormwater Monitoring Report any proposed changes to the monitoring program that could affect future data results for each *site.*

E. Monitoring the Effectiveness of Stormwater Treatment and Hydrologic Management Best Management Practices (BMPs)

1. WSDOT shall conduct a full-scale monitoring program to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs. Any BMPs listed in its Highway Runoff Manual (HRM) may be selected. Stormwater treatment and hydrologic BMPs not listed in the HRM, require engineering designs, specifications, and approval from a professional engineer.

2. WSDOT shall monitor at least two treatment BMPs, at no less than two sites per BMP. Monitoring shall continue until statistical goals are met (defined by Ecology's publication, "Guidance for Evaluating Emerging Stormwater Treatment Technologies, Technology Assessment Protocol" (TAPE). If the statistical goals are not achieved within the term of this permit, Ecology will consider continuing the monitoring effort in the next permit cycle.

   a. WSDOT may choose BMPs it has already started evaluating prior to issuance of this permit, provided the study meets the guidelines outlined below. WSDOT shall complete the evaluation during this permit cycle.
   b. WSDOT shall obtain written approval from Ecology for the BMPs WSDOT proposes to evaluate.
   c. WSDOT shall select BMPs from the following categories:
      i. Basic Treatment
      ii. Enhanced Treatment
      iii. Metals/Phosphorus Treatment
      iv. Oil Control
   d. WSDOT shall also select one flow reduction strategy BMP (such as LID) that is in use or planned for installation. Monitoring of a flow reduction strategy shall include continuous rainfall and surface runoff monitoring. Flow reduction strategies shall be monitored through either a paired study or against a predicted outcome.

3. For BMPs monitored under this section, WSDOT shall test BMPs that have been designed and installed in accordance with HRM unless Ecology approves of an alternate design in the QAPP review.

4. WSDOT shall use appropriate sections of Ecology's TAPE (available on Ecology's website) for preparing, implementing, and reporting the results of the BMP evaluation program.
    a. WSDOT shall use USEPA publication number 821-B-02-001, "Urban Stormwater BMP Performance Monitoring," as additional guidance for preparing the BMP evaluation monitoring and shall collect information pertinent to fulfilling the "National Stormwater BMP Data Base Requirements" in section 3.4.3. of that document.
    b. WSDOT shall determine mean and median effluent concentrations, and shall determine percent removals for each BMP type with a statistical goal of 90-95% confidence and 75-80% power for the parameters for which the facility is approved in the HRM. The initial QAPP shall commit to a monitoring program designed to achieve the statistical goal, but shall target collection of at least 12 influent and 12 effluent samples per year.
5. WSDOT shall monitor the following parameters at each test site:
    a. For Basic, Enhanced, or Phosphorus Treatment BMPs: total suspended solids, particle size distribution, pH, total phosphorus, ortho-phosphate, hardness, and total and dissolved copper and zinc.
    b. For Oil Control BMPs: pH, NWTPH-Dx and –Gx, and visible oil sheen
6. WSDOT shall sample the accumulated sediment at each test site for Basic, Enhanced, Phosphorus treatment, or Oil Control BMPs for the following parameters: total solids, particle size (grain size), total volatile solids, NWTPH-Dx, total phosphorous, and total cadmium, copper, lead, and zinc.
7. Reporting requirements for Stormwater Treatment and Hydrologic Management Best Management Practice (BMP) Evaluation Monitoring beginning with the 2013 Stormwater Monitoring Report WSDOT shall include the following information for *each sampling event from each site*:
    1. Sample event identification (date, time, location)
    2. Tabular water quality data and summary results for each monitored parameter;
    3. Antecedent dry period, enter-event period and total precipitation depth;
    4. A graphical representation of storm hyetograph and hydrograph for both the influent and effluent, with each aliquot collection point spatially located throughout the hydrograph; the sampled time period (% of hydrograph sampled), total runoff time period and total runoff volume.
8. Beginning with the 2013 monitoring annual report and annually thereafter until statistical goals are met, WSDOT shall include in each Annual Report for BMP Evaluation Monitoring the following information for each *site*:
    a. Status of implementing the monitoring program and a description of Stormwater Treatment and Hydrologic Management BMP Evaluation Monitoring programs that are still in progress at the end of the reporting year
    b. WSDOT shall compute and report cumulative (including previous years) performance data for each treatment BMP test site, and for both sites of the same treatment BMP type, consistent with the guidelines in appropriate sections of Ecology's guidance for "Evaluation of Emerging Stormwater Treatment Technologies" and USEPA publication number 821-B-02-001,

"Urban Stormwater BMP Performance Monitoring," including information pertinent to fulfilling the "National Stormwater BMP Data Base Requirements" in section 3.4.3. of that document.

c. Status of cumulative (including previous years) performance data in terms of statistical goals for each test site and for both test sites of the same treatment BMP type;
d. Status of performance data concerning flow reduction performance for the hydrologic reduction BMP; and
e. Any proposed changes to the monitoring program that could affect future data results.

9. A final report on each BMP monitored shall be submitted once the monitoring statistical goals are met. The final report shall include an analysis of the performance data collected on the BMPs as described in the appropriate sections of Ecology's TAPE (available on Ecology's website).

Appendix C Toxicity Guidance from the Permit

This Toxicity Guidance is copied directly from the WSDOT stormwater permit's Appendix 6 (Ecology, 2009a).

TOXICITY GUIDANCE

Guidance for Sampling and Toxicity Testing Required in S.7.C. of the WSDOT Municipal Stormwater Permit (WSDOT Permit)

This guidance document provides additional information to the requirements listed in S.7.C of the WSDOT Permit. S.7.C requires first-flush toxicity sampling at six stormwater monitoring locations. This Appendix contains guidance and multiple planning steps to ensure quality toxicity data is adequately collected. This Appendix should be used *in addition* to any required QAPP content demonstrated in Ecology's *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies* (2004). This Appendix includes guidance and references for:

- Sampling Strategies
- Attempts at toxicity
- Volume, Temperature and Holding Times
- Invalid and Anomalous Test Procedures
- Laboratory Testing Procedures and Quality Assurance
- Follow-up Actions
- Submittals
- Toxicity Identification/Reduction Evaluation Guidance
- Additional Resources and References for Toxicity Sampling

Sampling Strategies

Toxicity is required to be monitored at BMP effluent locations and from the edge of pavement. WSDOT may use the same sites for toxicity monitoring as other sites selected for monitoring throughout S7, but must meet the requirements pertinent each section. For example, if WSDOT uses an edge of pavement site to meet both S7.B and S7.C requirements, a flow-weighted sample must be collected for a first-flush storm. In this situation, WSDOT will receive credit for the sample if flow-weighted composite sampling techniques are used, the same sample stream of water is used as the sample volume and the storm event qualifies under both S7.B and S7.C. Any other variations from sampling requirements listed in S7.B or S7.C must be included in the QAPP submitted for Ecology review and approval.

In order to catch the first flush, storm forecasting models or advanced equipment should be used for adequate notification of incoming storms. WSDOT must then notify the toxicity laboratory 2 days prior to the date of the forecasted storm event. A general timeline should be well defined in the required QAPP for planning purposes to describe procedures for field staff communication with the laboratory. Any potential site constraints or logistical problems should be noted in the QAPP and documented by WSDOT.

The chemical analysis sampling requires analyzing the list of parameters specified in Section S.7.C. of the WSDOT Permit. In order to obtain the needed volume for the toxicity test and the full list of chemical parameters, WSDOT may use modified samplers, multiple samplers or establish field practices for replacing bottles. Attempts to obtain sufficient volumes should be

indicated in the QAPPs. If using more than one sampler, the samplers should be programmed the same and the sample should be collected from the same representative sample stream.

Further, for the chemistry analysis sample, MBAS results are needed to determine if toxicity is due to detergents or surfactants used in pesticide mixtures. MBAS testing will detect anionic surfactants, but if toxicant identity is unknown and nonionic surfactants are possible, then a cobalt thiocyanate activating substances (CTAS) test should also be done.

Attempts at Toxicity

Toxicity sampling should be conducted using composite sampling equipment at selected stormwater monitoring locations as indicated in the WSDOT Permit. Composite samplers should be used to collect samples for both toxicity testing (*H. azteca*) and chemical analysis sampling (TSS, chlorides, hardness, MBAS, Metals, pesticides, PAHs, phthalates and TPH). Samples should be collected during the seasonal first-flush occurring between August 1st and September 30th each year. During this time period, if a sample is unattainable, or if the first attempt is found to be invalid or anomalous, a second attempt is required. A second attempt may occur later than September 30th and after this date; no antecedent dry period is required prior to sample collection.

Volume, Temperature and Holding Times

Volume for Toxicity and Chemical Analysis

A sufficient sample for toxicity consists of the following:

- Approximately 6 liters (1.5 gallons) of sample water is needed for the toxicity test, and,
- A maximum of 14 liters (3.7 gallons) of sample water is needed to analyze the chemical parameters. This estimate includes a maximum volume for herbicides; however, herbicide analysis is only required at those sites where herbicides are used.

Table 1. Volume Estimate Table

	Recommended Quantity	Suggested Container Type	Holding Time	Preservation
Hyalella azteca 24-hour acute test (ASTM E1192-97)	1.5 gallons (6 liters)	glass	36 hours	Cool to 6º
Chemical Parameters				
Metals: Total Cu, Zn, Cd, Pb	350 ml	500 ml HDPE	6 months	HNO_3
Metals: Dissolved Cu, Zn, Cd, Pb	350 ml	500 ml Teflon, polyethylene, polycarbonate or polypropylene	6 months	Filter[1], the HNO_3
Herbicides	2 gallons	1 gallon glass	7 days	Cool to 4º
Total suspended solids	1000 ml	500 ml polyethylene	7 days	Cool to 4º
Chlorides	100 ml	500 ml polyethylene	28 days	Cool to 4º
Hardness	100 ml	125 ml poly	6 months	H_2SO_4
Methylene blue activated substances	250 ml	1-liter Amber glass	48 hours	Cool to 4º
PAHs[2]	1 gallon	1-gallon glass	7 days	Cool to 4º
Phthalates[2]	1 gallon	1-gallon glass	7 days	Cool to 4º
TPH (NWTPH-Gx*)	120 ml	(3) 40- ml glass vials	14 days	HCL
TPH-(NWTPH-Dx*)	1 gallon + 40 ml	1 gallon glass jar + 1 40 ml glass vial	7 days	HCL

Notes:

[1]Samples for dissolved metals should be field filtered as soon as practical after the last aliquot is taken in the composite sampler.

[2]PAHs should include at a minimum: acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorine, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene and pyrene

[2]Phthalates should include at a minimum: *bis*(2-Ethylhexyl)phthalate, Butyl benzyl phthalate, Di-n-butyl phthalate, Diethyl phthalate, Dimethyl phthalate and Di-n-octyl phthalate.

*Not to be collected in the sample volume collection through a composite sampler.

Chemistry analysis volume requirements can vary between laboratories and sites (depending on whether or not herbicides are required for analysis). To reduce the estimated volumes listed in Table 1, some parameters may be combined into single containers. The data for Table 1 was provided by Manchester Environmental Laboratory and Nautilus Laboratory. For information on analytical methods and reporting limits, see Appendix 5.

Replicates, Volumes, and, Concentrations and Controls Required for H. Azteca

A minimum of 2 liters is need for the toxicity test. If a volume less than 2 liters are collected, do not proceed with the toxicity test or analysis of chemical parameters. Ideally, 6 or more liters should be attained for the toxicity test. Table 2 provides guidance on replicates, sample concentrations and control for sample volumes between 2 and 6 liters.

Table 2. Replicates, Volumes, Concentrations and Control for the H. Azteca 24-hour Acute Test

Sample Volume Obtained	# of Replicates w/Volume	# of Sample Concentrations and a Control
6000 ml	4 of 250 ml each	5
3000 ml	4 of 125 ml each	5
2400 ml	4 of 100 ml each	5
2000 ml	4 of 100 ml each	4

If the sample volume available for toxicity testing is between the values above, then the instructions for the next lower sample volume shall be followed and the excess sample shall be stored for possible use in toxicant identification if the chemical analyses above do not find a likely toxicant. WSDOT is encouraged to collect as much sample as possible so that excess is available for follow-up actions if toxicity is detected.

If the total sample volume for the toxicity sample after the qualifying storm is less than needed, the number of replicates may be dropped to 3 and the lowest test concentration (6.25% sample) dropped from the test.

Sample Temperature

During sample collection, WSDOT must cool the chemical analysis sample between 0 - 4ºC and 0 – 6ºC for the toxicity sample. The samples should be sent to the laboratory immediately after field collection procedures. For the toxicity sample, if the sample temperature exceeds 6ºC at receipt by the laboratory, then the WET Coordinator, Randall Marshall (rmar461@ecy.wa.gov or 360-407-6445) may be contacted to propose acceptance for the sample temperature deviation. Acceptance is based on the Department of Ecology publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria* and will not be given for samples warmer than 14º C unless the sample is received by the laboratory within one hour after collection.

Holding Time

If the maximum holding time of the toxicity sample is exceeded (36 hours), staff will contact Ecology's WET Coordinator (rmar461@ecy.wa.gov or 360-407-6445) for conditional acceptance. Sample holding times in excess of 72 hours will not be accepted by the laboratory or Ecology. The date and time of test initiation should be recorded on field data forms or in field notebooks.

Invalid and Anomalous Test Procedures

Invalid toxicity tests are the result of the laboratory not following the test protocol or the test results not meeting the test acceptability criteria in the test protocol. If the control has less than 90% survival, the test is invalid and needs to be repeated on an additional sample meeting the terms of S8.C. The laboratory will usually identify invalid tests and inform WSDOT of the need to repeat them. The Department of Ecology will also identify invalid tests when a laboratory

does not do so and will inform WSDOT in writing to attempt to collect an additional sample meeting the terms of S8.C. and retest for toxicity.

The concentration- response relationship may also be declared anomalous in accordance with Appendix D of Ecology's *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*. Anomalous test results happen when the laboratory has conducted the toxicity test in accordance with the test protocol, but the results are considered unreliable according to the anomalous test identification criteria in Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*. The criteria for identification of anomalous test results help screen for adverse effects which are not caused by toxicity. Only the Department of Ecology may identify a test result as anomalous. If the Department determines the test results are anomalous, the Department may require the Permittee to attempt to collect a second toxicity test sample if the Department believes sufficient time remains to collect a sample meeting the toxicity storm event criteria.

WSDOT will be notified in writing if it is required to attempt to collect an additional sample meeting the terms of S8.C. Additional samples must include enough volume to repeat the analyses for the list of chemical parameters or to conduct a toxicity identification evaluation (TIE) if the sample is toxic. If WSDOT wishes to do a TIE instead of chemical analysis of the additional sample, a TIE plan must be prepared and approved in advance. If WSDOT is unable to collect and test a second sample, it must document its efforts in the annual report. WSDOT shall not be required to make more than two sample attempts for toxicity testing described in S8.C.

Laboratory Testing Procedures and Quality Assurance

Laboratory Testing Procedures

Conductivity, pH, dissolved oxygen and hardness will be measured at the toxicity laboratory upon sample receipt of the toxicity sample. An additional hardness sample may be collected from the receiving water by the permittee in order for the toxicity laboratory to adjust the sample hardness to match receiving water hardness. The permittee is encouraged to monitor receiving streams for pH, dissolved organic carbon, and common ions so the biotic ligand model can be used to estimate receiving water toxicity due to metals in the storm water. For the toxicity sample collected, the following testing procedures are illustrated in the following reference:

> *ASTM E 1192-97: Standard Guide for Conducting Acute Toxicity Tests on Aqueous Ambient Samples and Effluents with Fishes, Macroinvertebrates and Amphibians.*

An EC_{50} should be calculated for each test result using the Spearman-Karber Method. Abbot's correction may be applied to the data before deriving the point estimations. A minimum of five concentrations and a control should be used. If an EC_{50} is 100% sample or less, then the permit requires follow-up actions.

Required Test Conditions for 24-Hour Survival Test (ASTM E 1192-97)

Test Organism: *Hyalella azteca*

Test Chamber: 250 - 500 mL

Volume: 100 - 250 mL

Reps: 4

Concentrations: 5 plus control, standard 0.5 dilution series. If volume collected is low, 6.25% concentration will be dropped.

Substrate: square of nitex screen

animals per rep: 10

Age: 7 - 14 days, 1 - 2 day range in age

Feeding: Feed ground cereal leaf prior to testing. No feeding during testing.

Temperature: 23 degrees

Aeration: if below 4.0 mg/L

Light: 16/8

Test Acceptability Criteria: ≥ 90% survival in control

Control and Dilution Water: moderately hard synthetic water

Hardness Modification: Storm water sample hardness may be adjusted to match

Laboratory Quality Assurance

Toxicity tests must meet quality assurance criteria in the most recent versions of:

- Department of Ecology Publication #WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria*.

Follow-up Actions

If the EC_{50} from any valid and non-anomalous test is 100% stormwater or less, the following procedures are required:

- Chemical analytical results must be compared to the EPA's EcoTox database and the science literature to determine the presence of a detected toxicant within sixty (60) days after final validation of the data
- If a possible chemical contaminant(s) of concern is determined by the EPA database and science literature review, WSDOT shall prepare and submit a report summarizing:
    - The toxicity and chemical analysis results compared to EPA's EcoTox data
    - The review of relevant sources of literature
    - Summarize the possible chemical contaminant(s) of concern and explain how WSDOT's stormwater management program actions are expected to reduce stormwater toxicity

The follow-up actions when toxicity is detected should also anticipate adding a toxicity identification evaluation (TIE) to future testing events if the list of chemical analytical results did not point to a likely toxicant. Because test duration is 24 hours, any excess sample should be fresh enough for use in a TIE. WSDOT is encouraged to prepare a TIE plan in advance to allow time for review and approval by the department. The TIE plan should be based upon the relevant

procedures in the EPA TIE guidance found at http://www.epa.gov/npdes/pubs/owm0330.pdf and http://www.epa.gov/npdes/pubs/owmfinaltretie.pdf

WSDOT should enter the results of the chemical analyses into a database. This database can be an important resource for follow-up actions work. Examination of results at the same outfall over time and from different outfalls from around the state may reveal patterns of chemical analytical results related to toxicity test results. The follow-up actions when toxicity is detected should take this possibility into account if identification of toxicants is not successful after two years.

The permit requires that follow-up actions results are included in the annual report. The goal of the follow-up actions is to update the annual report with progress information when toxicity is detected and to update or implement WSDOT's Stormwater Management Program to reduce toxicity. Confirmation of toxicant identity is not necessary as long as this goal is being met.

Submittals

The Permittee shall submit all reports for toxicity testing in accordance with the most recent version of Department of Ecology Publication # WQ-R-95-80, *Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.* The Permittee shall prepare and submit a report in each Annual Report including the following information:

- Any invalid or anomalous test results, good faith attempts to collect the required volume, and any unsuccessful second attempts
- Bench sheets for toxicity tests
- An analytical report for the chemistry analysis
- A toxicity data analytical report (if available in electronic format, this is the preferred submittal method to Ecology)
- Reference toxicant results for test methods
- An explanation of how WSDOT's Stormwater Management Program is expected to reduce stormwater toxicity (if applicable)
- A description of the pathway to receiving water
- A description of any existing or planned BMPs within that pathway to receiving water

Toxicity Identification/Reduction Evaluations (TI/RE) Methodology and Guidance:

Since the *Hyalella* test in the permit is only 24 hours in duration, the lab will have time to begin a TI/RE on leftover sample held at 4º C since the beginning of the test. WAC 173-205-100(2)(b) says that a TI/RE must be based upon the procedures in the EPA documents referenced below but that any procedure that is not necessary may be excluded and that any procedure may be modified or added if it will improve the ability to identify or reduce toxicity. In addition, a TI/RE plan should be implemented with flexibility so that resources can be shifted when results begin to reveal promising directions and not squandered blindly following a plan.

United States Environmental Protection Agency. 1989. Generalized methodology for conducting industrial toxicity reduction evaluations (TREs). Cincinnati OH: Risk Reduction Laboratory. EPA/600/2-88/070.

United States Environmental Protection Agency. 1991. Methods for aquatic toxicity identification evaluations: phase I toxicity characterization procedures. second edition. Duluth MN: Environmental Research Laboratory. National Effluent Toxicity Assessment Center Technical Report 18-90. EPA/600/6-91/003.

United States Environmental Protection Agency. 1993. Methods for aquatic toxicity identification evaluations. Phase II toxicity identification procedures for samples exhibiting acute and chronic toxicity. Washington DC: Office of Research and Development. EPA/600/R-92/080.

United States Environmental Protection Agency. 1993. Methods for aquatic toxicity identification evaluations. phase III toxicity confirmation procedures for samples exhibiting acute and chronic toxicity. Washington DC: Office of Research and Development. EPA/600/R-92/081.

United States Environmental Protection Agency. 2001. Clarifications Regarding Toxicity Reduction and Identification Evaluations in the National Pollutant Discharge Elimination System Program. Washington DC: Office of Wastewater Management.

Ausley, LW, Arnold RW, Denton DL, Goodfellow WL, Heber M, Hockett R, Klaine S, Mount D, Norberg-King T, Ruffier P, Waller WT. 1998. Application of TIEs/TREs to whole effluent toxicity: principles and guidance. A report by the Whole Effluent Toxicity TIE/TRE Expert Advisory Panel. Pensacola FL: Society of Environmental Toxicology and Chemistry (SETAC).

Examples of TI/REs with *Hyalella azteca* and metals toxicity information:

Anderson BS, JW Hunt, BM Phillips, PA Nicely, KD Gilbert, V de Vlaming, V Connor, N Richard, RS Tjeerdema. 2003. Ecotoxicologic impacts of agriculture drain water in the Salinas River (California, USA). *Environ Toxicol Chem* 22:2375–2384.

Borgmann U, Y Couillard, P Doyle, DG Dixon. 2005. Toxicity of sixty-three metals and metalloids to *Hyalella azteca* at two levels of water hardness. *Environ Toxicol Chem* 24:641-652

Wheelock CE, JL Miller, MJ Miller, BM Phillips, SA Huntley, SJ Gee, RS Tjeerdema, BD Hammock. 2006. Use of carboxylesterase activity to remove pyrethroid-associated toxicity to *Ceriodaphnia dubia* and *Hyalella azteca* in toxicity identification evaluations. *Environ Toxicol Chem* 25:973-984.

Schubauer-Berigan MK, JR Dierkes, PD Monson, GT Ankley. 1993. pH-dependent toxicity of Cd, Cu, Ni, Pb and Zn to *Ceriodaphnia dubia*, *Pimephales promelas*, *Hyalella azteca* and *Lumbriculus variegatus*. *Environ Toxicol Chem* 12:1261-1266.

Additional Resources/References for Toxicity Sampling

- Ecology's Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria, June 2008b: http://www.ecy.wa.gov/biblio/9580.html
- ASTM E 1192-97: Standard Guide for Conducting Acute Toxicity Tests on Aqueous Ambient Samples and Effluents with Fishes, Macroinvertebrates and Amphibians.

Appendix D Traffic Control Plan and Safety Guidelines

Safety Guidelines

All WSDOT personnel and contracted individuals will follow the guidelines set forth in the WSDOT publication *Work Zone Traffic Control Guidelines* (WSDOT, September 2009b). Personnel sampling stormwater runoff near roadways will be trained in the following safety guidelines and requirements.

Personal Protective Equipment (PPE)

All personnel will wear and maintain the appropriate PPE as specified by WSDOT. This includes an ANSI or MUTCD-approved type II or better retroreflective safety vest and hard hat. Weather and work-appropriate clothing will be worn for the work zone. Hearing and eye protection may be advised, depending on site conditions.

Personal Attributes

All personnel will remain alert, keep a positive and safety-conscious attitude, and be responsible for their own safety as well as that of their co-workers. It is imperative to be mindful of what is happening around the work zone.

Pre-Activity Safety Plan (PASP)

All personnel will be involved with completing and reviewing the detailed pre-activity safety plan for stormwater field work before setting up the work zone. An example PASP is displayed on the following page as a guidance document for field work.

Short-Duration Work Zones

Short-duration work zones can be described as any activity where work duration lasts less than or up to 60 minutes. Most of the stormwater sampling or equipment-checking operations will be short duration. Any work that may take longer (such as station installation) will require WSDOT to develop a tailored work plan to best suit the operation. Refer to TCP-5, TCD-16, and the "Short Duration Don'ts and Do's" from Section 3-8 in the *Work Zone Traffic Control Guidelines*, for short-duration site setup specifications on and near shoulders of multilane highways.

Safety Equipment Needed

1 – Road Work Ahead sign

1 – Shoulder Work sign

8 – 24-inch retroreflective cones

1 – Traffic Warning Light (vehicle mounted) visible from 1,000 feet away

WSDOT vehicle used to provide space for personnel

PRE-ACTIVITY SAFETY PLAN

STORMWATER FIELD WORK

Date:_____ Employee:_____ PASP#____

1. Complete pre-travel checklist prior to travel.
2. Upon reaching the field site, team lead: evaluates work area, completes site description (below), and completes hazard assessment checklist (on back).
3. Team lead assembles field crew and reviews / discusses the Pre-activity Safety Plan controls for each safety hazard identified on the completed hazard assessment checklist.
4. Team lead maintains completed safety hazard checklist until all have returned to work station and/or have check in with their supervisor. Save document for the next person that might visit.

Site Information	Purpose of Site Visit	PPE's
Site Name: _____ Field Contact:_____ Phone #: (____) _____ - _____ Location: SR_____MP_____ County _____ Nearest Medical Facility: _____ Map Attached Traffic Control Needed Check-in Person :_____ Remote Location? Cell Phone Service Phone Available Scan Calling Card First Aid planning*** Known conditions/allergy medication available? Action planned _____	**Pre-Travel Checklist** □ Environmental Safety Hazard Assessment and Mitigation Booklet □ Washington State Hospital List □ Pre-Trip Vehicle Inspection and Familiarization □ 1st Aid Kit □ Flares/Triangles/Signs □ Emergency Contact Phone List □ Beacons/signage/traffic cones available in vehicle □ Check SR View for parking possibilities (http://www.srview.wsdot.wa.gov/home.htm)	☐ Vest ☐ Hard Hat ☐ Eye Protection ☐ Gloves ☐ Work Boots ☐ Hearing Protection ☐ Hip Boots or waders ☐ PFD ☐ Throw rope bag ☐ Sun block ☐ Insect repellent ☐ Other: _____

PARKING ISSUES

Park in areas that provide safe entrance and exit of the work area, do not create potential conflicts with other vehicles and equipment or fire hazard on tall grass.

1. Parking on roadside or near traffic. **(<2 ft. from fog line more than 15 minutes)** **□ Yes □ No**	**1. When stopped on shoulder or roadway use beacon lights per WAC 204-38* requirements.** **2. Follow the signage and work provisions in the M54-44* for short/long duration work zones.** **3. When backing in a vehicle larger than a sedan, you must honk twice before backing (Work Zone Safety)**	**Parking on roadside or near traffic.** **(<15 ft. from fog line more than 15 minutes)** **□ Yes □ No**	**1. Position cones behind vehicle if there is limited visibility or curves in road** **2. Field vehicles should be equipped with appropriate signage for a shoulder closure.** **3. Lane closures will need to be coordinated through Traffic Control.**

* *Details pending*. WAC 204-38 is available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=204-38

** *Details pending*. M54-44 is available at http://www.wsdot.wa.gov/Publications/Manuals/M54-44.htm

*** The PASP's shouldn't include medical information, but hazards like bee stings or poison oak should be identified. If employees elect to volunteer medical information to their supervisor and/or crew, that's allowed, but the supervisor and/or crew shouldn't be soliciting that information and it **should not be recorded on this form**. If a worker who is diabetic volunteers that information to co-workers or their supervisor, you can discuss options when a blood sugar episode happens, but if they choose not to let anybody know, it's their prerogative.

Task/Hazard	Control	Site Specific Comments	Requirements
2. Working near moving traffic □ Yes □ No	1. Face oncoming traffic while on foot. 2. Be aware of or develop emergency escape routes. 3. Always wear appropriate high visibility apparel, minimum is ANSI class II vest. 4. Avoid working alone.		□ Vest needed □ Hard Hat
3. Walking over uneven terrain. □ Yes □ No	1. Be aware of loose material, unstable slopes, excavation drop-offs, tripping hazards (ruts, holes, etc.), uneven ground and other obstructions. 2. Move carefully in areas with the potential for slips, trips, or falls. 3. Wear appropriate footwear with adequate traction and support.		□ Work boots □ Leather gloves (Optional but recommended in areas where blackberries are dominant)
4. Working on or around rip-rap □ Yes □ No	1. Evaluate rip-rap for loose, rolling, or unstable rocks. 2. Wear hard hat and evaluate need for leather gloves when loose or unstable rock conditions exist or when there is potential for falling rocks.		□ Work boots and gloves
5. Working in or around areas of shallow or slowly moving water □ Yes □ No	1. Evaluate water depth hazard. 2. Evaluate slippery/steep/hidden water edge conditions and need for avoidance or uphill partner. 3. Evaluate large woody debris hazard at the work site and downstream of it. 4. Assess depth of mud and evaluate safe exit. 5. Evaluate potential rescue options that are safe for the rescuer. When warranted, establish person with throw rope bag down slope of work area and between work area and any downstream hazard.		□ Hip boots or waders
6. Working around bridges, signs, light fixtures, power lines □ Yes □ No	1. Continuously assess potential for falling rock or other overhead hazards, especially in windy weather. 2. When possible, avoid, restrict time in, or work during times of least activity in hazard areas. 3. When in hazard area, wear hard hat, gloves, and safety glasses along with approved vest and footwear.		□ Hard hat, gloves, boots
7. Harmful / poisonous plants □ Yes □ No	1. Be aware of what poison ivy/oak/Giant Hogweed/Cow Parsnip/Water Hemlock/Wild Parsnip looks like (http://poisonivy.aesir.com/ has many images and information). 2. Be aware of potential for injury from vegetation around you, such as thorns from blackberries or the sharp edges of reed canary grass. 3. Bring hand-pruners and glasses to prevent injury in thick brush and briers.		□ Hand pruners □ Eye protection □ Gloves
8. Potential for transients or human biohazards □ Yes □ No	1. Avoid confrontations with transients. 2. Avoid contact with human waste, needles, or other drug paraphernalia. 3. Request assistance from maintenance to remove hazard, when necessary.		
9. Poisonous snake or large carnivore hazard □ Yes □ No	1. When working in a snake or large carnivore area, consider two or more people for site visits. 2. When in carnivore habitat, make your presence known by talking, whistling, etc. 3. Stay in sight of partner or in radio contact.		□ Two people on site □ Radios

10. Isolated sites / 'bad neighborhoods' □ Yes □ No	1. Consider whether location warrants two people or a team to minimize exposure time. 2. Have cell phone or check-in plan in case of emergency.		□ Two people on site □ Cell phone
11. Risk of insect / invertebrate problems □ Yes □ No	1. Determine if field staff are allergic to bees or yellow jackets. Bring appropriate first aid. Confirm location of nearest hospital. 2. Listen and look for bees frequently in the air and on the surface. When spotted, inform others in the field of the location. Evaluate carefully flagging location for future visits.		□ Person with allergy?
12. Working around natural overhead hazards. □ Yes □ No	1. Assess potential for falling rock, snags or other overhead hazards. 2. When possible, avoid or restrict time in the hazard area. 3. When in hazard area, wear hard hat, gloves, and safety glasses along with approved vest and footwear. 4. Request assistance from maintenance to remove hazard, if possible.		□ Hard hat, gloves, boots
13. Working around fall hazards □ Yes □ No	1. Do not work in the fall hazard area without appropriate safety equipment and training. 2. Observe fall protection rules in WAC 296-155 Part C-1.* Prepare a fall protection plan, WSDOT form 750-001, prior to performing the work		□ Fall protection plan needed
14a. Inclement weather (Hot)** □ Yes □ No	**1. In very warm conditions, consider field partner.** 2. Wear weather-appropriate clothing. **3. Rest as needed; take off hat and vests on breaks.** **4. Replenish fluids – drink one quart per hour.** 5. Bring sunscreen and hat for sun protection. 6. Stay in sight of partner or in radio contact. **7. Evaluate team for heat-related illness and monitor for need of medical attention.**	**Temperature thresholds where 1, 3, 4, & 7 apply:** $\geq 89^0$ for light clothing; $\geq 77^0$ for heavier clothes (jacket, sweatshirt, coveralls, etc.); and $\geq 52^0$ for non-breathing clothes (vapor barrier clothing or chemical resistant suits)	□ Two people on site □ Radios □ Hat, sunscreen
14b. Inclement weather (Cold) □ Yes □ No	1. In very cold/snow/stormy conditions, consider field partner. 2. Wear appropriate clothing – gloves, hat, thermal underwear, heavy jacket. 3. Stay in sight of partner or in radio contact 4. Is the vehicle equipped with chains/traction tires?		□ Two people on site □ Appropriate attire □ Vehicle equipped with appropriate cold weather gear
15. Bridge Work □ Yes □ No	1. Reference controls for: -Walking over uneven terrain -Working around a stream -Working around natural/manmade overhead hazards -Working around fall hazards 2. Coordinate with Maintenance personnel when working from bridge structures. Follow site specific PASP as required. 3. Box girder bridges may have confined spaces requiring training.		□ Hard hat

16. Working on a site with confined spaces. □ Yes □ No	1. Avoid all confined spaces (*Has limited or restricted entry or exit. Examples of spaces with limited or restricted entry are tanks, vessels, silos, storage bins, hoppers, vaults, excavations, and pits.)* without specialized equipment and training. 2. Observe confined space rules in WAC 296-809***		
17. Construction equipment and activities □ Yes □ No	1. PPE's required as necessary (Hearing protection, eye protection, hardhat for overhead work, etc) 2. Coordinate with PEO and/or Contractor to ensure compliance with their safety plans as applicable.		□ Hearing and/or eye protection, hard hat
18. Working around a stream defined as a water hazard (currents greater than 10cfs or deeper than 1-ft) □ Yes □ No	1. Evaluate potential rescue options that are safe for the rescuer. 2. Evaluate need for additional support from maintenance, bridge boat, or dive crews. 3. When appropriate, establish person with throw rope bag down slope of work area and any downstream in-channel hazard. 4. Evaluate the potential for loose material and unstable stream banks, and slippery/steep/hidden water edge conditions.		□ Throw rope bag □ Hip boots or waders □ PFD
19. Working in a stream defined as a water hazard □ Yes □ No	1. No wading under hazard conditions without safety equipment and training or specialized crews. 2. For in-water work, wear hip waders, tight-fitting neoprene chest wader, or equivalent. In rocky areas, boots with slip resistant felt-like material soles are recommended. 3. Wear personal flotation device in swift/deep water conditions. 4. Be aware of unstable/loose surfaces/hidden holes or objects under water.		□ Hip boots or waders
20. Machete	1. Wear PPE (gloves, boots, heavy clothing, and eye protection); keep hands dry, rest as needed.		□ Gloves, boots, heavy clothing, eye protection

* WAC 296-155 is available at: Fall Restraint and Fall Arrest-Chapter 296-155-Part C-1

** http://www.lni.wa.gov/Safety/Rules/Policies/PDFs/WRD1015.pdf

*** WAC 296-809 is available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=296-809

Excerpt from the *Work Zone Traffic Control Guidelines*, Section 3.8, (WSDOT, 2009b)

Short Duration Don'ts and Do's:

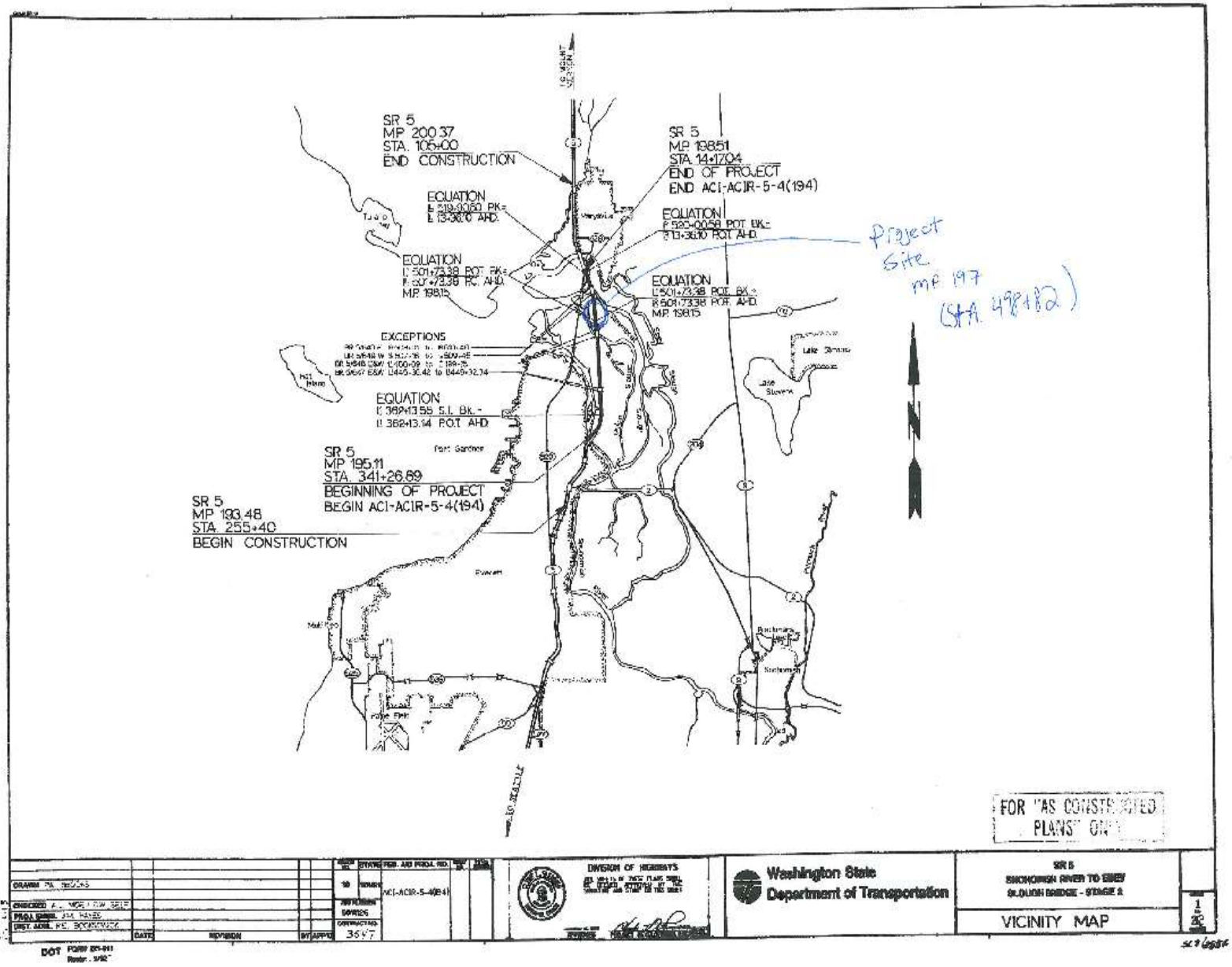
Don't –

- Take "short cuts" or hurry to accomplish work. Determination of all work zone hazards is a must.
- Run across or "dodge" traffic in live lanes.
- Work in a live lane under adverse traffic conditions or without proper traffic control in place . . . even if it is only for a few minutes or a few seconds.
- Assume that shoulder areas are automatically safe. Distracted, aggressive or impaired drivers may encroach. Also, oversize loads may present a hazard.
- Turn your back to oncoming traffic if possible.
- Put yourself in an unexpected location that may surprise a driver.

Do –

- Use the work vehicle as protection and warning whenever possible.
- Take advantage of any resources providing protection and warning without causing additional exposure. (TMAs, buffer/shadow vehicles, PCMSs, etc.)
- Plan ahead. Poor planning is not a valid excuse for lack of equipment, devices or awareness of traffic conditions.
- Find the safest available location to park or unload equipment.
- Avoid high traffic volume hours and locations. Plan ahead for better traffic conditions or consider alternate work operations.
- Work on the same side of the road as the work vehicle and warning beacon whenever possible.

Appendix E Highway As-Builts and Runoff Flow Calculations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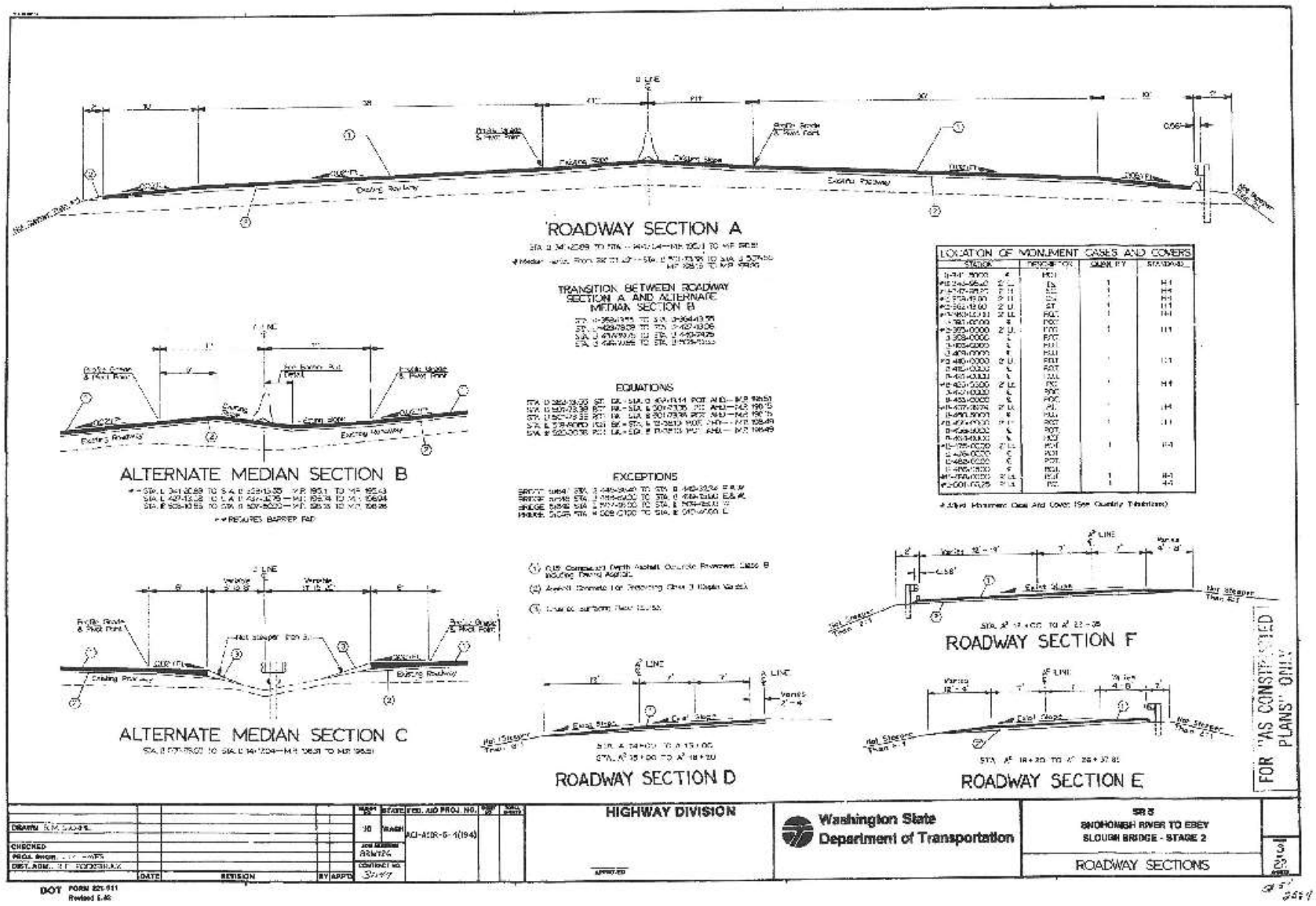
MP 200.37
STA. 105+00
END CONSTRUCTION
SR 5
MP 198.51
STA. 14+17.04
END OF PROJECT
END ACI-ACIR-5-4(194)
EQUATION
EQUATION
EQUATION
MP 198.15
EQUATION
MP 198.15
Project Site
MP 197
(Sta. 498+82)
EXCEPTIONS
EQUATION
SR 5
MP 195.11
STA. 341+26.69
BEGINNING OF PROJECT
BEGIN ACI-ACIR-5-4(194)
SR 5
MP 193.48
STA. 255+40
BEGIN CONSTRUCTION
FOR "AS CONSTRUCTED PLANS" ONLY
DIVISION OF HIGHWAYS
Washington State Department of Transportation
SR 5
SNOHOMISH RIVER TO EBEY
SLOUGH BRIDGE - STAGE 2
VICINITY MAP
ACI-ACIR-5-4(194)
3597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TRANSITION BETWEEN ROADWAY SECTION A AND ALTERNATE MEDIAN SECTION B
EQUATIONS
EXCEPTIONS
LOCATION OF MONUMENT CASES AND COVERS
ALTERNATE MEDIAN SECTION B
ALTERNATE MEDIAN SECTION C
ROADWAY SECTION D
ROADWAY SECTION E
ROADWAY SECTION F
FOR "AS CONSTRUCTED" PLANS ONLY
HIGHWAY DIVISION
Washington State Department of Transportation
SR 5
SNOHOMISH RIVER TO EBEY SLOUGH BRIDGE - STAGE 2
ROADWAY SECTIONS
DOT FORM 825-011 Revised 5-85

I-5 Northbound MP 197

MGSFLOOD

PROJECT REPORT

Program Version: MGSFlood 4.09

Program License Number: 200210003

Run Date: 02/09/2011 2:28 PM

Input File Name: SR005MP197FlowRates.fld

Project Name: SR 005 MP 197

Analysis Title: Determine Flow From Pavement

Comments: For MP 197.27 and MP 197.35

Edge of pavement Length = 39.37 ft long

2 Meters Collector = 78.74 ft long

4 Meters Collector = 78.74 ft long

Widths vary by site as shown in each basin calculation.

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Timeseries Selected

Climatic Region Number: 13

Full Period of Record Available used for Routing

Precipitation Station : 96004005 Puget East 40 in_5min 10/01/1939-10/01/2097

Evaporation Station : 961040 Puget East 40 in MAP

Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1

HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** WATERSHED DEFINITION **********

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 6

---------- Subbasin : MP 197.27 Edge of Pav ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.054
Subbasin Total	0.054

---------- Subbasin : MP 197.27 2M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.013
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.107
Subbasin Total	0.120

---------- Subbasin : MP 197.27 4M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.029
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.103
Subbasin Total	0.132

---------- Subbasin : MP 197.35 Edge of Pav ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.054
Subbasin Total	0.054

---------- Subbasin : MP 197.35 2M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.013
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.107
Subbasin Total	0.120

---------- Subbasin : MP 197.35 4M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.029
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.103
Subbasin Total	0.132

**********FLOOD FREQUENCY AND DURATION STATISTICS**********

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 6

Number of Links: 3

********** Subbasin: MP 197.27 Edge of Pav **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.020
5-Year	0.026
10-Year	0.029
25-Year	0.037
50-Year	0.047
100-Year	0.054
200-Year	0.056

********** Subbasin: MP 197.27 2M Collector **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.041
5-Year	0.053
10-Year	0.061
25-Year	0.079
50-Year	0.097
100-Year	0.115
200-Year	0.119

********** Subbasin: MP 197.27 4M Collector **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.041
5-Year	0.053
10-Year	0.062
25-Year	0.083
50-Year	0.097
100-Year	0.121
200-Year	0.123

********** **Subbasin: MP 197.35 Edge of Pav** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.020
5-Year	0.026
10-Year	0.029
25-Year	0.037
50-Year	0.047
100-Year	0.054
200-Year	0.056

********** **Subbasin: MP 197.35 2M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

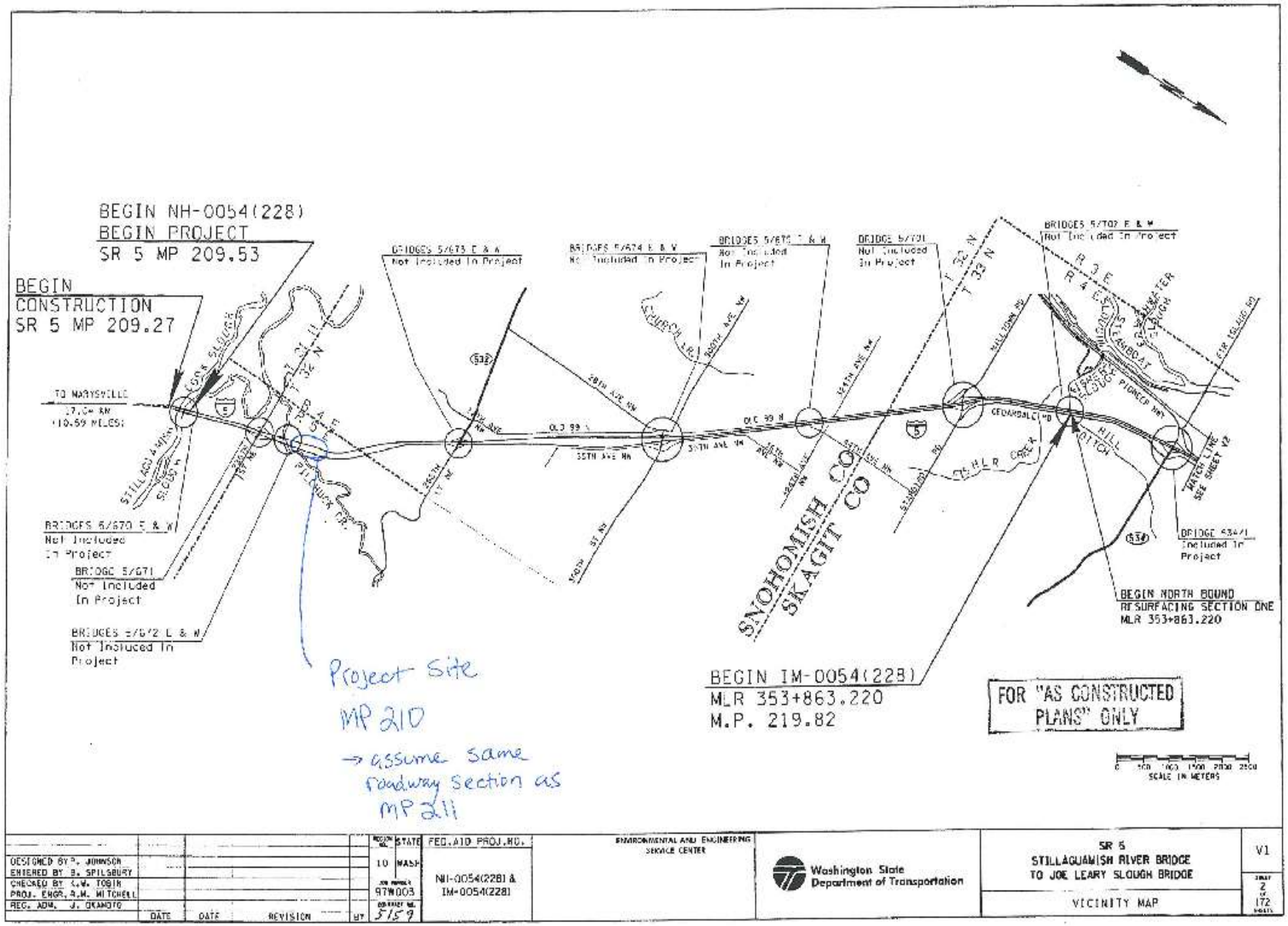
Tr (yrs)	Flood Peak (cfs)
2-Year	0.041
5-Year	0.053
10-Year	0.061
25-Year	0.079
50-Year	0.097
100-Year	0.115
200-Year	0.119

********** **Subbasin: MP 197.35 4M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.041
5-Year	0.053
10-Year	0.062
25-Year	0.083
50-Year	0.097
100-Year	0.121
200-Year	0.123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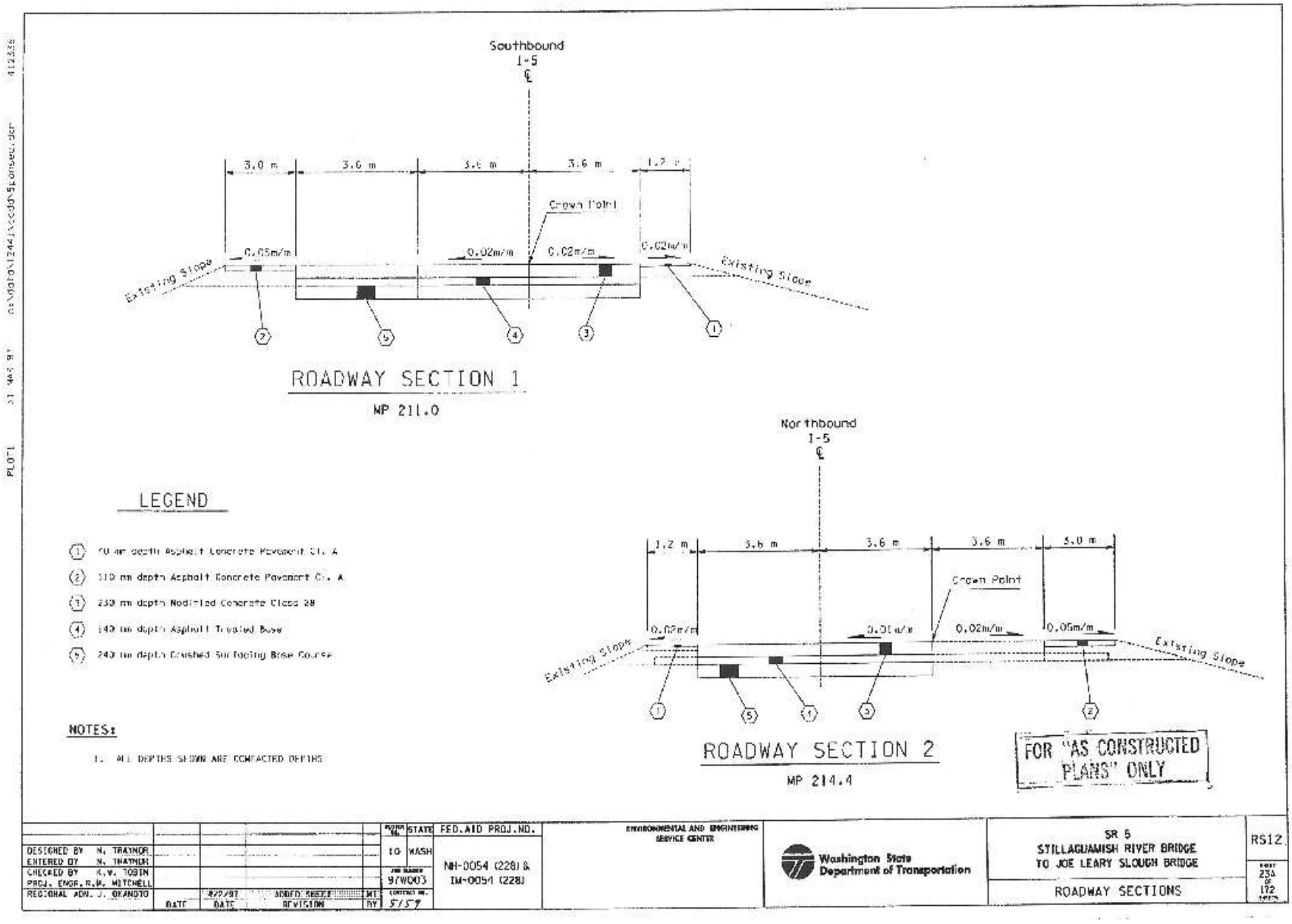
BEGIN PROJECT
SR 5 MP 209.53
BEGIN
CONSTRUCTION
SR 5 MP 209.27
TO MARYSVILLE
BRIDGES 5/673 E & W
Not Included In Project
BRIDGES 5/674 E & W
Not Included In Project
BRIDGE 5/701
Not Included In Project
BRIDGES 5/702 E & W
Not Included In Project
BRIDGES 5/670 E & W
Not Included In Project
BRIDGE 5/671
Not Included In Project
BRIDGES 5/672 E & W
Not Included In Project
SNOHOMISH CO
SKAGIT CO
BEGIN IM-0054(228)
MLR 353+863.220
M.P. 219.82
BEGIN NORTH BOUND
RESURFACING SECTION ONE
MLR 353+863.220
BRIDGE 534/1
Included In Project
FOR "AS CONSTRUCTED PLANS" ONLY
Project Site
MP 210
→ assume same roadway section as MP 211
SCALE IN METERS
DESIGNED BY P. JOHNSON
ENTERED BY B. SPILSBURY
CHECKED BY C.W. TOBIN
PROJ. ENGR. A.M. MITCHELL
REG. ADM. J. OKAMOTO
DATE
REVISION
STATE
10 WASH
97W003
5159
FED. AID PROJ. NO.
NH-0054(228) & IM-0054(228)
ENVIRONMENTAL AND ENGINEERING SERVICE CENTER
Washington State Department of Transportation
SR 5
STILLAGUAMISH RIVER BRIDGE
TO JOE LEARY SLOUGH BRIDGE
VICINITY MAP
V1
2 OF 172

;


Southbound
I-5
3.0 m
3.6 m
3.6 m
3.6 m
1.2 m
Crown Point
0.05m/m
0.02m/m
0.02m/m
0.02m/m
Existing Slope
Existing Slope
ROADWAY SECTION 1
MP 211.0
Northbound
I-5
1.2 m
3.6 m
3.6 m
3.6 m
3.0 m
Crown Point
0.02m/m
0.02m/m
0.02m/m
0.05m/m
Existing Slope
Existing Slope
ROADWAY SECTION 2
MP 214.4
LEGEND
NOTES:
1. ALL DEPTHS SHOWN ARE COMPACTED DEPTHS
FOR "AS CONSTRUCTED PLANS" ONLY
DESIGNED BY N. TRAYNOR
ENTERED BY N. TRAYNOR
CHECKED BY K.V. TOBIN
PROJ. ENGR. R.W. MITCHELL
REGIONAL ADM. J. OKANOTO
STATE
WASH
FED.AID PROJ.NO.
NH-0054 (228) &
IM-0054 (228)
ENVIRONMENTAL AND ENGINEERING SERVICE CENTER
Washington State Department of Transportation
SR 5
STILLAGUAMISH RIVER BRIDGE
TO JOE LEARY SLOUGH BRIDGE
ROADWAY SECTIONS
RS12

I-5 Southbound MP 210

MGSFLOOD

PROJECT REPORT

Program Version: MGSFlood 4.09

Program License Number: 200210003

Run Date: 02/09/2011 3:19 PM

Input File Name: SR005MP210FlowRates.fld

Project Name: SR 005 MP 210

Analysis Title: Determine Flow From Pavement

Comments: For MP 210.71 and MP 210.85

Edge of pavement Length = 39.37 ft long

2 Meters Collector = 78.74 ft long

4 Meters Collector = 78.74 ft long

Widths vary by site as shown in each basin calculation.

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Timeseries Selected

Climatic Region Number: 14

Full Period of Record Available used for Routing

Precipitation Station : 96004405 Puget East 44 in_5min 10/01/1939-10/01/2097

Evaporation Station : 961044 Puget East 44 in MAP

Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1

HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 6

---------- Subbasin : MP 210.71 Edge of Pav ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.032
Subbasin Total	0.032

---------- Subbasin : MP 210.71 2M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.013
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.063
Subbasin Total	0.076

---------- Subbasin : MP 210.71 4M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.029
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.057
Subbasin Total	0.086

---------- Subbasin : MP 210.85 Edge of Pav ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.032
Subbasin Total	0.032

---------- Subbasin : MP 210.85 2M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.013
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.063
Subbasin Total	0.076

---------- Subbasin : MP 210.85 4M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.029
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.057
Subbasin Total	0.086

**************************FLOOD FREQUENCY AND DURATION STATISTICS**********************

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 6

Number of Links: 3

********** **Subbasin: MP 210.71 Edge of Pav** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.012
5-Year	0.016
10-Year	0.019
25-Year	0.023
50-Year	0.028
100-Year	0.034
200-Year	0.035

********** **Subbasin: MP 210.71 2M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.026
5-Year	0.034
10-Year	0.041
25-Year	0.051
50-Year	0.061
100-Year	0.075
200-Year	0.077

********** **Subbasin: MP 210.71 4M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.026
5-Year	0.034
10-Year	0.040
25-Year	0.051
50-Year	0.063
100-Year	0.078
200-Year	0.080

********** **Subbasin: MP 210.85 Edge of Pav** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.012
5-Year	0.016
10-Year	0.019
25-Year	0.023
50-Year	0.028
100-Year	0.034
200-Year	0.035

********** **Subbasin: MP 210.85 2M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

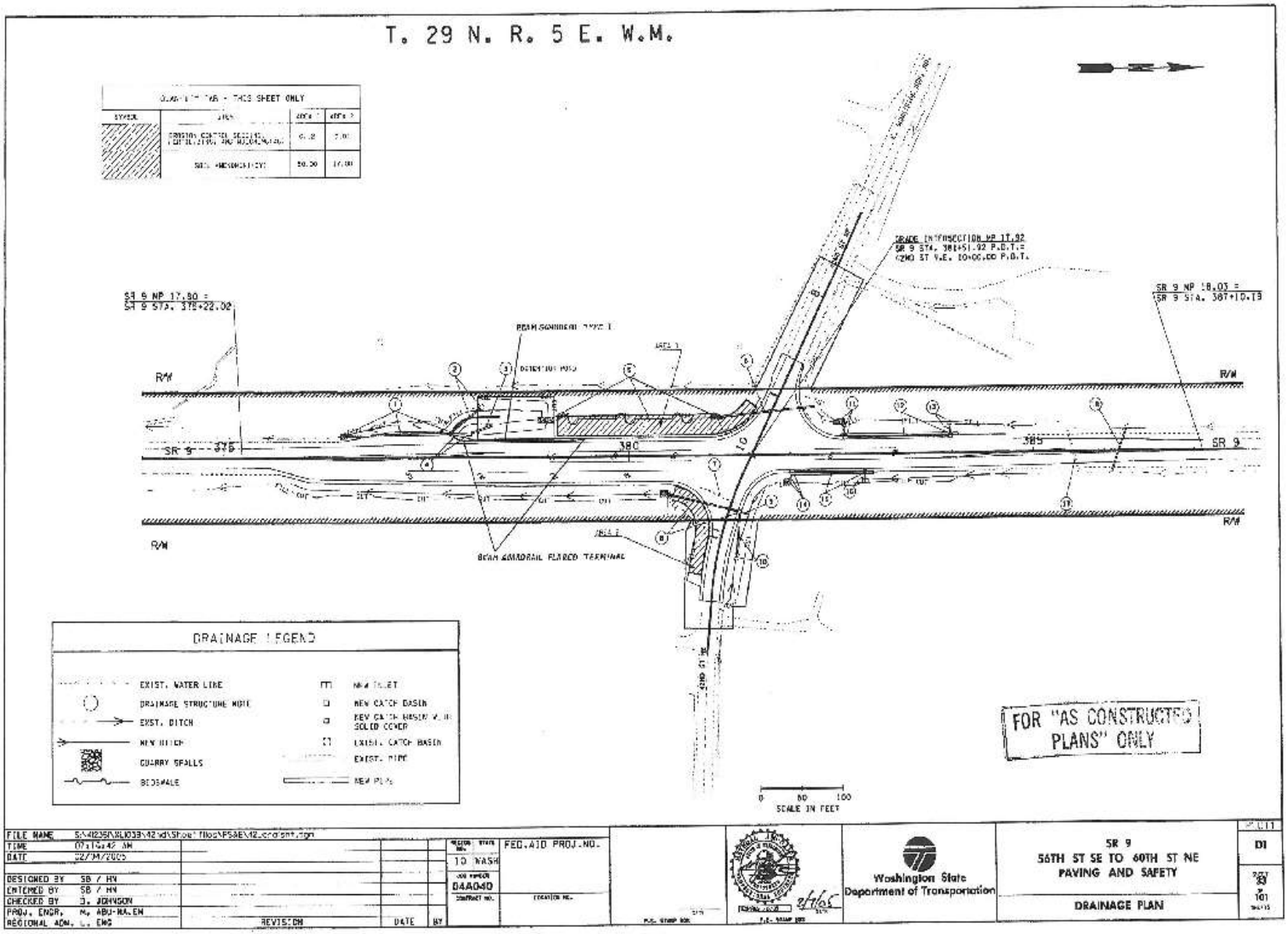
Tr (yrs)	Flood Peak (cfs)
2-Year	0.026
5-Year	0.034
10-Year	0.041
25-Year	0.051
50-Year	0.061
100-Year	0.075
200-Year	0.077

********** **Subbasin: MP 210.85 4M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.026
5-Year	0.034
10-Year	0.040
25-Year	0.051
50-Year	0.063
100-Year	0.078
200-Year	0.080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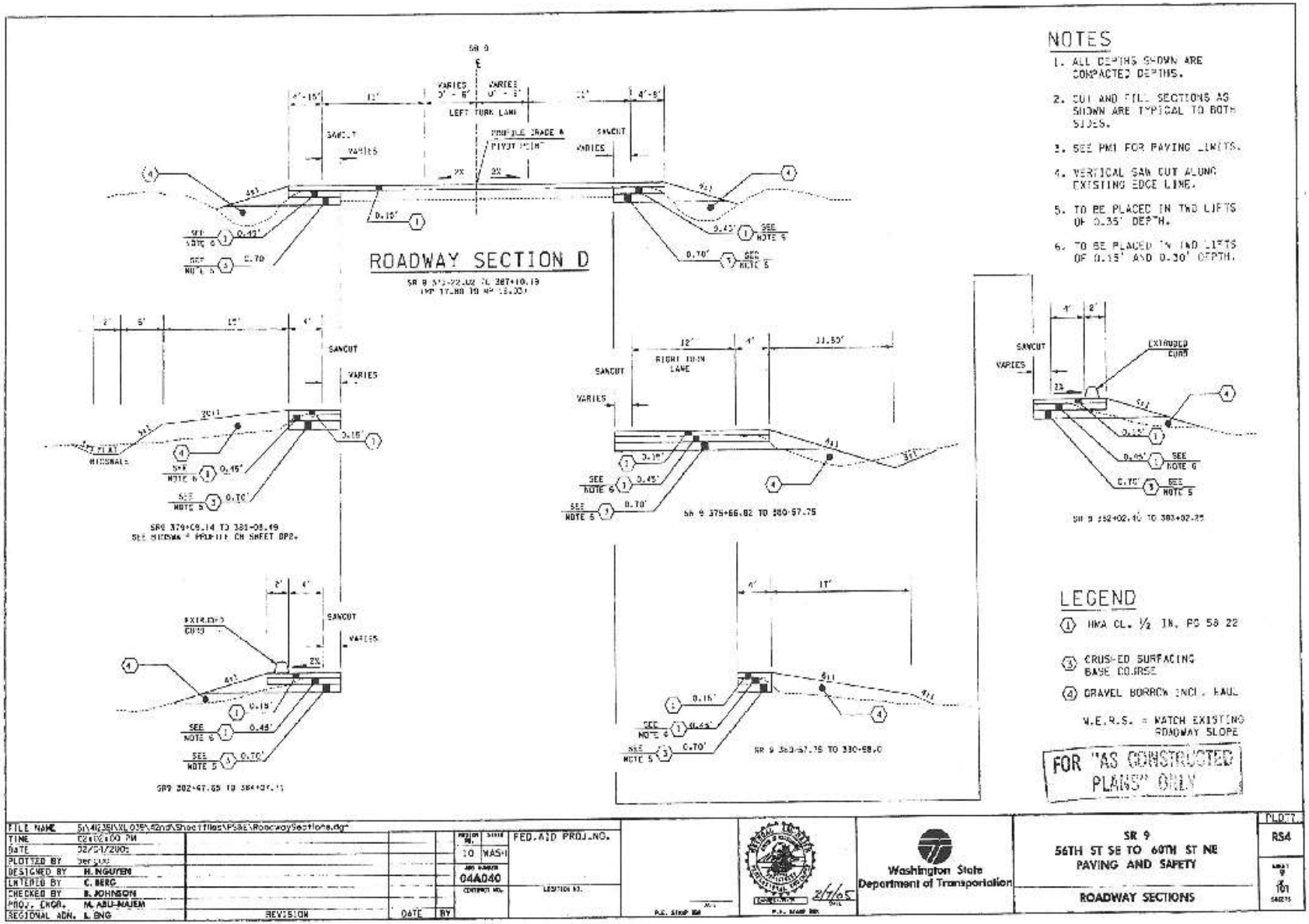
SR 9 MP 17.80 =
SR 9 STA. 378+22.02
SR 9 MP 18.03 =
SR 9 STA. 387+10.19
R/W
SR 9
375
380
385
BEAM GUARDRAIL FLARED TERMINAL
DRAINAGE LEGEND
EXIST. WATER LINE
DRAINAGE STRUCTURE NOTE
EXIST. DITCH
NEW DITCH
QUARRY SPALLS
SIDEWALK
NEW INLET
NEW CATCH BASIN
NEW CATCH BASIN W. IN SOLID COVER
EXIST. CATCH BASIN
EXIST. PIPE
NEW PIPE
FOR "AS CONSTRUCTED" PLANS" ONLY
0 50 100
SCALE IN FEET
FILE NAME
TIME
DATE
DESIGNED BY SB / HN
ENTERED BY SB / HN
CHECKED BY D. JOHNSON
PROJ. ENGR.
REGIONAL ADM.
REVISION
DATE
BY
FED. AID PROJ. NO.
WASH
04A040
Washington State Department of Transportation
SR 9
56TH ST SE TO 60TH ST NE
PAVING AND SAFETY
DRAINAGE PLAN
D1


NOTES
1. ALL DEPTHS SHOWN ARE COMPACTED DEPTHS.
2. CUT AND FILL SECTIONS AS SHOWN ARE TYPICAL TO BOTH SIDES.
3. SEE PMI FOR PAVING LIMITS.
4. VERTICAL SAW CUT ALONG EXISTING EDGE LINE.
5. TO BE PLACED IN TWO LIFTS OF 0.35' DEPTH.
6. TO BE PLACED IN TWO LIFTS OF 0.15' AND 0.30' DEPTH.
ROADWAY SECTION D
LEFT TURN LANE
RIGHT TURN LANE
SANCUT
VARIES
EXTRUDED CURB
LEGEND
① HMA CL. ½ IN. PG 58 22
③ CRUSHED SURFACING BASE COURSE
④ GRAVEL BORROW INCL. HAUL
W.E.R.S. = MATCH EXISTING ROADWAY SLOPE
FOR "AS CONSTRUCTED PLANS" ONLY
FILE NAME
TIME
DATE
PLOTTED BY
DESIGNED BY H. NGUYEN
LAYERED BY C. BERG
CHECKED BY B. JOHNSON
PROJ. ENGR. M. ABU-NAJEM
REGIONAL ADM. L. ENG
REVISION
DATE
BY
FED. AID PROJ. NO.
WASH
044040
Washington State Department of Transportation
SR 9
56TH ST SE TO 60TH ST NE
PAVING AND SAFETY
ROADWAY SECTIONS
PLOT
RS4

SR 9 Southbound MP 18

MGSFLOOD

PROJECT REPORT

Program Version: MGSFlood 4.09

Program License Number: 200210003

Run Date: 02/09/2011 4:50 PM

Input File Name: SR009_42ndSTNE_FlowRates.fld

Project Name: SR 009 42nd ST NE MP 17.80

Analysis Title: Determine Flow From Pavement

Comments: Edge of pavement Assumed Length = 39.37 ft long (12 M)

4 Meters Collector Assumed Length = 78.74 ft long (24 M)

Width of Pavement from Contract Plans = 21 ft

PRECIPITATION INPUT

Computational Time Step (Minutes): 15

Extended Precipitation Timeseries Selected

Climatic Region Number: 14

Full Period of Record Available used for Routing

Precipitation Station : 96004405 Puget East 44 in_5min 10/01/1939-10/01/2097

Evaporation Station : 961044 Puget East 44 in MAP

Evaporation Scale Factor : 0.750

HSPF Parameter Region Number: 1

HSPF Parameter Region Name : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) **********

********** **WATERSHED DEFINITION** **********

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 2

---------- Subbasin : SR 9 MP 17.8 Edge of Pav ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.000
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.019
Subbasin Total	0.019

---------- Subbasin : SR 9 MP17.8 4M Collector ----------

	-------Area(Acres) --------
Till Forest	0.000
Till Pasture	0.000
Till Grass	0.024
Outwash Forest	0.000
Outwash Pasture	0.000
Outwash Grass	0.000
Wetland	0.000
Green Roof	0.000
User	0.000
Impervious	0.038
Subbasin Total	0.062

**********FLOOD FREQUENCY AND DURATION STATISTICS**********

----------SCENARIO: POSTDEVELOPED

Number of Subbasins: 2

Number of Links: 1

********** **Subbasin: SR 9 MP 17.8 Edge of Pav** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs) Flood Peak (cfs)
==========

2-Year	7.376E-03
5-Year	9.647E-03
10-Year	0.011
25-Year	0.014
50-Year	0.016
100-Year	0.020
200-Year	0.021

********** **Subbasin: SR 9 MP17.8 4M Collector** **********

Flood Frequency Data(cfs)

(Recurrence Interval Computed Using Gringorten Plotting Position)

Tr (yrs)	Flood Peak (cfs)
2-Year	0.017
5-Year	0.023
10-Year	0.028
25-Year	0.035
50-Year	0.045
100-Year	0.055
200-Year	0.056

Appendix F BMP Design Specifications and Soil Properties

BMP Design Specifications

The following tables provide detailed information about the monitoring sites' characteristics and BMP Engineering Specifications.

Tables F-1, F-2, and F-3 list the technical design elements for each BMP. Information is primarily based on the HRM and the size of previously monitored unimproved embankments.

Table F-1 Technical details of BMPs at I-5 Northbound MP 197, Everett.

Facility Facts	Modified VFS	VFS
Land use	Highway paved surface	Highway paved surface
Imperviousness of contributing area	100%	100%
Drainage areas	See Appendix E.	
Sizing		
Volume	"In western Washington, the on-line design flow for runoff treatment is the flow rate derived from a continuous model (such as MGSFlood or WWHM) that calculates the flow rate from the drainage basin below which 91% of the average annual runoff volume occurs" (2008 HRM, pp 5-36). (See Appendix E.)	
Flow rate		
Hydraulic loading rate		
Depth	3" compost blanket will be applied to the existing road shoulder fill material	The VFS design is based on land cover (Manning's "n" coefficient for grass) and residence time. The depth of flow over a VFS is 1 inch at the design flow rate.
Length	24 meters	24 meters
Width	2 and 4 meters	2 and 4 meters
Depth of ponded water	1-inch maximum	1-inch maximum
Detention time	(to be learned by this study)	HRM design calls for 9 minute (at 4m)
Soils/Groundwater		
Groundwater presence	None detected to 12 ft below ground surface (bgs)[1]	
Control of run-on water	n/a	
Site soils	Approximately 12" of fill material, above the road base soil materials[1] (see WSDOT, in draft 2011b) Fill layer (uppermost) – Alluvial fine-grained silty sand to 5 feet below ground surface underlain by olive-gray, fine-grained silty sand to 10 feet bgs, and dark gray, fine-grained silty sand to the bottom of the boring at 11 feet bgs[1]	
Impermeable liner	n/a	n/a
Estimated infiltration losses	(to be learned by this study)	
Cation exchange capacity	(see WSDOT, in draft 2011b)	
Size gradation		
Compost mix	Will meet HRM specs	n/a
Design losses from compost	(to be learned by this study)	n/a
Media Description		
Vegetative species	Orchard grass (*Dactylis glomerata*),velvet grass (*Holcus lanatus*), hairy cat's ear (*Hypochaeris radicata*), tall fescue (*Schedonorus phoenix*), perennial ryegrass (*Lolium perenne*), English plantain (*Plantago lanceolata*) bluegrass (*Poa* spp.), Crane's bill (*Geranium molle*), and sheep sorrel (*Rumex acetosella*)[1]	
Sand thickness	n/a	n/a
Artificial media thickness	n/a	n/a
Compost thickness	3-inch compost blanket	n/a
Monitoring Locations		
Inlets	At edge of pavement interceptor	At edge of pavement interceptor
Outlets	2m and 4m interceptor discharge point	2m and 4m interceptor discharge point
Mid-BMP sediment	n/a	n/a
Sediment depth	n/a	n/a

bgs = below ground surface

[1] From WSDOT, 2010b.

Table F-2 Technical details of BMPs at I-5 Southbound MP 210, Pilchuck.

Facility Facts	Modified VFS	VFS	CAVFS
Land use	Highway paved surface	Highway paved surface	Highway paved surface
Imperviousness of contributing area	100%	100%	100%
Drainage areas	See Appendix E.		
Sizing			
Volume	"In western Washington, the on-line design flow for runoff treatment is the flow rate derived from a continuous model (such as MGSFlood or WWHM) that calculates the flow rate from the drainage basin below which 91% of the average annual runoff volume occurs" (2008 HRM, pp 5-36). (See Appendix E.)		CAVFS are designed to infiltrate and/or filter 91% or more of the total runoff volume
Flow rate			
Hydraulic loading rate			
Depth	3" compost blanket will be applied to the existing road shoulder fill material	The VFS design is based on land cover (Manning's "n" coefficient for grass) and residence time. The depth of flow over a VFS is 1 inch at the design flow rate.	3" of compost will be tilled in to the existing road shoulder fill material to a depth of 12"
Length	24 meters	24 meters	24 meters
Width	2 and 4 meters	2 and 4 meters	2 and 4 meters
Depth of ponded water	1-inch maximum	1-inch maximum	1-inch maximum
Detention time	(to be learned by this study)	HRM design calls for 9 minute (at 4m)	The CAVFS design is not based on residence time
Soils/Groundwater			
Groundwater presence	No	No	No [1]
Control of run-on water	n/a	n/a	n/a
Site soils	(see WSDOT, in draft 2011b)	Fill layer (~5 ft) densely compacted silty, gravelly sand with cobbles and a trace of clay – Soil under fill is stratified pebble, cobble, and boulder gravel	(see WSDOT, in draft 2011b)
Impermeable liner	n/a	n/a	n/a
Estimated infiltration losses	(to be learned by this study)		
Cation exchange capacity	(see WSDOT, in draft 2011b)		
Size gradation			
Compost mix	Will meet HRM specs	n/a	Will meet HRM specs
Design losses from compost	(to be learned by this study)	n/a	CAVFS are designed to infiltrate and/or filter 91% or more of the total runoff volume
Media Description			
Vegetative species	Vanilla grass (*Anthoxanthum odoratum*), vetch (*Vicia americana*), tall fescue (*Schedonorus phoenix*), hairy cat's ear (*Hypochaeris radicata*), velvet grass (*Holcus lanatus*), oxeye daisy (*Leucanthemum vulgare*), St. Johnswort (*Hypericum perforatum*), red clover (*Trifolium pratense*), alfalfa (*Medicago sativa*), Canada thistle (*Cirsium arvense*), wild carrot (*Daucus carota*), English plantain (*Plantago lanceolata*), hop clover (*Trifolium campestre*))[1]		

Table F-2 Technical details of BMPs at 1-5 Southbound MP 210, Pilchuck.

Facility Facts	Modified VFS	VFS	CAVFS
Sand thickness	n/a	n/a	n/a
Artificial media thickness	n/a	n/a	n/a
Compost thickness	3-inch compost blanket	n/a	Will meet HRM specs
Monitoring Locations			
Inlets	See VFS	At edge of pavement interceptor	See VFS
Outlets	2m and 4m interceptor discharge point	2m and 4m interceptor discharge point	2m and 4m interceptor discharge point
Mid-BMP sediment	n/a	n/a	n/a
Sediment depth	n/a	n/a	n/a

bgs = below ground surface

[1] From WSDOT, 2010b.

Table F-3 Technical details of SR 9 MP 18 near Marysville.

Technical Elements	VFS
Drainage Area Details	
Land use	Highway paved surface
Imperviousness of contributing area	100%
Sizing	
Volume	"In western Washington, the on-line design flow for runoff treatment is the flow rate derived from a continuous model (such as MGSFlood or WWHM) that calculates the flow rate from the drainage basin below which 91% of the average annual runoff volume occurs" (2008 HRM, pp 5-36).
Depth	
Hydraulic loading rate	
Width	4 meters
Depth of ponded water	1-inch maximum
Detention time	Design calls for 9 minute (at 4m)
Soils/Groundwater	
Groundwater presence	No
Control of run-on water	n/a
Site soils	Tokul 72; hydrologic soil group C
Impermeable liner	n/a
Estimated infiltration losses	(see WSDOT, in draft 2011b)
CEC	
Size gradation	
Compost mix	n/a
Design losses from compost	n/a
Media Description	
Vegetative species	Till grass
Sand thickness	n/a
Artificial media thickness	n/a
Compost thickness	n/a
Monitoring Locations	
Inlets	At edge of pavement interceptor
Outlets	4m interceptor discharge point
Mid-BMP sediment	n/a
Maintenance	
Sediment depth	n/a

Soil Cores and Lab Results

For further site-specific details, see:

WSDOT, in draft. 2011b. Geotechnical Evaluation Report for BMP Effectiveness Stormwater Monitoring Sites on I-5 and SR-9. Under development by WSDOT and estimated to be finalized in October, 2011. The draft report is available for review; please contact Fred Bergdolt at 360-570-6648 to obtain a copy.

Appendix G Toxicity Details and Follow-Up Actions

Toxicity Details and Follow-Up Actions

First flush toxicity testing using the *Hyalella azteca* 24-hour test is required under S7.C of the permit. After each toxicity test is complete, the laboratory or Ecology will inform WSDOT when the results are invalid and need to be repeated. Ecology will inform WSDOT if test results are anomalous. In order to make determinations on test validity and reliability of results, Ecology will need the test record submitted as a CETIS export as soon as possible after test completion. If the results are invalid or anomalous, Ecology may require WSDOT to collect an additional first flush toxicity sample. Annually, toxicity results will be summarized in a report to Ecology. WSDOT will also maintain all toxicity data and associated reports.

Results of the toxicity testing will be reported as the median effect concentration (EC_{50}) which is a calculated estimation of the % stormwater that causes 50% of the organisms to show an effect. S7.C.7 of the permit requires follow-up actions if the EC_{50} is 100% stormwater or less. The permit follow-up action is stated as "WSDOT shall prepare a study design to further refine the knowledge of toxicant concentrations in stormwater discharged to receiving waters from WSDOT's roads and highways." Specific components that must be included in the study design are outlined in Table G-1.

The permit requires the results of all follow-up actions to be included in the annual report. The goal of the follow-up actions is to update the annual report with progress information when toxicity is detected and to update or implement WSDOT's SWMP to reduce toxicity. Confirmation of the identity of toxicants is not necessary as long as this goal is being met.

Table G-1 Toxicity follow-up study design if the EC_{50} is 100% sample or less.

Action Item		Description	Source
1.1	Mapping of site-specific MS4s		S7.C.7*
1.2	Installed or planned structural BMPS		S7.C.7
1.3	Proposed sampling and analysis		S7.C.7
1.4	Description of toxicity pathways to receiving water		S7.C.7
2.0	If necessary to produce knowledge from the study useful in source control or BMP improvement, WSDOT will include a toxicity identification/reduction evaluation (TI/RE) in the study design.	The TI/RE shall be based upon instructions in WAC 173-205-100. The TI/RE process includes the action items 1.1-1.4 and 2.1 and may include items 2.2-2.3 if needed.	S7.C.7
2.1	Compare to EcoTox Database	Chemical results from the seasonal first flush stormwater toxicity monitoring event must be compared to EPA EcoTox database and the science literature within 60 days of data validation.	Appendix 6*
2.1.1	If a likely toxicant is identified in item 2.1 a summary report on EcoTox to Ecology	The report to Ecology will summarize: • The toxicity and chemical analysis results compared to EPA's EcoTox data • The review of relevant sources of literature • The possible chemical contaminant(s) of concern and explain how WSDOT's stormwater management program actions are expected to reduce stormwater toxicity	Appendix 6
2.2	Search facility records that may explain the toxicity	This search may include operating records for herbicide application, spill reports, or weather records	WAC 173-205-100
2.2.1	If an issue is identified in item 2.2 a summary report on facility records will be submitted to Ecology	The report to Ecology will summarize: • The relevant data used to identify the issue. • The possible chemical contaminant(s) of concern and explain how WSDOT's stormwater management program actions are expected to reduce stormwater toxicity	WAC 173-205-100
2.3	If item 2.1 does not identify a toxicant or group of toxicants likely to be causing toxicity a toxicant identification plan may be developed to aid in the identification process. The plans focus will be to add steps to future toxicity sampling efforts required by the permit, that provide additional information for toxicant identification.[1]	The toxicity identification plan will follow WAC 173-205-100 and include a study design using any elements of EPA's TIE process that are practical in meeting S7.C.7 of the permit. The plan may also include elements not in EPA's TIE process.	S7.C.7 and Appendix 6

[1] Additional testing will only be conducted if adequate sample volume remains after toxicity and chemistry aliquots required in the permit are removed.

* Ecology, 2009a.

Toxicity Identification/Reduction Evaluation (TI/RE)

The TI/RE is meant to be a general process for addressing the cause(s) of toxicity. The result of this process may be changes to maintenance procedures or BMPs that aim to reduce the toxicity. Table G-1 summarizes the follow-up steps to be used for this process. While toxicant identification may improve source control or BMPs, it is not necessary to implement actions to reduce toxicity.

Toxicant Identification

The first method of toxicity identification that will be utilized if the EC_{50} is 100% or less is to compare the chemistry data from the same storm event to EPA's EcoTox database and the scientific literature. If a likely toxicant or group of toxicants is identified through this method, no further actions will be performed to identify the toxicant. WSDOT will perform this action any time the EC_{50} is 100% or less and report the findings to Ecology as specified in action item 2.1.1.

If the toxicant of concern is not identified after action item 2.1 is conducted, then additional identification procedures may be implemented. WSDOT will consult with NewFields and Ecology to determine what additional procedures are appropriate for the situation. Elements of EPA's TIE process or other guidance may be followed but will be tailored to the specific conditions of the monitoring effort under the NPDES permit. Additional testing will be conducted only if all other toxicity testing and chemistry analyses can also be performed with the sample volume available.

An example of appropriate additional identification testing may be to run an EDTA-treated stormwater sample concurrently with permit-required testing. EDTA treatment is used in EPA's TIE process to determine whether metals are the cause of toxicity. While this additional step uses EPA phase I TIE guidance it is not a full TIE. The information gained from this additional step would then be used to inform future toxicity testing.

Receiving Water Monitoring

Receiving water may be sampled for hardness at the same time as the stormwater. This will be determined on a case-by-case basis by the Project Manager.

The permit toxicity guidance (see Appendix C) encourages, but does not require, the permittee to make two extra efforts to characterize the potential receiving water when conducting a toxicity test.

- The first extra effort stated by the permit is "An additional hardness sample may be collected from the receiving water by the permittee in order for the toxicity laboratory to adjust the sample hardness to match receiving water hardness." This is recommended because the toxicity of a metal in a low hardness stormwater sample can greatly exceed its respective toxicity in a receiving water with a higher hardness. If a receiving water body is directly receiving runoff from the selected BMP effectiveness and highway characterization monitoring sites, then a hardness sample will be collected either before the planned storm event sampling date or during the storm event.
- The second extra effort stated by the permit is "The permittee is encouraged to monitor receiving streams' pH, dissolved organic carbon, and common ions so the biotic ligand model can be used to estimate receiving water toxicity due to metals in the stormwater."

Common ions include Ca, Mg, Na, K, SO_4, and Cl (HydroQual Inc., 2007). Monitoring the receiving water for pH, dissolved organic carbon, and common ions would only occur if a receiving water body is directly receiving runoff from the selected BMP effectiveness and highway characterization monitoring sites. The Project and Program Managers will decide whether there are sufficient resources to pursue receiving water monitoring.

Appendix 6 of the permit (copied to this QAPP as Appendix C) requires that permittees follow a list of test conditions derived from *ASTM E 11-92-97: Standard Guide for Conducting Acute Toxicity Tests on Aqueous Ambient Samples and Effluents with Fishes, Macroinvertebrates, and Amphibians.*

Reference

HydroQual Inc., June 2007. Biotic Ligand Model, Windows Interface, Version 2.2.3., *User's Guide and Reference Manual*. 1200 MacArthur Blvd. Mahwah, NJ 07430. (201) 529-5151.

Appendix H Example Storm Tracking Forms

Storm Tracking Sheet

Pre-storm

Date:
Time:
Source of Forecast (web, news, etc.):
Location of Forecasted Storm (region):
Monitoring Sites in Area of Anticipated Storm:
Predicted Rainfall:
Predicted Storm Duration:
Toxicity sample Planned? **Y / N**

1. Attach a copy of the forecast to this sheet. If initial observation was from television news, access their website and print a copy of their forecast.

2. Contact the field supervisor for the "*Go*" decision.

3. If deployment is OK'd, contact field staff and inform them of the storm characteristics and duration.

4. Contact laboratories and notify of intent to sample

5. Monitor the telemetry files for stations in the region of the storm event. Notify field staff of storm status and if rain begins to fall on-site.

Mid-storm

Time of first rainfall on-site:
Field teams on-site for first rainfall? **Y / N**
Grab/composite samples collected? **Y / N**

6. Upon successful sample collection, notify labs of sample delivery. If no successful samples collected, notify labs.

Post-Storm

Time of last rainfall on-site:
Samples processed and sent to lab? **Y / N**
Verify reset of station parameters via telemetry files? **Y / N**

COMMENTS:

Appendix I Example Packing Lists and Trip Checklists

PRE/POST FIELD TRIP CHECKLIST

Before Embarking in the Field

All Staff Must –

1. Arrange for lodging (if necessary).
2. Update outlook calendar indicating location and duration of trip.
3. Notify Field Lead or contacts (if necessary).
4. Prepare field plan form with emergency contact information for specific trip location and duration.
5. Be sure to check vehicle and equipment checklists and perform a pre-trip vehicle inspection before embarking.

Pre-Trip Vehicle Inspection

1. Inspect tires for wear/damage on both sides of sidewall. Be sure to check tire pressure as well.
2. Check fluid levels (oil, transmission, windshield washer, radiator) before embarking in order to minimize possible breakdowns. Refer to the vehicle log to check and see if maintenance is due before embarking.
3. Make sure that the vehicle safety equipment is packed and that a spare tire, jack, and lug wrench are in the vehicle and in working order.
4. If any of these listed items are not in satisfactory working order, please notify the Field Lead as soon as possible. Do not embark with a vehicle that is in need of service or may be damaged.
5. Be sure to pack plenty of water and be sure that the standard first aid/emergency gear is packed.

Pre-Trip Equipment Prep

1. Assemble the required amount of precleaned autosampler tubing (amount varies per site and per trip).
2. Assemble the right size and required amount of precleaned autosampler bottles for site visit.
3. Pack sample bottles, filters, sample tags, forms, and coolers (with ice packs) needed for trip.
4. Pack extra gloves and plastic bags for equipment storage and handling.
5. Pack pole sampler (if needed) and all necessary grab sampling equipment.

Proceed with Field Excursion as Planned

Upon Return from the Field

End of Day –

1. If staying at a hotel, notify your contact person each evening that you are finished with field sampling so they do not initiate the rescue protocol. If your trip is only a day trip, refer to end of trip protocol.

End of Trip –

1. Pack and send samples to lab (if samples have been taken).
2. Upon return from the field, please unload your gear and equipment.
3. Don’t forget to download DCP files to your laptop or desktop.
4. Unload spent batteries from vehicle and inspect for damage/leaks.
5. Place spent batteries on appropriate chargers after servicing them.
6. Hang any wet gear in their designated locations to dry.
7. Clean and store tubing and bottles in their designated locations to prevent contamination/damage.
8. Clean the interior of the vehicle (if needed).
9. Close field plan and notify contact person that your trip is over.

Vehicle and Equipment Checklist

Vehicle Equipment

This equipment should be present any time the vehicle is used.

- Cell Phone and charger

Vehicle Folder

- Mileage logs
- Emergency information
- Fuel card
- Maps

Safety Equipment

- First aid kit
- MUTCD-compliant type II or better Safety Vests (2)
- Road Cones (28" retro refl.)
- Signs (RWA, shoulder work)
- MUTCD-compliant Hard Hats (2)
- Orange Strobe (1,000 ft. visibility)

Tools / Other

- Mechanic's toolbox
- Shovel
- Loppers/clippers/machete
- Tire chains
- Spare keys
- Jack, jack handle, adequate spare tire
- Flashlight
- Lighter (for shrink tubing)
- Electrical tool box
- Pens
- Pencils
- Notepaper
- Flagging tape
- Orange spray paint
- Spare bucket
- Bubble level for weirs
- Tool for clearing sediment from interceptors

Field Gear

Field Equipment Box

- Survey pins and hammer
- Laser level
- Stadia rod and bubble level
- Thermistor
- Spare batteries for thermistor and laser
- Multi-meter (for batteries)
- Logger Menu Flow Chart
- Station/site keys
- Other keys as needed
- Appropriate DCP batteries

Station Visit Folder

- Station Visit Sheets (storm, servicing, COC)
- Station Visit Thumb Drive
- Autosampler forms
- Sample tags
- Maps/station directions
- SOPs

Autosampler Gear

- Replacement tubing
- Replacement bottles
- Replacement batteries
- DI water
- Filters for samples
- Pump for filtering samples

Personal Equipment

- Water
- Food
- Spare dry clothes
- Rain gear
- Sunscreen
- Gloves
- Boots
- Notebook w/extra Station Visit Sheets

Appendix J Example Field Sampling Forms

Field staff name	Date
Station name/ID Number	Time
Storm Event Number	Weather observation
Qualified storm ☐ Yes ☐ No	
First Flush sampling ☐ Yes ☐ No	
Flow conditions	
Number of composite samples collected	
Number of grab samples collected	

Composite Sample			
Pre-sample collection		**Post-sample collection**	
Equipment inspected		Sampler working correctly	☐ Yes ☐ No
Tubing damaged/clogged	☐ Yes ☐ No	Sample bottles inspected	☐ Yes ☐ No
Tubing replaced*	☐ Yes ☐ No	Sample bottle problems	☐ Empty ☐ Low
Equipment sample blank added	☐ Yes ☐ No		☐ Damaged ☐ Spillage
Volume calibrated	☐ Yes ☐ No	*Sample bottles*	
Gas bubbler checked	☐ Yes ☐ No	Labeled	☐ Yes ☐ No
O-line connection checked	☐ Yes ☐ No	Preservation added	☐ Yes ☐ No
Data logger program checked	☐ Yes ☐ No	Readied for transportation	☐ Yes ☐ No
Clean bottles placed in sampler	☐ Yes ☐ No	COC form filled out	☐ Yes ☐ No
Autosampler program started	☐ Yes ☐ No	Sample line rinsed	☐ Yes ☐ No
		Clean bottles inserted	☐ Yes ☐ No
		Autosampler program reset	☐ Yes ☐ No

Grab Sample	
Sample type	☐ Hand ☐ Pole
Labeled	☐ Yes ☐ No
Preservation added	☐ Yes ☐ No
Placed in correct transportation container	☐ Yes ☐ No
COC documents filled out	☐ Yes ☐ No

Rain Gage	
Inspected	☐ Yes ☐ No
Debris removed	☐ Yes ☐ No
Data downloaded	☐ Yes ☐ No
Cleared	☐ Yes ☐ No
Reset	☐ Yes ☐ No

One sample per wet season and dry season	Wet / dry
Composite field duplicate	
Grab field duplicate	
Field blank (autosampler containers)	
Field blank (sample containers)	
Equipment blank (autosampler samples)	
Equipment blank (grab samples)	
Transport blank	

Battery	
Voltage	
Weir/flume	
Inspected for debris	
Debris removed	
Level checked	

Stage	
Logger (ft)	
Staff plate or weir (ft)	

Appendix K Example Chain of Custody

Laboratory Analyses Required

Page ____ of ____

Project Name: ______________________________

SIC: ___ ___ ___ ___ ___ Program: ______________________________

Send Results to: ____________________ Mail Stop: ______________

☐ Preliminary Investigation ☐ For HW Designation

☐ Monitoring ☐ For NPDES

Date Results needed by: ______________

Name/Reference # of QAPP for this project: __________________________

Sampling: Date (Year: ☐) Mo Day	Sampling: Time (Military) 0001 - 2400 Hr Mn	Field Station Identification	Manchester Lab Sample Number	Matrix Code	Source Code	No. of Containers	General Chemistry	Micro	Metals	Organic Chemistry

General Chemistry: Alkalinity; Conductivity; pH; Turbidity; ☐ Chloride ☐ Sulfate; Fluoride; Total Suspended Solids; Total Dissolved Solids; ☐ Total Solids ☐ % Sol ☐ % Vol Sol; TOC; DOC; BOD5; Oil & Grease (HEM); Ammonia; Nitrite/Nitrate; Total Phosphorus; Orthophosphate; TPN; Chlorophyll ☐ filters

Micro: Fecal Coliform ☐ MF ☐ MPN; Total Coliform ☐ MF ☐ MPN; E. Coli ☐ MF ☐ MPN; % Klebsiella; Enterococcus

Metals: PP Mets; Mercury (Hg) ☐ low level; Hardness; Individual Elements (please list) ☐ Total ☐ Dissolved

Organic Chemistry: VOA; BTEX; TPHG; TPHD; HCID Only (Hydrocarbon ID); PCB aroclors; ☐ Pest 1 ☐ w/PCB aroclors; ☐ Pest 2 ☐ w/PCB aroclors; ☐ Pest 3 ☐ w/PCB aroclors; Carbamates; PESTMS; Herbicides; PBDE; BNA; PAH

Project Officer: ____________________

Phone Number: ____________________

Cell Number: ____________________

Samplers: ____________________

____

____

Chain of Custody Record

Relinquished By:	Received By:	Yr	Mo	Da	Hr	Mn	Seal I.D.	Condition of Seals	Comments (Temperature, Preserv., etc.)

Recorder: ____________________

Comments: ____

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ECY 040-115 (Rev. 10/05)

Appendix L International Stormwater BMP Database Data Submittal Requirements

From "Urban Stormwater BMP Performance Monitoring" (USEPA 2002b)

3.4.3 Report Results

The results of your monitoring program should be presented in one or more reports. The appropriate report frequency and content depends on your monitoring program objectives and your audience. If you are monitoring to comply with a permit, the permit will generally specify the minimum frequency and content of the reports.

Most monitoring programs involve two types of reports: status (or progress) reports and final reports. To determine the appropriate frequency of status reports, consider your monitoring frequency and objectives, particularly any permit requirements. Many programs produce status reports on a quarterly or semi-annual basis. A typical status report may contain the following information:

- Summary of work accomplished during the reporting period
- Summary of findings
- Summaries of contacts with representatives of the local community, public interest groups, or state federal agencies
- Changes in key project personnel
- Projected work for the next reporting period

You should prepare more comprehensive reports at the end of the monitoring program (for short-term programs) or at the end of each year (for multi-year programs). Consider including the above-listed information and the following information in your annual or final report:

- Executive summary
- Monitoring program background and objectives
- Monitoring station descriptions, analytical parameters, analytical methods, and method reporting limits
- Summary descriptions of the conditions and stations, equipment inspections and calibrations, etc.
- Sample collection, precipitation, and flow measurement methods
- Flow, precipitation, and water quality results and data validation information
- Qualitative and statistical data evaluations/hypothesis testing as required for your specific program objectives (see Section 3.4.2 and Appendix I)
- Summary and conclusions, including any caveats or qualifying statements that will help the reader understand and use the reported information in the appropriate context
- Recommendations regarding management actions (e.g., changes in monitoring program, implementation of BMPs)

3.4.3.1 International Stormwater BMP Database Requirements

This section is designed to provide guidance for consistent reporting of results collected from BMP monitoring studies. The protocols described are based on those specified in the International Stormwater Best Management Practices Database, which has been developed by the Urban Water Resources Research Council of ASCE under grant funding from EPA to serve

as a tool for data organization and reliable comparison of BMPs. Minimum requirements for acceptance in the International Database are outlined in this section, and standard format examples that can be used as templates for reporting results of stormwater monitoring studies are provided. The International Stormwater BMP Database was developed to provide a scientifically sound tool for the determination of the effectiveness of BMPs under various conditions for a range of design parameters. The data fields included in this database have undergone intensive review by many experts and encompass a broad range of parameters including test site location, watershed characteristics, climatic data, BMP design and layout, monitoring instrumentation, and monitoring data for precipitation, flow and water quality. In order to effectively compare the performance of different BMPs under a variety of conditions, a set of "required" database fields were identified. These "required" fields are considered the minimum requisites for acceptance into the International Stormwater BMP Database. The database requirements vary with the different types of BMPs, and special requirements exist for unique hydraulic conditions. Database requirement categories and fields are as follows:

Information required for all BMPs (Table 3.5)

- General Test Site Information
- Watershed Information
- Monitoring Station Information
- Precipitation Data
- Flow Data
- Water Quality Data

General Information

Data Element	Description
Test Site	
Test Site Name	
City	
State	
Zip Code	
Country	
Site Elevation	
Unit	
Number of Watersheds	
Number of BMPs	
Type of Study Code	

Test Site/Study Documentation Information

Data Element	Description
Study Information	
Year Submitted to Database	
Data Provider	
Report Title or Data Source	
Report Authors	
Year of Publication	
Report Attached?	
Photos Attached?	
BMP Layout Attached?	
QAPP/SAP Attached?	
Abstract	

Sponsoring and Monitoring Agencies

Data Element	Description
Agencies	
Agency Name	
Agency Responsibility	
Agency Type Code	
Address	
City	
State	
Zip Code	
Country	
Phone	

Location Information

Data Element	Description
Climate Information	
State Code	
Station ID	
GIS Information	
Latitude (Decimal)	
Longitude (Decimal)	
Reference Datum	
Hydrologic Unit Code	
EPA Reach Code	

Monitoring Event Description

Data Element	Description
Monitoring Events	
Event Start Date	
Event Start Time	
Event Type	
QA/QC Description	

General Watershed Information

Data Element	Description
Watershed	
Watershed Name	
Watershed Type Code	
Total Watershed Area	
Units	
% Total Impervious Area in Watershed	

Watershed Roads and Parking Lot Information

Data Element	Description
Roads and Parking Lots	
Watershed Name	

Land Use

Data Element	Description
Land Use	
Watershed Name	
Land Use Type	
% of Land Use in Watershed	

BMP General Information

Data Element	Description
BMP (General)	
Watershed Name	
BMP Name	
Type of BMP Being Tested (Enter Code)	
Basis of Design (e.g., 2-yr, 24-hr storm or design treatment flow rate)	
Purpose of BMP (treatment objectives)	
Source of Design Guidance for BMP	
Date Facility Placed in Service	
Number of Inflow Points	
BMP Designed to Bypass or Overflow	
Description, Types, and Designs of Outlets	
Upstream Treatment Provided?	
Describe Upstream Treatment (if any)	
Name of Upstream BMP(s) (comma separated list upstream to downstream)	
General Configuration of BMP in Tributary Watershed (i.e., end of pipe, source control, off-line, on-line)	
Was qualified engineering oversight provided at construction? (Y/N; unknown)	
Was structure installed as designed? (Y/N; unknown)	
General Description of Site Activities/ Conditions Influencing Pollutant Loading to BMP	
Maintenance Type and Frequency	
Last Rehabilitation Date	
Type of Rehabilitation	
Qualitative Evaluation of BMP Condition (vegetation, soils, odors, etc.)	
For BMPs without permanent pool, does surface ponding exist beyond design drain time? (Y/N)	

Identify Relationships of Monitoring Stations to Each BMP

Data Element	Description
Monitoring Station Relation	
BMP Name	
Station Name (User Defined)	
Monitoring Station Type (from pick-list)	

Instrumentation

Data Element	Description
Instrumentation	
Station Name (previously defined)	
Date Installed	
Instrument Type Code (from pick-list)	
Data Type Code (from pick-list)	
Type of Control Structure	

Precipitation Events

Data Element	Description
Precipitation	
Enter Previously Defined Event #	
Monitoring Station Name	
Start Date	
Start Time	
End Date	
End Time	
Total Depth	
Units	
Peak One-Hour Precipitation Rate	
Units	

Flow Data

Data Element	Description
Flow	
Previously Defined Event #	
Monitoring Station Name	
Flow Start Date	
Flow Start Time	
Flow End Date	
Flow End Time	
Total Flow Volume	
Units	
Peak Flow Rate	
Units	
Total Bypass Volume	
Units	
Peak Bypass Flow Rate	
Units	
Baseflow Rate	
Units	
% Hydrograph Captured	
Estimate of De Minimus Flow Contributions (not measured)	
Appropriate for Volume Comparison? (Yes or No)	

Water Quality Samples

Data Element	Description
Water Quality	
Event # (previously defined)	
Monitoring Station (previously defined)	
Water Quality Sampling Start Date	
Water Quality Sampling Start Time	
Sample Medium (from pick-list)	
Sample Type (from pick-list)	
# of Samples, if Composite	
WQX Characteristic (Water Quality Constituent) (from pick-list)	
Value	
Units	
Qualifier	
Detection Limit	
Detection Limit Type	
Analysis Method	
Appropriate for Performance Analysis? (Yes or No)	

Particle Settling Velocity Distribution

Data Element	Description
Settling Velocity	
Event Number (previously defined)	
Monitoring Station	

Grass Filter Design Information

Data Element	Description
Grass Filters	
BMP Name	
Grass Strip's Length	
Units	
Grass Strip's Width	
Units	
Longitudinal Slope	
Flow Depth during 2-Year Storm	
Units	
2-Year Peak Flow Velocity	
Units	
Grass Species and Densities	
Is Strip Irrigated?	
Hydrologic Soil Group	

Low Impact Development Design Information

Data Element	Description
LID	
BMP Name	
List LID Practices	
Describe Site Design	
Describe Monitoring Design	
Method for Flood Control (e.g., are centralized detention measures provided in addition to decentralized LID techniques?)	
Conservation Features	
Minimizing Disturbance	
Minimizing Building Coverage	
Minimizing Travelway Coverage	
Maintaining Natural Drainage Patterns and Designing Drainage Paths to Increase Time of Concentration	
Source Controls	
Permeable Pavements	
Natural Drainage System Elements	
Stormwater Harvesting	
Green Roof (vegetated)	
Other Site Features (including traditional BMPs)	
List BMPs Monitoring Within LID Site (as entered into BMP Database)	
Comments/ Other Description	