QUALITY ASSURANCE PROJECT PLAN

Low Impact Development Research Program: Permeable Pavement Performance Monitoring

Prepared for

Washington State University
Puyallup Research and Extension Center
2606 W. Pioneer
Puyallup, Washington 98371-4998

September 2010 Rev.
Note:
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Puyallup, Washington  98371-4998

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September 17, 2010  Rev.
QUALITY ASSURANCE PROJECT PLAN
Low Impact Development Research Program: Permeable Pavement Stormwater Treatment Performance Monitoring

September 2010

Approved by:

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Date

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Introduction

Washington State University (WSU) is collaborating with the City of Puyallup, Washington and other partners to implement the Low Impact Development (LID) Research Program on the campus of the WSU Research and Extension Center in Puyallup (Figure 1). The LID Research Program is funded by a Washington State Department of Ecology (Ecology) grant with the primary objective of improving stormwater management on the 110-year-old campus using LID practices. Performance monitoring is also required under the grant program; however, WSU is providing significant in-kind resources to design, install, and implement a LID research program within a functional stormwater management system.

Initially, the LID Research Program will focus on two practices: permeable pavement and bioretention. To facilitate performance evaluations of these practices, the largest parking area on campus (impervious asphalt) was removed and replaced with pervious asphalt and concrete. In addition, a 0.24-hectare (0.6-acre) gravel area adjacent to the parking lot was also removed and replaced with 39 bioretention cells. Sixteen of the bioretention cells are conventional rain garden installations in the ground, and 20 of the bioretention cells are deep tanks or “mesocosms” for performing more controlled testing on different bioretention soil mixes.

This installation has two unique characteristics. First, the permeable paving and bioretention research plots are full-scale and replicated. This provides a unique opportunity for bioretention research because flow control and water quality treatment performance are largely driven by plant soil interactions and the ecology that develops within these systems. The full-scale systems will also operate long-term and thus allow for a more complex ecology to develop compared to laboratory scale research. Second, the permeable pavement and bioretention systems can receive stormwater from natural storms delivered by gravity flow; alternatively, synthetic stormwater can be blended and applied from cisterns at specific flow rates, volumes, and pollutant concentrations.

This document is the Quality Assurance Project Plan (QAPP) for the performance monitoring to be performed on the permeable pavement described above. Separate QAPPs will be prepared for the mesocosm and rain garden performance monitoring. This QAPP was jointly prepared by WSU and Herrera Environmental Consultants (Herrera). It specifically describes the data collection, processing, and analysis procedures that will be used to meet monitoring requirements that are specified in the grant for the LID Research Program. This QAPP was prepared in accordance with Ecology’s Guidelines for Quality Assurance Project Plans (Ecology 2004), and includes the following:

- **Background** – An explanation of why the project is needed
- **Project Description** – Project goals and objectives, and the information required to meet the objectives
- **Organization and Schedule** – Project roles and responsibilities, and the schedule for completing the work
Quality Objectives – Performance (or acceptance) thresholds for collected data

Sampling Process Design – The sampling process design for the study, including sample types, monitoring locations, and sampling frequency

Sampling Procedures – A detailed description of sampling procedures and associated equipment requirements

Measurement Procedures – Laboratory procedures that will be performed on collected samples

Quality Control – Quality control (QC) requirements for both laboratory and field measurements

Data Management Procedures – How data will be managed from field or laboratory recording to final use and archiving

Audits and Reports – The process that will be followed to ensure this QAPP is being implemented correctly and the quality of the data is acceptable

Data Verification and Validation – The data evaluation process, including the steps required for verification, validation, and data quality assessment

Data Quality (Usability) Assessment – The procedures that will be used to determine if collected data are of the right type, quality, and quantity to meet project objectives
Figure 1. Vicinity map of the Washington State University LID research center, Puyallup, WA.
Background

An extensive body of monitoring and research suggests that land use development and associated stormwater are primary causes of fresh and marine water degradation. Increased runoff volume, peak flows and flow durations accelerate sediment delivery, scour stream channels, reduce habitat complexity, and change hydroperiods in wetlands. A wide range of pollutants are associated with stormwater flows including heavy metals, oil and grease, pesticides, polycyclic aromatic hydrocarbons, sediment, and nutrients (nitrogen and phosphorus). In some land use settings, pollutant concentrations in stormwater runoff can exceed levels that are considered acutely toxic. Pollutant concentrations can also exceed chronic toxicity levels in urbanized streams. Little is known about the impacts of mixtures of pollutants on aquatic biota, but recent research indicates synergism or increased toxicity for mixtures of pesticides. Suspended sediment and nutrients in stormwater also impact aquatic biota through various mechanisms.

The current structural approach to stormwater has limitations for fully mitigating the flow from and water quality impacts of urban development. Increasingly, stormwater engineers and designers are exploring and implementing distributed, low impact development (LID) strategies that seek to preserve the natural hydrologic regime of watershed by managing stormwater as close to its source as possible. In western Washington (northwestern U.S.), LID will be required in all Phase I communities (cities and counties with populations greater than 100,000) by 2011. Low impact development will likely be required in all Phase II communities (cities and counties with populations greater than 10,000) in the next 4 to 5 years.

Research focused on LID practices has increased dramatically over the past few years in the U.S.. Four major university research programs exist in the eastern U.S.. This year, WSU and project partners will complete the construction of the first university LID Research Program in the western U.S.. The program will focus on permeable pavement and bioretention initially, and use full-scale replicated research plots to test the water quality treatment and flow control performance of these systems.
Project Description

The primary objective of the permeable pavement research is to examine water quality treatment and flow control performance of permeable asphalt and concrete. To meet this objective, monitoring will be performed on replicate “treatment cells” for both maintained and unmaintained permeable asphalt and concrete. Replicate cells with impervious asphalt will serve as controls for assessing the performance of these treatment cells.

During the initial phase of the LID Research Program, the performance of the permeable pavement will be assessed based on stormwater that is delivered to the treatment cells in connection with “natural storms”; in a later phase of the program, stormwater will be pumped to each treatment cell to create “synthetic storms” for characterizing treatment performance at specific flow volumes, rates, and pollutant concentrations. In either case, the following data will be collected in connection with the treatment cells:

- The volume of water discharged as surface runoff from the impervious asphalt cells relative to the volume discharged as surface runoff and underdrain flow for the pervious asphalt cells
- Pollutant concentrations and loads measured in surface runoff from the impervious asphalt cells relative to pollutant concentrations and loads measured in surface runoff and underdrain flow for the pervious asphalt cells
- Surface infiltration rates in the pervious asphalt and pervious concrete treatment cells over time
- Continuous monitoring of water elevations within the aggregate subbase for the concrete cells and the underlying native soils
- Build up of pollutants over time in the aggregate subbase and native soils underlying the concrete cells

Pollutants of interest include suspended sediment, heavy metals, polycyclic aromatic hydrocarbons (PAH), and nutrients.
Organization and Schedule

WSU is collaborating with the City of Puyallup and other project partners to implement the LID Research Program. Funding for the program was obtained through a grant from Ecology’s Stormwater Management Implementation Grant Program. WSU is also providing significant in-kind resources to fund major elements of the program. A more detailed breakdown of the funding from these sources is provided in Appendix A. Key personnel members for the permeable pavement research component of the program are shown in Table 1 with their roles and responsibilities.

Key milestones for the permeable pavement component of the LID Research Program are summarized in Table 2.
### Table 1. Key personnel for the permeable pavement research component of the Low Impact Development Research Program.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Role</th>
<th>Responsibilities</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtis Hinman</td>
<td>Washington State University</td>
<td>Program Director</td>
<td>Responsible for ensuring tasks and other requirements of this QAPP are executed on time. Responsible for verifying the QAPP is followed and the study is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Supervises all assigned study personnel. Tracks project schedule and budgets.</td>
<td>Office: (253) 445-4590</td>
</tr>
<tr>
<td>Craig Cogger</td>
<td>Washington State University</td>
<td>Soil Science Technical Lead</td>
<td>Responsible for coordinating project technical issues related to soil chemistry and analysis.</td>
<td>Office: (253) 445-4512</td>
</tr>
<tr>
<td>Andy Barry</td>
<td>Washington State University</td>
<td>Compost Science Technical Lead</td>
<td>Responsible for coordinating project technical issues related compost chemistry and analysis.</td>
<td>Office: (253) 445-4500</td>
</tr>
<tr>
<td>Rita Hummel</td>
<td>Washington State University</td>
<td>Plant Science Technical Lead</td>
<td>Responsible for coordinating project technical issues related to plant growth and development</td>
<td>Office: (253) 445-4524</td>
</tr>
<tr>
<td>Eric Miltner</td>
<td>Washington State University</td>
<td>Plant Science Technical Lead</td>
<td>Responsible for coordinating project technical issues related to plant growth and development</td>
<td>Office: (253) 445-4594</td>
</tr>
<tr>
<td>Mark Harris</td>
<td>Analytical Resources Incorporated</td>
<td>Laboratory Manager for Water Analyses</td>
<td>Responsible for supervision of laboratory personnel involved in generating water quality analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.</td>
<td>Office: (206) 695-6200</td>
</tr>
</tbody>
</table>
### Table 1 (continued). Key personnel for the permeable pavement research component of the Low Impact Development Research Program.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Role</th>
<th>Responsibilities</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent Thyssen</td>
<td>Soiltest Farm Consultants</td>
<td>Laboratory Manager for Soil Analyses</td>
<td>Responsible for supervision of laboratory personnel involved in generating soil analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.</td>
<td>Office: (509) 765-1622</td>
</tr>
<tr>
<td>Deborah Cornett</td>
<td>Washington State Department of Ecology</td>
<td>Grant Manager</td>
<td>Acts as the grant manager for the Ecology. Ensures the grant requirements for the project are met. Approves QAPP for grant.</td>
<td>Office: (360) 407-7269</td>
</tr>
<tr>
<td>John Lenth</td>
<td>Herrera Environmental Consultants</td>
<td>Contractor Project Manager for QAPP Development</td>
<td>In coordination with WSU staff, responsible for overseeing preparation of the QAPP. Ensures monitoring procedures specified in the QAPP meet requirements that are specified in the grant for the LID Research Program and Section S.8.F of the City of Seattle’s Phase I Municipal Stormwater Permit.</td>
<td>Office: (206) 441-9080 x144 Mobile: (206) 245-7539</td>
</tr>
<tr>
<td>To be determined</td>
<td>Washington State University</td>
<td>Quality Assurance Coordinator</td>
<td>Oversees review of all water quality and hydrologic data to verify they meet quality objectives specified in this QAPP.</td>
<td>Office: (253) 445-4500</td>
</tr>
</tbody>
</table>

LID: low impact development  
QA/QC: quality assurance/quality control  
QAPP: quality assurance project plan  
SOP: standard operating procedures  
WSU: Washington State University
Table 2. Schedule of key milestones for the permeable pavement research component of the Low Impact Development Research Program.

<table>
<thead>
<tr>
<th>Project Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draft QAPP Submitted</td>
<td>March 2010</td>
</tr>
<tr>
<td>Final QAPP</td>
<td>September 2010</td>
</tr>
<tr>
<td>Permeable Pavement Construction and Baseline Monitoring</td>
<td>Fall 2010</td>
</tr>
<tr>
<td>Phase 1 Monitoring Initiation</td>
<td>Winter 2010</td>
</tr>
<tr>
<td>Phase 2 Monitoring Initiation</td>
<td>No earlier than October 2012</td>
</tr>
</tbody>
</table>

QAPP: quality assurance project plan
Quality Objectives

A primary purpose of this QAPP is to ensure that the data collected for this study are scientifically accurate, useful for the intended analysis, and legally defensible. Therefore, the collected data will be evaluated using the following indicators of quality assurance:

- **Bias**: The systematic or persistent distortion of a measurement process that causes errors in one direction (i.e., the measured mean is different from the true value)
- **Precision**: A measure of the variability in the results of replicate measurements due to random error
- **Representativeness**: The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency and duration, and sampling methods
- **Completeness**: The amount of data obtained from the measurement system
- **Comparability**: The ability to compare data from the current study to data from other similar studies, regulatory requirements, and historical data

Measurement quality objectives (MQOs) are performance or acceptance criteria that are established for each of these quality assurance indicators. The specific MQOs to be used for this study are described below in separate subsections for hydrologic and laboratory data, respectively.

### Measurement Quality Objectives for Hydrologic Data

Hydrologic monitoring will involve direct measurement of discharge, water level, and precipitation depth. MQOs for these measurements are expressed in terms of bias, precision, representativeness, completeness, and comparability. The associated MQOs for hydrologic monitoring are defined below.

#### Bias

Bias in discharge data collected through this study will be assessed based on periodic comparisons of actual readings from tipping bucket flow meters (see description below in *Sampling Process Design* section) to their theoretical accuracy, as specified from the manufacturer. The actual readings will be determined by adding water incrementally to each tipping bucket flow meter and measuring the volume of water required to initiate one tip of the
associated bucket mechanism. The actual readings will then be compared to the manufacturer’s specified volume for initiating one tip of the bucket mechanism to evaluate potential bias in the discharge data. The MQO for discharge data will be a difference of no more than 15 percent between the actual reading and the manufacturer’s specified volume.

Similarly, bias in precipitation data will be assessed using periodic comparisons of actual readings from the rain gauge (see description below in Sampling Process Design section) to its theoretical accuracy, as specified from the manufacturer. Again, actual readings will be determined by adding incremental drops of water to the rain gauge and measuring the volume of water required to initiate one tip of the associated bucket mechanism. The actual readings will then be compared to the manufacturer’s specified volume for initiating one tip of the bucket mechanism to evaluate potential bias in the precipitation data. The MQO for precipitation data will be a difference of no more than 5 percent between the actual reading and the manufacturer’s specified volume.

Bias in the water level data will be assessed based on comparisons of monitoring equipment readings to an independently measured “true” value. In this case the true value will be derived from a manual measurement of water level at each monitoring location. If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment’s reading and the manual measurement of water level (“instrument drift”) should remain at zero over time and varying water depths. In reality the instruments will drift and equipment readings and manual readings will diverge. Therefore, bias in these data will be assessed based on the change in the instrument drift value relative to all previous measurements. Specifically, a change in the instrument drift value of plus or minus 2 standard deviations relative to the mean from all previous measurements will trigger an assessment of the monitoring equipment to determine proper functioning.

**Precision**

Precision will be assessed by taking replicate measurements during constant hydrologic conditions. For the tipping bucket flow and rain gauges, the volume of water required to tip the mechanism (see description in previous subsection) will be recorded during each of three replicate measurements. The relative percent difference (RPD) among these measurements will subsequently be calculated using the following equation.

$$ RPD = \left( \frac{V_1 - V_2}{V_1 + V_2} \right) \times 200\% $$

Where: $RPD$ = Relative percent difference  
$V_1$ and $V_2$ = Tip volumes
The RPD for each possible replicate pair will be calculated and subsequently averaged. The precision method quality objective for both the tipping bucket flow and rain gauges is for the RPD not to exceed 15 percent.

**Representativeness**

The representativeness of the flow and water elevation data will be ensured by the proper installation of the associated monitoring equipment. Additionally, monitoring will be conducted in a sampling process design that allows for monitoring of replicate cells for the permeable pavement treatment types. The replication will help ensure that the final hydrologic results are representative of true mean conditions for each treatment type.

Representativeness of the precipitation data will be ensured by placing the rain gauge in a location which is unobstructed by adjacent structures but still sheltered from strong winds. The rain gauge will also be placed in close proximity to the permeable pavement research facility, so it can be assumed that the precipitation measured at the device is representative of the precipitation that falls on the associated treatment cells.

**Completeness**

Completeness will be assessed on the basis of gaps in the data record for all hydrologic monitoring equipment. The associated MQO is less than 10 percent of the total data record will be missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and the immediate implementation of corrective actions if problems arise.

**Comparability**

There is no numeric MQO for this data quality indicator; however, standard monitoring procedures, units of measurement, and reporting conventions will be applied in this study to meet the goal of data comparability.

**Measurement Quality Objectives for Water Quality and Soil Data**

Quality assurance objectives for laboratory data are expressed in terms of bias, precision, representativeness, completeness, and comparability. The specific MQOs that have been identified for this project are described below and summarized in Tables 3 and 4. Note that the term “reporting limit” in this document refers to the practical quantification limit established by the laboratory, not the method detection limit.
### Table 3. Measurement quality objectives for water quality data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Laboratory Method Blank</th>
<th>Rinsate Blank</th>
<th>Control Standard Recovery</th>
<th>Surrogate Recovery</th>
<th>Matrix Spike Recovery</th>
<th>Laboratory Duplicate (Splits)</th>
<th>Field Duplicate RSD&lt;sub&gt;p&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solids</td>
<td>≤RL</td>
<td>NA</td>
<td>80-120%</td>
<td>NA</td>
<td>NA</td>
<td>≤20% or ±2 × RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Suspended sediment concentration</td>
<td>≤RL</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Hardness</td>
<td>≤RL</td>
<td>NA</td>
<td>80-120%</td>
<td>NA</td>
<td>75-125%</td>
<td>≤20% or ±2 × RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>≤RL</td>
<td>NA</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Orthophosphorus</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>≤RL</td>
<td>NA</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Nitrate + nitrite nitrogen</td>
<td>≤RL</td>
<td>NA</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Dissolved cadmium, copper, and zinc</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total cadmium, copper, and zinc</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>80-120%</td>
<td>NA</td>
<td>75–125%</td>
<td>≤20% or ±2 x RL</td>
<td>≤35%</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>30-115%</td>
<td>23-120%</td>
<td>30-115%</td>
<td>≤30% or ±2 x RL</td>
<td>≤45%</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>56-103%</td>
<td>35-131%</td>
<td>56-103%</td>
<td>≤30% or ±2 x RL</td>
<td>≤45%</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td>≤RL</td>
<td>≤ 2 x RL</td>
<td>30-160%</td>
<td>NA</td>
<td>30-160%</td>
<td>≤30% or ±2 x RL</td>
<td>≤45%</td>
</tr>
</tbody>
</table>

<sup>a</sup> For inorganics, the Contract Laboratory Program Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).

<sup>b</sup> 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.

<sup>c</sup> The pooled relative standard deviation will only be calculated for values that exceed 5 times the RL.

NA = not applicable.

RL = reporting limit.

RPD = relative percent difference.

RSD<sub>p</sub> = pooled relative standard deviation.
Table 4. Measurement quality objectives for soil data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Laboratory Method Blank</th>
<th>Reference Sample Recovery</th>
<th>ISV Recovery</th>
<th>Control Standard Recovery</th>
<th>Matrix Spike Recovery</th>
<th>Laboratory Duplicate (Splits) RPD</th>
<th>Field Duplicate RSDp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss on ignition</td>
<td>≤ MDL</td>
<td>a</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Percent total solids</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>≤MDL</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Bulk density</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>≤MDL</td>
<td>a</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>≤MDL</td>
<td>b</td>
<td>80-120%</td>
<td>80-120%</td>
<td>50-150%</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Total cadmium, copper, zinc, and lead</td>
<td>≤MDL</td>
<td>b</td>
<td>80-120%</td>
<td>80-120%</td>
<td>50-150%</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>DTPA-extractable cadmium, copper, and zinc</td>
<td>≤MDL</td>
<td>a</td>
<td>80-120%</td>
<td>80-120%</td>
<td>50-150%</td>
<td>≤20%</td>
<td>≤35%</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>≤MDL</td>
<td>NA</td>
<td>80-120%</td>
<td>50 – 150%</td>
<td>≤35%</td>
<td>≤45%</td>
<td></td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td>≤MDL</td>
<td>NA</td>
<td>NA</td>
<td>50-90%</td>
<td>38-99%</td>
<td>≤35%</td>
<td>≤45%</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td>≤MDL</td>
<td>NA</td>
<td>NA</td>
<td>50-90%</td>
<td>38-99%</td>
<td>≤35%</td>
<td>≤45%</td>
</tr>
</tbody>
</table>

a Reference sample recovery will be based on North American Proficiency Testing Program sample statistics.

b Reference sample recovery will be based on Environmental Resource Associates QC sample statistics.

DTPA = Diethylenetriamine penta-acetic acid.

ISV = internal standard verification.

MDL = method detection limit

NA = not applicable.

RPD = relative percent difference.

RSDp = pooled relative standard deviation.
Bias

Bias will be assessed based on analyses of method blanks, equipment rinsate blanks, matrix spikes, and laboratory control samples (LCS). The values for method blanks will not exceed the reporting limit, and values for equipment rinsate blanks will not exceed 2 times the reporting limit. Bias in matrix spikes will be evaluated based on their percent recovery, as calculated using the following equation:

\[
\% R = \frac{(S - U)}{C_{sa}} \times 100\%
\]

Where:
- \( % R \) = Percent recovery
- \( S \) = Measured concentration in spike sample
- \( U \) = Measured concentration in unspiked sample
- \( C_{sa} \) = Actual concentration of spike added

If the analyte is not detected in the unspiked sample, then a value of zero will be used in the equation.

The specific MQO’s for the percent recovery in matrix spikes are defined in Tables 3 and 4 for water quality and soil parameters, respectively.

Bias in LCS will also be evaluated based on their percent recovery. In this case, percent recovery will be calculated using the following equation:

\[
\% R = \frac{M}{T} \times 100\%
\]

Where:
- \( % R \) = Percent recovery
- \( M \) = Measured value
- \( T \) = True value

The specific MQO’s for the percent recovery in LCS are defined in Tables 3 and 4 for water quality and soil parameters, respectively.

Precision

In this study, overall project data quality will be based on total precision and analytical precision. Total precision is measure of the variability in the results of replicate measurements due to random error that is introduced during sample collection and processing in the field and the
laboratory analytical procedure. Total precision will be estimated based on the pooled relative standard deviation \((RSD_p)\) of the field duplicates from all sampling events. The \(RSD_p\) of these samples will be calculated using the following formula:

\[
S_p = \sqrt{\frac{\sum (C_i - C_j)^2}{2m}} \quad \text{and} \quad RSD_p = \frac{S_p}{\bar{x}} \times 100\%
\]

Where:
- \(S_p\) = Pooled standard deviation
- \(RSD_p\) = Pooled relative standard deviation
- \(C_i\) and \(C_j\) = Concentration values
- \(m\) = Number of pairs
- \(\bar{x}\) = Mean of all concentration values

When one or both values are less than or equal to 5 times the reporting limit for water parameters or method detection limit for soil parameters, they will not be included in the \(RSD_p\) calculation. The specific MQO’s for total precision are defined in Tables 3 and 4 for water quality and soil parameters, respectively.

Analytical precision is measure of the variability in the results of replicate measurements due to random error that is introduced from just the laboratory analytical procedure. Analytical precision will be assessed based on the relative percent difference \((RPD)\) of laboratory duplicates (splits) that are run with each batch of samples. The \(RPD\) of these samples will be calculated using the following formula:

\[
RPD = \left(\frac{|C_1 - C_2|}{C_1 + C_2}\right) \times 200\%
\]

Where:
- \(RPD\) = Relative percent difference
- \(C_1\) and \(C_2\) = Concentration values

The specific MQO’s for analytical precision are defined in Tables 3 and 4 for water quality and soil parameters, respectively. The \(RPD\) must be ±2 times the reporting limit for water parameters or ±2 times the method detection limit for soil parameters if the duplicate concentrations are both within 5 times the applicable reporting limit or method detection limit. If either of the duplicate concentrations is at or below the reporting limit or method detection limit, the \(RPD\) cannot be calculated.
Representativeness

Sample representativeness will be ensured by collecting an adequate number of samples for characterizing the variability in stormwater treatment performance across a wide range of storm event conditions with respect to rainfall volume, rainfall intensity, and antecedent dry period. To meet this goal, the following criteria for defining the acceptability of specific storm events for sampling were adopted from Ecology (2008) guidelines for monitoring emerging stormwater treatment technologies:

- **Target storm depth:** A minimum of 0.15 inches of precipitation over a 24 hour period
- **Antecedent conditions:** A period of at least 6 hours preceding the event with less than 0.04 inches of precipitation
- **Minimum duration:** Target storms must have a duration of at least 1 hour
- **End of storm:** A continuous 6-hour period with less than 0.04 inches of precipitation

During each event, the goal will be to collect flow-weighted composite samples that provide representative event-mean concentrations (EMCs) for each targeted parameter. To meet this goal, the following sampling criteria were also adopted from Ecology (2008) guidelines for monitoring emerging stormwater treatment technologies:

- Samples shall be collected for at least **75 percent of the storm event hydrograph** as measured by volume for the first 24 hours of the sampled event.
- The maximum time period over which samples are to be collected is **36 hours**.
- A minimum of **10 sample aliquots** is collected for compositing during each storm event.

Finally, the representativeness of both water quality and soil samples collected through this study will be ensured by employing consistent and standard sampling procedures, as identified in this QAPP.

Completeness

Completeness will be calculated by dividing the number of valid values by the total number of values. Valid sample data consists of unflagged data and estimated data that has been assigned a $J$ qualifier. A qualitative assessment will be made as to which $J$ flagged data may need to be excluded from this calculation prior to annual reporting. If less than 95 percent of the samples
submitted to the laboratory are judged to be valid, then additional samples will be collected until at least 95 percent are judged to be valid.

**Comparability**

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied in this study to meet the goal of data comparability.
Sampling Process Design

As described in the Project Description section above, the primary goal of this study is to examine the hydrologic and water quality treatment performance of permeable pavement. This section describes the sampling process design that will be used to meet this goal, including the physical components of the permeable pavement research facility, and descriptions of monitoring activities to be performed during each phase of the monitoring program.

Permeable Pavement Research Facility Design

The permeable pavement performance monitoring program will be implemented on the WSU campus in Puyallup, Washington (see vicinity map in Figure 1). Figure 2 shows a general site plan for the campus, and Figure 3 provides a detail of the campus area devoted to the permeable pavement research facility. The permeable pavement research facility is 0.32 hectares (0.8 acre) and the largest parking area on the campus. It consists of two separate 33.5 meter (110 feet) by 18.3 meter (60 feet) areas that are devoted to pervious asphalt and pervious concrete research, respectively. Each area has 24 parking stalls that are isolated from the remainder of the parking lot by concrete curbs (see Figure 3). Separate subsections below provide more detailed information on the physical components of the pervious asphalt and pervious concrete research areas, respectively. The cistern and flow distribution systems that will be used to generate artificial storms (see Introduction and Project Description sections) are then described in a concluding subsection.

Pervious Asphalt Test Facility

The pervious asphalt research facility is divided into nine individual cells (3 meter by 18.3 meter) with three replicates for each of the following three asphalt treatment types:

- Unmaintained pervious asphalt cells (UPACs)
- Maintained pervious asphalt cells (MPACs)
- Maintained impervious asphalt cells (MIACs)

The UPACs will receive no maintenance through the course of the study whereas the MPACs will be cleaned with a regenerative air street sweeper (from the City of Puyallup) on an annual basis. The specific location of each cell for these respective treatment types is shown in Figure 3. These cells are sequentially numbered from one to nine in Figure 3. Table 5 identifies the specific cell numbers for each type of treatment.

All the asphalt treatment cells (MIACs, UPACs, and MPACs) slope gently at a 2 percent grade to the southwest directing water to monitoring locations (Figure 3). Each individual cell was constructed with two parking stalls and driveway for accessing the stalls.
Table 5. Cell identification numbers for each pavement treatment type.

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Pavement Treatment</th>
<th>Code</th>
<th>Cell Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impervious Asphalt</td>
<td>Maintained</td>
<td>MIAC</td>
<td>1, 6, 8</td>
</tr>
<tr>
<td>Pervious Asphalt</td>
<td>Maintained</td>
<td>MPAC</td>
<td>2, 5, 7</td>
</tr>
<tr>
<td>Pervious Asphalt</td>
<td>Unmaintained</td>
<td>UPAC</td>
<td>3, 4, 9</td>
</tr>
<tr>
<td>Pervious Concrete</td>
<td>Maintained</td>
<td>MPCC</td>
<td>11, 13, 14</td>
</tr>
<tr>
<td>Pervious Concrete</td>
<td>Unmaintained</td>
<td>UPCC</td>
<td>10, 12, 15</td>
</tr>
</tbody>
</table>

As shown in the cross section view that is presented in Figure 4a, each of the UPACs and MPACs were constructed with the following major components:

- **Pervious asphalt**: 7.6 centimeter (3 inch) surface layer of pervious asphalt
- **Aggregate subbase**: 45.7 centimeter (18 inch) layer of crushed surface top course below pervious asphalt layer
- **Liner**: an impermeable cell liner with protective non-woven geotextile at interface between the aggregate subbase and native soil (installed during construction as shown in Figure 5)
- **Surface drain**: V-notch drain installed in downgradient end of each cell to capture surface runoff
- **Elevated drain (U-shaped)**: a 10.2 centimeter (4 inch) half cut PVC pipe located 5.1 centimeter (2 inch) below the asphalt layer that intercepts water moving through the aggregate subbase
- **Underdrain**: 10.2 centimeter (4 inches) polyvinyl chloride (PVC) slotted drain pipe below aggregate subbase that intercepts water at interface between impermeable liner and aggregate subbase

Detailed specifications for the impervious asphalt used to construct the UPACs and MPACs is provided in Appendix B. These specifications were developed based on recommendations from two pervious pavement summits involving local and regional experts that were convened during the early stages for the LID Research Program.

The MIACs will be used as controls for assessing the hydrologic and water quality treatment performance of the MIACs and UPACs. As shown in the cross section view that is presented in Figure 4b, each of the MIACs was constructed with the following major components:

- **Asphalt**: 7.6 centimeter (3 inch) surface layer of hot mix asphalt
- **Aggregate subbase**: 10.2 centimeter (4 inch) layer of crushed surface top course below asphalt layer
Quality Assurance Project Plan—LID Research Program: Mesocosm Performance Monitoring

- **Surface drain**: V-notch drain installed in downgradient end of each cell to capture surface runoff

**Pervious Concrete Test Facility**

The pervious concrete research facility is divided into six individual cells (5.7 meter x 18.3 meter) with two replicates for each of the following asphalt treatment types:

- Unmaintained pervious concrete cells (UPCCs)
- Maintained pervious concrete cells (MPCCs)

The UPCCs will receive no maintenance through the course of the study whereas the MPCCs will be cleaned with a regenerative air street sweeper (from the City of Puyallup) on an annual basis. The specific location of each cell for the respective treatment types is shown in Figure 3. To facilitate their reference within this QAPP and subsequent reporting of associated monitoring results, these cells were sequentially numbered from 10 to 15 in Figure 3. Table 5 identifies the specific cell numbers for each type of treatment.

As shown in the cross section view that is presented in Figure 4c, each of the UPCCs and MPCCs were constructed with the following major components:

- **Pervious concrete**: 20.3 centimeter (8 inch) surface layer of pervious concrete
- **Aggregate subbase**: 45.7 centimeter (18 inch) layer of crushed surface top course below pervious concrete layer
- **Surface drain**: V-notch drain installed in downgradient end of each cell to capture surface runoff
- **Elevated drain**: one 10.2 centimeter (4-inch) PVC slotted drain pipe located 5.1 cm (2 inches) below the concrete layer that intercepts water moving through the aggregate subbase
- **Underdrain**: one 10.2 cm (4-inch) PVC slotted drain pipe at base of aggregate subbase that intercepts water at interface between native soil and aggregate subbase
- **Subsurface water level observation port**: one vertical 12-inch PVC pipe (see Figure 6 for photograph of subsurface observation port installed during construction) to facilitate water elevation monitoring in the aggregate subgrade and native soils below each cell to a depth of 15 feet.
- **Soil sampling ports (6)**: six vertical 6-inch PVC pipes (see Figure 6 for photograph of soil sampling ports installed during construction) to facilitate monitoring of pollutant concentrations within the native soils below each cell
Detailed specifications for the impervious concrete used to construct the UPCCs and MPCCs is provided in Appendix B. Like the pervious asphalt, these specifications were developed based on recommendations from two pervious pavement summits that were convened during the early stages for the LID Research Program.

**Cistern and Flow Distribution System**

To facilitate controlled testing of permeable pavement performance, stormwater from the roof of an office building (Kalkus Hall) adjacent to the permeable pavement research facility will be collected and stored in a 45,480 liter (12,000 gallon) cistern. The cistern’s location on the campus and associated roof drainage area are shown in Figure 3. Using a pump and sprayer system, stormwater from this cistern can be delivered to the individual pavement treatment cells at specific flow rates, volumes, and pollutant concentrations to produce synthetic storms. As described in the next section, this system would be employed to provide supplemental performance data for different influent flow and chemistry scenarios that cannot be achieved during natural storms.

**Permeable Pavement Monitoring Design**

Monitoring activities will occur in three phases that are hereafter referred to as Baseline monitoring, Phase 1 monitoring, and Phase 2 monitoring. Baseline monitoring will characterize the physical and chemical properties of drainage from the asphalt and concrete permeable pavement prior to the onset of Phase 1 monitoring activities that will be performed to quantify their treatment performance. Phase 1 monitoring will involve quantifying the treatment performance of the asphalt and concrete permeable pavement during natural storms. Phase 2 will involve quantifying treatment performance of the asphalt and concrete permeable pavement using stormwater that is stored in the cistern and pumped to individual treatment cells at specific flow rates, volumes, and pollutant concentrations to generate synthetic storms.

Baseline monitoring will be performed in the fall of 2010 after construction of the permeable pavement research facility is complete. Phase 1 monitoring will then initiate during winter 2010 and be ongoing thereafter. Phase 2 monitoring will be implemented to provide supplemental performance data from different influent flow and chemistry scenarios that cannot be achieved during natural storms in the Phase 1 monitoring. Given this consideration, it is anticipated that Phase 2 monitoring will not initiate any earlier than water year 2012.

The specific activities that will be performed during these monitoring phases are described in the following subsections.

**Baseline Monitoring**

Baseline monitoring will involve the collection of water quality samples from the pervious asphalt treatment cells, the measurement of surface infiltration rates on both the pervious
Figure 3.
Plan view of pervious pavement test facility.

Legend
- IMPERVIOUS ASPHALT PAVEMENT
- PERVIOUS ASPHALT PAVEMENT
- PERVIOUS CONCRETE PAVEMENT
- UNMAINTAINED CELL
- MAINTAINED CELL
- SOIL SAMPLING PORT
- OBSERVATION PORT
- WEATHER STATION

ROOF DRAINAGE AREA TO CISTERN
4a. Cross section of pervious asphalt cell with associated monitoring equipment.

4b. Cross section of an impervious asphalt cell with associated monitoring equipment.

4c. Cross section of a pervious concrete cell.
Figure 5. Impermeable liner for pervious asphalt treatment cells during construction.

Figure 6. Pervious concrete cell with subsurface water level observation port and soil sampling ports during construction.
asphalt and pervious concrete treatment cells, and sampling to characterize baseline pollutant concentrations in soils underlying the treatment cells. A more detailed description of the design for each of these monitoring elements is provided in the following subsections.

**Water Quality Monitoring**

The goal of the baseline water quality monitoring is to characterize pollutant concentrations in stormwater that is discharged from the pervious asphalt treatment cells immediately following their construction. In order to meet this goal, runoff from the asphalt treatment cells will be sampled during 4 to 6 storm events in water year 2011. During each storm event, whole-flow composite samples (i.e., the entire storm volume will be captured) will be collected from the elevated drains described above for the UPACs and MPACs. The collected composite samples will be submitted to an accredited laboratory where they will be analyzed for the following parameters:

- Total suspended solids
- Total phosphorus
- Orthophosphate phosphorus (soluble reactive phosphorus)
- Total and dissolved cadmium, copper, and zinc
- Polycyclic aromatic hydrocarbons.

**Infiltration Testing**

The goal of the baseline infiltration testing is to quantify surface infiltration rates in the pervious asphalt and pervious concrete treatment cells immediately following their construction. Data from infiltration testing conducted during Phase I monitoring (see description below) will then be compared to these “baseline” data in order to assess changes in surface infiltration rates over time. This testing will occur once in water year 2011 within all cells for the following treatment types: UPACs, MPACs, UPCCs, and MPCCs. Each test will involve the controlled measurement of surface infiltration rates for water at three locations within each treatment cell: two in parking spots and one in the driving area.

**Soil Monitoring**

The goal of this monitoring will be to collect soil samples for characterizing “baseline” pollutant concentrations in native soils underlying the permeable pavement research facility. The data from these samples will then be compared to data from soil samples that are collected from soil sampling ports in each concrete cell (see description above) during the Phase 1 monitoring in order to quantify pollutant buildup in soils underlying the concrete treatment cells over time. A total of six soil cores will be collected for this purpose in water year 2011. From each core, separate samples will be obtained to represent the following soil depths: surface, 0 to 3 inch, 3 to 6 inch, and 6 to 12 inch. These samples will then be submitted to an accredited laboratory where they will be analyzed for the following parameters:

- Total cadmium, copper, and zinc
- Water soluble cadmium, copper, and zinc
Phase 1 Monitoring

The goal of Phase 1 monitoring will be to quantify the treatment performance of the asphalt and concrete permeable pavement using stormwater that is generated during natural storms. To meet this goal, Phase 1 monitoring will include the following design elements:

- Weather monitoring
- Flow monitoring in asphalt treatment cells
- Water quality monitoring in asphalt treatment cells
- Infiltration testing in permeable asphalt and concrete treatment cells
- Water elevation monitoring in concrete treatment cells
- Soil monitoring in concrete treatment cells

Each of these design elements is described in more detail in the following subsections.

Weather Monitoring

To facilitate the permeable pavement monitoring, a weather station with two tipping bucket rain gauges will be used to continuously monitor precipitation totals at the monitoring site (Figure 3). These data will be used to delineate qualifying events for sampling and to assess permeable pavement hydrologic performance relative to precipitation depth, duration, peak intensity, and average intensity. The weather station will also monitor wind speed and direction, solar radiation and relative humidity. Evapotranspiration will be calculated using these data and the Penman-Montieth equation.

Flow Monitoring

Flow monitoring will be performed in association with the asphalt treatment cells to meet the following goals:

- Determine the effectiveness of pervious asphalt for reducing flow volumes, peak discharges rates, and flow durations relative to impervious asphalt
- Compare the relative effectiveness of maintained and unmaintained pervious asphalt for reducing flow volumes over time

To meet this goal, automated equipment will be installed to continuously measure flow rates from the surface drains for the MIACs, and the underdrains for the UPACs and MPACs. In addition, the total volume of water discharged from surface drains and elevated drains for the UPACs and MPACs will be measured manually during 8 to 10 discrete storm events annually.

To assess the hydrologic treatment performance of the pervious asphalt relative to impervious asphalt, the compiled data from this monitoring will be evaluated as follows:
Reductions in surface runoff volumes will be evaluated by comparing flow volumes measured using automated equipment at the surface drains for the MIACs to those measured manually at the surface drains for the UPACs and MPACs during 8 to 10 discrete storm events.

Peak flow attenuation will be evaluated by comparing flow rates measured at the surface drains for the MIACs to those measured at the underdrains for the UPACs and MPACs during discrete storm events. This evaluation assumes that peak flows at surface drains for the UPACs and MPACs will be negligible, and the primary mechanism for attenuating peak flows will be storage within the associated aggregate subbase (see description above).

Flow duration attenuation will be evaluated by comparing flow durations measured at the surface drains for the MIACs to those measured at the underdrains for the UPACs and MPACs during discrete storm events. Again, this evaluation assumes that flow durations at surface drains for the UPACs and MPACs will be negligible, and the primary mechanism controlling flow durations will be storage within the associated aggregate subbase.

In addition to these evaluations, flow volumes measured during discrete storm events at the surface drains for the UPACs and MPACs will also be compared over time to evaluate the relative effectiveness of maintained and unmaintained pervious asphalt for reducing flow volumes. It is hypothesized that flow volumes measured from the UPACs will begin to increase while those for the MPACs will remain relatively constant if maintenance (i.e., cleaning with a regenerative air street sweeper) prevents clogging of the void structure within the asphalt permeable pavement.

Water Quality Monitoring

Water quality monitoring will be performed in association with the asphalt treatment cells to meet the following goals:

- Determine the water quality treatment effectiveness of pervious asphalt relative to impervious asphalt
- Compare the water quality treatment effectiveness of maintained and unmaintained pervious asphalt

In order to meet these goals, water quality sampling will be conducted in connection with the asphalt treatment cells starting in water year 2011. In addition, representative “street dirt” will be periodically applied to the asphalt treatment cells in order raise pollutant concentrations in the associated runoff to levels that are considered treatable. These elements of the sampling process design for water quality monitoring are described in more detail within the following subsections.
**Water Quality Sampling**

Water quality sampling will be conducted during 8 to 10 storm events annually commencing in water year 2011. During each storm event, flow-weighted composite samples will be collected from surface drains for MIACs, and the underdrains for the UPACs and MPACs. In addition, whole-flow composite samples (i.e., the entire storm volume will be captured) will be collected from surface and elevated drains for UPACs and MPACs. The collected composite samples will be submitted to an accredited laboratory where they will be analyzed for the following parameters:

- Particle size distribution (surface drain samples from MIACs only)
- Total suspended solids
- Suspended sediment concentration
- Hardness
- Total phosphorus
- Orthophosphate phosphorus (soluble reactive phosphorus)
- Total Kjehldahl nitrogen
- Nitrate+nitrite nitrogen
- Chemical oxygen demand
- Total and dissolved cadmium, copper and zinc
- Polycyclic aromatic hydrocarbons (only analyzed during the first storm event of each water year)

In addition to the composite samples, grab samples will also be collected from the surface drains for MIACs, and the underdrains for the UPACs and MPACs during monitored storm events. These samples will be submitted to an accredited laboratory for analysis of total petroleum hydrocarbons.

**Street Dirt Application**

Because the asphalt treatment cells will generally be subject to low traffic volumes from cars utilizing the associated parking stalls, it is anticipated that pollutant concentrations in runoff from the asphalt may be close to levels that are considered irreducible using conventional treatment practices. Consequently, with “background” concentrations so low, the water quality treatment benefits of pervious asphalt may be impossible to quantify. This would, of course, negate the whole purpose of the test facility.

In order to raise pollutant concentrations in runoff from the asphalt treatment cells to levels that are considered treatable, representative “street dirt” will be obtained from high efficiency street sweepers and spread evenly across all treatment cells with a drop spreader at a rate of 75 g/m². This application rate represents the median street dirt yield for residential land uses in Seattle (SPU and Herrera 2009). Initially, the sweeper waste will be applied on a quarterly basis; however, the application frequency may be adjusted up or down if measured pollutant concentrations are frequently below levels that or considered treatable or above levels that are considered representative of urban stormwater runoff.
It is anticipated that street sweeper waste will be obtained in unique “batches” from local municipalities (e.g., Tacoma or Puyallup) for use in this study. Prior to applying this material to the asphalt treatment cells, two field-duplicate split samples will be collected from each batch. One sample will be permanently archived (by freezing) while the other will be submitted to an accredited laboratory where it will be analyzed for the following parameters:

- Total solids
- Total nitrogen
- Total phosphorus
- Total cadmium, copper, and zinc
- Water soluble cadmium, copper, and zinc
- Polycyclic aromatic hydrocarbons
- Total petroleum hydrocarbons

In addition to the above parameters, WSU will perform the following soil analyses at a non-accredited laboratory located on the WSU Puyallup campus:

- Loss on ignition (total volatile solids)
- Particle size distribution
- Bulk density

Results from these laboratory analyses will serve to document the physical and chemical properties of the street dirt that was applied to the asphalt treatment cells during any given monitoring period.

To determine the water quality treatment effectiveness of pervious asphalt relative to impervious asphalt, pollutant concentrations and loads measured at the surface drains for the MIACs will be compared to pollutant concentrations and loads measured at the surface drains, elevated drains, and under drains for the UPACs and MPACs. To evaluate potential differences in the water quality treatment effectiveness of maintained and unmaintained pervious asphalt, pollutant concentrations and loads measured at the respective surface drains, elevated drains, and under drains for the UPACs and MPACs will be compared.

**Infiltration Testing**

The goal of the Phase 1 infiltration testing is to track surface infiltration rates in the pervious asphalt and pervious concrete treatment cells over time relative to the baseline infiltration rates measured in connection with the Baseline monitoring (see description above). This testing will occur annually starting in water year 2011 in all cells for the following treatment types: UPACs, MPACs, UPCCs, and MPCCs. Each test will involve the controlled measurement of surface infiltration rates for water at three locations within each treatment cell: two in parking spots and one in the driving area. The tests will be performed in the same locations during each annual monitoring cycle. Infiltration rates will be assessed versus time by pairing the data collected at each location with the data collected from the same location during the subsequent infiltration test. Data will be compared between pavement types and maintenance treatments by grouping
the data according to the following scheme. For asphalt cells there will be 3 locations per cell and 3 cells per treatment (maintained versus unmaintained), consequently the n-value will be 9. For the concrete cells there will be 3 locations per cell and 2 cells per treatment; n-value will be 6. These grouped data will be compared among treatments and pavement types using a Mann-Whitney U-test.

**Water Elevation Monitoring**

Automated equipment will be installed in observation ports located in each UPCC and MPCC to facilitate continuous monitoring of water elevations within each cell’s aggregate subbase and the underlying native soils to a depth of 15 feet. One observation port will be constructed in association with each cell, as shown in Figure 5. The water elevation data from each cell will be used to meet the following goals:

- Monitor water storage within the aggregate subbase during storm events
- Monitor the infiltration of water into the native soils from the aggregate subbase during storm events
- Monitor saturated conditions in the native soils during and after storms due to infiltration from the treatment cells

This monitoring will initiate in water year 2011 and be ongoing thereafter.

**Soil Monitoring**

Soil samples will be collected from sampling ports installed in association with each UPCC and MPCC to monitoring the accumulation of pollutants in the underlying native soils over time due to stormwater that infiltrated within each cells. A total of six soil sampling ports will be installed in each cell for this purpose, as shown in Figures 3 and 5. A soil core will be collected from one randomly selected sampling port in each cell on an annual basis. From each core, separate samples will be obtained to represent the following soil depths: surface, 0 to 3 inch, 3 to 6 inch, and 6 to 12 inch. These samples will then be submitted to an accredited laboratory where they will be analyzed for the following parameters:

- Total cadmium, copper, and zinc
- Water soluble cadmium copper, and zinc
- Total petroleum hydrocarbons
- Polycyclic aromatic hydrocarbons

This monitoring will initiate in water year 2012 and be ongoing thereafter.
Phase 2 Monitoring

Phase 2 monitoring will be implemented to provide supplemental performance data for different influent flow and chemistry scenarios that cannot be achieved during natural storms in the Phase 1 monitoring. Phase 2 monitoring will specifically involve capturing stormwater runoff in the cistern (see description above and Figure 3), adding a pollutant (or an appropriate surrogate) to the stormwater to achieve a desired concentration, and then pumping the stormwater to the individual pavement treatment cells to produce synthetic storms. This will allow treatment performance of the permeable asphalt and permeable concrete to be evaluated across a wider range of influent pollutant concentrations relative to what is present in the stormwater runoff during natural storm events.

By varying the pumping rate of stormwater from the cistern, it will also be possible to test the effect of runoff rate (pumping rate in this case) on chemical and/or hydrological treatment performance. Finally, using pumped synthetic stormwater instead of natural stormwater will make it possible to quantify the effects of pavement age on treatment performance. This could be achieved, for example, by adding the equivalent of 10 years of pollutant loading to each treatment cell using synthetic storm events to artificially “age” the pavement.

Phase 2 monitoring will not occur until a sufficient amount of data have been collected through the Phase 1 monitoring to identify supplemental data needs for the permeable pavement research. Given this consideration, it is anticipated that Phase 2 monitoring will not begin before water year 2012. Consequently, Phase 2 monitoring will occur during a period that falls outside the grant period for Phase I. Prior to beginning the Phase 2 monitoring, an addendum to this QAPP will be prepared to describe the following elements of the design:

- Goals and objectives
- Target parameters
- Target influent concentrations
- Target influent flow rates
- Number of synthetic storms to be sampled per treatment cell
Sampling Procedures

This section describes in detail the sampling procedures that will be followed by field personnel during each phase of the monitoring. This section has been divided into subsections for Baseline monitoring, Phase 1 monitoring, and Phase 2 monitoring, respectively.

Baseline Monitoring

Baseline monitoring will involve water quality monitoring in the asphalt treatment cells and controlled infiltration testing in both the permeable asphalt and permeable concrete treatment cells. The field procedures that will be used for each of these monitoring elements are presented in this section.

Water Quality Monitoring

As described in the Sampling Process design section, runoff from the asphalt treatment cells will be sampled during four to six storm events in early water year 2011. During each storm event, whole-flow composite samples (i.e., the entire storm volume will be captured) and grab samples will be collected from the elevated drains for the UPACs and MPACs.

During implementation of the Baseline monitoring, long-range precipitation forecasts from the Center for Ocean-Land-Atmosphere Studies (http://wxmaps.org/pix/meteograms.html) will be examined daily to determine if specific storms should be tracked for sampling based on the criteria identified in the Quality Objectives section for representative storms. Within 72 hours of an approaching storm, short-range precipitation forecasts will be examined for a more accurate assessment of the storm characteristics relative to these criteria. The short-range forecasts will be obtained primarily from Quantitative Precipitation Forecasts (QPF) that are generated by the National Oceanic and Atmospheric Administration (NOAA) and accessible via the following website (http://www.weather.gov/forecasts/xml/SOAP_server/ndfdXML.htm). The QPFs show forecasted rainfall totals for the next 72 hours in 6-hour increments. Monitoring personnel will review these data to determine the expected precipitation total, duration, and intensity of an approaching storm. In addition to the QPF data, Table 6 lists secondary sources for short-range precipitation forecasts that may also be reviewed by the weather monitoring lead to obtain this information.

Based on information obtained from the short-range forecasts, the Program Director (Table 1) will make a “go” or a “no go” decision for sampling a particular storm event. If a decision is made to target a storm event for sampling, the laboratory will be notified, and the sampling teams will be mobilized to conduct a pre-event site visit in preparation for the event.

During the pre-event site visits, field personnel will place a pre-cleaned 22.7 L glass sample container directly below each elevated drain to capture the associated discharge (see Figure 4a).
Field personnel will also inspect and remove debris from the drain outlets at this time. Finally, field personnel will pack ice around each sample container to prevent sample temperature from exceeding 6°Celsius (C) during the event. (Ice is estimated to keep the sample container cool for 48 hours; consequently, ice will be added no more than 24 hours before a targeted storm event.) The bottles will then be left in place during the entire event to collect whole-flow composite samples from each elevated drain.

### Table 6. Sources for short-range precipitation forecasts.

<table>
<thead>
<tr>
<th>Source</th>
<th>Website URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center for Ocean-Land-Atmosphere Studies, Global Forecast System; 180-hour meteogram</td>
<td><a href="http://wxmaps.org/pix/seagfs.png">http://wxmaps.org/pix/seagfs.png</a></td>
</tr>
<tr>
<td>Center for Ocean-Land-Atmosphere Studies, Global Forecast System; 84-hour meteogram</td>
<td><a href="http://wxmaps.org/pix/seanam.png">http://wxmaps.org/pix/seanam.png</a></td>
</tr>
<tr>
<td>University of Washington, Department of Atmospheric Sciences, Weather Loops; MM5 Real-Time Forecasts</td>
<td><a href="http://www.atmos.washington.edu/~ovens/loops/wxloop.cgi/mm5d1_pcp3+///3">http://www.atmos.washington.edu/~ovens/loops/wxloop.cgi/mm5d1_pcp3+///3</a></td>
</tr>
</tbody>
</table>

During the actual storm event, field personnel will periodically check the status of the 22.7 L glass sample containers. If any of these containers appear close to filling prior to the completion of the storm event, the nearly full container will be removed and replaced with an empty sample container. The nearly full container will be immediately placed on ice and kept below 6°C until delivery to the laboratory.

After each targeted storm event, the field personnel will seal the container with a cap, label each 22.7 L glass sample container and then weigh the container. The container weight will be compared with the tare weight of the empty container to calculate the weight of the sample. Sample weight will then be converted to sample volume by assuming the density of the sample is 1 g/mL. All the containers will then be transferred to the laboratory on ice to maintain their temperature below 6°C. If more than one sample container was collected from a single elevated drain, the laboratory will be instructed to produce a single, whole-flow composite sample by compositing the individual sample containers in proportion to their volumes. Once this step is complete, water from each sample containers will be used to fill pre-cleaned, preserved (where appropriate) sample bottles for the required analyses. The specific analyses to be performed are identified in the Sampling Process Design section.

During pre-event, mid-event, and post-event field visits, detailed notes will be kept in standardized field forms specifically developed for the project.
Infiltration Testing

Baseline infiltration testing will be performed to quantify surface infiltration rates in the pervious asphalt and pervious concrete treatment cells immediately following their construction. In each cell, infiltration testing will be conducted at three separate locations: two in parking spots and one in the driving area. A stainless steel washer secured with masonry nails will permanently mark each test location. The infiltration tests will follow the following procedure. Place a 61-cm cylinder at selected/marked points on the pervious pavement cell and attach with plumbers putty pressed into the joint between the cylinder and the pavement. Pour in 15 liters of water into the cylinder and time drain-down as soon as all water is in cylinder. Repeat three times and take average. If water leakage is excessive (surface water is observed over more than 50% of the area immediately outside the cylinder and the surface water extends >4 inches from the cylinder) then reseal the cylinder and repeat test.

The field data from each test will be recorded on standardized forms. The resultant water depth in the cylinder and time data will subsequently be processed to determine the infiltration rate at each test location.

Soil Monitoring

Baseline soil samples will be collected at three representative surface locations in the subgrade beneath the permeable pavement research facility for characterizing “baseline” pollutant concentrations in the underlying native soils. These samples will be placed in sample containers that are labeled with the date and time, field technician name, and sampling station. The containers will then be stored on dry ice at or below 6°C until delivery to the laboratory. Once at the laboratory, the collected samples will then be analyzed for the parameters identified in the Sampling Process Design section for baseline soil monitoring. All field activities related to the soil monitoring will be documented on standardized field forms.

Phase 1 Monitoring

As described in the Sampling Process Design section, Phase 1 monitoring will include the following design elements:

- Weather monitoring
- Flow monitoring in asphalt treatment cells
- Water quality monitoring in asphalt treatment cells
- Infiltration testing in permeable asphalt and concrete treatment cells
- Water elevation monitoring in concrete treatment cells
- Soil monitoring in concrete treatment cells

The field procedures for these activities are presented below.
Weather Monitoring

To monitor precipitation, two Hydrological Services TB3 tipping bucket rain gauges (see detailed specifications in Appendix C) will be installed in an area adjacent to the mesocosm research facility that is unobstructed by buildings and/or trees (Figure 3). One rain gauge will be mounted on an 5 foot pole and the other will be mounted flush with the ground surface. Both gauges will be leveled upon installation. Data from the gauges will be recorded on an 120 volt alternating current (AC) powered Campbell Scientific CR1000 datalogger (see detailed specifications in Appendix C). The datalogger will be programmed to scan every 10 seconds and record totalized rainfall on a 5 minute interval. The stored data will be automatically downloaded on a daily basis via radio telemetry to a central server located in and adjacent campus building. On at least a monthly basis, field personnel will check the rain gauges to ensure they are still level. On an annual basis, the calibration of the gauges will be checked and adjusted if necessary (see Quality Control section below).

Flow Monitoring

As described in the Sampling Process Design section, flow rates from the surface drains for the MIACs, and the underdrains for the UPACs and MPACs will be continuously recorded in connection with the Phase 1 monitoring. To facilitate this monitoring, water that is discharged from each of these locations will be routed through separate Hydrological Services TB1-L tipping bucket flow gauges (see detailed specifications in Appendix C) that will be installed in association with each treatment cell (Table 7, Figures 4a and 4b). The tipping bucket flow gauges will be connected to a single CR1000 datalogger that will record each tip of the flow gauge bucket mechanism and convert the signal to a volume estimate. The volume estimates will then be totalized for each monitoring location over a 5 minute logging interval, converted to an estimate of discharge for that period, and stored within the datalogger. The stored data will be automatically downloaded on a daily basis via radio telemetry to a central server located in an adjacent campus building.

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Drain Location</th>
<th>Monitoring Method</th>
<th>Flow Components Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPACs and MPACs</td>
<td>Surface drains</td>
<td>Event Based (22.7 L container)</td>
<td>flow volume, average discharge (estimated)</td>
</tr>
<tr>
<td></td>
<td>Elevated drains</td>
<td>Event Based (22.7 L container)</td>
<td>flow volume, average discharge (estimated)</td>
</tr>
<tr>
<td></td>
<td>Underdrains</td>
<td>Continuous (tipping bucket)</td>
<td>peak discharge, average discharge, storm volume, flow duration</td>
</tr>
<tr>
<td>MIACs</td>
<td>Surface drains</td>
<td>Continuous (tipping bucket)</td>
<td>peak discharge, average discharge, storm volume, flow duration</td>
</tr>
</tbody>
</table>

In addition to the continuous flow monitoring described above, the total volume of water discharged from surface drains and elevated drains for the UPACs and MPACs will be measured during 8 to 10 discrete storm events annually. Because discharge volumes from these locations
are expected to be very low, this monitoring will involve placing 22.7 L glass containers directly below each surface drain and elevated drain prior to specific storm events event (see Table 3, Figure 4a) to capture the associated discharge. (The procedures for tracking and identifying specific storms for monitoring are described in the section above for Baseline water quality monitoring.) The containers will then be left in place during the storm event to collect the entire volume of water that is discharged from each surface drain and elevated drain. To the extent possible, this monitoring will be performed in conjunction with the Phase 1 water quality monitoring described below (i.e., the same container used for flow monitoring will be used to collect water quality samples). It should be noted that peak discharge, average discharge, flow start and stop times, and flow duration cannot be determined for each monitoring location because this method does not provide continuous flow data.

**Water Quality Monitoring**

As described in the Sampling Process Design section, water quality sampling will be conducted in connection with the asphalt treatment cells during 8 to 10 storm events annually commencing in water year 2011. In addition, representative “street dirt” will be obtained from high efficiency street sweepers and spread evenly across all treatment cells. Samples will be collected from each batch of this material to document the physical and chemical properties of the street dirt that was applied to the asphalt treatment cells during any given monitoring period. The specific field procedures that will be used in connection with activities are described in the following subsections.

**Water Quality Sampling**

As described above, water quality sampling will be conducted in connection with the asphalt treatment cells during 8 to 10 storm events annually. During each storm event, flow-weighted composite samples will be collected from surface drains for MIACs, and the underdrains for the UPACs and MPACs. To facilitate this monitoring, ISCO Model 6700 series automated sampler (see detailed specification in Appendix C) will be installed in association with each monitoring location (Table 8, Figures 4a and 4b). The automated sampler intakes will be suspended upstream of each station’s tipping bucket flow gauge (see description in previous section) and positioned to ensure the homogeneity and representativeness of the collected samples. Specifically, sampler intakes will be installed to make sure adequate depth is available for sampling, and to avoid capture of litter, debris, gross solids, or floatables that might be present in the flow stream.

The procedures for tracking and identifying specific storms for monitoring are described in the section above for Baseline water quality monitoring. If a decision is made to target a storm event for sampling, the laboratory will be notified, and the sampling teams will be mobilized to conduct a pre-event site visit in preparation for the event. During the pre-event site visits, field personnel will perform routine maintenance activities on the monitoring equipment as described in the Quality Control section below. Once these activities are complete, field personnel will perform the following steps to prepare each automated sampler for sampling:
Flush sample line for each automated sampler with deionized water

Attach sample line to automated sampler and position the associated intake in the respective sampling locations for surface and underdrains

Place a clean 20 L glass sample bottle into the automated sampler and pack ice around each sample bottle

Attach the automated sampler head to its base

Initiate the automated sampler’s program

During the storm event sampling, each automated sampler will be programmed to enable in response to a predefined increase in flow at the respective station. The automated samplers will then collect 400-milliliter (mL) sample aliquots at preset flow increments with the goal of collecting at least 10 sample aliquots, covering at least 75 percent of each storm’s runoff volume for the first 24 hours of the event. Sample pacing for the automated samplers will be determined based on rainfall versus runoff relationships that are developed using linear regressions of data that were collected during previous storm events. These regressions will be continually updated throughout the year to reflect changing hydrologic conditions. The rainfall versus runoff regressions will be used to convert forecast rainfall totals into runoff volumes. The resultant runoff volume (cubic feet) will then be divided by 25 (the median number of 400 mL aliquots that a 20 L bottle will hold) to estimate the sample pacing (cubic feet) volume necessary to collect an adequate number (greater than 10) of aliquots across at least 75 percent of the storm for the first 24 hours of the event.

During the actual storm event, the Campbell Scientific CR1000 datalogger described in the previous subsection will send an alarm when the flow rate at surface drains for the MIACS reach a user-customizable threshold. This alarm will notify field personnel that an event is underway and that a grab sample needs to be collected. Field personnel will then collect grab samples for total petroleum hydrocarbons at each surface drain and underdrain in pre-labeled 1 L amber glass bottles. Sample bottles will be immediately placed on ice and kept below 6°C until delivery to the laboratory. During the grab sample field visit, field personnel will also check the field equipment and perform any maintenance that is necessary without interfering with the functioning of the sampling equipment.

After each targeted storm event, field personnel will make visual and operational checks on each automated sampler and determine the total number of aliquots composited. Pursuant to the sampling goals identified in the Measurement Quality Objectives section above, the minimum number of aliquots that constitutes an acceptable sample is ten. (A minimum volume of approximately 4 L must be collected to perform all the targeted analyzes in this study with the associated laboratory quality control requirements.) If the sample is acceptable, the sample bottle will be immediately capped, removed from the automated sampler, and kept below 6°C until delivery to the laboratory. Once in the laboratory, water from the carboy will be used to fill pre-cleaned, preserved (where appropriate) sample bottles for the required analyses. All collected
flow-weighted composite samples will then be analyzed for the parameters identified in the
Sampling Process Design section for Phase 1 water quality monitoring.

In addition to the flow-weighted composite samples, whole-flow composite samples will also be
collected from surface and elevated drains for UPACs and MPACs during 8 to 10 storms
annually. Samples from these locations will be collected in 22.7 L glass sample containers using
the same field procedures that were described above for sampling the elevated drains during
Baseline water quality sampling (Table 8, Figure 4a). The collected whole-flow composite
samples will then be analyzed for the parameters identified in the Sampling Process Design
section for Phase 1 water quality monitoring.

Table 8. Overview of water quality sampling locations, methods, and parameters.

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Sampling Location</th>
<th>Composite Sampling Method</th>
<th>Composite Sample Parameters</th>
<th>Grab Samples Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPACs and MPACs</td>
<td>Surface drains</td>
<td>Whole-flow composite (22.7 L glass container)</td>
<td>total suspended solids suspended sediment concentration hardness total phosphorus orthophosphorus total Kjeldahl nitrogen nitrate+nitrite total copper, zinc, and cadmium dissolved copper, zinc, and cadmium polycyclic aromatic hydrocarbons a</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Elevated drains</td>
<td>Whole-flow composite (22.7 L HPDE container)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Underdrains</td>
<td>Composite (ISCO automated sampler)</td>
<td></td>
<td>total petroleum hydrocarbons</td>
</tr>
<tr>
<td>MIACs</td>
<td>Surface drains</td>
<td>Composite (ISCO automated sampler)</td>
<td>Particle size distribution total suspended solids suspended sediment concentration hardness total phosphorus orthophosphorus total Kjeldahl nitrogen nitrate+nitrite total copper, zinc, and cadmium dissolved copper, zinc, and cadmium polycyclic aromatic hydrocarbons a</td>
<td></td>
</tr>
</tbody>
</table>

a Polycyclic aromatic hydrocarbons will only analyzed during the first storm event of each water year.
NA: not applicable.

All field activities from pre-event, mid-event, and post-event field visits will be documented on
standardized field forms specifically developed for this study.

Street Dirt Application

As described in the Sampling Process Design section, representative “street dirt” will be obtained
from high efficiency street sweepers and spread evenly across all treatment cells with a drop
spreader at a rate of 75 g/m². This application rate represents the median street dirt yield for
residential land uses in Seattle (SPU and Herrera 2009). It is anticipated that street sweeper waste
will be obtained in unique “batches” from local municipalities (e.g., Tacoma or Puyallup) for use in this study. Prior to applying this material to the asphalt treatment cells, two field-duplicate split samples will be collected from each batch. One sample will be permanently archived while the other will be submitted to an accredited laboratory where they will be analyzed for suite of parameters identified in the Sampling Process Design section for Phase 1 water quality monitoring. The following procedures will be used to obtain these samples:

1. A stainless steel scoop or spoon will be used to collect subsamples from nine different locations within the batch of street dirt.

2. All the subsamples will be combined in a clean stainless steel bowl and then homogenized using a stainless steel spoon.

3. The contents from the bowl will be used to fill pre-labeled sample bottles for the required parameters that will be obtained from the analytical laboratory. A separate pre-labeled sample bottle will also be filled for the archive sample.

4. The bottles for the analytical laboratory will be placed in a cooler with ice, and transported to the laboratory within the allowable limits for sample holding times and with the appropriate chain of custody documentation.

Infiltration Testing

In connection with the Phase 1 monitoring, infiltration testing will be performed annually at three permanently established locations within each pervious asphalt and concrete treatment cell. These locations, and procedures to be used during this testing, are described in the Baseline monitoring section above.

Water Elevation Monitoring

During the Phase 1 monitoring, water elevations within observation ports located in each UPCC and MPCC (see description in the Sampling Process Design section) will be monitored continually. To facilitate this monitoring, Campbell Scientific CS450-L pressure transducers (see detailed specifications in Appendix C) will be installed in each observation port and programmed to log water elevations on a 5-minute time interval. These data will be stored in the same datalogger that was described above in connection with the Phase 1 flow monitoring. The stored data will be automatically downloaded on a daily basis via radio telemetry to a central server located in an adjacent campus building.

Soil Monitoring

Beginning in water year 2012, soil samples will be collected from the soil sampling ports installed in association with each UPCC and MPCC (see description in Sampling Process Design
Field personnel will collect a single soil sample from one randomly selected sampling port in each treatment cell on an annual basis. To collect the sample, a concrete saw will be used to cut a hole within the sampling port and the aggregate subgrade will be removed with a hand trowel until the native soil is exposed. Field personnel will then collect a soil core and separate the core into surface, 0 to 3 inch, 3 to 6 inch, and 6 to 12 inch samples. Each sample will be placed in a sample container that is labeled with the date and time, field technician name, sampling station, and core depth. The containers will then be stored on ice at 6°C until delivery to the laboratory. Once at the laboratory, the collected samples will then be analyzed for the parameters identified in the *Sampling Process Design* section for Phase 1 soil monitoring. All field activities related to the soil monitoring will be documented on standardized field forms.

After the samples are collected the aggregate subgrade will be replaced and a new pervious concrete cap will be poured to match grade. The port will then be marked to indicate that a sample has been collected from that station. Each pervious concrete cell contains six soil sampling ports so this process can be repeated six times through the duration of the study before a port needs to be revisited.

### Phase 2 Monitoring

As described in the *Sampling Process Design* section above, an addendum to this QAPP will be prepared to describe specific elements of the sampling process design for Phase 2 monitoring, once supplemental data needs have been identified through the Phase 1 monitoring. It is anticipated that field procedures related to flow monitoring, infiltration testing, water elevation monitoring, and soil monitoring during Phase 2 monitoring will remain unchanged relative to those described above for Phase 1 monitoring. However, the field procedures related to water quality sampling will be altered because natural storms will no longer be tracked and sampled. Instead, synthetic storm events will be generated and storm volumes and flow rates controlled. Because flow rates and storm volumes will be pre-determined, there will be no need for rainfall versus runoff relationships to estimate what the storm volume might be. Due to this consideration, collecting adequate sample volume across the duration of the “event” should be relatively simple.
Measurement Procedures

This section describes the laboratory methods that will be used for the analysis of samples collected for the permeable pavement research. This information is presented in separate subsections below for water quality and soil samples, respectively.

Water Quality Measurement Procedures

Laboratory analytical procedures for water quality parameters will generally follow methods that are approved in the Federal Register by the U.S. Environmental Protection Agency (U.S. EPA 2007). These methods provide reporting limits that are low enough to assess state and federal regulatory criteria or guidelines. The preservation methods, analytical methods, reporting limits, and sample holding times for all water quality parameters to be evaluated in this study are presented in Table 9.

The Federal Register indicates that dissolved metals and orthophosphorus samples must be filtered within 15 minutes of the end of a qualifying event. However, when collecting flow paced composite samples during storm events, this requirement generally cannot be met because the collection time of the last sample aliquot cannot be reliably predicted. Therefore, in lieu of this guideline, a pre-filtration holding time of 12-hours will be used for this study. Once the samples are retrieved and delivered to the laboratory, the laboratory staff will be required to split the composite sample and immediately filter the dissolved metals and orthophosphate samples. If sample retrieval occurs during the laboratory’s non-business hours or the laboratory is not able to receive, filter or process the samples; sampling staff will split, filter, and preserve the samples as soon as possible after retrieval. The samples will then be stored in a secure refrigerator and maintained at the required holding temperature until they can be delivered to the laboratory the morning of the next business day.

The laboratory identified for this project (Analytical Resources Incorporated) is certified by Ecology and participates in audits and interlaboratory studies by Ecology and the U.S. Environmental Protection Agency. These performance and system audits have verified the adequacy of the laboratory’s standard operating procedures, which include preventive maintenance, data reduction, and quality assurance/quality control (QA/QC) procedures.

The laboratory will provide the analytical results within 30 days of receipt of the samples in standardized reports that are suitable for evaluating the project data. Each report will be provided in both hardcopy format and as an Electronic Data Deliverable (EDD). These reports will specifically include the following information:

- All raw values including those below the reporting limit and between the method detection limit and the laboratory reporting limit
- The laboratory method detection limits and reporting limits for all parameters for each batch
All laboratory quality assurance (QA) results, including matrix spike, laboratory duplicates (splits), laboratory blanks, and laboratory control sample results

The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, and changes to the referenced method, and an explanation of data qualifiers.

**Soil Measurement Procedures**

Laboratory analytical procedures for soil parameters are identified in Table 10 with associated preservation methods, analytical methods, reporting limits, and sample holding times. The WSU-Puyallup campus is an agricultural research center that has non-accredited laboratory facilities capable of processing and analyzing soil samples. Consequently, the following parameters will be analyzed on campus:

- Organic material by loss on ignition
- Particle size distribution
- Bulk density

The remainder of the soil parameters will be analyzed at Soiltest Farm Consultants, Inc. This laboratory is certified by Ecology and participates in audits and interlaboratory studies by Ecology and the U.S. Environmental Protection Agency. These performance and system audits have verified the adequacy of the laboratory’s standard operating procedures, which include preventive maintenance, data reduction, and QA/QC procedures.

The laboratory will report the analytical results within 30 days of receipt of the samples. These reports will provided in both a hardcopy and electronic format, and contain the same information as described above for water quality parameters.
# Table 9. Methods and detection limits for water quality analyses.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analytical Method</th>
<th>Method Number</th>
<th>Volume of Water Required for Analysis</th>
<th>Field Sample Container</th>
<th>Pre-Filtration Holding Time</th>
<th>Total Holding Time</th>
<th>Field Preservation</th>
<th>Laboratory Preservation</th>
<th>Reporting Limit/Resolution Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solids</td>
<td>Gravimetric</td>
<td>SM 2540D</td>
<td>1 L</td>
<td>NA</td>
<td>7 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C</td>
<td>1.0 mg/L</td>
<td>mg/L</td>
</tr>
<tr>
<td>Suspended sediment concentration</td>
<td>Gravimetric</td>
<td>ASTM D3977-97C</td>
<td>1 L</td>
<td>NA</td>
<td>6 months</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, HNO₃ to pH &lt; 2</td>
<td>0.5 mg/L</td>
<td>mg/L</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>Sieve and Coulter Counter</td>
<td>TAPE Appendix</td>
<td>1 L</td>
<td>NA</td>
<td>28 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.1 microns</td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>Trimmometric (EDTA)</td>
<td>SM2340-C</td>
<td>100 mL</td>
<td>NA</td>
<td>6 months</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, HNO₃ to pH &lt; 2</td>
<td>0.1 mg/L</td>
<td>microns</td>
</tr>
<tr>
<td>Chemical Oxygen Demand (COD)</td>
<td>Closed reflux</td>
<td>EPA 410.4</td>
<td>250 mL</td>
<td>22.7 L Glass bottle for whole flow composite samples</td>
<td>12 hours a</td>
<td>48 hours f</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.002 (ARI=0.016) mg/L</td>
<td></td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>Strong Acid</td>
<td>EPA 365.3</td>
<td>200 mL</td>
<td>NA</td>
<td>28 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.001 (ARI=0.004) mg P/L</td>
<td></td>
</tr>
<tr>
<td>Orthophosphate phosphorous</td>
<td>Heteropoly Blue</td>
<td>EPA 365.3</td>
<td>200 mL</td>
<td>NA</td>
<td>28 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.2 (ARI=0.6) mg/L</td>
<td></td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>Digest, ISE</td>
<td>EPA 351.2</td>
<td>20 L Glass bottle for flow-weighted composite samples</td>
<td>24 hours</td>
<td>28 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.1 mg/L</td>
<td></td>
</tr>
<tr>
<td>Nitrate + nitrite nitrogen</td>
<td>Cd-red, Auto-NED</td>
<td>EPA 353.2</td>
<td>20 L Glass bottle for flow-weighted composite samples</td>
<td>24 hours</td>
<td>28 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.001 (ARI=0.004) mg/L</td>
<td></td>
</tr>
<tr>
<td>Cadmium, dissolved</td>
<td>ICP-MS</td>
<td>EPA 200.8</td>
<td>200 mL</td>
<td>NA</td>
<td>6 months</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.004 (ARI=0.002) mg/L</td>
<td></td>
</tr>
<tr>
<td>Cadmium, total</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.004 (ARI=0.002) mg/L</td>
<td></td>
</tr>
<tr>
<td>Copper, dissolved</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.004 (ARI=0.005) mg/L</td>
<td></td>
</tr>
<tr>
<td>Copper, total</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.004 (ARI=0.005) mg/L</td>
<td></td>
</tr>
<tr>
<td>Zinc, dissolved</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.001 (ARI=0.004) mg/L</td>
<td></td>
</tr>
<tr>
<td>Zinc, total</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.001 (ARI=0.004) mg/L</td>
<td></td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>GC/MS</td>
<td>EPA 8270D</td>
<td>2 x 500 mL</td>
<td>2 x 500 mL</td>
<td>7 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.05 (ARI=0.25) mg/L</td>
<td></td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td>GC/FID</td>
<td>NWTPH-Dx</td>
<td>2 x 500 mL</td>
<td>1 L glass bottle</td>
<td>7 days</td>
<td>7 days</td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.1 (ARI=0.5) mg/L</td>
<td></td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td></td>
<td>NA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintain ≤ 4°C, H₂SO₄ to pH &lt; 2</td>
<td>0.05 (ARI=0.25) mg/L</td>
<td></td>
</tr>
</tbody>
</table>

* ASTM method numbers are from ASTM (2003); EPA method numbers are from U.S. EPA (1983; 1984); TAPE methods are from the Washington State Department of Ecology (Ecology 2008); NWTPH-Dx method is from the Washington State Department of Ecology (Ecology 2007)


b A 0.45 micron fiber nylon filter will be used for dissolved metals (copper and zinc) filtration.

b A 0.45 micron fiber nylon filter will be used for dissolved metals (copper and zinc) filtration.

c Washington State Department of Ecology methods (Ecology 2007) includes silica gel extract cleanup step.
c Washington State Department of Ecology methods (Ecology 2007) includes silica gel extract cleanup step.

d Washington State Department of Ecology methods (Ecology 2007) includes silica gel extract cleanup step.
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e EPA requires filtering for dissolved metals within 15 minutes of the collection of the last aliquot. This goal is exceedingly difficult to meet when conducting flow-weighted sampling. A more practical proxy goal for this study is 12 hours, both goals will be reported with the data.
e EPA requires filtering for dissolved metals within 15 minutes of the collection of the last aliquot. This goal is exceedingly difficult to meet when conducting flow-weighted sampling. A more practical proxy goal for this study is 12 hours, both goals will be reported with the data.

f WA Department of Ecology includes silica gel extract cleanup step.
f WA Department of Ecology includes silica gel extract cleanup step.

C = Celsius.
C = Celsius.

ICP-MS = inductively coupled plasma/mass spectrometry.
ICP-MS = inductively coupled plasma/mass spectrometry.

GC/MS = gas chromatography/mass spectrometry.
GC/MS = gas chromatography/mass spectrometry.

L = liter
L = liter

mg/L = milligrams per liter.
mg/L = milligrams per liter.

μg/L = micrograms per liter.
μg/L = micrograms per liter.

NA = not applicable.
NA = not applicable.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analytical Method</th>
<th>Method Number</th>
<th>Volume Required for Analysis</th>
<th>Field Sample Container</th>
<th>Pre-processing Holding Time</th>
<th>Total Holding Time</th>
<th>Field Preservation</th>
<th>Laboratory Preservation</th>
<th>Reporting Limit/ Resolution Units</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss on ignition</td>
<td>Gravimetric</td>
<td>S-9.20</td>
<td>0.5 g</td>
<td>Double 1 gallon zip-lock bags</td>
<td>48 hours</td>
<td>NA</td>
<td>Room Temperature</td>
<td>Maintain &lt; 6°C</td>
<td>0.01 %</td>
<td>%</td>
<td>NA</td>
</tr>
<tr>
<td>Percent total solids</td>
<td>Gravimetric</td>
<td>P-1.10</td>
<td>50 g</td>
<td>NA</td>
<td>48 hours</td>
<td>NA</td>
<td>Room Temperature</td>
<td>Maintain &lt; 6°C</td>
<td>0.10 %</td>
<td>%</td>
<td>NA</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>Sieve/Hydrometer</td>
<td>ASTM D422</td>
<td>500 g</td>
<td>NA</td>
<td>6 months</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>0.10 g/l</td>
<td>g/l</td>
<td>NA</td>
</tr>
<tr>
<td>Bulk density</td>
<td>Volumetric</td>
<td>TMECC 03.01-A</td>
<td>200 g</td>
<td>NA</td>
<td>7 days</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>4.3 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>Combustion</td>
<td>ASTM D573</td>
<td>0.5 g</td>
<td>NA</td>
<td>48 hours</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>0.01 %</td>
<td>%</td>
<td>NA</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>ICP</td>
<td>EPA 3050A/6010B</td>
<td>0.5 g</td>
<td>NA</td>
<td>48 hours</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>0.10 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Water soluble cadmium, copper, and zinc</td>
<td>SPLP/ICP</td>
<td>EPA 1312</td>
<td>10 g</td>
<td>NA</td>
<td>48 hours</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>Cd: TBD/Cu: 0.3/Zn: 0.3 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>GC/MS</td>
<td>EPA 8270D</td>
<td>25 g</td>
<td>48 hours</td>
<td>14 days</td>
<td>NA</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>Cd:0.5/Cu: 0.2/Zn: 0.5 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Total cadmium, copper, and zinc</td>
<td>ICP</td>
<td>EPA 6010B</td>
<td>0.5 g</td>
<td>8 oz glass jar</td>
<td>6 months</td>
<td>2 years</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>100 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td>GC/FID</td>
<td>NWTPH-Dx</td>
<td>200 g</td>
<td>8 oz glass jar</td>
<td>14 days</td>
<td>40 years</td>
<td>Maintain &lt; 6°C</td>
<td>Room Temperature</td>
<td>25 mg/kg</td>
<td>mg/kg</td>
<td>NA</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

| Notes                                         |                         |               |                              |                        |                          |                     |                   |                        |                                   |        |       |
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Quality Control

Quality control procedures are identified below for field and laboratory activities. The overall objectives of these procedures are to ensure that data collected for this project are of a known and acceptable quality, and that data quality objectives are met.

Field Quality Control Procedures

Quality control procedures that will be implemented for field activities are described below. The frequency and type of quality control samples to be collected in the field in connection with Phase 1 monitoring are also summarized in Tables 11 and 12 for water quality and soil parameters, respectively.

Instrument Maintenance and Calibration

On a monthly basis and before each targeted event, routine maintenance and operational inspections will be performed to ensure that the equipment is functioning properly. Maintenance activities and operational inspections will include:

- Inspection of power connections
- Inspection of desiccant in data loggers enclosures, automated samplers, and pressure transducers
- Inspection of the rain gauge, including level check and debris removal
- Inspection of tipping bucket flow gauges, including level check and debris removal
- Inspection of automated sampler tubing, including checks for kinks and debris removal

Instrument maintenance and calibration activities will be documented on standardized field forms.

The rain gauge and tipping bucket flow gauges (see Sampling Procedures section) are robust instruments that will only require annual calibration. During each calibration event, water will metered into the gauges with a burette until the tipping bucket mechanism triggers. This process will be repeated and adjustments on the gauges will be made until an equivalent volume of water triggers the tipping mechanism in either direction. For the rain gauge, each bucket tip is calculated as equivalent to 0.01 inches of rain; consequently, the volume of water that should initiate a bucket tip equals 0.01 inches multiplied by the area (in square inches) of the top of the
Table 11. Anticipated annual number of samples during Phase 1 monitoring and associated quality assurance requirements for each water quality parameter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Samples per Station</th>
<th>Number of Stations</th>
<th>Total Number of Samples</th>
<th>Laboratory Method Blanks</th>
<th>Rinsate Blanks</th>
<th>Laboratory Control Standard</th>
<th>Matrix Spike</th>
<th>Lab Duplicates a</th>
<th>Field Duplicates b</th>
<th>Total Annual Number of Samples c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total suspended solids</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>NA</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 220</td>
</tr>
<tr>
<td>Suspended sediment concentration</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>NA</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 220</td>
</tr>
<tr>
<td>Particle size distribution</td>
<td>8 - 10</td>
<td>3</td>
<td>24 - 30</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>NA</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 220</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Orthophosphorus</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Total Kjeldahl nitrogen</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 220</td>
</tr>
<tr>
<td>Nitrate + nitrite nitrogen</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 220</td>
</tr>
<tr>
<td>Cadmium, dissolved</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Cadmium, total</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Copper, dissolved</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Copper, total</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Zinc, dissolved</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Zinc, total</td>
<td>8 - 10</td>
<td>21</td>
<td>168 - 210</td>
<td>1/batch a</td>
<td>2</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>176 - 222</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>1</td>
<td>21</td>
<td>21</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>22</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td>8 - 10</td>
<td>9</td>
<td>72 - 90</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>80 - 100</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td>8 - 10</td>
<td>9</td>
<td>72 - 90</td>
<td>1/batch a</td>
<td>NA</td>
<td>1/batch a</td>
<td>1/batch a</td>
<td>2/batch a</td>
<td>1/batch</td>
<td>80 - 100</td>
</tr>
</tbody>
</table>

a Laboratory quality assurance samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.
b Field duplicates will be collected and analyzed for at least 5 percent of the total number of submitted samples.
c Total annual number of samples includes project samples, rinsate blanks, and field duplicates.

NA: not applicable.
Table 12. Anticipated annual number of samples during Phase 1 monitoring and associated quality assurance requirements for each soil parameter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Samples per Cell</th>
<th>Number of Cells</th>
<th>Total Number of Samples</th>
<th>Laboratory Method Blanks</th>
<th>Laboratory Control Standard</th>
<th>Matrix Spike</th>
<th>Lab Duplicates</th>
<th>Field Duplicates</th>
<th>Total Annual Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cadmium, copper, zinc, and lead</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>25</td>
</tr>
<tr>
<td>Water soluble cadmium, copper, and zinc</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>25</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>1/batch</td>
<td>25</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (motor oil)</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1/batch</td>
<td>1/batch</td>
<td>NA</td>
<td>1/batch</td>
<td>1/batch</td>
<td>25</td>
</tr>
<tr>
<td>Total petroleum hydrocarbons (diesel)</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1/batch</td>
<td>1/batch</td>
<td>NA</td>
<td>1/batch</td>
<td>1/batch</td>
<td>25</td>
</tr>
</tbody>
</table>

* Field duplicates will be collected and analyzed for at least 5 percent of the total number of submitted samples.

b Total annual number of samples includes project samples and field duplicates.

NA: not applicable.
rain gauge. For the flow gauges, the tipping buckets will be calibrated such that each tip is equivalent to 1 L.

Because the tipping bucket flow gauges hold a larger mass of water and tip more frequently than the rain gauge, it will also be necessary to conduct dynamic calibration checks of these gauges. To conduct these checks, field personnel will run water through each tipping bucket flow gauge with a metered hose that is connected to the cistern described in the Sampling Process Design section (Figure 3 and 4). The flow from the cistern will be measured with a rotometer; flow from the rotometer will then be compared with the flow from the tipping bucket flow gauge to assess instrument accuracy. This procedure will be repeated twice at 1 L per minute and twice at 25 L per minute for each tipping bucket flow gauge. Tests at each flow rate will be performed for 10 minutes. The dynamic calibrations will be conducted on an annual basis or as needed.

Field Notes

During each pre- and post-storm site visit to each monitoring station, the following information will be recorded on a waterproof, standardized field form:

- Treatment cell identification number
- Date/time of visit and last sample collected (if sampled)
- Name(s) of field personnel present
- Weather and flow conditions
- Rain gauge condition
- Desiccant condition
- Sample volume (if sampled)
- Sampler pacing (if sampled)
- Sample duplicated? (if sampled)
- Presence of obstructions in system and remedial actions taken
- Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
- Modifications of sampling procedures

During each soil sampling field visit, the following information will be recorded on a waterproof standardized field form:
• Treatment cell identification number
• Date/time of visit
• Name(s) of field personnel present
• Weather and flow conditions
• Number of samples collected
• Sample depth
• Sample duplicated?
• Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
• Modifications of sampling procedures

Bottle Blanks

To assess if sample bottles are a source of sample contamination, a bottle blank will be collected at a randomly selected elevated drain of the MPAC and UPAC cells. For the remaining water quality sampling stations bottle contamination will be assessed through the collection of equipment rinsate blanks (see next section). Bottle blanks will be collected by field personnel twice annually concurrent with the collection of equipment rinsate blanks. Field personnel will fill an empty sample container with laboratory grade deionized water in the field adjacent to the sample collection point. The sample will then be processed in the same manner as any other project sample.

Once in the laboratory, the water from the 20 L glass bottle will be analyzed for the following subset of parameters:

• Total phosphorus
• Orthophosphorus
• Dissolved cadmium, copper, and zinc
• Total cadmium, copper, and zinc

If any of these parameters are detected in a bottle blank at concentrations greater than 2 times the reporting limit, additional testing may be performed to identify the source of the contamination (see Data Verification and Validation section).
Equipment Rinsate Blanks

Equipment rinsate blanks will be collected at a randomly selected MIAC surface drain or UPAC/MPAC underdrain to verify that the automated sampler tubing or bottle is not a source of contamination. At a minimum, two equipment rinsate blanks will be collected for this purpose; the first prior to sampling the first storm event in any given monitoring year, and the second midway through the monitoring year.

Samples will be collected using the following procedure:

1. The sample line will be rinsed with deionized water in accordance with pre-storm event set-up procedures described in the Sampling Procedures section.

2. A pre-cleaned 20 L glass bottle from the laboratory will be placed in the automated sampler.

3. The sample line will be detached at the point of sample collection and placed in a carboy of reagent grade water.

4. The sampler will be programmed to draw 20 L of reagent grade water through the sampler tubing and into the 20 L glass bottle.

5. The 20 L glass bottle will then be removed from the automated sampler, placed on ice, and submitted to laboratory as a separate (blind) sample.

Once in the laboratory, the water from the 20 L glass bottle will be analyzed for the following subset of parameters:

- Total phosphorus
- Orthophosphorus
- Dissolved cadmium, copper, and zinc
- Total cadmium, copper, and zinc

If any of these parameters are detected in a rinsate blank at concentrations greater than 2 times the reporting limit, additional testing may be performed to identify the source of the contamination (see Data Verification and Validation section).

Concurrent Field Duplicate Samples – Water

Concurrent field duplicate samples will be collected at a sufficient frequency to represent 5 percent of the total number of project samples analyzed. The specific number of field duplicates to be collected during the sampling season is listed in Table 11. Water quality concurrent field duplicate split samples will be collected by deploying additional duplicate automated samplers at randomly selected stations. The duplicate samplers will be stationed adjacent to the primary samplers and controlled by the data logger in an identical manner to the
primary samplers. The sampler intakes will be placed next to each other in the outlet flow control structure.

All duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples. The resultant data from these samples will then be used to assess variation in the analytical results that is attributable to environmental (natural), sub-sampling, and analytical variability (see Quality Objectives section).

Field Duplicate Split Samples – Soil

Field duplicate split samples will be collected at a sufficient frequency to represent 5 percent of the total number of project samples analyzed. The number of field duplicates to be collected during the sampling season is listed in Table 12. Soil sample field duplicate split samples will be collected by mixing the sample in a pre-cleaned stainless steel bowl with a pre-cleaned stainless steel spoon until the mixture is homogenous. The sample will subsequently be split in two and placed in separate sample containers. Duplicate sampling stations will be selected randomly.

All duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples. The resultant data from these samples will then be used to assess variation in the analytical results that is attributable to environmental (natural), sub-sampling, and analytical variability.

Sample Handling, Delivery, and Processing

Ice will be placed around the 20 L glass bottles in each automated sampler before each sampled storm event. In addition, ice will be placed around the 22.7 L glass bottles used for whole-sample composite sampling. Ice will not be allowed to sit for more than 24 hours before the initiation of an event (with the goal of keeping sample temperatures below 6 degrees Celsius). After each targeted storm event, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere. All field personnel will wear clean nitrile gloves when handling samples in the field. During delivery to the laboratory, all sample containers will be transported in coolers with ice and kept below 6 degrees Celsius. The volume of ice should be equal to or greater than the volume occupied by samples (twice the volume of ice to samples is recommended during warm temperatures) (USGS 2003). The temperature of the samples will be measured upon sample delivery and recorded on the chain of custody form.

Once in the laboratory, the composite samples will be transferred from the 22.7 L and 20 L glass bottles for composite samples to pre-cleaned sample containers for the required analyses. Composite samples will be split into separate sample containers with the use of a 22 L churn splitter. During the churn splitting, one individual will first agitate the sample and pour the entire contents into the churn. This same individual will then operate the churn handle while another individual operates the spigot at the bottom of the churn. To minimize exposure of the samples to human, atmospheric, and other potential sources of contamination, laboratory staff will process the samples using “clean” techniques pursuant to protocols developed by the U.S. EPA (1996).
Sample Identification and Labeling

Each treatment cell will be referenced using its unique identification from Table 5 and Figure 3. Specific sampling location within a treatment cell will be identified as follows:

- SD: surface drain
- ED: elevated drain
- UD: underdrain
- SSP#: soil sampling port 1 through 6

All sample containers will be labeled with the following information using indelible ink and labeling tape:

- Treatment cell identification number (e.g., 4)
- Treatment cell sampling location (e.g., SD)
- Date of sample collection (year/month/day: yyyy/mm/dd)
- Time of sample collection (international format [24 hour])
- Field personnel initials

QA samples (field duplicates and rinsate blanks) will only be labeled as QA1, QA2, etc. for delivery to lab, but field staff will maintain a cross-check list of which stations and sample types the QA samples represent. When results from these samples are returned from the laboratory, the station name and QA sample type will referenced to the associated result in the data management system for the study.

Sample Containers and Preservation

Clean, decontaminated sample containers will be obtained from the analytical laboratory in advance of each storm event. Spare sample containers will be carried by the sampling team in case of breakage or possible contamination. Sample containers and preservation techniques will follow U.S. EPA (2007) guidelines. After samples are processed, laboratory personnel will clean the 22.7 L and 20 L glass bottles used for composite samples with a four step process:

1. Liquinox detergent rinse
2. Reagent grade water rinse
3. 10 percent hydrochloric acid rinse
4. Reagent grade water rinse

Chain-of-Custody Record

A chain-of-custody record will be maintained for each sample batch listing the sampling date and time, sample identification numbers, analytical parameters and methods, persons relinquishing...
and receiving custody, dates and times of custody transfer, and temperature of sample upon delivery.

**Laboratory Quality Control Procedures**

Quality control procedures that will be implemented in the laboratories are described in the following subsections. The frequency and type of quality control samples to be analyzed by the laboratories are also summarized in Tables 11 and 12 for water quality and soil parameters, respectively.

**Method Blanks**

Method blanks consisting of de-ionized and micro-filtered pure water will be analyzed with every laboratory sample batch (Tables 11 and 12). A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. Blank values will be presented in each laboratory report.

**Control Standards**

Control standards for each parameter will be analyzed by the laboratory with every sample batch (Tables 11 and 12). A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. Raw values and percent recovery (see formula in the **Quality Objectives** section) for the control standards will be presented in each laboratory report.

**Matrix Spikes**

For applicable parameters, matrix spikes will be analyzed by the laboratory with every sample batch (Tables 11 and 12). A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. Raw values and percent recovery (see formula in the **Quality Objectives** section) for the matrix spikes will be presented in each laboratory report.

**Laboratory Duplicate Split Samples**

Laboratory split-sample duplicates for each parameter will be analyzed for specifically labeled QA samples submitted with every sample batch (Tables 11 and 12). This will represent no less than 10 percent of the project submitted samples. Raw values and relative percent difference (see formula in the **Quality Objectives** section) of the duplicate results will be presented in each laboratory report.
Data Management Procedures

Data from the datalogger associated with the rain gauge, flow gauges, and pressure transducers (see description in Sampling Procedures section) will be remotely transferred on a daily basis and/or at the beginning and end of each targeted storm event. These data will be immediately checked for evidence of an equipment malfunction or other operational problem. The hydrologic data from each monitoring station will then be imported directly into a database for subsequent analysis and archiving purposes. The database will be used to produce event-based hydrologic summary statistics (e.g., station runoff volume, storm precipitation total, storm duration) for each applicable monitoring location.

Analytical data for the project will be stored in a database with related event-based hydrologic summary statistics from each storm. EDDS that are received from the laboratory will be imported directly into the database to prevent data entry errors. For data that must be entered manually, the project Quality Assurance Coordinator (Table 1) will perform an independent review of the date entry to ensure that sample values were transcribed without error. Specifically, ten percent of the sample values will be randomly selected for rechecking and crosschecking with the laboratory analytical reports. If errors are detected, they will be corrected and then an additional 10 percent of the sample values will be selected for validation. This process will be repeated until no errors are found in the data.

Both the laboratory and WSU will retain project related data for 5 years after completion of the project.
Audits and Reports

During this study, routine audits of the compiled data will be performed to ensure this QAPP is being implemented correctly. In addition, the data from this study will be summarized in annual reports. The activities are described in more detail in the following subsections.

Audits

Audits will be performed to detect potential deficiencies in the hydrologic, water quality, and soil data that will be being collected for this project. Audits for hydrologic data will occur at least monthly and following each sampled storm event. In connection with these audits, the project Quality Assurance Coordinator (Table 1) will examine the new data collected from each monitoring location in relation to data from prior monitoring to identify potential QA issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies in the flow data. Any data generated from calibration checks that were performed at a particular monitoring location will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. In the event that QA issues are identified on the basis of these audits, the Quality Assurance Coordinator will immediately perform a site visit to troubleshoot the problem and to implement corrective actions if possible. Any QA issues that are detected through these audits will be documented in the electronic data record.

Audits performed for water quality and soil data will occur within seven days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Results from these audits will be documented in standardized quality assurance worksheets that will be prepared for each batch of samples. In the event that a potential quality assurance issue is identified through these audits, the Quality Assurance Coordinator for the study will review the data to determine if any response actions are required. Response actions might include the collection of additional samples or the reanalysis of existing. Any QA issues that are detected through these audits will be documented in the quality assurance worksheets.

Reports

Annual reports will be prepared through the course of this study to present compiled data, analysis results, and major study conclusions. Each report will summarize data from a specific water year (i.e., October through September) and include the following specific information:

- Results from hydrologic monitoring performed in connection with each treatment cell
- Results from water quality and soil sampling performed in connection with each treatment cell
- Graphical and tabular summaries for the collected data
- Results from any statistical analyses that are performed on the data
- Major conclusions from monitoring performed over the water year
- Appendices with tabular compilations of all raw monitoring data, field data sheets, laboratory analytical reports, chain of custody documentation, and the Data Quality Assurance Memorandum (see Data Quality Assessment section)

Finally, relevant raw water quality chemistry data from study will be submitted to Ecology in an electronic format (Excel file) that is suitable for upload to the Information Management System (EIM) database.
Data Verification and Validation

Data verification and validation will be performed to determine the quality of the compiled data. This process involves a detailed examination of the associated quality control results to determine if the MQOs specified in the Quality Assurance section have been met. The specific procedures that will be used to verify and validate hydrologic and chemistry data are described in the following sections.

Hydrologic Data Verification and Validation

The verification and validation process for hydrologic data will involve the following steps:

1. Precipitation data from the study will be reviewed to identify any significant gaps. If possible, these gaps will be filled using data obtained from a nearby rain gauge.

2. The available discharge data from each tipping bucket flow gauges and pressure transducer will be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events. Gross anomalies (e.g., data spikes), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are quality assurance issues associated with the data that limit their usability.

3. Results from field calibration checks (see Quality Assurance section) will be reviewed to determine if specific MQOs for the hydrologic data have been met (see Quality Objectives section).

4. If minor quality assurance issues are identified in any portion of the discharge record from a particular station and storm event, the data from that station and event will be considered as an estimate and assigned a (j) qualifier. If major quality assurance issues are identified in any portion of the data from a particular station and/or storm event, the data from that station and event will be rejected and assigned an (r) qualifier. Estimated values will be used for evaluation purposes while rejected values will not.

Water Quality and Soil Data Verification and Validation

Water quality data obtained for the study will be reviewed by the Quality Assurance Coordinator to verify that all samples were collected in accordance with the procedures identified in this QAPP and that all required quality assurance/quality control (QA/QC) information was provided by the laboratory. The Quality Assurance Coordinator will then examine the data to determine if
there were any errors or omissions. Finally, the Quality Assurance Coordinator will validate the data by comparing the laboratory quality QA/QC results to the specific MQOs that were established for the study (see Quality Objectives section).

For soil data, values associated with minor quality control problems will be considered estimates and assigned J. Values associated with major quality control problems will be rejected and qualified R. Estimated values may be used for evaluation purposes, while rejected values will not be used.

For water quality data, each flow-weighted composite is interpreted to represent the mean concentration for the sampled storm event. However, flow gauge or laboratory error can lead to compromised data which is not representative of the target population (i.e., the true flow-weighted mean concentration of the targeted storm hydrograph). Therefore, the water quality data collected for this study will be labeled with unique quality assurance flags for both laboratory and field data QA issues. Table 13 presents the flagging scheme that will be used in reports produced for this project. Again, estimated values may be used for evaluation purposes, while rejected values will not be used.

<table>
<thead>
<tr>
<th>Data Qualifier</th>
<th>Definition</th>
<th>Criteria for Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Value is an estimate based on analytical results.</td>
<td>MQOs for field duplicates, laboratory duplicates, matrix spikes, laboratory control samples, holding times, or blanks have not been met.</td>
</tr>
<tr>
<td>R</td>
<td>Value is rejected based on analytical results.</td>
<td>Major quality control problems with the analytical results.</td>
</tr>
<tr>
<td>j</td>
<td>Value is an estimate based on storm sampling criteria.</td>
<td>Hydrograph is compromised from gage error, but is still deemed an adequate estimate.</td>
</tr>
<tr>
<td>r</td>
<td>Value is rejected based on storm sampling criteria.</td>
<td>Hydrograph is compromised from gage error, and has rendered the EMC non-representative.</td>
</tr>
<tr>
<td>Jj</td>
<td>Value is an estimate based on analytical results and storm sampling criteria.</td>
<td>Analytical and storm sampling criteria have not been met, but data is still usable.</td>
</tr>
<tr>
<td>Jr</td>
<td>Value is an estimate based on analytical results and rejected based on storm sampling criteria.</td>
<td>Analytical criteria have not been met but data still usable; Hydrograph is compromised from gage error, and has rendered the EMC non-representative.</td>
</tr>
<tr>
<td>U</td>
<td>Value is below the reporting limit.</td>
<td>Based on laboratory method reporting limit.</td>
</tr>
<tr>
<td>UJ</td>
<td>Value is below the reporting limit and is an estimate based on analytical results.</td>
<td>Based on laboratory method reporting limit; MQOs for analytical results have not been met.</td>
</tr>
<tr>
<td>Ur</td>
<td>Value is below the reporting limit and is rejected based on storm sampling criteria.</td>
<td>Based on laboratory method reporting limit; Hydrograph is compromised from gage error, and has rendered the EMC non-representative.</td>
</tr>
<tr>
<td>Uj</td>
<td>Value is below the reporting limit and is an estimate based on storm sampling criteria.</td>
<td>Based on laboratory method reporting limit; Analytical and storm sampling criteria have not been met, but data is still usable.</td>
</tr>
</tbody>
</table>

EMC: event mean concentration
MQO: method quality objective
The following sections describe in detail the data validation procedures for these specific quality control elements:

- Completeness
- Methodology
- Holding times
- Blanks
- Reporting limits
- Duplicates
- Matrix spikes and matrix spike duplicates
- Calibration and control standards

**Completeness**

Completeness will be assessed by comparing valid sample data with the data collection goals identified in this QAPP. Completeness will be calculated by dividing the number of valid values by the total number of expected values. Additional samples may be collected if completeness does not meet the specified MQO in the *Quality Objectives* section.

**Methodology**

Methodologies for analytical procedures will follow U.S. EPA approved methods specified in Tables 9 and 10. Field procedures will follow the methodologies described in this quality assurance project plan. Any deviations from these methodologies must be approved by Ecology and documented in an addendum to this QAPP. The project database will include a field for identifying analytical method. Deviations that are deemed unacceptable will result in rejected values (R) and will be corrected for future analyses.

**Holding Times**

Holding times for each analytical parameter in this study are summarized in Tables 9 and 10. Filtration and analysis dates and times will be reported by the laboratory. Holding times will be assessed by comparing the filtration and analysis dates and times to the sample collection dates and times. For flow waited composite samples, the sample collection date and time will be defined based on the data and time the last sample aliquot was collected.

The following guidelines will be applied when evaluating analysis holding times for parameters with holding times in excess of 7 days:

- Data from samples that exceed the specified maximum post-filtration holding times by less than 48 hours will be considered estimates (J).
- Data from samples that exceed the maximum post-filtration holding times by more than 48 hours will be rejected values (R).
The following guidelines will be applied when evaluating holding times for parameters with holding times that are less than 7 days:

- Data from samples that exceed the specified maximum post-filtration holding times by less than 24 hours will be considered estimates ($J$).
- Data from samples that exceed the maximum post-filtration holding times by more than 24 hours will be rejected values ($R$).

**Method Blanks**

Method blank values will be compared to the MQOs that have been identified for this project (see *Quality Objectives* section). If an analyte is detected in a method blank at or below the reporting limit, no action will be taken. If blank concentrations are greater than the reporting limit, the concentration measured in the blanks will become the de facto reporting limit for that analyte. Any sample concentrations below this de facto limit will be flagged with a $U$, while sample concentrations within 5 times this de facto reporting limit will be flagged with a $J$ (Grepogrove 2007). In each case, the de facto reporting limit for that analyte will be recorded with the raw data instead of the method reporting limit.

**Rinsate Blanks**

Rinsate blank values will be compared to the MQOs that have been identified for this project (see *Quality Objectives* section). If an analyte is detected in a rinsate blank at concentrations that exceed 2 times the reporting limit, the concentration measured in the blank will become the de facto reporting limit for that analyte for all samples collected at that station since the last rinsate blank was collected. Any sample concentrations below this de facto limit will be flagged with a $U$, and sample concentrations within 5 times this de facto reporting limit will be flagged with a $J$ (Grepogrove 2007). In each case, the de facto reporting limit for that analyte will be recorded with the raw data instead of the method reporting limit. In addition, the sampling lines for all automated samplers will be cleaned or replaced. Finally, the laboratory will be contacted to evaluate the adequacy of bottle cleaning procedures.

**Reporting Limits**

Both raw values and reporting limits will be presented in each laboratory report. If the proposed reporting limits are not met by the laboratory, the laboratory will be requested to reanalyze the samples and/or revise the method, if time permits. Proposed reporting limits for this project are summarized in Tables 9 and 10.

**Duplicates**

Duplicate results exceeding the MQOs for this project (see *Quality Objectives* section) will be recorded in the raw data tables, and noted in the quality assurance worksheets; and associated
values will be flagged as estimates (J). If the objectives are severely exceeded (e.g., more than twice the objective), then associated values will be rejected (R).

**Matrix Spikes**

Matrix spike results exceeding the MQOs for this project (see Quality Objectives section) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (J). However, if the percent recovery exceeds the MQOs and a value is less than the reporting limit, the result will not be flagged as an estimate. Non-detected values will be rejected (R) if the percent recovery is less than 30 percent.

**Control Standards**

Control standard results exceeding the MQOs for this project (see Quality Objectives section) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (J). If the objectives are severely exceeded (e.g., more than twice the objective), then associated values will be rejected (R).
Data Quality Assessment

The subsection below describes the process for determining whether the data meet project objectives once the data results are compiled. Data analysis procedures that will be used to meet these objectives are then summarized in the following subsection.

Data Usability Assessment

Based on the results from the processes described in the Data Verification and Validation section, the Quality Assurance Coordinator will prepare annual Data Quality Assurance Memoranda to summarize quality control results, identify when data quality objectives were not met, and discuss the resulting limitations, if any, on the use or interpretation of the data. Specific QA information that will be noted in each data validation memorandum is as follows:

- Changes in the monitoring and quality assurance plan
- Results of performance and/or system audits
- Significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact (if any) on decision-making
- Limitations on use of the measurement data

These Data Quality Assurance Memoranda will establish the usability of data and will be included as an appendix to data reports (see Audits and Reports section) that are prepared for each water year.

Data Analysis Procedures

The sections below present data analysis procedures that will be used to evaluate the flow control and water quality treatment performance of the permeable pavement.

Flow Control Performance

To evaluate the flow control performance of the permeable asphalt, the following information will be compiled from individual storm events for each treatment cell:
Storm precipitation depth
Storm duration
Storm average precipitation intensity
Storm peak precipitation intensity
Storm antecedent dry period
Flow volumes, peak discharge rates, and flow durations measured at surface drains for MIACs
Flow volumes, peak discharge rates, and flow durations measured at underdrains for MPACs and UPACs
Flow volumes measured during select storm events at elevated drains and surface drains for MPACs and UPACs

Once this information is compiled, additional analyses will be performed to identify a subset of storms that had sufficient precipitation totals and/or intensities to produce measurable runoff from the treatment cells. Specifically, any storm event that produced a measurable flow volume at the surface drains for MIACs will be flagged as runoff-producing.

Statistical analyses will then be performed on the data from the runoff-producing storms to compare flow control performance of the various treatment cells. The specific null hypotheses (H₀) and alternative hypotheses (Hₐ) for these analyses is as follows:

Hypothesis 1:
H₀: Surface runoff volumes from the UPACs and MPACs are equal to or higher than those from the MIACs.
Hₐ: Surface runoff volumes from the UPACs and MPACs are less than those from the MIACs.

Hypothesis 2:
H₀: Peak discharge rates measured at the underdrains for the UPACs, and MPACs are equal to or higher than those at the surface drains the MIACs.
Hₐ: Peak discharge rates measured at the underdrains for the UPACs, and MPACs are lower than those at the surface drains the MIACs.

Hypothesis 3:
H₀: Flow durations measured at the underdrains for the UPACs, and MPACs are equal to or higher than those at the surface drains the MIACs.
Hₐ: Flow durations measured at the underdrains for the UPACs, and MPACs are lower than those at the surface drains the MIACs.
Hypothesis 4:

\[ H_0: \text{Surface runoff volumes from MPACs are equal to or higher than those from the UPACs.} \]
\[ H_a: \text{Surface runoff volumes from MPACs are less than those from the UPACs.} \]

To evaluate these hypotheses, the data for each measure of treatment performance (i.e., flow duration, peak flow rate, and flow duration) will be analyzed using Analysis of Variance (ANOVA) tests (or a non-parametric analogue) to determine if there are significant differences between the treatment cells. Where significant differences are detected through these tests, follow-up multiple range tests will be applied to the data to determine which specific treatment cells are different from the others. In all tests, statistical significance will be assessed based on an alpha (\(\alpha\)) level of 0.05.

Water Quality Treatment Performance

Data analyses will be performed to evaluate the water quality treatment performance of the permeable asphalt following procedures identified by Ecology (2008). In these analyses, pollutant concentrations and loads in runoff from the permeable and impermeable asphalt will be compared to determine if the permeable asphalt meets the following treatment goals identified in Ecology (2008):

- **Basic Treatment** – 80 percent removal of TSS for influent concentrations that are greater than 100 milligrams/liter (mg/L), but less than 200 mg/L. For influent concentrations greater than 200 mg/L, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/L, the facilities are intended to achieve an effluent goal of 20 mg/L TSS.

- **Enhanced Treatment** – Provide a higher rate of removal of dissolved metals than most basic treatment facilities. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/L, and dissolved zinc ranging from 0.02 to 0.3 mg/L. Data collected for an “enhanced” best management practice (BMP) should demonstrate significantly higher removal rates than basic treatment facilities.

- **Phosphorus Treatment** – 50 percent removal of TP for influent concentrations ranging from 0.1 to 0.5 mg/L.

- **Oil Treatment** – No ongoing or recurring visible sheen, a daily average total petroleum hydrocarbon concentration no greater than 10 mg/L, and a maximum of 15 mg/L for a discrete (grab) sample.

These treatment goals are to be evaluated with a 95 percent statistical confidence and 80 percent power. The specific procedures that will be used in the evaluation of these goals are as follows:
- Statistical comparison of pollutant concentrations and loads in runoff from the impermeable and permeable asphalt, respectively
- Calculation and evaluation of pollutant reduction efficiencies
- Evaluation of pollutant reduction efficiencies relative to efficiencies for representative basic treatment facilities
- Evaluation of effluent concentrations
- Correlation analysis to examine the influence of storm characteristics on treatment performance

Each of these procedures is described in more detail in the following subsections.

**Statistical Comparisons of Influent and Effluent Pollutant Concentrations and Loads**

Statistical analyses will be performed to determine if there are significant differences in pollutant concentrations and loads in runoff from impermeable and permeable asphalt, respectively. The specific null hypothesis ($H_0$) and alternative hypothesis ($H_a$) for these analyses are as follows:

**Hypothesis 1:**

$H_0$: Pollutant concentrations and loads measured in surface drains for the UPACs and MPACs are equal to or higher than those measured in surface drains for the MIACs.

$H_a$: Pollutant concentrations and loads measured in surface drains for the UPACs, and MPACs are less than those measured in surface drains for the MIACs.

**Hypothesis 2:**

$H_0$: Pollutant concentrations and loads measured in elevated drains for the UPACs and MPACs are equal to or higher than those measured in surface drains for the MIACs.

$H_a$: Pollutant concentrations and loads measured in elevated drains for the UPACs, and MPACs are less than those measured in surface drains for the MIACs.

**Hypothesis 3:**

$H_0$: Pollutant concentrations and loads measured in underdrains for the UPACs and MPACs are equal to or higher than those measured in surface drains for the MIACs.

$H_a$: Pollutant concentrations and loads measured in elevated drains for the UPACs, and MPACs are less than those measured in surface drains for the MIACs.
Hypothesis 3:

\[ H_0: \text{Aggregate pollutant load measured in surface drains, elevated drains, and underdrains for the UPACs and MPACs are equal to or higher than those measured in surface drains for the MIACs.} \]

\[ H_a: \text{Aggregate pollutant loads measured in surface drains, elevated drains, and underdrains for the UPACs and MPACs are less than those measured in surface drains for the MIACs.} \]

To evaluate these hypotheses, pollutant concentrations and loads from the treatment cells will be analyzed using Analysis of Variance (ANOVA) tests (or a non-parametric analogue) to determine if there are significant differences between the treatment cells. Where significant differences are detected through these tests, follow-up multiple range tests will be applied to the data to determine which specific treatment cells are different from the others. In all tests, statistical significance will be assessed based on an alpha (\(\alpha\)) level of 0.05.

**Calculation and Evaluation of Pollutant Reduction Efficiencies**

Pollutant reduction efficiencies for permeable asphalt treatment cells will be quantified relative to the impermeable asphalt treatment cells using the methods described below.

**Method #1: Individual Storm Reduction in Pollutant Concentration**

The reduction (in percent) in pollutant concentration during each individual storm (\(\Delta C\)) will be calculated as:

\[
\Delta C = 100 \times \left(\frac{C_{iperm} - C_{perm}}{C_{perm}}\right)
\]

Where:

- \(C_{iperm}\) = pollutant concentration measured in surface drain from the MIACs
- \(C_{perm}\) = pollutant concentration measured in surface drains, elevated drains, or underdrains for MPACs and UPACs

For TSS and total phosphorus, the median percent reduction in concentrations and associated 95 percent confidence interval about the median will be estimated using a bootstrapping approach (Helsel and Hirsch 2002). The lower confidence interval about the median for each parameter will then be used to determine whether the treatment goals identified above for basic and phosphorus treatment have been met. Specifically, if the lower confidence limit is higher than the specified removal efficiency goals for each treatment category, it can be concluded that the treatment goal was met with the required 95 percent confidence that is specified in Ecology (2008).
Method #2: Individual Storm Reduction in Pollutant Loading

Pollutant load reduction (in percent) in individual storms ($\Delta L$) will be calculated as:

$$\Delta L = 100 \times \frac{\left( \frac{C_{iperm} \times V_{iperm}}{C_{perm} \times V_{perm}} \right) - \left( \frac{C_{perm} \times V_{perm}}{C_{perm} \times V_{perm}} \right)}{\left( \frac{C_{perm} \times V_{perm}}{C_{perm} \times V_{perm}} \right)}$$

Where:
- $C_{iperm} =$ pollutant concentration measured in surface drain from the MIACs, and
- $V_{iperm} =$ flow volume measured in surface drain from the MIACs, and
- $C_{perm} =$ pollutant concentration measured in surface drain, elevated drain, or underdrain for MPACs and UPACs, and
- $V_{perm} =$ flow volume measured in surface drain, elevated drain, or underdrain for MPACs and UPACs

Like the Method #1 calculations above, the median percent reduction in loads for TSS and total phosphorus will be estimated using a bootstrapping approach along with the associated 95 percent confidence interval about the median (Helsel and Hirsch 2002). The lower confidence interval about the median will then be compared to the treatment goals identified above for basic and phosphorus treatment to determine if they have been met with the required 95 percent confidence that is specified in Ecology (2008).

Evaluation of Pollutant Reduction Efficiencies Relative to Efficiencies for Representative Basic Treatment Facilities

As described above, the Ecology (2008) indicates that the data collected for an “enhanced” BMP should demonstrate significantly higher removal rates for dissolved metals than basic treatment facilities. To determine if any of the asphalt permeable pavement meets this goal with a specific level of statistical confidence, a one-tailed Mann Whitney U test will be used to compare reduction efficiencies for dissolved zinc and dissolved copper to the representative reduction efficiencies for basic treatment facilities that are in the International Stormwater Best Management Practices Database (ASCE 2009). The specific null and alternate hypotheses that will be assessed in these tests are as follows:

- **Ho:** Asphalt permeable pavement reductions efficiencies are equal to or lower than those for basic treatment facilities.
- **Ha:** Asphalt permeable pavement reductions efficiencies are greater than those for basic treatment facilities.

Pursuant to the guidelines in Ecology (2008), statistical significance in these tests will be evaluated at an alpha ($\alpha$) level of 0.10.
Evaluation of Effluent Concentrations

To evaluate the treatment goals identified above for TSS and oil control that are based on target effluent concentrations, the median effluent concentration for the associated parameters will be estimated using a bootstrapping approach (Helsel and Hirsch 2002) along with the 95 percent confidence interval about the median. The upper confidence interval about the median for each parameter will then be used to determine whether the treatment goals identified have been met. Specifically, if the upper confidence limit is lower than the specified effluent concentration goals for each treatment category, it can be concluded that the treatment goal was met with the required 95 percent confidence that is specified in Ecology (2008).

Correlation Analysis to Examine Influence of Storm Characteristics

Kendall’s tau correlation coefficients will be used to evaluate whether the following storm event characteristics influence the treatment performance of the asphalt permeable pavement:

- Storm precipitation depth
- Storm average intensity
- Storm peak intensity
- Storm antecedent dry period
- Storm duration
- Peak influent discharge
- Average influent discharge
- Sample date

These tests will specifically examine potential relationships between these storm event characteristics and the following variables that either directly measure or indirectly influence system performance: influent concentration, effluent concentration, and pollutant removal efficiency estimates. In all cases, the statistical significance of these tests was evaluated at an alpha level (α) of 0.05.
References


APPENDIX A

Project Funding Details
<table>
<thead>
<tr>
<th>ELEMENTS (Tasks or Objects)</th>
<th>TOTAL PROJECT COST (TPC)</th>
<th>TOTAL ELIGIBLE COST (TEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Project Management</td>
<td>$133,500</td>
<td>$95,000</td>
</tr>
<tr>
<td>2 – Environmental Assessment and Project Design</td>
<td>$84,107</td>
<td>$84,107</td>
</tr>
<tr>
<td>3 – Plans and Specifications</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>4 – Construction Management</td>
<td>$40,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>5 – Construction of LID Integrated Management</td>
<td>$844,140</td>
<td>$785,726</td>
</tr>
<tr>
<td>6 – LID Monitoring and Analysis; Training, Education and Outreach</td>
<td>$228,500</td>
<td>$228,500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,430,247</strong></td>
<td><strong>$1,333,333</strong></td>
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The DEPARTMENT's Fiscal Office will track to the Total Eligible Cost.

**MATCHING REQUIREMENTS**

<table>
<thead>
<tr>
<th>DEPARTMENT Share: maximum 75% of TEC</th>
<th>$1,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>RECIPIENT Share: minimum 25% of TEC</td>
<td>$333,333</td>
</tr>
</tbody>
</table>

RECIPIENT Share of ineligible project costs:
Funding source: Cash

$96,914
APPENDIX B

Detailed Specifications for Pervious Asphalt and Pervious Concrete
Table B-1. Pervious asphalt specification.

<table>
<thead>
<tr>
<th>Material</th>
<th>3/8&quot; (#4)</th>
<th>#4-#8 sand</th>
<th>#4-0</th>
<th>#8-#30 sand</th>
<th>Combined Gradation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>68%</td>
<td>14%</td>
<td>12%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>99.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>99</td>
</tr>
<tr>
<td>U.S. #4</td>
<td>10.0</td>
<td>73.0</td>
<td>89.0</td>
<td>100.0</td>
<td>34</td>
</tr>
<tr>
<td>U.S. #8</td>
<td>2.0</td>
<td>6.0</td>
<td>54.0</td>
<td>75.0</td>
<td>13</td>
</tr>
<tr>
<td>U.S. #14</td>
<td>1.8</td>
<td>3.0</td>
<td>35.8</td>
<td>46.0</td>
<td>9</td>
</tr>
<tr>
<td>U.S. #30</td>
<td>1.5</td>
<td>1.0</td>
<td>24.3</td>
<td>22.0</td>
<td>5</td>
</tr>
<tr>
<td>U.S. #50</td>
<td>1.0</td>
<td>0.6</td>
<td>17.2</td>
<td>4.0</td>
<td>3</td>
</tr>
<tr>
<td>U.S. #100</td>
<td>0.9</td>
<td>0.4</td>
<td>13.5</td>
<td>1.0</td>
<td>2</td>
</tr>
<tr>
<td>U.S. #200</td>
<td>0.7</td>
<td>0.2</td>
<td>10.5</td>
<td>0.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Recommended</td>
</tr>
<tr>
<td>Percent Binder by Total Mix Weight</td>
<td>6.00%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Binder by Dry Agg Weight</td>
<td>6.38%</td>
<td>5.75 – 6.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Voids (Va)</td>
<td>21.9</td>
<td>16 - 25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain Down at Mix Temperature</td>
<td>0.1%</td>
<td>&lt;0.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D6390-05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain down Above Mix Temperature</td>
<td>0.2%</td>
<td>&lt;0.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D6390-05 (18°F) above</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B-2. Pervious concrete specification.

<table>
<thead>
<tr>
<th>Material</th>
<th>Batch Weight</th>
<th>Material Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8” (ASTM 8)</td>
<td>2,750.00 lbs</td>
<td>16.32</td>
</tr>
<tr>
<td>Lafarge Type I-II (cement)</td>
<td>510.00 lbs</td>
<td>2.59</td>
</tr>
<tr>
<td>Water</td>
<td>130.00 lbs</td>
<td>1.08</td>
</tr>
<tr>
<td>Air (design)</td>
<td>18.00%</td>
<td>4.86</td>
</tr>
<tr>
<td>Viscosity modifier (Rheomac VMA358)</td>
<td>95.00 lbs</td>
<td>0.10</td>
</tr>
<tr>
<td>Retarder (Delvo)</td>
<td>27.00 oz</td>
<td>0.03</td>
</tr>
<tr>
<td>Fibermesh 150 (Stealth)</td>
<td>1.00 lb</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Cement may be as high as 530 lbs depending on grading of aggregate
APPENDIX C

Equipment Specification Sheets
Isco's 6700 Series Portable Samplers have set the industry standard, providing the most comprehensive and durable performance available. With the introduction of our new 6712, Isco takes another step toward the ultimate by including SDI-12 interface capabilities.

This full-size portable lets you take full advantage of the advanced 6712 Controller, with its powerful pump, versatile programming, and optional plug-in modules for integrated flow measurement. Setup is fast and simple, with online help just a key stroke away.

The environmentally-sealed 6712 controller delivers maximum accuracy and easily handles all of your sampling applications, including:

- Flow-paced sampling with or without wastewater effluent
- stormwater monitoring
- CSO monitoring
- permit compliance
- pretreatment compliance

In the Standard Programming Mode, the controller walks you through the sampling sequence step-by-step, allowing you to choose all parameters specific to your application. Selecting the Extended Programming Mode lets you enter more complex programs.

Optional land-line and GSM and CDMA cellular telephone modems allow programming changes and data collection to be performed remotely, from a touch-tone phone. They also provide dial-out alarm.

Versatile and Convenient

With eleven bottle choices, Isco's 6712 Sampler lets you quickly adapt for simple or intricate sampling routines. Up to 30 pounds (13.5 kg) of ice fits in the insulated base, preserving samples for extended periods, even in extreme conditions. The 6712 with the “Jumbo Base” option holds bottles up to 5.5 gallon (21 liter).

Tough and Reliable

The 6712 Portable Sampler features a vacuum-formed ABS plastic shell to withstand exposure and abuse. Its tapered design and trim 20-inch (50.8 cm) diameter result in easy manhole installation and removal. Large, comfortable handles make transporting safe and convenient—even when wearing gloves.

Isco's 6712 Portable Sampler carries a NEMA 4X, 6 (IP67) enclosure rating.

Superior capability, rugged construction, and unmatched reliability make the 6712 the ideal choice for portable sampling in just about any application.
Specifications

**Isco 6712 Full-size Portable Sampler**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (Height x Diameter):</td>
<td>27 x 20 inches (50.7 x 68.6 cm)</td>
</tr>
<tr>
<td>Weight:</td>
<td>Dry, less battery - 32 lbs (15 kg)</td>
</tr>
<tr>
<td>Bottle configurations:</td>
<td>24 - 1 liter PP or 350 ml Glass &lt;br&gt; 24 - 1 liter ProPak Disposable Sample Bags &lt;br&gt; 12 - 1 liter PE or 950 ml Glass &lt;br&gt; 8 - 2 liter PE or 1.8 liter Glass &lt;br&gt; 4 - 3.8 liter PE or Glass &lt;br&gt; 1 - 5.5 liter (21 Liter) PE or 5 gallon (19 Liter) Glass, (with optional Jumbo Base)</td>
</tr>
<tr>
<td>Power Requirements:</td>
<td>12 V DC (Supplied by battery or AC power converter)</td>
</tr>
</tbody>
</table>

**Pump**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake suction tubing:</td>
<td>3 to 99 feet (1 to 30 m)</td>
</tr>
<tr>
<td>Material</td>
<td>Vinyl or Teflon</td>
</tr>
<tr>
<td>Inside dimension</td>
<td>3/8 inch (1 cm)</td>
</tr>
<tr>
<td>Pump tubing life:</td>
<td>Typically 1,000,000 pump counts</td>
</tr>
<tr>
<td>Maximum lift:</td>
<td>28 feet (8.5 m)</td>
</tr>
<tr>
<td>Typical Repeatability</td>
<td>±5 ml or ±5% of the average volume in a set</td>
</tr>
<tr>
<td>Typical line velocity at Head height: of</td>
<td>3.0 ft./s (0.91 m/s) &lt;br&gt; 2.9 ft./s (0.87 m/s) &lt;br&gt; 2.7 ft./s (0.83 m/s)</td>
</tr>
<tr>
<td>Liquid presence detector:</td>
<td>Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.</td>
</tr>
</tbody>
</table>

**Controller**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight:</td>
<td>13 lbs. (5.9 kg)</td>
</tr>
<tr>
<td>Size (HxWxD):</td>
<td>10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)</td>
</tr>
<tr>
<td>Operational temperature:</td>
<td>32° to 120°F (0° to 49°C)</td>
</tr>
<tr>
<td>Enclosure rating:</td>
<td>NEMA 4X, 6 (IP67)</td>
</tr>
<tr>
<td>Program memory:</td>
<td>Non-volatile ROM</td>
</tr>
<tr>
<td>Flow meter signal input:</td>
<td>5 to 15 volt DC pulse or 25 millisecond isolated contact closure.</td>
</tr>
<tr>
<td>Number of composite samples:</td>
<td>Programmable from 1 to 999 samples.</td>
</tr>
<tr>
<td>Clock Accuracy:</td>
<td>1 minute per month, typical, for real time clock</td>
</tr>
</tbody>
</table>

**Software**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample frequency:</td>
<td>1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses</td>
</tr>
<tr>
<td>Sampling modes:</td>
<td>Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)</td>
</tr>
<tr>
<td>Programmable sample volumes:</td>
<td>10 to 9,990 ml in 1 ml increments</td>
</tr>
<tr>
<td>Sample retries:</td>
<td>If no sample is detected, up to 3 attempts; user selectable</td>
</tr>
<tr>
<td>Rinse cycles:</td>
<td>Automatic rinsing of suction line up to 3 rinses for each sample collection</td>
</tr>
<tr>
<td>Program storage:</td>
<td>5 sampling programs</td>
</tr>
<tr>
<td>Sampling Stop/Resume:</td>
<td>Up to 24 real time/date sample stop/resume commands</td>
</tr>
<tr>
<td>Controller diagnostics:</td>
<td>Tests for RAM, ROM, pump, display, and distributor</td>
</tr>
</tbody>
</table>

**Ordering Information**

**Note:** Power source, bottle configuration, suction line, and strainer must be ordered separately. Many options and accessories are available for 6712 Samplers; see separate literature for 700 Series Modules and other components to expand your monitoring capabilities. Contact Isco, or your Isco representative for pricing and additional information.

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>6712 Portable Sampler, Full-size</td>
<td>68-6710-070</td>
</tr>
<tr>
<td>Includes controller with 512kB RAM, top cover, center section, base, distributor arm, instruction manual, pocket guide.</td>
<td></td>
</tr>
<tr>
<td>6712 Portable Sampler, with Jumbo Base</td>
<td>68-6710-082</td>
</tr>
<tr>
<td>As described above</td>
<td></td>
</tr>
</tbody>
</table>

Teledyne Isco, Inc.
4700 Superior Street
Lincoln NE 68504 USA
Phone: (402) 464-0231
USA and Canada: (800) 228-4373
Fax: (402) 465-3022
E-Mail: iscoinfo@teledyne.com
Internet: www.isco.com

*Teledyne Isco, Inc. reserves the right to change specifications without notice.*

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SDM-IO16
16-Channel I/O Expansion Module

The SDM-IO16’s 16 digital I/O ports function similarly to the control ports included on the majority of our dataloggers. When configured as an input, each port can monitor logic state, count pulses, measure signal frequency, and determine duty cycle. An option in the pulse counting mode enables switch debounce filtering, allowing the SDM-IO16 to accurately count switch closures. The SDM-IO16 can also be programmed to send an interrupt signal to the datalogger when one or more input signals change state.

When configured as an output, each port can be set to 0 or 5 V by the datalogger. A ‘boost’ circuit allows an output that is set HI to source a current of up to 100 mA for controlling external devices such as low voltage valves or relays.

SDM Operation
The SDM-IO16 is a synchronously addressed datalogger peripheral. Three ports on the datalogger are used to address the SDM-IO16. Advanced error checking techniques ensure correct data transmission to and from the SDM-IO16. Up to sixteen SDM-IO16 modules can be addressed allowing up to 256 ports to be controlled by the datalogger.

Datalogger Connection
The CABLE5CBL-L is recommended for connecting the module to the datalogger. A 1-ft cable length should be sufficient when both datalogger and SDM-IO16 are housed within an ENC12/14 enclosure; a 2-ft length may be required if the datalogger and SDM-IO16 are housed at opposite ends of an ENC16/18 Enclosure.

The cable length should be as short as possible. Typically, the maximum cable length is 20 ft. Contact Campbell Scientific if the length needs to be longer.

Compatible Dataloggers
All of the functions are supported by our CR800, CR850, CR1000, CR3000, CR5000 CR10X (OS 1.17 or later) and CR23X (OS 1.14 or later) dataloggers. Several of our dataloggers support the output mode only. These dataloggers include our CR7, CR10, and 21X. Please note that the SDM-IO16 is not compatible with the CR200-series, CR9000(X), CR500, or CR510 dataloggers.

Software Requirements
Support for all the functions requires CRBasic’s SDMIO16 instruction or Edlog’s Instruction 188. Instruction 188 is available in Edlog templates that post date March 2002 (LoggerNet version 2.1 contains this template). Edlog templates that predate March 2002 can support only the output mode using Instruction 104. The SDMCD16AC instruction supports only the output mode in CRBasic.

Power Considerations
The datalogger’s rechargeable power supply can power the SDM-IO16 for most pulse counting or status input applications. However, when driving loads, the SDM-IO16 power requirements may be large compared to most Campbell Scientific products. For these applications, an external power supply is recommended.

Mounting
Mounting brackets are provided for attaching the SDM-IO16 to the backplate of an ENC12/14 or larger enclosure.

Ordering Information

<table>
<thead>
<tr>
<th>Synchronous Device for Measurement</th>
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<tr>
<td>SDM-IO16</td>
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</tbody>
</table>

SDM-to-Datalogger Cable
CABLE5CBL-L 5-conductor, 24 AWG cable with drain wire and Santoprene jacket. Enter cable length, in feet, after the -L. Must choose a cable termination option (see below).

<table>
<thead>
<tr>
<th>Cable Termination Options (choose one)</th>
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<tbody>
<tr>
<td>PT</td>
</tr>
<tr>
<td>PW</td>
</tr>
</tbody>
</table>
### Specifications

**SDM and I/O Port:**
- 0/5 V logic level ports for connecting to the data-logger's control/SDM ports

**EMC Status:**
- Complies with EN 61326:1997

### Power

**Operating Voltage:**
- 12 Vdc (nominal 9 to 18 V)

**Current Drain**

| Typical Standby (assumes all ports high, no load, excludes pulse counting) | 600 μA |
| Maximum (active with all 16 ports counting pulses at 2 kHz and no output load) | 3 mA |

**Typical Standby:**

| Current Drain | 600 μA |
| Maximum | 3 mA |

**Voltage (no load):**

- **ON/HI:** nomial 5 V, minimum 4.5 V
- **OFF/LO:** nominal 0 V, maximum 0.1 V

**Sink Current:**
- Output will sink 8.6 mA from a 5 V source

**Source Current:**
- Output will source 42 mA at 3 V; 133 mA short-circuited to ground

**Maximum Current (total all outputs):**
- Limited by 12 V supply

### Input

**Voltage**

- **High:** 4.0 V minimum threshold
- **Low:** 1.0 V maximum threshold

**Protection:**
- Input clamped at -0.6 V and ±5.6 V relative to ground via a 33 ohm resistor to withstand a continuous current flow of 200 mA

**Source Current:**
- Output will source 42 mA at 3 V; 133 mA short-circuited to ground

**Impedance:**
- Biased to +5 V relative to ground by a 100 kohm resistor

### Pulse Counting

**Maximum Frequency:**
- 2.0 kHz on all channels simultaneously with switch debounce-mode turned off with a 50/50 duty cycle.
- 150 Hz on all channels with default switch debounce mode enabled and a 50/50 duty cycle.

**Minimum frequency:**
- 0 Hz is reported if there are less than two high-to-low signal transitions in the measurement interval.

**Minimum Pulse Width:**
- 244 μs

### Default Switch

**Debounce Timing:**
- Input and ground must remain closed for 3.17 ms then remain open for 3.17 ms to be counted as a closure

### Internal Clock Accuracy

(--25°C to +50°C):
- ±0.01%, worst case

**Max. Measurement Interval:**
- 15.9375 s

### Physical

**Operating Temperature:**
- -25°C to +50°C

**Dimensions:**
- 9 in. x 4 in. x 1 in.; 23.0 cm x 10.0 cm x 2.4 cm

**Weight:**
- 12 oz (350 g)

---

1Current consumption is roughly proportional to input signal frequency and number of ports used. Current drawn from any output must be added to the quiescent level to obtain the total current drain.
CR1000 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that the system configuration and critical specifications are confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE
10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS
8 differential (DF) or 16 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM252 multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. Resolution of DF measurements with input reversal is half the Basic Res.

Input Referred Noise Voltage

<table>
<thead>
<tr>
<th>Input Range (mV)</th>
<th>Basic Res (µV)</th>
<th>DF Basic Res (µV)</th>
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</thead>
<tbody>
<tr>
<td>±5000</td>
<td>667</td>
<td>333</td>
</tr>
<tr>
<td>±2500</td>
<td>333</td>
<td>166</td>
</tr>
<tr>
<td>±250</td>
<td>33.3</td>
<td>16.6</td>
</tr>
<tr>
<td>±25</td>
<td>3.33</td>
<td>1.66</td>
</tr>
<tr>
<td>±7.5</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>±2.5</td>
<td>0.33</td>
<td>0.16</td>
</tr>
</tbody>
</table>

1Resolution of DF measurements with input reversal.

ACCURACY:

±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

1Resolution of all ranges to guarantee that full-scale values will not cause over-range.

OFFSET:

Offset values are reduced by a factor of 2 when full-scale values will not cause over-range.

INPUT NOISE VOLTAGE:

±0.3°C, -25° to 50°C

RANGING AND RESOLUTION:

Choice of DF measurements with input reversal includes two integrations with recorded offsets, which full-scale values will not cause over-range.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution).

MAXIMUM CUMULANTS PER SCAN: 16 x T^6

CHEMICALS

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERESIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V

One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT

Control ports 1, 3, 5, and 7 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE

UNDER (S)TANDARD(S) WHICH CONFORMITY IS DECLARED: IEC61132:2002

CPU AND INTERFACE

PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage.

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

PARALLEL INTERFACE: 40-pin interface for attaching data storage or communication peripherals such as the CFM100 module.

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc (reverse polarity protected)

TYPICAL CURRENT DRAIN:

Sleep Mode: ~0.6 mA

1 Hz Scan (8 diff. meas., 60 Hz rej., 2 pulse meas.) w/RS-232 communication: 19 mA w/o RS-232 communication: 4.2 mA
1 Hz Scan (8 diff. meas., 250 µs integ., 2 pulse meas.) w/RS-232 communication: 16.7 mA w/o RS-232 communication: 1 mA
100 Hz Scan (4 diff. meas., 250 µs integ.) w/RS-232 communication: 27.6 mA w/o RS-232 communication: 16.2 mA

CR1000KD CURRENT DRAIN:

Inactive: negligible
Active w/backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal

PHYSICAL SPECIFICATIONS

MEASUREMENT & CONTROL MODULE SIZE:

8.5 x 3.9 x 0.85 (21.6 x 9.9 x 2.2 cm)

CR1000DP WIRING PANEL SIZE: 9.4 x 4 x 2.4 (23.9 x 10.2 x 6.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 2.1 lbs (1 kg)

WARRANTY

Three years against defects in materials and workmanship.
TIPPING BUCKET FLOW GAUGE
Model TB1L

Features
- Non-Corrosive, Robust PVC & Stainless Steel Construction
- Dual Reed Switch
- Suitable for Pipe Flow Measurement and water drain measurement
- Bucket Tip Volumes can be between 0.5 Litre up to 1.0 Litre
- Suitable for Harsh Environment

Description
The Hydrological Services Flow Gauge is considered to be one of the most accurate flow gauges used for measuring water flow coming out of a pipe or a drain. The unit comes with a dual reed switch, thus, when connected to a Hydrological Services data logger, the data can be stored and collected when required. In addition, the flow gauge can be telemetred by connecting one of the hydrological services data loggers to a GSM or PSTN modem.

Applications
- Connected to a data logger for collection and storage
- Connected to a data logger and a modem for telemetry
- Connected to a TRD (Total Rainfall Display)

Specifications
Material: PVC Plastic and Stainless Steel
Reed Switch: dual reed switches potted in soft silicon rubber with varistor protection.
- Max Capacity: 12 VA (0.5 amp max.) (24VDC are available on request)
- Resistance: Initial contact resistance 0.1 Ω
- M.T.B.F.: $10^8$ to $10^9$ Operations
Flow Rate: 25 litres/minute.
Accuracy: ±2%
Dimensions: Length 390mm, Width 180mm, Height 345mm.

Accessories
a. Minilog Digital Data Logger
b. WinComLog
c. Modem (GSM or 3G or PSTN)
d. TRD Counter
TIPPING BUCKET RAINGAUGE

Model TB3

INTRODUCTION

The Hydrological Services Tipping Bucket Raingauge is recognised as the world standard for measuring rainfall and precipitation in remote and unattended locations. The integrated syphon mechanism delivers high levels of accuracy across a broad range of rainfall intensities. Each unit consists of a collector funnel with leaf filter, an integrated syphon control mechanism, an outer enclosure with quick release fasteners, and base which houses the tipping bucket mechanism. The unit includes dual output reed switches with varistor protection as well as dual rainfall discharge outlets for water collection and/or analysis.

Special points of interest:

- World standard 200mm catch
- Accuracy not affected by rainfall intensity
- Bucket sizes: 0.01 inch / 0.2mm / 0.5mm / 1.0mm
- Long term stable calibration
- Leaf filter resists blocking
- Optional internal Data Logger, with no external power requirement
- In-built discharge outlets at base for water collection and analysis
- Dual output signal for data collection and transmission
- World class meteorological instrument
- Easy to service with low maintenance requirement

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Designed & Manufactured By
Hydrological Services Pty Ltd

Address:
48-50 Scrivener Street
Liverpool, NSW, 2170, Australia
Ph. 61 2 9601 2022  Fax. 61 2 9602 6971
Web: www.hydrologicalservices.com
Email: sales@hydrologicalservices.com

Distributed By:
Operation

The bucket tips when precipitation of 0.01 inch, 0.2mm, 0.5mm or 1.0mm has been collected. A pulse from each tip is sensed by the reed switch and logged to a data logger. The dual reed switch can also transmit the pulse to a telemetry system.

The Tipping Bucket Raingauge can be used in conjunction with Hydrological Services data logger model ML1. The logger is rugged and compact, it records the date and time of occurrence of tips from the raingauge up to 100,000 events with 1 Second Resolution can be stored in the ML1's memory. The data is stored in a flash EPROM.

Specifications

<table>
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<tr>
<th>TB3 bucket capacity</th>
<th>Intensity</th>
<th>Accuracy</th>
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</thead>
<tbody>
<tr>
<td>0.1mm, 0.2mm &amp; 0.01”</td>
<td>0-250mm/hr</td>
<td>± 2 %</td>
</tr>
<tr>
<td></td>
<td>250-400 mm/hr</td>
<td>± 3 %</td>
</tr>
<tr>
<td>0.5mm &amp; 1.0 mm</td>
<td>0-500 mm/hr</td>
<td>± 2 %</td>
</tr>
</tbody>
</table>

Long term stable calibration.

Humidity: 0 to 100 %

Temperature: -20 to +70°C

Contact system: dual reed switches potted in soft silicon rubber with varistor protection.

- Max Capacity: 24 Volts (0.5 amp max.)
- Resistance: Initial contact resistance 0.1 OHMS
- M.T.B.F: $10^9$ to $10^{10}$ Operations

Syphon: 0.4 mm capacity of rainfall - made from brass with a non hydroscopic outer case.

Bucket: two types of buckets, synthetic ceramic coated brass bucket balanced to ±0.05 gms, and injection moulded non hydroscopic plastic ABS UV stabilised balanced ±0.05 gms.

Base: Cast aluminium.

Level: bulls eye level adhered to aluminium base.

Mounting holes: three 10 mm diameter mounting holes with 117 mm p.c.d. cast in feet attached to outside diameter of base.

Drain fittings: to attach 12 mm inside diameter tubing, to catch rainfall after passing through buckets.

Pivots: ground sapphire pivots with hard stainless steel shaft.

Insect covers: stainless steel mesh on all openings to prevent insects and ants entering gauge.

Outer enclosure: keyed to enable the release of the outer enclosure without the need for the removal of the three securing screws.

Height / Weight: 330mm / 3 kg

Packed Dimensions: 5 kg 0.03m³

Accessories

<table>
<thead>
<tr>
<th>Description</th>
<th>Part No.</th>
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<tr>
<td>Data Logger</td>
<td>ML1/ML1-FL</td>
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<tr>
<td>RS232 to USB Converter</td>
<td>DL307</td>
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<td>Field Calibration Device</td>
<td>TB320 / FCD</td>
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<tr>
<td>TB3 Heater Kit</td>
<td>TB323</td>
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<tr>
<td>TB3 Bird Guard</td>
<td>TB333</td>
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<tr>
<td>TB3 Pole Mounting Bracket</td>
<td>TB334</td>
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</tbody>
</table>