High Point Phase I Block Scale Monitoring
Quality Management System Planning Document

Quality Assurance Project Plan

High Point Phase I Block Scale Monitoring

Document No. QAPP C06-061

Revision: R1D0

Effective date: 9/13/2007

Science, Sustainability, & Watersheds
Seattle Public Utilities
Seattle , Washington

This document is part of the Quality Management System providing in one place a clear, concise, and complete plan for environmental data management and its quality objectives, and for identifying key project personnel.

Note:
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1. TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

High Point Phase I Block Scale Monitoring

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Acronyms

EPA	Environmental Protection Agency
HSPF	Hydrological Simulation Program - FORTRAN
LID	Low Impact Development
LIMS	Laboratory Information Management System
MQO	Measurement Quality Objective
NDS	Natural Drainage System
NPDES	National Pollutant Discharge Elimination System
PSDMH	Public Storm Drain Manhole
QA	Quality Assurance
QAM	Quality Assurance Manual
QAPP	Quality Assurance Project Plan
QA/QC	Quality assurance/quality control
RPD	Relative Percent Difference
SIC	Science Information Catalog
SOP	Standard Operating Procedure
SPU	Seattle Public Utilities
WQI	Water Quality Indicator

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Quality Assurance Project Plan

High Point Phase I Block Scale Monitoring

3. BACKGROUND

Seattle Public Utilities (SPU) is implementing a large scale Natural Drainage System (NDS) project in conjunction with the redevelopment project for the High Point neighborhood in West Seattle. NDS swales are part of what is termed a "Low Impact Development" (LID) approach to managing stormwater runoff. The goal of the LID approach is to minimize the effect that changes in land use associated with urbanization can have on the natural hydrology. As opposed to conventional stormwater systems that route runoff directly to storm drains, the NDS swales first route runoff through a vegetated/compost amended swale, slowing runoff and allowing for infiltration into the groundwater. Excess runoff is then routed to a conventional stormwater system. Increased infiltration decreases the rate and volume of runoff. The end result is decreased erosion, improved water quality, and improved downstream habitat.

Herrera Environmental Consultants, Inc. (Contractor) is currently working with SPU to implement a block-scale monitoring program of NDS swales that have been installed at the High Point project site. The High Point NDS swales, unlike previous NDS swales constructed by SPU, predominantly consists of shallow surface ponding (3 to 10 inches) with 3 to 4 feet of biorention soil and an underdrain collection system. The project is being funded by Seattle Public Utilities, the Washington State Department of Ecology (Ecology), and U.S. Environmental Protection Agency (U.S. EPA) with the goal of quantifying the flow retention performance of the NDS swales in order to: provide a basis for potential design refinements, improve NDS performance, and/or reduce installation costs. This document presents the Quality Assurance Project Plan (QAPP) that will be implemented to meet these goals. This QAPP specifically documents the procedures that will be employed during this monitoring program to ensure the quality and integrity of the collected data, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and ultimately provides results which are scientifically and legally defensible. This document was prepared in accordance with SPU (Seattle 2006) and Ecology (2004) guidelines for preparing QAPPs.

The subsections below present additional background information for this monitoring project (hereafter referred to as the High Point Phase I Block Scale Monitoring [HPBSM] project). Included is a description of the study area, a summary of potential logistical problems that might be encountered during the implementation of this project, and a short overview of the project's history. The parameters of concern are then presented, and previous studies are summarized. Finally, applicable flow control and water quality standards are presented.

3.1. Study Area

The study area is located on the High Point redevelopment project in West Seattle (Figure 1). This project site lies within the Longfellow Creek drainage basin and is generally bounded to the north by SW Juneau Street, to the west by 34th Avenue

SW, to the south by SW Myrtle Street, and to the east by a designated steep slope greenbelt. The actual monitoring for the HPBSM project will occur in a representative NDS swale that runs along Highpoint Way SW between SW Graham and SW Bataan Street (Figure 2). This swale was constructed in 2004 and 2005 as part of Phase I of the project.

3.1.1. Logistical Problems

Logistical problems associated with the project include the potential for vandalism and theft of monitoring equipment due to their installation in an urban area that receives considerable public foot traffic. To reduce the threat of vandalism, all reasonable efforts will be made to conceal the monitoring equipment and/or to place it in areas that are minimally accessible to the public. Furthermore, the monitoring equipment will be housed in vandal resistant enclosures with locking lids.

Finally, storm event sampling associated with the project may also introduce potential logistical problems. Specifically, field monitoring efforts must be closely coordinated to collect hydrologic and water quality data during sporadic and transitory storm events. To minimize staffing problems, the Contractor will implement an established system for tracking incoming storms, mobilizing the required staff, and completing the required storm sampling tasks. This system utilizes Internet accessible data for predicting rainfall amounts to provide adequate lead-time to prepare for sampling, and Doppler radar images to detect and track the progress of a storm during the actual event. Dedicated field staff will be alerted in advance of any storm and subsequently mobilized at the onset of rainfall. Because storm sampling may be performed during weekends and other off-hours, public concerns over trespassing and criminal activity will also be addressed by requiring all field personnel to wear appropriate attire (i.e., hardhats and field vests) and drive vehicles that are clearly marked with a company logo. For some monitoring related to this QAPP, signage and traffic cones will also be placed at strategic locations on the monitoring site approximately 24-hours in advance of the required activities to alert residents and prevent parked vehicles from interfering with the field crew's data collection efforts.

3.1.2. History

The High Point neighborhood was initially developed as a short-term solution for addressing a housing shortage at the start of World War II. However, housing demand continued to grow and it was converted to low-income housing in 1952 and remained as such through the 1990s. In 2003, the Seattle Housing Authority took the lead in implementing a six-year project to begin redevelopment of the site into a mixed-income community. The redevelopment actions began by removing all existing housing, roads, and utilities. In their place, new roads, underground infrastructure, housing, and community facilities are being built. When completed, High Point will have approximately 1,600 housing units, divided evenly between rentals and homeownership units. It will also feature the largest NDS project that the City has undertaken, and marks the first time that a natural drainage strategy of this scale has been used in such a high-density urban setting. Designed in partnership with the Seattle Housing Authority, this NDS project will treat about 10 percent of the watershed draining to Longfellow Creek, one of Seattle's biggest creek watersheds.

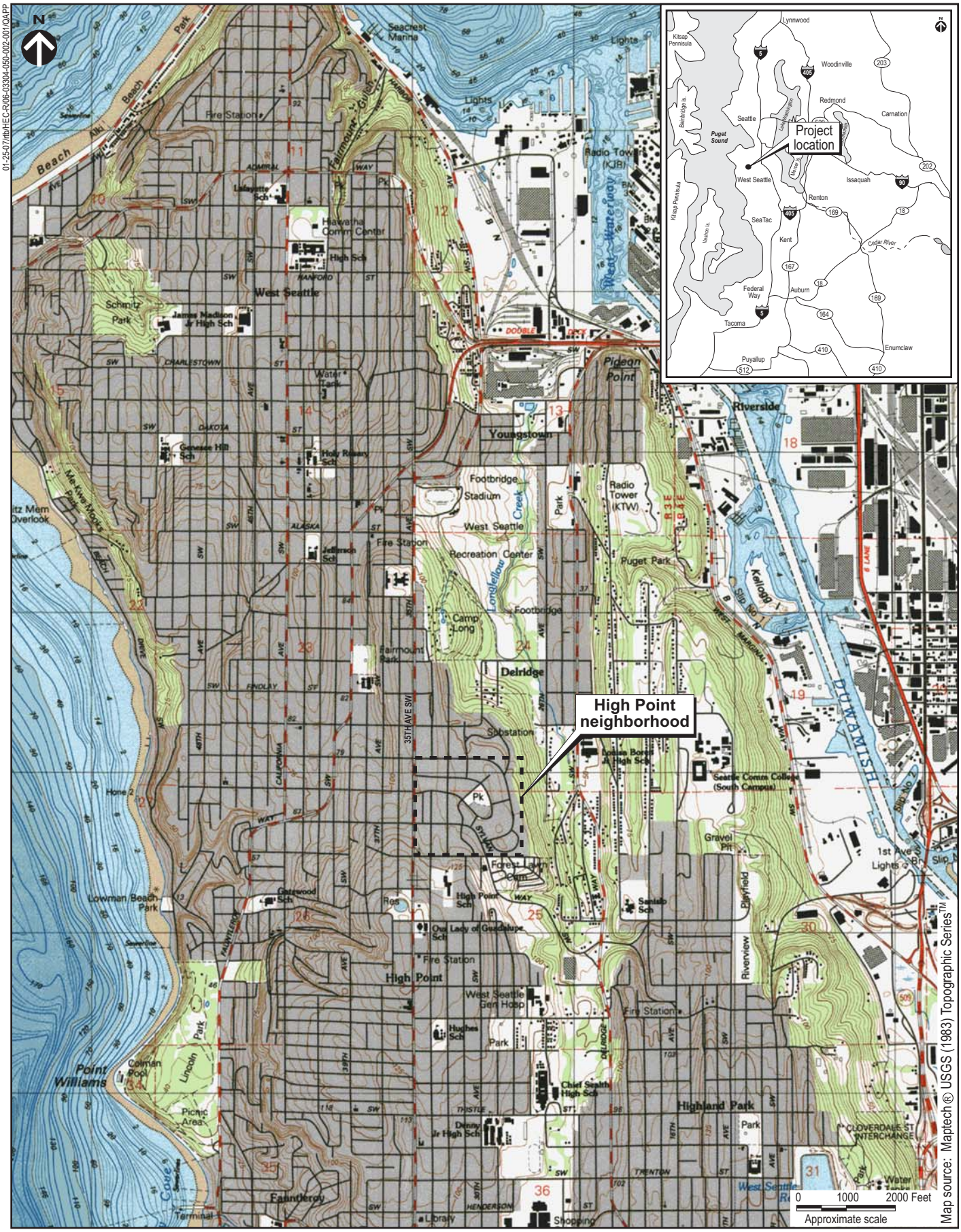

Figure 1. Vicinity map for the High Point redevelopment project site in Seattle, Washington.

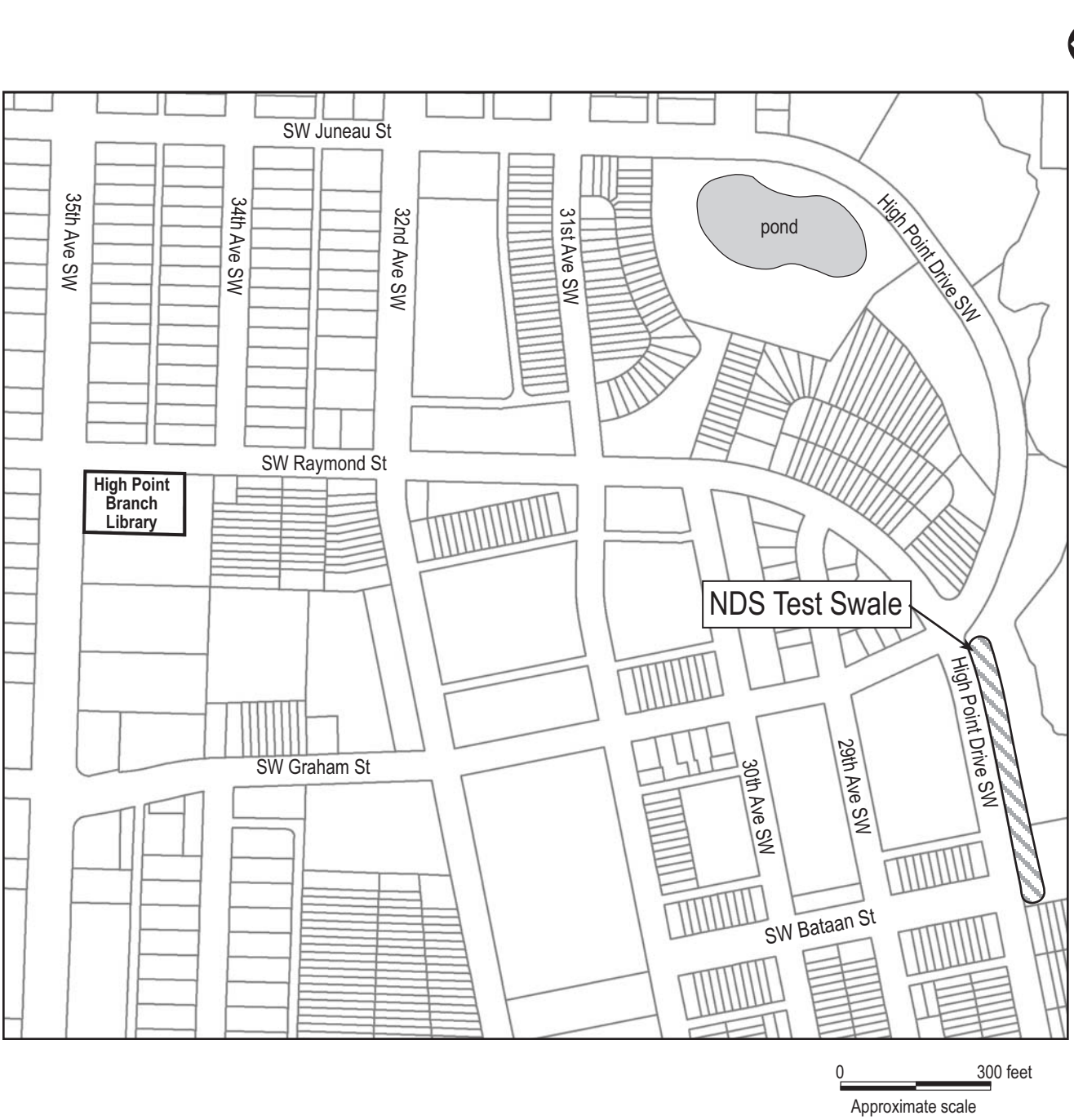

Figure 2. Site map for the High Point redevelopment project site showing the location of the natural drainage system (NDS) test swale.

01-25-07/rtb/HEC-R/06-03304-050-002-001/QA/PP

3.2. Parameters of Concern

Land use changes in urban areas have been shown to substantially alter the hydrology and geomorphology of streams (May et al. 1997). Conversion from natural ground cover to impervious surfaces in these areas results in higher and more frequent peak flows, greater streambed scour, erosion, and stream channel expansion. Increased impervious area may also result in a greater volume of surface runoff thereby reducing groundwater recharge. These effects negatively affect the ability of a stream to provide habitat to support a host of animal and plant species.

The degradation of water quality as a result of urbanization is a byproduct of both the effects of increased impervious surface on the hydrograph (i.e., higher peak flows) and changes in land use. Higher peak flow rates and volumes in streams cause greater scour and erosion that, in turn, increases the amount of suspended solids and turbidity in the water. Urbanization also leads to a greater concentration of pollution generating land activities (e.g., auto use, industrial and commercial development). Pollutants generated from these activities can severely impact the quality of nearby receiving waters. Specific pollutants of concern in urban runoff include sediment from development and new construction; oil, grease, heavy metals, and toxic chemicals from automobiles and industrial activity; nutrients and pesticides from turf management and gardening; and pathogens from pet wastes and combined sewer overflows.

Hydrologic and water quality parameters for this project were selected to evaluate the effectiveness of a representative NDS swale for mitigating problems associated with urbanization. The hydrologic parameters are flow and rainfall. Water quality parameters are total suspended solids, suspended sediment concentration, total phosphorus, soluble reactive phosphorus, total copper, dissolved copper, total zinc, and dissolved zinc, fecal coliform bacteria, and *Escherichia coli* (*E. coli*).

3.2.1. Previous Studies

Given the above considerations, SPU is actively investigating the feasibility of using NDS and other LID technologies in conjunction with redevelopment projects to mitigate the negative impacts from stormwater. While no previous studies have been conducted to assess the performance of the NDS project in the High Point neighborhood, studies of similar LID projects have been implemented in other Seattle neighborhoods through cooperative agreements between SPU and the University of Washington. For example, a study conducted by Horner et al. (2004) examined the effectiveness of two stormwater flow control projects located in the Piper's Creek watershed in North Seattle. The Viewlands Cascade Drainage System (VCDS) project replaced a narrow, partially concreted ditch with a wide series of stepped pools. Monitoring data for the project showed the pool system is capable of reducing the peak flow rates by approximately 60 percent, and the total runoff volume by more than half. However, little or no reduction of either peak flow rate or volume was observed during very large storms. Horner et al. (2004) also examined the effectiveness of the Street Edge Alternative (SEA) project that involved the complete reconstruction of a street to reduce its impervious area and to route associated stormwater through a series of detention ponds. Monitoring data showed the project eliminated all dry season flow and reduced the wet season runoff by 99 percent. A comparison of the two projects indicated that the SEA project was more efficient in

terms of volume of runoff detained per unit area, but that the VCDS project was more cost effective in terms of the volume of runoff detained per dollar.

3.2.2. Criteria and/or Standards

Pursuant to Federal Clean Water Act mandates, the Washington State Department of Ecology (Ecology) regulates the impacts of non-point pollution on water quality through the issuance of National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits. As a condition of the City of Seattle's NPDES permit, the City is required to regulate development and land use activities that impact the quality and quantity of stormwater runoff. These regulations include the application and enforcement of flow control and water quality treatment standards that are design to protect and enhance the health of Seattle's creeks, lakes, and bays. The specific flow control and water quality standards that are applicable to the HPBSM project are describe in separate subsections below.

3.2.2.1 Flow Control Criteria

The City regulates development and land use activities that impact the quality and quantity of stormwater runoff through the Seattle Municipal Code (SMC). However, in advance of forthcoming revisions to the SMC that will allow greater use of LID practices for treating stormwater, a City ordinance was passed in 2003 that allows stormwater LID features to be employed in the High Point redevelopment project. The specific flow control requirements for these features were identified in an associated Drainage Covenant. Pursuant to these requirements, the NDS swales, in combination with a stormwater detention pond on the project site, must attenuate the 2-year, 24-hour storm to pre-developed pasture conditions on a system-wide scale.

3.2.2.2 Water Quality Standards

Pursuant to Washington Administrative Code (WAC) 173-201A, Ecology has promulgated standards for common pollutants to protect the quality of the State's surface waters. These standards vary depending on specific designated uses that have been established for the water body in question. As noted above, the High Point neighborhood is located within the Longfellow Creek watershed. The designated aquatic life uses for Longfellow Creek are as follows: salmon and trout spawning, noncore rearing, and migration. The designated recreational use is primary contract recreation. Water quality standards for these designated uses are summarized in Table 1 for the specific parameters that will be targeted in monitoring efforts for the HPBSM project.

The U.S. EPA (2000) has also promulgated recommended ambient water quality criteria that are intended to address the adverse effects of excessive nutrients on streams and rivers. These criteria are empirically derived based on data that have been compiled from individual ecoregions and are intended to represent conditions of surface waters that have been minimally affected by anthropogenic activities. More specifically, these criteria are derived based on the 25th percentile of data from all streams in each ecoregion. Recommended criteria that are applicable to Longfellow Creek are summarized in Table 1 for the specific parameters that will be targeted through this monitoring effort. Results will be compared to these surface water criteria, although they are not directly applicable to stormwater.

Table 1. Applicable water quality standards and criteria in Longfellow Creek for monitoring parameters targeted by the HPBSM project.

Parameter	Standard	Criteria	Source
Total Phosphorus	NA	19.5 μg/L	U.S. EPA (2000)
Dissolved Copper [a]	Acute[b]: 4.6 μg/L Chronic[c]: 3.5 μg/L	NA	WAC 173-201A
Dissolved Zinc [a]	Acute[b]: 35 μg/L Chronic[c]: 32 μg/L	NA	WAC 173-201A
Fecal Coliform Bacteria	Not to exceed geometric mean value of 100 colonies/100 mL with not more than 10% of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL	NA	WAC 173-201A

[a] Standards vary with water hardness. Values presented are based on a median hardness of 25 mg/L as CaCO3 for western Washington (Herrera 2006).
[b] A 1-hour average concentration not to be exceeded more than once every three years on average.
[c] A 4-day average concentration not to be exceeded more than once every three years on average.
NA: not applicable.
μg/L: microgram/liter.

In order to protect the quality of Longfellow Creek, the Drainage Covenant identified above (see Section 3.2.2.1) also identified water quality treatment requirements for NDS swales on the project site. Pursuant to these requirements, the NDS swales must provide water quality treatment for the 6-month storm on a system-wide scale.

4. PROJECT DESCRIPTION

This section provides a brief overview of the project starting with the overall goals and objectives. Separate subsections then provide details on the following topics related to the project: information requirement, target population, study boundaries, practical constraints, data collection, and decision making.

4.1. Project Goals

The goal of the HPBSM project is to increase the understanding of the performance effectiveness and potential limitations of NDS swales. This information on NDS performance will then provide a basis for NDS design refinements that might be considered to improve performance, and/or reduce installation costs.

4.2. Project Objectives

In order to meet the project goal identified above, the following study objectives have been identified for the HPBSM project:

- Measure surface water infiltration rates within NDS swales over 3-years
- Measure ponding depth within NDS swales over 3-years
- Evaluate attenuation of peak flows and flow volumes within NDS swales relative to model predictions from the design phase of the project and provide calibration basis for future modeling efforts.
- Collect preliminary data for assessing the water quality treatment performance of NDS swales.

4.3. Information Requirements

The proposed monitoring program will track water inputs and outputs from a representative NDS test swale over a three-year monitoring period. This will require flow and rainfall measurements. In addition, infiltration rates on the surface of the NDS test swale will be measured through controlled testing procedures on three occasions. Finally, water quality sampling for the following parameters will be conducted before and after treatment in the NDS test swale: total suspended solids, suspended sediment concentration, total phosphorus, soluble reactive phosphorus, total copper, dissolved copper, total zinc, and dissolved zinc, fecal coliform bacteria, and *Escherichia coli* (*E. coli*)

4.4. Target Population

The target population is stormwater. For the Hydrological Simulation Program – FORTRAN (HSPF) calibration monitoring and water quality sampling target, the 2-year, 24-hour event would be ideal. However, given the relative infrequency of this event and their difficulty to predict, targeted storms will be those anticipated to generate enough runoff to sample. Continuous flow monitoring will be conducted over a 3-year period.

4.5. Study Boundaries

This study is located in the High Point neighborhood of West Seattle (Figure 1), with the specific NDS test swale selected for this study located between SW Graham and SW Bataan St. on the eastside of Highpoint Drive SW (Figure 2). The total length of the NDS test swale is approximately 500 feet. The contributing drainage basin to the NDS test swale includes approximately 0.53 acres of impervious area and 1.61 acres of pervious area, and extends one block to the south and west, and one-half block to the north and east. This project will be conducted over a 3-year period.

4.6. Practical Constraints

Practical restraints for this project include:

- Logistical challenges stemming from the continuous deployment of monitoring equipment in a highly urbanized environment over the three-year project duration
- Weather anomalies (e.g., drought) that may make it difficult to complete required storm event sampling activities associated with the project.

4.7. Data Collection

Data collection will be associated with the following for tasks:

- Continuous flow and rainfall monitoring
- Flow monitoring for HSPF calibration
- Infiltration monitoring
- Water quality monitoring

Data collection for the HPBSM project will be initiated in the winter of 2006 and conclude in September of 2009.

4.8. Decision-making

Results from this project may contribute to NDS design refinements and influence SPU's interest in constructing similar projects.

5. ORGANIZATION AND SCHEDULE

This section describes the roles and responsibilities of the project team, the project timeline and schedule, and the project documentation requirements.

5.1. Roles and Responsibilities

Table 2 identifies the internal and external team members for the HPBSM project with their associated roles and responsibilities.

Table 2. Roles and responsibilities for the High Point Block Scale Monitoring project.

Title/Name/Affiliation	Roles and Responsibilities
Client Quality Assurance Facilitator Shelly Basketfield/TBD Seattle Public Utilities	Responsible for management and oversight of the SPU Quality Management System Program. Oversees the development of quality assurance (QA) guidance for the quality management system (QMS) program. Monitors the effectiveness of the program quality system. Reviews and approves all QAPPs, internal QA audits, corrective actions, reports, work plans, and contracts. Enforces corrective action(s), as required. Ensures SPU personnel are fully trained and adequately staffed.
Client Project Manager Andy Rheaume Seattle Public Utilities	Responsible for ensuring that tasks and other requirements in the contract are executed on time and with available budget. Responsible for the review, approval, and internal distribution of the QAPP and other project deliverables. Responsible for maintaining internal project records. Point of contract for Contractor project manager.
Contractor Project Manager John Lenth Herrera Environmental Consultants	Responsible for coordinating the development and implementation of the QAPP. Ensures that all field and laboratory work for the project are performed in accordance with the procedures identified in the QAPP. Ensures that project milestones and deliverables are completed on schedule and within the available budget. Responsible for coordinating all QA reviews associated with the project and for implementing appropriate corrective actions where necessary. Point of contact for Client Project Manager regarding for all project-related issues including schedule and budget.
Contractor Quality Assurance Coordinator Rob Zisette Herrera Environmental Consultants	Responsible for final QA review during development and implementation of the QAPP. Notifies the Contractor Project Manager of particular circumstances which may adversely affect the quality of data. Responsible for final validation and verification of all collected data.
Contractor Field Supervisor Niklas Christensen Herrera Environmental Consultants	Responsible for supervising all aspects of the field sampling and data collection; ensures data collection procedures identified in the QAPP are followed in the field; responsible for field work scheduling including staffing and equipment use; ensures that staff are appropriately trained for required field work.
Contractor Data Manager/QA Officer Rebecca Dugopolski Herrera Environmental Consultants	Oversees data management for the study. Ensures data are collected, processed, and stored in accordance with procedures identified in the QAPP. Contractor point of contact for resolving issues related to the data. Provide QA/QC review of collected data.

Title/Name/Affiliation	Roles and Responsibilities
Laboratory Manager Steve Lazoff Aquatic Research, Inc.	Responsible for supervision of laboratory personnel involved in generating analytical data for the project. Responsible for ensuring that laboratory personnel have adequate training and a thorough knowledge of Standard Operating Procedures (SOPs) relevant to the project. Responsible for oversight of all laboratory operations. Ensures that documentation and reporting from laboratory analyses are complete and accurate.
Laboratory Quality Assurance Officer Steve Lazoff Aquatic Research, Inc.	Conducts internal audits to identify potential problems and ensure compliance with written SOPs. Responsible for verifying that all quality assurance/quality control (QA/QC) procedures are followed during laboratory analyses. Responsible for providing results from laboratory QA/QC checks in a standardized format for subsequent review by the Contractor Data Manager/QA Officer.

5.1.1. Special Training Needs/Certification

All personnel that are required to enter manholes for equipment installations, maintenance, and repairs will have confined space entry training in accordance with Occupational Safety and Health Administration requirements.

5.2. Timeline/Project Schedule

Work on the HPBSM project will be initiated in December of 2006 and will continue over a three-year period until December 2009. Key milestones and timelines for major project elements are summarized in Table 3.

Table 3. Key project milestones and timelines for major project elements to be completed for the High Point Block Scale Monitoring project.

Project Element	Schedule
Monitoring equipment installation	Completed in January 2007
HSPF calibration monitoring	Six storm events over period from January 2007 through September 2007
Continuous hydrologic monitoring	Continuous from January 2007 through September 2009
Controlled infiltration tests	February 2007, March 2007, and September 2009
Water quality monitoring	Six storm events over the period from January 2007 through September 2007
HSPF modeling	Work to be initiated upon receipt of written approval from SPU

HSPF: Hydrological Simulation Program –FORTRAN.

5.2.1. Project Deliverables

Project deliverables for the HPBSM project are identified in Table 4 with their associated schedule for completion.

5.2.2. Project Success Factors

The primary success factor for this project will be the generation of a robust data set for evaluating the treatment performance of existing NDS swales. This information may then be used by SPU and others to make design improvements that will reduce costs and/or improve the overall performance of future systems. It is also anticipated that information sharing related to this project will lead to an increased awareness and acceptance of LID treatment systems in general by regulatory agencies and the public.

Table 4. Project deliverables for the High Point Block Scale Monitoring project and associated schedule for completion.

Project Deliverable	Schedule
Technical memoranda summarizing results from controlled infiltration tests	To be completed within four weeks of each infiltration test (see Table 3 for testing schedule)
Technical memorandum documenting HSPF modeling methods and results	To be completed within four weeks of completing required HSPF modeling for the project (see Table 3 for modeling schedule)
Water year 2007 draft data report	November 30, 2007
Water year 2007 final data report	December 21, 2008
Water year 2008 draft data report	November 30, 2008
Water year 2008 final data report	December 21, 2008
Water year 2009 draft data report	November 30, 2009
Water year 2009 final data report	December 21, 2009

5.3. Document and Records

This section documents laboratory and electronic data reporting requirements for the HPBSM project. It also provides information on document retention (archival) requirements and outlines procedures that would be used to modify this QAPP should it become necessary.

5.3.1. Laboratory Data Reports

Laboratory data reports will clearly and accurately present test results. The data reports will include the information necessary for interpretation and validation of analytical data including:

- Report title
- Name and address of laboratory
- Name and address of client and project name
- Subcontractor results clearly identified
- Description and unambiguous name of tested sample
- Date and time of sample collection, date of sample receipt, and date of analysis
- Identification of test method
- QC results for laboratory duplicates, field duplicates, and relative percent difference of laboratory duplicates
- Raw data sheets used to calculate final results

- An explanation of failed QC and any non-standard conditions that may have affected the data quality
- A signature and title of the laboratory director or designee.

5.3.2. Electronic Data

Field and laboratory data for the HPBSM project will be entered into an Excel® spreadsheet for all subsequent data management and archiving tasks. The Contractor QA Coordinator will perform an independent review to ensure that all the data were entered without error (see Section 11.4). Upon completion of the project, water quality data will be submitted to SPU in a format that is compatible with the City's Laboratory Information Management System (LIMS). Hydrologic monitoring data will also be submitted to SPU in a format compatible with the Hydstra data management software package.

5.3.3. Records and Documents Retention Requirements

Retentions requirements for records and documents associated with this project are outlined in Table 5.

Table 5. Records and document retention requirements.

Document/Record	Location	Retention	Form
QAPP, amendments, and appendices	Contractor/SPU	5 years	Paper/Electronic
QAPP distribution documentation	Contractor/SPU	5 years	Paper/Electronic
Field notebooks or field data sheets	Contractor	5 years	Paper
Chain of custody records	Contractor	5 years	Paper
Field SOPs	Contractor	5 years	Paper/Electronic
Laboratory data reports/results	Contractor/Lab/SPU	5 years	Paper/Electronic
Corrective action documentation	Contractor/Lab/SPU	5 years	Paper
Hydrologic monitoring data	Contractor/SPU	5 years	Electronic
HSPF Model Documentation	Contractor	5-years	Paper/Electronic
Infiltration Test Technical Memoranda	Contractor/SPU	5 years	Paper/Electronic
Annual Data Reports	Contractor/SPU	5 years	Paper/Electronic

5.3.4. Revisions to the QAPP

In the event that significant changes to this QAPP are required prior to the completion of the project, a revised version of the document shall be prepared and submitted to the Client Project Manager for review. The approved version of the QAPP shall remain in effect until the revised version has been approved.

5.3.5. Expedited Changes

Requests for expedited changes to the QAPP will be allowed to accommodate unique or unanticipated circumstances. The Contractor Project Manager will submit these requests to the Client Project Manager in writing for review. They will become

effective immediately upon approval by the Client Project Manager. Justifications, summaries, and details of expedited changes to the QAPP will be documented and distributed to all persons on the QAPP distribution list by the Client Project Manager. Expedited changes will be incorporated into a revised QAPP within 30 days of their initial approval in cases where such changes are deemed significant by the Client Project Manager.

6. QUALITY OBJECTIVES

The goal of this QAPP is to ensure that the data collected through this study are scientifically and legally defensible. To meet this goal, the collected data will be evaluated relative to the following QA objectives:

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

Method Quality Objectives (MQOs) are performance or acceptance criteria that are established for each of these QA objectives. The specific MQOs that will be used in the assessment of hydrologic and water quality data for this project are presented in the following sections.

6.1. Measurement Quality Objective for Hydrologic Monitoring

This section describes the MQOs for the hydrologic monitoring component of the study. Hydrologic monitoring will specifically involve measurements of discharge, water level, and precipitation depth. QA objectives for these measurements are expressed in terms of bias, representativeness, completeness, and comparability. (Precision generally cannot be readily assessed due to the difficulty associated with obtaining repeat measurements from hydrologic monitoring equipment during continuously changing site conditions.) The associated MQOs for hydrologic monitoring are defined in the subsections below.

6.1.1. Precision

The precision of hydrologic monitoring data will be assessed based on comparisons of the monitoring equipment's actual accuracy (accuracy is equal to precision if there is no bias) to its maximum theoretical accuracy as identified in the manufacturer specifications. Actual accuracy will be assessed based on a comparison of monitoring equipment readings to an independently measured "true" value. The MQO for discharge measurements will be a difference of no more than 10 percent between the instrument's actual accuracy and maximum theoretical accuracy. For water level and precipitation depth measurements, the difference between the instrument's actual accuracy and maximum theoretical accuracy will be within 5 percent.

6.1.2. Bias

Bias will be assessed based on a comparison of monitoring equipment readings to an independently measured "true" value. The MQO for discharge measurements will be a difference of no more than 10 percent between the instrument reading and the independently measured value. For water level and precipitation depth measurements, the difference between the instrument reading and the independently measured value will be within 5 percent. For reference, Table 6 shows the theoretical accuracy of hydrologic monitoring equipment to be used in the HPBSM project based on measurements that were made by the manufacturers under controlled conditions.

Table 6. Hydrologic monitoring equipment accuracy based on manufacturer specifications.

Monitoring Equipment	Measurement Type	Accuracy
DataGator	Discharge	Open Channel: ±3 percent [a] Full Pipe: ±3 percent [a] Full Pipe Below Transition: ±10 percent [a] Open Channel (>9% submergence): ±5 percent [a]
Campbell Scientific CS445-L submersible pressure transducer	Water Level	±0.1% of full span or ±0.01 feet
Hydrologic Services TB3 tipping bucket rain gauge	Precipitation Depth	±2% for rainfall intensities ranging from 1 to 28 inches/hour

[a] Accuracy is expressed as a percentage of maximum discharge.

6.1.3. Representativeness

The representativeness of the hydrologic data in this project will be ensured through the selection of a test NDS swale that has typical design features for High Point project site. Rainfall patterns, stormwater conveyance features, and surrounding land uses were also considered in the identification of monitoring locations and sampling frequencies to ensure representative data for the target conditions of this study will be obtained.

6.1.4. Completeness

Completeness will be assessed based on the occurrence of gaps that may occur in the data record for all monitoring equipment. The associated MQO is less than 5

percent of the total data record 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 should problems arise.

6.1.5. Comparability

Standard monitoring procedures, units of measurement, and reporting conventions will be applied in this study to meet the goal of data comparability.

6.2. Measurement Quality Objectives for Water Quality Monitoring

This section describes the MQOs for the water quality monitoring component of the study. QA objectives for water quality data are expressed in terms of precision, bias, representativeness, completeness, and comparability. The associated MQOs are defined in the subsections below and summarized in Table 7. Not that the term reporting limit in this document refers to the practical quantitation limit established by the laboratory, not the method detection limit.

Table 7. Quality objectives for water quality data.

Parameter	Method Blanks	Control Standard Recovery	Matrix Spike Recovery	Laboratory Duplicate RPD [a]	Field Duplicate RPD [a]
Total suspended solids	<RL	90 – 110%	NA	≤25% or ±2 × RL	≤25% or ±2 × RL
Suspended sediment concentration	<RL	90 – 110%	NA	≤25% or ±2 × RL	≤25% or ±2 × RL
Total phosphorus	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Soluble reactive phosphorus	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Hardness	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Copper, dissolved	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Copper, total	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Zinc, dissolved	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Zinc, total	<RL	90 – 110%	75 – 125%	≤20% or ±2 × RL	≤20% or ±2 × RL
Fecal coliform bacteria	<2x RL	NA	NA	≤25% or ±2 × RL	≤35% or ±2 × RL
Escherichia coli (*E. coli*)	<2x RL	NA	NA	≤25% or ±2 × RL	≤35% or ±2 × RL

[a] The relative percent difference (RPD) will be less than or equal to the indicated percentage for values that are greater than 5 times the reporting limit, and ±2 times the reporting limit for values that are less than or equal to 5 times the reporting limit.
RPD: relative percent difference.
RL: reporting limit.
NA: not applicable.

6.2.1. Precision

Precision will be assessed using laboratory and field duplicates. Two levels of precision will be evaluated for laboratory and field duplicates. For values that are greater than 5 times the reporting limit, the relative percent difference (RPD) of laboratory and field duplicates will be as follows: ≤25 percent for total suspended solids and suspended sediment concentration; and ≤20 percent for total phosphorus,

soluble reactive phosphorus, and metals. For values that are less than or equal to 5 times the reporting limit, duplicate values will be within ±2 times the reporting limit. In all cases, the RPD of duplicate samples will be calculated using the following equation:

$$RPD = \frac{(C_1 - C_2) \times 100\%}{(C_1 + C_2)/2}$$

where: RPD = relative percent difference

C_1 = larger of two values

C_2 = smaller of two values.

6.2.2. Bias

Bias will be assessed based on analyses of method blanks, matrix spikes, and control standards. The values for method blanks will not exceed the reporting limit. The percent recovery of matrix spikes will be between 75 and 125 percent. The percent recovery of control standards will be within 90 and 110 percent for all parameters. Percent recovery for matrix spikes will be calculated using the following equation:

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

where: %R = percent recovery

S = measured concentration in spike sample

U = measured concentration in unspiked sample

C_{sa} = actual concentration of spike added.

6.2.3. Representativeness

The sampling design will provide samples that represent a wide range of water quality conditions during storm flow conditions. Sample representativeness will be ensured by employing consistent and standard sampling procedures. Representativeness will also be ensured by the selection of specific NDS swale for monitoring that was designed in accordance with standard specifications.

6.2.4. Completeness

Completeness will be calculated by dividing the number of valid values by the total number of values targeted for collection. Valid sample data consists of data that have not been qualified as estimates (J) or rejected (R). If less than 95% of the samples submitted to the laboratory are judged to be valid, then additional samples will be collected until at least 95% are judged to be valid. An equipment check list will be used to prevent loss of data resulting from missing containers or sample collection equipment during field sampling trips.

6.2.5. 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. The results will be tabulated in standard spreadsheets to facilitate comparison with other study results and water quality threshold limits (e.g., WAC 173-201A).

7. SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

NDS swales have five primary components: a grass or vegetated planting strip, an engineered soil layer, a gravel drain layer, a perforated underdrain pipe, and a solid-walled conveyance pipe (see Figure 3). During operation, stormwater runoff from the surrounding drainage basin enters the planting strip via sheetflow where it is retained for a sufficient period of time to allow for infiltration to the underlying engineered soil layer. Absorption and filtration processes within the engineered soil layer then provide water quality treatment. Storage within the engineered soil layer also serves to attenuate stormwater runoff flow rates and volumes. Under saturated conditions, stormwater will infiltrate from the engineered soil layer down to the gravel drain layer. The gravel drain layer provides additional storage for attenuating stormwater runoff flow rates and volumes. Overflow from the gravel drain layer is first collected in the perforated underdrain pipe and then discharged to the solid-walled pipe for conveyance out of the NDS swale.

This study will quantify the hydrologic and water quality treatment performance of an NDS swale that was constructed in 2004 and 2005 as part of the High Point neighborhood redevelopment project. This test swale is representative of other NDS swales that are being constructed in this project. This study will track water inputs and outputs from the NDS test swale over a three-year monitoring period. In addition, infiltration rates on the surface of the NDS test swale will be measured through controlled testing procedures on three occasions. Finally, water quality samples will be will be collected for pollutants in stormwater before and after treatment in the NDS test swale. The data obtained from this study will ultimately be used to evaluate the benefits of NDS swales and provide a basis for design refinements that might be considered to improve performance, and/or reduce installation costs.

The subsections below provide a more detailed description of the experimental design for the four primary study components of the HPBSM project:

- HSPF Model Calibration Monitoring
- Continuous Hydrologic Monitoring
- Controlled Infiltration Tests
- Water Quality Monitoring

The purpose and specific location of monitoring stations associated with these study components also are summarized in Table 8.

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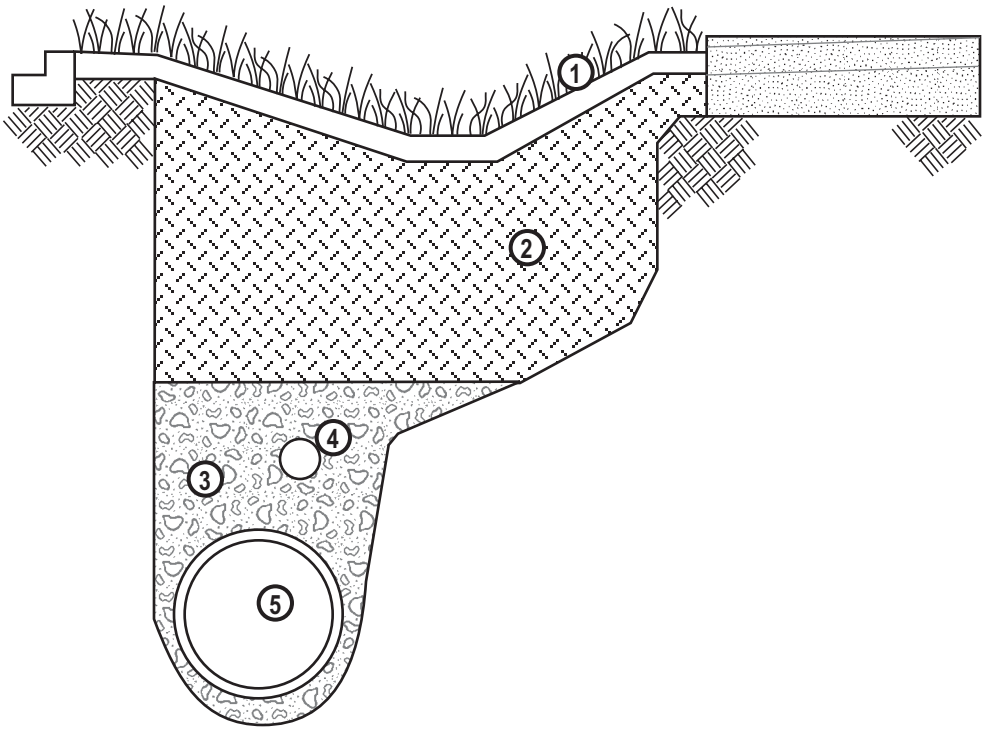

KEY

1. Grass or vegetated planting strip
2. Engineered soil layer
3. Gravel drain layer
4. 8” perforated underdrain pipe
5. Solid-wall conveyance pipe

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Figure 3. Schematic diagram of a typical NDS swale cross-section.

Table 8. Location, purpose, and sampling frequency for monitoring stations to be established for the High Point Phase I Block Scale Monitoring project.

Station	Station Type	Station Location	Station Purpose	Sampling Frequency
D1	Discharge	NDS test swale overflow drain located on Highpoint Way SW approximately mid-block between SW Bataan Street and SW Graham Street	Monitor stormwater inputs to the NDS test swale during discrete storm event. Data to be used for HSPF model calibration	Monitoring during six discreet storm events in water year 2007
D2	Discharge	PSDMH 5.60 located on Highpoint Way SW approximately mid-block between SW Bataan Street and SW Graham Street	Continuously monitor stormwater outputs from the NDS test swale	Continuous monitoring that will initiate in January 2007 and conclude in September of 2009
D3	Discharge	PSDMH 5.50 located near the intersection of Highpoint Way SW and SW Graham Street	Continuously monitor stormwater outputs from the NDS test swale	Continuous monitoring that will initiate in January 2007 and conclude in September of 2009
WL1	Water Level	NDS test swale overflow drain located on Highpoint Way SW approximately mid-block between SW Bataan Street and SW Graham Street	Continuously monitoring ponding depth at the surface of the NDS test swale and track the occurrence of overflow events	Continuous monitoring that will initiate in January 2007 and conclude in September of 2009
WQ1	Water Quality	NDS test swale overflow drain located on Highpoint Way SW approximately mid-block between SW Bataan Street and SW Graham Street	Monitor influent stormwater quality for NDS test swale	Monitoring during six discreet storm events in water year 2007
WQ2	Water Quality	PSDMH 5.50 located near the intersection of Highpoint Way SW and SW Graham Street	Monitor effluent stormwater quality for NDS test swale	Monitoring during six discreet storm events in water year 2007
RG1	Precipitation	High Point Public Library at 3411 SW Raymond Street	Continuously monitor precipitation depth	Continuous monitoring that will initiate in January 2007 and conclude in September of 2009

PSDMH: Public storm drain manhole.

7.1. HSPF Calibration Monitoring

Because stormwater will enter the NDS test swale as highly diffuse sheet flow, direct measurement of inflow rates and volumes is not practical over the long-term. Therefore, surface inflow to the NDS test swale will be estimated using output from an HSPF model that is developed for the associated subbasin. In order to obtain calibration data for this HSPF model, the Contractor will monitor inflow rates to the

NDS test swale during up to six discret storm events. The Contractor will specifically target storms ranging in size from the 6-month to 2-year event. During these events, a temporary monitoring station (designated D1 in Figure 4) will be established in association with the test swale where runoff from the surrounding drainage basin will be concentrated at a single collection point. Monitoring equipment will be installed at this station to continuously record discharge rates. It is anticipated that the following activities will be performed in connection with each event:

- Prior to each storm event, Contractor personnel will block the curb cuts that convey water into the NDS test swale from Highpoint Drive SW. With the curb cuts blocked, all stormwater that would normally enter the NDS test swale will concentrate at the low point in the street where the overflow drain for the system is located (see Figure 4). In conjunction with blocking the curb cuts, Contractor personnel will also install a primary measuring device (i.e., compound weir) in the overflow drain. Automated monitoring equipment (i.e., a pressure transducer and data logger) will then be installed in association with the primary measuring device to facilitate continuous discharge monitoring for water that enters the overflow drain from the street.

- During each storm event, Contractor personnel will visit the NDS test swale at two to four hour intervals to ensure that flows are properly routed through the temporary collection system and that the monitoring equipment is functioning correctly. Contractor personnel will also record manual measurements within the primary measuring device to check the calibration of the automated monitoring equipment.

- After each storm event, Contractor personnel will remove the temporary collection system, primary measuring device, and the automated equipment.

It is anticipated that all storm event monitoring related to this study component will be completed during water year 2007. Monitoring data obtained from each test will be processed for use in subsequent HSPF model calibration efforts. With the availability of these data, it is anticipated that inflows to the NDS test swale can be predicted with an error rate of between 10 and 20 percent.

7.2. Continuous Hydrologic Monitoring

Continuous hydrologic monitoring will be performed to track the outputs of stormwater from the perforated underdrain pipe for the NDS test swale over the three-year monitoring period. In addition, automated instrumentation will be installed on the surface of the NDS test swale to continuously measure the ponding depth near the overflow drain. This instrumentation will also be used to track the occurrence (i.e., presence or absence) and duration of overflow events. Finally, precipitation will also be monitored continuously to provide data for interpreting the other monitoring results. In order to facilitate this monitoring, the following stations will be established in association with the NDS test swale:

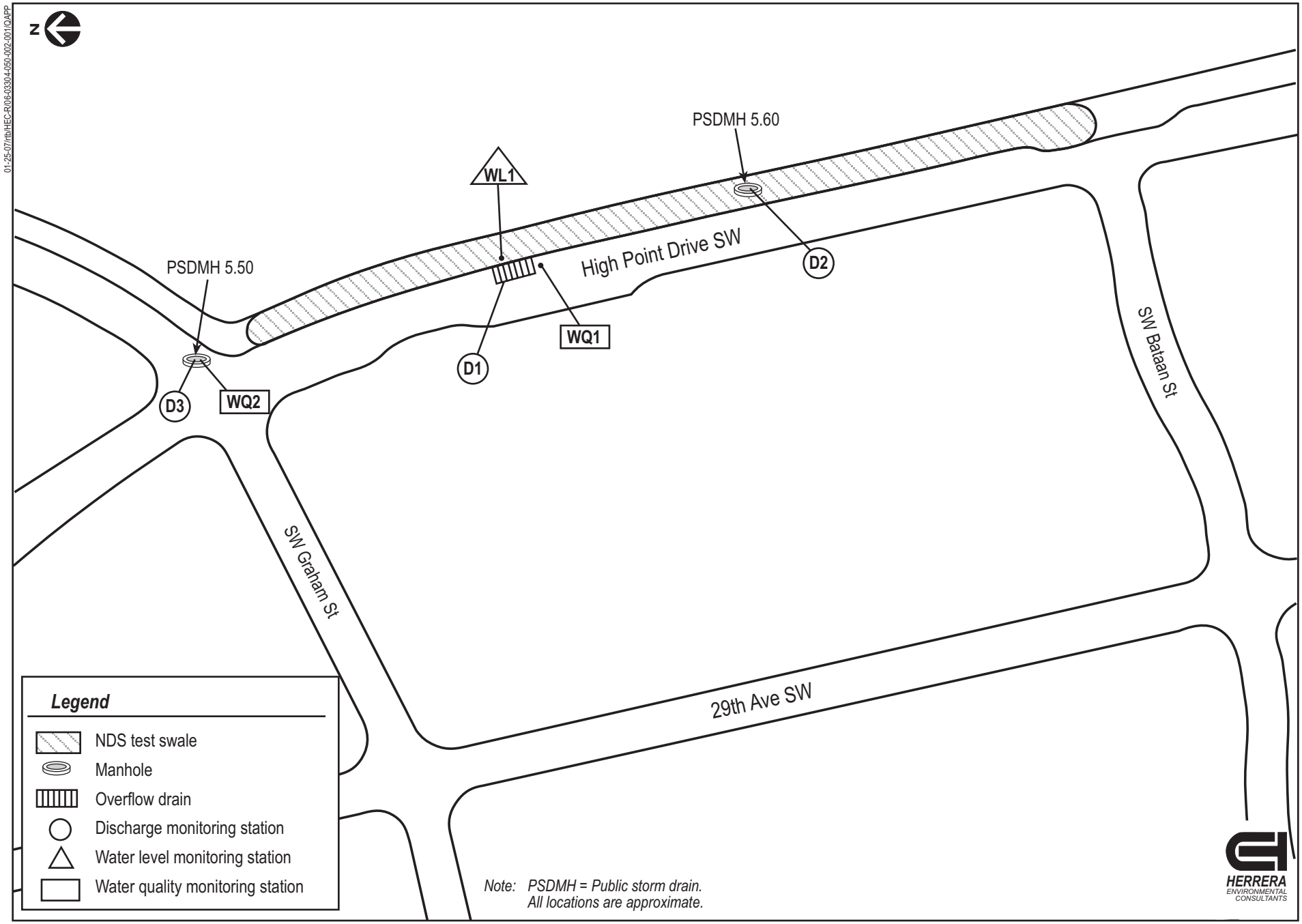

Figure 4. Plan view of NDS test swale and monitoring station locations for the High Point Phase I Block Scale monitoring.

- A precipitation monitoring station (designated RG1) will be established on the roof of the High Point Public Library at 3411 SW Raymond Street (see Figure 2). A rain gauge and data logger installed at this station will be used to continuously monitor precipitation over the duration of the project.

- Flow monitoring stations will be established at the outlets for two separate sections of perforated underdrain pipe that convey water from the gravel drain layer of the NDS test swale. One station (designated D2 in Figure 4) will be established in public storm drain manhole (PSDMH) 5.60 that is located at approximately the midpoint of the NDS test swale. This station receives flow from approximately a 250 foot long section of perforated underdrain pipe that extends south from PSDMH 5.60 to the intersection of SW Bataan Street and Highpoint Way SW. The other station (designated D3 in Figure 4) will be established in PSDMH 5.50 near the intersection of SW Graham Street and Highpoint Way SW. This station receives flow from approximately a 250 foot long section of perforated underdrain pipe that extends south from PSDMH 5.50 to PSDMH 5.60. Automated flow monitoring equipment will be installed in association with each of these stations to continuously monitor stormwater outputs from the NDS test swale.

- One water level monitoring station (designated WL1 in Figure 4) will be established on the surface of the NDS test swale near the overflow drain. Automated equipment will be installed at this station to continuously record ponding depth and the occurrence and duration of overflow events.

This monitoring instrumentation will be installed in January 2007 and operated continuously through the end of September 2009. A spreadsheet model will be developed using data from these instruments and the HSPF model to track stormwater inputs and outputs for the NDS test swale using a mass balance approach. This model will ultimately be used to quantify the attenuation of peak flows and flow volumes within the NDS test swale.

7.3. Controlled Infiltration Tests

The Contractor will coordinate with the SPU Materials Lab to perform three separate tests to measure surface water infiltration rates within the NDS test swale. Specifically, two initial infiltration tests will be conducted during the first and second months of the three-year monitoring program (see Section 5.2). A final test will then be performed at the end of the third year of the monitoring program. During each test, it is assumed that some variation of the following procedure will be used:

- Water will be added to the NDS test swale to maintain a constant water level just below the invert of the overflow drain. A rotameter or similar device will be used to measure the flow rate of the water added during this process.

- Every 15 to 30 minutes, the cumulative volume and instantaneous flow rate that is necessary to maintain a constant water level will be recorded.

- After the flow rate has stabilized, the water will be turned off and the rate of infiltration in inches per hour will be measured until there is no longer any standing water in the NDS test swale.

The actual testing procedure will be implemented by SPU personnel from the Materials Lab. Contractor personnel will provide technical oversight and logistical support during the tests and document the associate results in separate technical memorandum for each test.

7.4. Water Quality Monitoring

Stormwater quality sampling will also be conducted in association with the NDS test swale during six separate storm events to characterize stormwater pollutant concentrations before and after treatment. Pollutant concentrations will be characterized based on grab samples collected at a representative inflow (before treatment) and outflow points (after treatment) for stormwater entering and leaving the NDS test swale. The inflow monitoring station (designated WQ1 in Figure 4) will be located where stormwater runoff from Highpoint Way SW concentrates near the overflow drain for the NDS test swale. The outflow monitoring station (designated WQ2 in Figure 4) will be located where at the point where the section of perforated underdrain pipe discharges into PSDMH 5.50 (see description above in Section 7.2). Each collected sample will be analyzed for total suspended solids, suspended sediment concentration, total phosphorus, soluble reactive phosphorus, hardness, total copper, dissolved copper, total zinc, and dissolved zinc, fecal coliform bacteria, and *Escherichia coli* (*E. coli*). It is anticipated that all sampling related to this study component will be performed in water year 2007.

The data obtained from this sampling will be summarized in the Data Report that is prepared for water year 2007 (see Section 5.2.1). These data will ultimately be used to assess the need for more comprehensive water quality monitoring in subsequent phases of the project.

8. SAMPLING PROCEDURES

This section presents the sampling procedures that will be employed during the implementation of the HPBSM project. It begins with a description of the specific sampling procedures that will be utilized for hydrologic monitoring and water quality monitoring activities related to the project. It then presents procedures that will be used for documenting field sampling activities and non-direct measurements.

8.1. Hydrologic Monitoring

Hydrologic monitoring for this project will involve measurements for discharge, water level, and precipitation. The specific sampling procedures to be used for each of these measurement types are presented in separate subsections below.

8.1.1. Discharge Monitoring

Discharge monitoring will be performed in conjunction with the HSPF Calibration Monitoring and Continuous Hydrologic Monitoring study elements identified above. The specific procedures that will be used for each of these study elements are described below.

8.1.1.1 HSPF Calibration Monitoring

As described above, temporary monitoring station D1 (see Figure 4) will be established in association with the NDS test swale to facilitate HSPF calibration monitoring during six separate storm events. Prior to each storm event, Contractor personnel will block the curb cuts that convey water into the NDS test swale from Highpoint Drive SW. Each curb cut will be blocked with a combination of 4-foot long tube sand bags, impermeable plastic garbage bags, and plywood barriers that are fitted with weather stripping to form a seal with the curb and street. With the curb cuts blocked, all stormwater that would normally enter the NDS test swale will concentrate at the low point in the street where the overflow drain for the system is located.

In conjunction with blocking the curb cuts, Contractor personnel will also install a primary measuring device in the overflow drain. The primary measuring device will be incorporated into a custom fabricated box made of ¾ inch marine plywood and having the following interior dimensions: length = 23 inches; width = 8.25 inches; depth = 20 inches. This box will be temporarily mounted at the top of the overflow drain where it will collect all of the stormwater that is diverted from the blocked curb cuts. All seams within the box will be caulked to prevent water leakage and weather stripping will be placed around the box's interface with the storm drain to prevent water from bypassing the box. A two-stage weir will be cut into one side of the box to allow flow estimates to be derived from water level measurements within the box. The two-stage weir will consist of a 45-degree v-notch for use during low to moderate flows (i.e., 0.02 to 0.50 cubic feet per second [cfs]) and a 23-inch rectangular weir (without end constrictions) for use during high flows (i.e., 0.50 to 1.2 cfs). (These weir dimensions were selected based on preliminary output from the Western Washington Hydrologic Model software package that indicated discharge rates of approximately 0.35 and 0.70 cfs can be expected for the 2- and 10-year storm events, respectively.) An energy dissipater will also be installed inside the box to reduce the turbulence of water prior to its discharge over the two-stage weir. Photographs of the box in its preliminary stages of construction are presented in Appendix A.

Automated monitoring equipment will then be installed inside the primary measuring device to facilitate the continuous monitoring of discharge. More specifically, a Campbell Scientific CS445-L submersible pressure transducer will be fitted to the bottom of the box to measure the depth of water over the two-stage weir. The pressure transducer will be integrated with a Campbell Scientific CR200 datalogger that is programmed to record water level measurements with a 1-minute logging interval. Data from the datalogger will be downloaded after each storm event and subsequently exported to an Excel spreadsheet for data management and archiving purposes. The water level measurements will then be converted to estimates of discharge based on standard hydrologic equations (Grant and Dawson 1997).

During the actual HSPF calibration monitoring, Contractor personnel will visit the NDS test swale at two to four hour intervals throughout the storm event to ensure that flows

are properly routed through the primary measuring device and that the monitoring equipment is functioning correctly. Contractor personnel will also make manual measurements within the primary measuring device to check the calibration of the automated monitoring equipment.

8.1.1.2 Continuous Hydrologic Monitoring

As described above, stations D2 and D3 (see Figure 4) will be established to measure discharge from the perforated underdrain pipe sections for the NDS test swale. In order to facilitate this monitoring, DataGator® flow metering systems from Renaissance Instruments will be installed in the perforated underdrain pipe sections at their point of discharge into PSDMH 5.50 and PSDMH 5.60.

Each DataGator flow metering systems has two components: a modified Venturi flow tube with three strategically positioned pressure transducers to measure flow; and a data logger that allows the continuous recording of flow measurements. In accordance with the manufacturer's instructions, the flow tubes will be securely fastened to each 8-inch perforated underdrain pipe with a stainless steel mounting base and leveled with threaded leveling rods. The dataloggers will be attached to a ladder rung at the top of each PSDMH using short sections of cable and then interfaced with the pressure transducers in the flow tubes using manufacturer supplied communication cables. Finally, the dataloggers will be programmed to continuously record discharge measurements from the flow tubes with a 15-minute logging interval.

One week after installation, Contractor field personnel will visit the site to confirm the DataGator Flow metering systems were installed correctly and are functioning properly. After this initial check, the Contractor will perform monthly site visits to upload data, check and replace batteries as necessary, visually inspect all system components from the top of the manhole, and check the calibration of each flow metering system (see Section 10.2.3.1). Any operational problems that are identified during these site visits will be addressed immediately. Contractor field personnel will take detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will also be used to document maintenance, calibration, and troubleshooting activities (see example form in Appendix B). Contractor field personnel will take detailed notes to document any equipment maintenance or repairs that are required during these site visits. On the day following each site visit, data from the flow metering systems will be exported to an Excel spreadsheet for data management and archiving purposes. At this time, the data will also undergo a QA audit (see Section 12). Any operational problems that are identified through this review will be addressed immediately.

8.1.2. Water Level Monitoring

Monitoring station WL1 (see Figure 4) will be established to continuously monitor water levels on the surface of the NDS test swale near the overflow drain. To facilitate this monitoring, a Campbell Scientific CS445-L submersible pressure transducer will be installed at a low point within the NDS test swale. The pressure transducer will be integrated with a Campbell Scientific CR200 datalogger that is programmed to continuously record water levels in the swale with a 15-minute

logging interval. Both the pressure transducer and datalogger will be housed in vandal resistant enclosures that are hidden from public view to the extent possible.

One week after installation, Contractor field personnel will visit the site to confirm that the water level monitoring equipment was installed correctly and is functioning properly. After this initial check, the Contractor will perform monthly site visits to upload data, check and replace the battery pack as necessary, visually inspect all system components, and check the calibration of the water level monitoring equipment (see Section 10.2.3.2). Any operational problems that are identified during these site visits will be addressed immediately. Contractor field personnel will take detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will also be used to document maintenance, calibration, and troubleshooting activities (see example form in Appendix B). On the day following each site visit, data from the water level monitoring equipment will be exported to an Excel spreadsheet for data management and archiving purposes. At this time, the data will also undergo a QA audit (see Section 12). Any operational problems that are identified through this review will be addressed immediately.

In conjunction with the water level monitoring equipment described above, a staff gauge will also be installed in the NDS test swale near the overflow drain. Survey equipment will then be used to reference the elevation of both the pressure transducer and overflow drain to the datum on the staff gauge. Using this relationship, the data from the automated monitoring equipment will be used to track the occurrence and duration of overflow events at the surface of the NDS test swale.

8.1.3. Precipitation Monitoring

As described above, monitoring station RG1 will be established at the High Point Branch Public Library (see Figure 2) to continuously measure precipitation amounts over the duration of the project. To facilitate this monitoring, a Hydrologic Services TB3 tipping bucket rain gauge will be affixed to the library's roof on a 10-foot pole and leveled in accordance with the manufacture's specifications. The rain gauge will be interfaced with a Campbell Scientific CR200 Datalogger that is programmed to record precipitation depths with a 15-minute logging interval. The datalogger will be housed in a locking, vandal resistant enclosure that is hidden from public view to the extent possible.

One week after installation, Contractor field personnel will visit the site to confirm the rain gauge was installed correctly and is functioning properly. After this initial check, the Contractor will perform monthly site visits to upload data, check and replace the battery pack as necessary, and visually inspect all system components. Any operational problems that are identified during these site visits will be addressed immediately. Contractor field personnel will take detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will also be used to document maintenance, calibration, and troubleshooting activities (see example form in Appendix B). On the day following each site visit, data from the rain gauge will be exported to an Excel spreadsheet for data management and archiving purposes. At this time, the data will also undergo a QA audit. Any operational problems that are identified through this review will be

addressed immediately. In addition to the monthly site visits, an annual site visit will also be performed to check the calibration of the rain gauge (see Section 10.2.3.3).

8.2. Water Quality Sample Collection

Water quality samples will be collected during six separate storm events over water year 2007 at the monitoring stations described above (i.e., WQ1 and WQ2). During each storm event, one sample will be collected from each station to obtain a total of 12 samples (2 stations × 6 events). The following conditions will serve as guidelines for defining the acceptability of specific storm events for sampling:

- **Target storm depth**: minimum of 0.25 inches of precipitation in a 24-hour period.
- **Antecedent conditions**: A period of at least 12-hours preceding the event with less than 0.01 inches of precipitation.
- **End of storm**: A continuous 12-hour period with no measurable rainfall.

The storm depth criterion was established to target only those storms that will provide substantial runoff from the High Point development while the antecedent conditions criterion was established to allow some time for pollutant buildup on impervious surfaces between storm events. These criteria were adapted from Ecology's *Guidance for Evaluating Emerging Stormwater Technologies: Technology Assessment Protocol – Ecology (TAPE)* (Ecology 2002).

Precipitation forecasts from the Center for Ocean Land-Atmosphere Studies (http://wxmaps.org/pix/meteograms.html) will be reviewed on a weekly basis to determine if specific storm events should be targeted for sampling. Immediately prior to sampling, incoming storms will be tracked using Doppler radar images for the region that can be accessed via the King 5 weather website (http://www.king5.com/weather/doppler/?seattle). To the extent possible, the timing of sample collection from each monitoring station will be targeted to capture the rising limb of the storm hydrograph.

Sample collection at each monitoring station will follow procedures identified in *Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region* (U.S. EPA 1991). Samples from station WQ1 (see Figure 4) will be collected by submerging pre-cleaned bottles supplied by the laboratory in stormwater that has concentrated along the street curb near the point of discharge into the overflow drain. If the flow at this location is too shallow for the bottles to be fully submerged, a clean, wide-mouth bottle will be used to collect the water and then to fill the required sample bottles. Samples from station WQ2 (see Figure 4) will be collected by mounting the bottles to an extendable pole and then lowering them into PSDMH 5.50. At this location, the sample bottles will then be positioned to capture water that is discharging from the perforated underdrain pipe and allowed to fill.

Following collection, each sample bottle will be placed in a cooler with ice and kept at 4°C for transport to the laboratory. All samples will be delivered to the laboratory within 12 hours of collection. A completed chain-of-custody record will be submitted with each batch of samples. Each collected sample will then be analyzed for total suspended solids, suspended sediment concentration, total phosphorus, soluble reactive phosphorus, hardness, total copper, dissolved copper, total zinc, and dissolved zinc, fecal coliform bacteria, and .

8.2.1. Sample Requirements/Preservation

Samples for total suspended solids and suspended sediment concentration will be collected in separate 1 liter polyethylene bottles. Samples for total phosphorus and soluble reactive phosphorus will be collected in a single 500 milliliter (ml) polyethylene bottle. Samples for copper (dissolved and total) and zinc (dissolved and total) will also be collected in a single 500 ml polyethylene bottle. Finally, samples for fecal coliform bacteria and *E. coli* will be collected in single 300 ml amber glass bottles. Sample preservation requirements are identified in Table 9 with associated holding times, where applicable. Sample analysis holding times are also presented in Table 9. All samples will be clearly labeled in the field with indelible ink using the following nomenclature:

site name – sample collection date and time – initials of sampler

An example sample label with this nomenclature is as follows:

WQ2 – 09/12/07 8:25 - JL

8.3. Documentation of Field Sampling Activities

Field sampling activities will be recorded in a waterproof field notebook during the collection of hydrologic data and water quality samples by Contractor field personnel. Documentation of field sampling activities will include the station ID, location, sampling time, sampling date, preservatives added to samples, and sample collector's name/signature. Any relevant observations on site conditions at the time of sampling will also be recorded including water appearance, weather, biological activity, unusual odors, specific sample information, days since the last significant rainfall, flow rates, and precipitation totals. Standardized field forms will also be used to document equipment maintenance, calibration, and troubleshooting activities (see example form in Appendix B). Once the field personnel have returned to the office, the field notes and standardized forms will be reviewed by the Contractor QA Coordinator for completeness and conformity with the procedures identified in this QAPP.

8.4. Non-direct Measurements

As described above, HSPF modeling will be performed to estimate inflow discharge rates to the NDS test swale over the three-year monitoring period. The HSPF model will be developed in accordance with SPU standard practices for modeling bioretention. Such standard practices are currently under development and it is anticipated that they will be completed by the time modeling is required for this project. If this proves not to be the case, the HSPF model will be developed based on technical guidelines that have been promulgated by the Puget Sound Action Team and Washington State University (Hinman 2005) for LID applications.

9. MEASUREMENT PROCEDURES

Laboratory measurement procedures will follow methods approved by the U.S. Environmental Protection Agency (APHA et al. 1992; U.S. EPA 1983, 1984). The analytical methods, preservation methods, container specifications, holding times, and detection limits are presented in Table 9. The analytical methods were selected to provide low enough detection limits to enable reliable comparisons to applicable surface water quality standards.

The laboratory identified for this project (Aquatic Research, Inc.) is certified by Ecology and participates in audits and interlaboratory studies conducted by Ecology and U.S. EPA. The adequacy of the standard operating procedures in the laboratory has been verified by these performance and system audits.

Within 30 days of receiving the samples, the laboratory will report the analytical results in standardized reports that will include sample and quality control data. The reports are suitable for evaluating the project data and also will include a case narrative that summarizes any problems encountered during the analyses.

10. QUALITY CONTROL

To ensure the data quality objectives for this study are met, quality control procedures are identified in separate sections below for analytical and field activities. The overall objective of these procedures is to ensure that data of a known and acceptable quality are collected for this project.

10.1. Analytical Quality Control

Quality control procedures that will be implemented during laboratory analytical procedures are described in the following subsections.

10.1.1. Method Blanks

Method blanks consisting of deionized distilled water will be analyzed with every sample batch that is delivered to the laboratory. Blank values will be presented in each laboratory report.

10.1.2. Control Standards

Control standards for each parameter will be analyzed by the laboratory with every sample batch. Percent recovery (see formula in Section 6.2) for the control standards will be presented in each laboratory report.

10.1.3. Matrix Spikes

For applicable parameters, matrix spikes will be analyzed by the laboratory with every sample batch. Percent recovery (see formula in Section 6.2) for the matrix spikes will be presented in each laboratory report.

Table 9. Methods and detection limits for laboratory measurement procedures.

Parameter	Bottle Type	Preservation Method	Analytical Method	Method Number [a]	Reporting Limit [b]	Sample Holding Times
Total suspended solids	1L, P	Cool, 4°C	Gravimetric, 103°C	EPA 160.2	0.50 mg/L	7 days
Suspended sediment concentration	1L, P	Cool, 4°C	Wet sieving filtration Gravimetric, 103°C	ASTM D 3977-97C	0.50 mg/L (sand) 0.50 mg/L (fines)	7 days
Total phosphorus	500 ml, P	Cool, 4°C; H_2SO_4 to pH<2	Automated ascorbic acid	EPA 365.1	0.002 mg/L	28 days
Soluble reactive phosphorus	500 ml, P	Cool, 4°C; filtration, 0.45 μm	Automated ascorbic acid	EPA 365.1	0.001 mg/L	48 hours [c]
Hardness	500ml, P	Cool, 4°C; HNO_3 to pH<2	EDTA titrimetric	SM 2340C	2 mg/L as $CaCO_3$	6 months
Copper, dissolved	500 ml, P	Cool, 4°C; filtration, 0.45 μm; HNO_3 to pH<2	GFAA	EPA 220.2	0.001 mg/L	14 days [c]
Copper, total	500 ml, P	Cool, 4°C; HNO_3 to pH<2	GFAA	EPA 220.2	0.001 mg/L	6 months
Zinc, dissolved	500 ml, P	Cool, 4°C; filtration, 0.45 μm; HNO_3 to pH<2	ICP	EPA 200.7	0.005 mg/L	6 months [c]
Zinc, total	500 ml, P	Cool, 4°C; HNO_3 to pH<2	ICP	EPA 200.7	0.005 mg/L	6 months
Fecal coliform bacteria	300 ml, G	Cool, 4°C	Membrane filter	SM 9222D	2 CFU/100 ml	12 hours
Escherichia coli (*E. coli*)	300 ml, G	Cool, 4°C	Membrane filter	EPA 10029	2 CFU/100 ml	12 hours

[a] SM method numbers are from APHA et al. 1992; EPA method numbers are from U.S. EPA 1983; 1984.

[b] Reporting limit refers to the practical quantitation limit.

[c] Sample filtration and/or preservation will occur within 12 hours of sample collection.

EDTA = ethylenediaminetetracetic acid

GFAA = graphite furnace atomic absorption.

ICP = inductively coupled plasma.

mg/L = milligrams per liter.

P = polyethylene, polypropylene, fluoropolymer.

10.1.4. Laboratory Duplicates

Laboratory duplicates for each parameter will be analyzed for a randomly selected sample with every sample batch. Data for batch samples (i.e., samples from other projects analyzed with samples from this project) will be acceptable as long as duplicates are analyzed at a frequency of at least 5 percent. The relative percent difference (see formula in Section 6.2) of the duplicate results will be presented in each laboratory report.

10.2. Field Quality Control

The following procedures will be used during field activities to ensure that data quality objectives will be met.

10.2.1. QC Samples

Field duplicates will be collected by filling a second sample bottle immediately after the collection of the regular sample. One field duplicate will be collected during the first and third storm events that will be sampled in connection with this QAPP. The station where the field duplicates are collected will be chosen at random in advance of the storm event. 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), sampling, and analytical variability. RPD values (see formula in Section 6.2) will be calculated for each set of field duplicates from the laboratory results.

10.2.2. Instrument/Equipment Testing, Inspection, and Maintenance

All monitoring equipment will be tested prior to installation to ensure it is functioning correctly. One week after installation, Contractor field personnel will also visit the site to confirm the monitoring equipment was installed correctly and is functioning properly.

After this initial check, site visits will be performed at least monthly to perform routine maintenance on the equipment. Maintenance activities will include:

- Check and replace batteries as necessary
- Visually inspect all system components for wear or damage
- Remove any debris that may have accumulated on monitoring equipment
- Replace desiccant for water level monitoring probes.

Contractor field personnel will take detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will also be used to document maintenance, calibration, and troubleshooting activities (see example form in Appendix B).

10.2.3. Instrument/Equipment Calibration and Frequency

The calibration of all monitoring equipment will also be checked on a regular basis. The specific calibration procedures and frequency that will be applied to the discharge, water level, and precipitation monitoring equipment, respectively, are described in the following subsections.

10.2.3.1 Discharge Monitoring Equipment Calibration and Frequency

Site visits will be made at least twice annually in order to check the calibration of discharge monitoring equipment installed at Stations D2 and D3. During each site visit, Contractor field personnel will perform a confined space entry to manually measure discharge from the perforated underdrain pipes using a calibrated bucket or handheld flow meter. Contractor field personnel will also note the flow monitoring equipment's reading at the time of the manual measurements. The difference between these two values will be tracked over time by means of control charts to detect potential instrument drift and other operational problems. They will also be used to assess the QA objectives that are identified in Section 6.1. Corrective actions will then be implemented if the data do not meet the specific MQOs that have been defined for each objective. These corrective actions may include rezeroing or recalibration of the flow monitoring equipment as necessary.

10.2.3.2 Water Level Monitoring Equipment Calibration and Frequency

Site visits will be made to check the calibration of the water level monitoring equipment at Station WL1 at a minimum frequency of six times annually. During each site visit, Contractor field personnel will make a manual measurement of water level in the NDS test swale from the installed staff gauge and then immediately note the monitoring equipment's reading. The difference between these two values will be tracked over time by means of control charts to detect potential instrument drift and other operational problems. This information will also be used to assess the QA objectives that are identified in Section 6.1. Corrective actions will then be implemented if the data do not meet the specific MQOs that have been defined for each objective.

10.2.3.3 Precipitation Monitoring Equipment Calibration and Frequency

Annual site visits will be conducted to check the calibration of the rain gauge at Station RG1. During each site visit, Contractor field personnel will determine the exact volume of water required to initiate one tip of the rain gauge bucket by adding incremental drops of water with a pipette. The measurements will be repeated ten times and then averaged. The resultant value will be compared to the manufacturer's specifications for the volume required to initiate one bucket tip. The difference between these values will be used to assess the QA objectives that are identified in Section 6.1. Corrective actions will then be implemented if the data do not meet the specific MQOs that have been defined for each objective.

10.2.4. Inspection/Acceptance of Supplies and Consumables

Pre-cleaned sample containers will be obtained from the analytical laboratory in advance of sampling for all monitoring parameters. Spare sample containers will be

carried by the sampling team in case of breakage or possible container contamination. Sample containers and preservation techniques will follow U.S. EPA (1990; 40 Code of Federal Regulations [CFR] 136, July 1, 1992) guidelines.

11. DATA MANAGEMENT PROCEDURES

The following section describes the procedures that will be used to manage data that are obtained through the HPBSM project. This section includes the following elements:

- Description of the path data will take from generation to final use/storage;
- Description of standard recordkeeping and data storage procedures;
- Examples of forms or checklists to be used in the management of data;
- Description of data handling procedures;
- Description of hardware/software configurations that will be required to manage and analyze the data; and
- Description of the process for assuring that applicable information and resource management requirements are satisfied.

11.1. Data Path

Hydrologic data collected through this project will follow the path outlined below from generation to final use/storage:

- Upload data from monitoring equipment at monthly intervals using laptop computer in field. If appropriate, make manual measurements on site for equipment calibration purposes.
- Transfer data from laptop computer to Contractor's server on day following upload. Export data from equipment's proprietary communication software to Microsoft® Excel spreadsheet to facilitate all subsequent data management, analysis, and archiving activities. Enter manual measurements in Microsoft® Excel spreadsheet to facilitate tracking of instrument calibration results using control charts. Perform data audit (see Section 12)
- At conclusion of annual monitoring period, conduct verification and validation review (see Section 13). If possible, fill-in any data gaps using estimated values or other data sources. Add QA flags to the data record to indicate estimated or rejected values based on results from the verification and validation review. Approve

finalized data for subsequent analyses and reporting activities based on final data quality assessment (see Section 14).

- Conduct analyses on finalized data in accordance with project goals and objectives. Summarize results in annual data report.

- At conclusion of project, provide SPU win an electronic copy of the data in a format compatible with the Hydstra data management software package. Archive data on secure storage media that is maintained by the Contractor for the period identified in Table 3.

Water quality data collected through this project will follow the path outlined below from generation to final use/storage:

- Obtain analytical results as hard copy reports from the laboratory.

- Within 7 days of receiving analytical results from laboratory, enter the data into a Microsoft® Excel spreadsheet to facilitate all subsequent data management, analysis, and archiving activities. Perform data audit (Section 12).

- At the conclusion of the annual monitoring period, conduct a verification and validation review (see Section 13). Add QA flags to the data record to indicate estimated or rejected values based on results from the verification and validation review. Approve the finalized data for subsequent analyses and reporting activities based on the final data quality assessment (see Section 14).

- Conduct analyses on the finalized data in accordance with the project goals and objectives. Summarize the results in the annual data report.

- At the conclusion of the project, provide SPU with an electronic copy of the data in a format compatible with the LIMS. Archive the data on a secure storage media that is maintained by the Contractor for the period identified in Table 3. An electronic copy of the data will also be provided to Ecology in a format that is compatible with the Environmental Information Management (EIM) database.

11.2. Record-keeping and Data Storage

Field notes, standardized field forms, and laboratory reports will be stored within a project file in the Contractor's offices or at a secure off-site document archiving facility (i.e., DataSite Business Archives, Inc.) in accordance with the record-retention schedule in Table 5. Electronic data will be stored on the Contractor's network server and backed-up on a regular basis to a secure storage media that is maintained off-site. The electronic data will also be maintained in accordance with the record-retention schedule presented in Table 5.

11.3. Forms and Checklists

Standardized forms and checklists will be used on this project to ensure that all data are collected with maximum efficiency and to prevent gaps and inaccuracy in the data record. Example forms and checklists are provided in Appendix B.

11.4. Data Handling

All field and laboratory monitoring data will be entered into a Microsoft® Excel spreadsheet for subsequent data management and archiving tasks. Laboratory data for each analytical batch will be combined into one spreadsheet with one row for each sample, which allows for sorting and statistical analyses. Field data will also be combined into spreadsheets with one row for each observation or measurement. The Data Manager (see Table 2) will perform an independent review to ensure that all the data have been entered 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.

11.5. Hardware and Software Requirements

Software required for the data management and analysis tasks related to this project will include but not be limited to Microsoft® Excel, HSPF, and Statistica®. (Statistica® is a data analysis and visualization software package). Commensurate with these software requirements, the minimum hardware requirement for this project is a Windows® 2000/XP compatible personal computer operating in a networked environment.

11.6. Information Resource Management Requirements

The Contract will maintain sufficient information technology resources for this project to facilitate data storage, sharing, and archiving via a high-speed local area network and Internet connection.

12. AUDITS AND REPORTS

Routine audits will be conducted to ensure that this QAPP is being implemented correctly and the quality of the data is acceptable. In the event that QA issues are identified during these audits, corrective actions will be implemented as necessary. Monitoring data obtained through implementation of this QAPP will also be summarized in annual data reports. The sections below describe in detail the steps that will be carried out in connection with each of these activities.

12.1. Deficiencies, Nonconformances and Corrective Action

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

Routine audits will be performed in order to detect potential deficiencies in the hydrologic and water quality data that are being collected for this project. Audits for hydrologic data will occur on a monthly basis on the day following each site visit that is made to upload data obtained from the monitoring stations. In connection with these audits, the data collected from each monitoring station over the previous month will be examined in relation to data from prior months to identify potential QA issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies between the discharge, water level, and/or precipitation data from the various monitoring stations. Any data generated from calibration checks that were performed at a particular monitoring station will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. In the event that QA issues are identified on the basis of these audits, a site visit will be performed immediately to troubleshoot the problem and to implement corrective actions if possible. Any QA issues that are detected through these audits will be documented in the electronic data record and in separate tracking forms.

Audits performed for water quality 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. Specific quality control elements for the data (see Table 7) will also be examined to determine if the MQOs for the project have been met. Results from these audits will be documented in QA worksheets that will be prepared for each batch of samples. In the event that a potential QA issue is identified through these audits, the Contractor QA Coordinator (see Table 2) will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples or the reanalysis of existing samples.

Deficiencies detected through routine audits will be documented in accordance with the procedures identified above. The Project Manager, in consultation with the Contractor QA Facilitator, will determine if the deficiency constitutes a nonconformance. If it is determined a nonconformance exists, the Contractor QA Coordinator will decide the disposition of the nonconforming data and any necessary corrective action(s). Corrective actions may include the qualification of the data as estimated (J) or rejected (R) values. All deficiencies, nonconformances, and corrective actions will be documented in annual Data Quality Assessment Reports for the project (see Section 14).

12.2. Reports to Management

The contractor will prepare three annual data reports to summarize the collected data and related analysis results. In accordance with the schedule identified in Table 4, each data report will present the monitoring data collected in a specific water year (i.e., 2007, 2008, and 2009). These data reports will include the following information:

- Overview of the HPBSM program goals and objectives
- Description of the data collection procedures
- Hydrologic monitoring results for each station

- Water quality monitoring results for each station
- Graphical and/or tabular representations of the data as necessary
- Output from HSPF modeling efforts for the project
- Evaluation of NDS test swale performance based on the compiled monitoring data.

Appendices to the report will also include tabular compilations of raw monitoring data, field data sheets, laboratory analytical reports, chain of custody documentation, and the Data Quality Assessment Report. Each report will be submitted to SPU for review, comment, and approval.

13. DATA VERIFICATION AND VALIDATION

This section discusses the procedures that will be used during the verification and validation review of hydrologic and water quality data. It begins with an overview of the process and then presents more detailed information on the specific procedures to be employed during the actual review.

13.1. Data Review, Verification, and Validation

Data verification involves examining the data to ensure that they are consistent, correct, and complete (Ecology 2004). Furthermore, data verification is performed to confirm that the methods and protocols specified in the QAPP were followed. Data validation is an analyte-specific and sample-specific review that extends beyond the verification process to determine the analytical quality of a specific data set. It involves a detailed examination of the data to confirm whether the specific MQOs that were established for the project (see Section 6) were met. The Contractor QA Coordinator will be responsible for overseeing the verification and validation process to ensure that all data used in subsequent analyses and reporting meet the QA objectives for the project.

13.2. Verification and Validation Methods

Data verification and validation will be performed on both the hydrologic and water quality data that are collected through the HBSM project. The specific procedures that will be used to verify and validate of each type of data are described in the following sections:

13.2.1. Verification and Validation Methods for Hydrologic Data

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

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

- The precipitation record will then be analyzed to identify each individual storm that occurred during the monitoring period. Individual storms will be defined based on a minimum 12-hour dry period separation between each event. Once defined, these storms will be sequentially numbered starting with the first storm in the monitoring period and progressing through to the final storm event.

- The available discharge and water level data from each monitoring station will then be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events defined above in Step 2. Gross anomalies (e.g., data spikes), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are QA issues associated with the data that limit their usability.

- If minor quality assurance issues are identified in any portion of the discharge record or in the water level data 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.

13.2.2. Verification and Validation Methods for Water Quality Data

Water quality data obtained for the project will be reviewed by the Contractor QA Coordinator to verify that all samples were collected in accordance with the procedures identified in this QAPP and that all required QA/QC information was provided by the laboratory. The Contractor QA Coordinator will then examine the data to determine if there were any errors or emissions. Finally, the Contractor QA coordinator will validate the data by comparing the laboratory QA/QC results to the specific MQOs that were established for the project (see Section 6). Values associated with minor quality control problems will be considered estimates and assigned a *J* qualifier. Values associated with major quality control problems will be rejected and qualified as *R*. Estimated values will be used for evaluation purposes, while rejected values will not.

The following subsections describe in detail the specific data validation procedures that will be used for these QC objectives:

- Completeness
- Methodology
- Holding times
- Blanks
- Reporting limits
- Duplicates

- Matrix spikes
- Control standards.

13.2.2.1 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. Water quality samples may be re-analyzed or re-collected if completeness does not meet the specified MQO in Section 6.

13.2.2.2 Methodology

Methodologies for analytical procedures will follow U.S. EPA approved methods (APHA et al. 1992; U.S. EPA 1983, 1984). Field procedures will follow the methodologies described in this QAPP. Any deviations from these methodologies must be approved in writing by SPU in accordance with the procedures outlined in Sections 5.3.4 and 5.3.5. Deviations that are deemed unacceptable will result in rejected values (*R*).

13.2.2.3 Holding Times

Analysis dates will be reported by the laboratory. Holding times will be assessed by comparing the analytical dates and times to the sample collection dates and times. Data from samples that exceed the maximum holding time by less than 48 hours will be considered as estimates (*J*). Data from samples that exceed the maximum holding times by more than 48 hours will be rejected values (*R*). Holding times for each analytical parameter in this study are summarized in Table 3.

13.2.2.4 Blanks

Blank values will be compared to the MQOs that have been identified for this project (see Table 7). Sample values that are less than 5 times a detected method blank value will be considered estimates (*J*).

13.2.2.5 Reporting Limits

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

13.2.2.6 Duplicates

Duplicate results exceeding the MQOs for this project (see Table 7) 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 the associated values will be rejected (*R*).

13.2.2.7 Matrix Spikes

Matrix spike results exceeding the MQOs for this project (see Table 7) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (*J*). However, if the percent recovery exceeds the 75 to 125 range and a value is less

than the reporting limit, the result will not be flagged as an estimate. Nondetected values will be rejected (*R*) if the percent recovery is less than 30 percent.

13.2.2.8 Control Standards

Control standard results exceeding the MQOs for this project (see Table 7) will be noted in the quality assurance worksheets, and the associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (e.g., more than twice the objective), then the associated values will be rejected (*R*).

14. DATA QUALITY (USABILITY) ASSESSMENT

This section 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 also summarized.

14.1. Data Quality Assessment

The Contractor QA Coordinator will conduct an independent review of the quality control data from each water year (i.e., 2007, 2008, 2009) in accordance with the MQOs that have been identified in this QAPP (see Section 6). Based on these reviews, annual Data Quality Assurance Mermoranda will be prepared 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 quality assurance information that will be noted in the data validation memorandum include the following:

- 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 the data reports for each water year.

14.2. Data Analysis Methods

To facilitate their interpretation, hydrologic data collected through this study will be summarized in tabular and graphical formats. These data will also be processed to

compile the following information for each storm that occurred during the monitoring period:

- Storm precipitation depth from station RG1
- Storm duration from station RG1
- Storm average intensity from station RG1
- Storm peak intensity from station RG1
- Storm antecedent dry period station RG1
- Peak water level from station WL1
- Peak effluent discharge rate from stations D1 and D2
- Effluent volume from stations D1 and D2
- Peak influent discharge rate from HSPF modeling
- Influent volume from HSPF modeling

The precipitation data will then be screened to identify storm events with precipitation totals that approximate the 2-year, 24-hour event (i.e., 1.68 inches). Influent and effluent peak discharge rates and volumes from this subset of storms will then be evaluated to determine the effectiveness of the NDS swale at attenuating peak flows relative to design expectations. In addition, influent and effluent volumes measured over each water year of the monitoring program will be examined to determine if the NDS test swale is infiltrating 91 percent of the average annual runoff volume.

Water quality data will also be summarized in tabular and graphical formats with comparisons to the water quality standards presented in Table 1 provided where applicable. To evaluate the performance of the NDS test swale at improving water quality, influent and effluent pollutant concentrations from stations WQ1 and WQ2, respectively, will be compared and used to estimate the system's treatment effectiveness for specific parameters.

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List of Revisions

The current list of revisions for this SOP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R1D0	**9/13/2007**	**Approved**	**John Lenth**	**QAPP revised based on SPU and Washington State Department of Ecology comments**

APPENDIX A

Photographs of primary control device for monitoring station D1

High Point Block Scale Monitoring Project
Appendix A – Photographs of primary control device for monitoring station D1

Photo Number	Photo Description
1	Primary measuring device for HSPF calibration monitoring with two stage weir consisting of a 45° V-notch and 3" rectangular weir.
2	Location of the pressure transducer within the two stage weir.

1

2

APPENDIX B

Example for field forms

HERRERA ENVIRONMENTAL CONSULTANTS

2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
(206) 441-9080
FAX (206) 441-9108

CHAIN OF CUSTODY RECORD

PROJECT NAME:	PROJECT NUMBER:	CLIENT:
REPORT TO:		COPY TO:
SAMPLED BY:		DELIVERY METHOD:
LABORATORY:	REQUESTED COMPLETION DATE:	TOTAL # OF CONTAINERS:
LAB USE:		

ANALYSES REQUESTED

SAMPLE ID:	DATE:	TIME:	SAMPLE DESCRIPTION	# OF CONTAINERS:																

REMARKS:

RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:
RELINQUISHED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:	RECEIVED BY (NAME/CO.):	SIGNATURE:	DATE/TIME:

High Point Monitoring Project Data Download and Maintenance Checklist

Name: _____ Date: _____ Time: _____ Date of last site visit: _____
Conditions: _____
Purpose of visit: _____
_____

Station RG1 – Rain Gauge: _____
Data Upload:
Upload: YES / NO Time: _____ Memory clear: YES / NO

Maintenance:
Change Battery: YES / NO Voltage before change: _____ Voltage after change: _____
Change desiccant: YES / NO Clean funnel: YES / NO
Comments: _____
_____

Station WL1 – Water Level: _____
Data Upload:
Upload: YES / NO Time: _____ Memory clear: YES / NO Staff gauge reading:_____

Maintenance:
Change Battery: YES / NO Voltage before change: _____ Voltage after change: _____
Change desiccant: YES / NO Staff gauge and pressure sensor checked with a level: YES / NO
Comments: _____
_____

Station D2 – South DataGator: _____
Data Upload:
Upload: YES / NO Time: _____ Memory clear: YES / NO

Maintenance:
Change Battery: YES / NO Voltage before change: _____ Voltage after change: _____
DataGator secure/level: YES / NO Any discharge: YES / NO Any sign of leakage: YES / NO
Calibration Test: YES / NO Instrument reading: _____ Manual reading: _____
Comments: _____
_____

Station D3 – North DataGator: _____

Data Upload:

Upload: YES / NO Time: _____ Memory clear: YES / NO

Maintenance:

Change Battery: YES / NO Voltage before change: _____ Voltage after change: _____

DataGator secure/level: YES / NO Any discharge: YES / NO Any sign of leakage: YES / NO

Calibration Test: YES / NO Instrument reading: _____ Manual reading: _____

Comments: _____

_____

Action items: _____

_____

_____

_____

_____

_____

Date of next servicing: _____