Section S8D - Stormwater Characterization
Quality Management System Planning Document

Quality Assurance Project Plan

NPDES Phase I Municipal Stormwater Permit

Permit No.: WAR04-4503

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Seattle Public Utilities
Seattle, Washington

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

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1. TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

(2) High Point Bioretention Swales
NPDES Phase I Municipal Stormwater Permit

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ACRONYMS

AWRL	Ambient Water Reporting Limit
BMP	Best Management Practice
CAR	Corrective Action Report
COC	Chain of Custody
CWA	Clean Water Act
DMP	Data Management Plan
DMRG	Data Management Reference Guide
DQI	Data Quality Indicator
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
EPA	Environmental Protection Agency
GIS	Geographic Information System
MDL	Method Detection Limit
MQO	Measurement Quality Objective
NCR	Nonconformance Report
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PO	Project Officer
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
RPD	Relative Percent Difference
SIC	Science Information Catalog
SIMS	Science Information Management System
SLOC	Station Location Form
SOP	Standard Operating Procedure

TABLE OF CONTENTS

Title and Approval Sheet iii
Distribution List v
Acronyms vi
Table of Contents vii
Element I. Goals and Objectives of the Study 3
3 Background 3
3.1 The Problem 3
3.1.1 Driver 4
3.1.2 Decision-making 4
3.2 Study Area 4
3.3 Parameters of Concern 6
4 Project Description 9
4.1 Study Goals 9
4.2 Study Objectives 10
4.3 Information Requirements 10
4.4 Study Boundaries 11
4.4.1 Spatial Boundary 11
4.4.2 Temporal Boundaries 11
4.4.3 Target Populations 12
4.4.4 Practical Constraints 12
5 Organization and Schedule 15
5.1 Roles & Responsibilities 15
5.2 Special Training Needs/Certification 17
5.3 Timeline/study schedule 18
5.3.1 Study Deliverables 19
5.3.2 Study Success Factors 19
Element II. Type, Quality, and Quantity of Data Needed 22
6 Quality Objectives 22
6.1 Data Quality Objectives 22
6.2 Measurement Quality Objectives 22
6.2.1 Precision, Bias, and Accuracy 23
6.2.2 Representativeness 23
6.2.3 Completeness, and Comparability 24
6.2.4 Sensitivity (Reporting Limits) 24
7 Sampling Process Design (Experimental Design) 24
7.1 Monitoring Location Selection Methodology 25
7.1.1 Land Use Estimate Methodology 26
7.1.2 Drainage Area Confirmation Methodology 27
7.1.3 Times of Concentration Methodology 27
7.2 Stormwater Monitoring Strategy 27
7.2.1 Parameters and Analytical Methods 28
7.2.2 Sampling Techniques and Types 30
7.2.3 Qualifying Sample Criteria 30
7.2.4 Equipment Selection Strategy 32
7.3 Residential Basin – R1 (Venema) Monitoring Strategy 33
7.3.1 Monitoring Site Characteristics 33
7.3.2 Equipment Monitoring Strategy 39
7.4 Industrial Basin – I1 (Norfolk) Monitoring Strategy 39
7.4.1 Monitoring Site Characteristics 40
7.4.2 Equipment Monitoring Strategy 45
7.5 Commercial Basin (UD) 45

7.5.1 Monitoring Site Characteristics ... 46
7.5.2 Equipment Monitoring Strategy ... 48
8 Sampling (Field) Procedures ... 48
8.1 Equipment Decontamination Procedures ... 49
8.1.1 Water Sampling Equipment ... 49
8.1.2 Sediment Sampling Equipment ... 49
8.2 Sample Collection Procedures ... 49
8.2.1 Automatic Flow-weighted Composite Samples ... 50
8.2.2 Manual Grab Samples ... 52
8.2.3 Sediment ... 52
8.2.4 Flow and Rain Data ... 53
8.3 Sample Handling & Custody ... 54
8.3.1 Sample Identification ... 54
8.3.2 Sample Transportation ... 54
8.3.3 Sample Preservation ... 54
8.3.4 Sample Processing ... 55
8.3.5 Holding Times ... 55
8.3.6 Chain of Custody ... 55
8.4 Non-direct Measurements ... 56
9 Measurement Procedures ... 56
9.1 Water Quality & Sediment Analysis ... 56
9.2 Toxicity Testing ... 56
9.2.1 Testing Procedures ... 56
9.2.2 Follow Up Actions ... 57
Element IV. Study Implementation QA/QC Procedures ... 59
10 Quality Control ... 59
10.1 Analytical Quality Control ... 59
10.2 Field Quality Control ... 59
11 Data Management & Documentation Procedures ... 60
11.1 Documents and Records ... 60
11.1.1 Field Operation Records ... 60
11.1.2 Laboratory Records ... 61
11.1.3 Data Handling Records ... 62
11.2 Revisions to the QAPP ... 62
12 Audits and Reports ... 62
12.1 Assessments and Response Actions ... 62
12.2 Deficiencies, Nonconformances and Corrective Action ... 63
Element V. Assessment Procedures ... 65
13 Data Verification and Validation ... 65
13.1 Data Review, Verification, and Validation ... 65
13.2 Verification and Validation Methods ... 66
14 Data Quality (Usability) Assessment ... 66
14.1 Data Usability Assessment ... 67
14.1.1 Data Processing Guidelines ... 68
14.1.2 Identification of Outliers ... 68
14.1.3 Descriptive Statistics ... 68
14.1.4 Roles, Responsibility, and Documentation ... 68
14.2 Data Reduction Methods ... 69
14.2.1 Event Mean Concentration ... 69
14.2.2 Pollutant Load ... 69
14.3 Data Quality Assessment Methodology ... 73
14.3.1 Graphical Trend Testing ... 74
14.3.2 Hypothesis Trend Testing ... 74
15 Data Analysis & Presentation ... 74
15.1 Site Summary ... 75

15.2 Comprehensive Data Summary 75
15.3 Quality Assurance/Quality Control Summary 76
References 77
List of Revisions 79
Tables 80
Glossary 94
Drawings 101

List of Tables

Table 1. Stormwater characterization monitoring proposed sites summary. 5
Table 2. Stormwater characterization monitoring sites basin land use distribution. 5
Table 3. Common stormwater pollutants and their sources (Ecology 2006, modified). 6
Table 4. Water quality parameters to be analyzed from samples collected by automatic composite sampler. 8
Table 5. Water quality parameters to be analyzed from samples collected by manual grab. 9
Table 6. Sediment quality parameters to be collected by sediment trap. 9
Table 7. Stormwater characterization monitoring proposed sites 12
Table 8. Study Team contact information. 15
Table 9. Roles & responsibilities 16
Table 10. Target equipment installation and testing schedule. 19
Table 11. Study deliverable schedule and events sampled timeline. 20
Table 12. Anticipated additional plans to support sampling activities. 21
Table 13. Sampling design summary. 25
Table 14. Monitoring site characterization summary. 26
Table 15. Volume requirements for stormwater chemistry and toxicity analyses. 28
Table 16. Required composite sample analysis priority order (S8D, paragraph 2c). 29
Table 17. Required sediment sample analysis priority order (S8D, paragraph 2(f)(iii)). ..30
Table 18. Qualifying storm event criteria and sampling frequency. 31
Table 19. Qualifying sampler collection criteria. 31
Table 20. Three proposed sampler configurations. 32
Table 21. Stormwater quality composite sampler equipment specifications. 33
Table 22. Residential basin rain gage RG07 summary information (from SPU 2003). 38
Table 23. Residential basin rainfall-frequency results for RG07 through 2003 (from SPU 2003). 38
Table 24. Flow equipment specifications for residential site 39
Table 25. Industrial rain gage RG10 summary information (from SPU 2003). 44
Table 26. Industrial basin rainfall-frequency results for RG10 through 2003 (from SPU 2003). 44
Table 27. Flow equipment specifications for industrial site. [28] 45
Table 28. Commercial basin rain gage RG03 summary information (from SPU 2003).). 47
Table 29. Commercial basin rainfall-frequency results for RG03 through 2003 (from SPU 2003). 47
Table 30. Flow equipment specifications for commercial site. [28] 48
Table 31. Toxicity follow-up reporting schedule. 58
Table 32. Laboratory Quality Control Samples by Matrix. 59
Table 33. Field quality control sample schedule. 60
Table 34. Assessment and response action schedule. 62
Table 35. Data review levels. 66
Table T-36. Quality assurance planning document cross-walk. 80

Table T-37. Standard Operating Procedure List (draft). 81
Table T-38. Sampling schedule for a complete water year. 82
Table T-39. Data Quality Indicators and their MQO criteria..... 83
Table T-40. MQOs for analytical precision, accuracy, and bias. 85
Table T-41. MQOs for hydrological accuracy and bias..... 85
Table T-42. Sensitivity MQOs in stormwater collected by automatic sampler 86
Table T-43. Sensitivity MQOs in stormwater collected by manual grab sample [37]..... 88
Table T-44. Sensitivity MQOs in sediment [37]..... 88
Table T-45. Containers, holding time, and preservation for water..... 89
Table T-46. Containers, holding time, and preservation for sediments. 90
Table T-47. Unique sample identification scheme..... 91
Table T-48. Sample data path. 92
Table T-49. Study data qualifier flags. 93

List of Figures

Figure 1. Normal monthly precipitation at SeaTac for the water year. 12
Figure 2. Organization chart illustrating study organization & lines of communication. ... 16
Figure 4. Residential monitoring station configuration..... 34
Figure 5. Typical Palmer-Bowlus flume. 35
Figure 6. Residential site installation details in MH No. 5..... 36
Figure 7. Residential basin site duration curve predicted by WWHM3..... 38
Figure 8. Residential basin rainfall-frequency curves for RG07 (from SPU 2003). 39
Figure 9. Industrial site existing conveyance system..... 40
Figure 10. Industrial site schematic. 41
Figure 11. NF/MLK conveyance upgrades design event hyetograph..... 42
Figure 12. Industrial site water quality sampling equipment layout. 43
Figure 13. Industrial basin rainfall-frequency curves for RG10 (from SPU 2003). 45
Figure 14. Commercial site sampling location (plan view)..... 46
Figure 15 . Commercial basin rainfall-frequency curves for RG03 (from SPU 2003)..... 48
Figure 16. Flow-weighted composite auto-sampler bottle configuration schematic. 51
Figure 17. SPU sediment trap mounting bracket..... 53
Figure 18. Typical sediment trap installation. 53

List of Drawings

Drawing 1. Study basin location map (with RG stations)..... 103
Drawing 2. Study location map for residential basin (Venema)..... 104
Drawing 3. Study location map for industrial basin (Norfolk)..... 105
Drawing 4. Study location map for commercial basin (UD). 106

Quality Assurance Project Plan

NPDES Phase I Municipal Stormwater Permit

This Quality Assurance Project Plan (Plan), prepared by Seattle Public Utilities (SPU) with assistance from Taylor Associates, Inc. (TAI) for the City of Seattle (City), describes management of the *stormwater characterization monitoring study* required under Section S8D of the Phase I Municipal Stormwater Permit, permit number WAR04-4503.

The permit, issued by the Washington Department of Ecology (Ecology) on January 17, 2007 with an effective date of February 16, 2007, under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for discharges from Large and Medium Municipal Separate Storm Sewer Systems (Ecology 2007), requires three types of monitoring under section S8:

Stormwater characterization – field monitoring which is intended to characterize stormwater runoff quantity and quality to allow analysis of loadings and changes in conditions over time and generalization across the Permittees' jurisdiction.

Program effectiveness - monitoring which is intended to improve stormwater management efforts by evaluating at least two stormwater management practices that significantly affect the success of or confidence in stormwater controls.

BMP Effectiveness - full scale field monitoring to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs applied in their jurisdiction.

This Plan is one of three that will be submitted to the Ecology to meet the permit requirements of Section S8 and covers the *stormwater characterization monitoring* component of section S8D. The City submitted a "*Monitoring Approach Proposal*" to Ecology on October 7, 2007 and received approval from Ecology on December 12, 2007 to monitor the following stormwater characterization basins:

- Venema, representing residential land use,
- Norfolk/Martin Luther King Jr. Way, representing industrial land use, and
- University District, representing commercial land use.

A draft version of this Plan was submitted to Ecology on August 25, 2008. Ecology reviewed the Plan and submitted comments to the draft letter in a letter data September 26, 2008. This final version of the Plan addresses Ecology's comments and updates project information.

The primary goal of this Plan is to define procedures that assure the quality and integrity of the collected samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and ultimately delivers defensible products and decisions for stormwater characterization monitoring described in Section S8D.

This document was developed with guidance from Ecology, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004). A cross-walk with the Environmental Protection Agency Quality Assurance Project Plan (QAPP) format is included in Table T-36.

This Plan is organized and presented using the following elements:

I. Goals and objectives of the study,

II. Type, quality, and quantity of data needed to meet the objectives,

III. Sampling and measurement procedures needed to acquire those data,

IV. Study implementation Quality Assurance (QA)/Quality Control (QC) procedures to ensure the QAPP is implemented as prescribed, and

V. Assessment procedures to determine if the data conform to the specified criteria will satisfy the project objectives and the analysis and format for presentation of the results.

Large tables that will be used often during the project life have been located in a Tables section. These tables are noted with a "T" prefix.

A series of Standard Operating Procedures (SOPs) will be developed to provide guidance to users of this Plan. Table T-37 presents the proposed list of SOPs to be developed by the NPDES Phase I Permittees Collaboration Team. If the Collaboration Team SOP development schedule meets the needs of this study, these SOPs will be adopted. Otherwise, SOPs will be developed independently of the Collaboration Team.

Element I. Goals and Objectives of the Study

This element covers basic project management, including project history and objectives, roles and responsibilities of participants, and other factors to ensure that the project has a defined goal and clear outcomes understood by all the participants. This element includes the following sections:

Section 3 – Background,

Section 4 – Project Description, and

Section 5 – Organization and Schedule.

3 BACKGROUND

In July 1995, Ecology issued three NPDES wastewater discharge general permits to regulate municipal stormwater discharges. These permits required development and implementation of stormwater management programs to reduce the discharge of pollutants to the maximum extent practicable. The permits expired on July 5, 2000. The Washington Department of Ecology (Ecology) administratively extended permit coverage until they issued the revised permit in January 2007.

Ecology combined the three current general permits for the Island/Snohomish, Cedar/Green, and South Puget Sound Water Quality Management Areas (WQMA) into a single statewide general permit. The general permit applies to all entities required to have permit coverage under current (Phase I) U.S. Environmental Protection Agency (EPA) stormwater regulations. This includes cities and unincorporated portions of counties whose populations exceed 100,000. The 1995 Phase I permittees include:

- King County
- Pierce County
- Snohomish County
- Clark County
- City of Seattle
- City of Tacoma

Phase I Secondary Permittees include:

- Port of Seattle
- Port of Tacoma

Ecology intends for the combination of intensive monitoring from all Phase I Permit tees throughout the state to provide them with a sufficient data set from which to draw conclusions about the effectiveness of programs on a region-wide basis.

3.1 The Problem

Stormwater quality is difficult to manage because discharges are not continuous, and storm events can be unpredictable. Rather, discharges are intermittent and weather-dependent (i.e., rainfall and snowmelt). There is a wide range of pollutants in stormwater, and concentrations vary depending on storm events. Further difficulty in controlling municipal stormwater discharges comes from the large number of outfalls where stormwater is being discharged. These features of stormwater runoff make it difficult to apply conventional end-of-pipe treatment options to existing discharges.

Stormwater management is expensive. Knowledge of pollutant loads and of average event mean concentrations from representative areas drained by the municipal storm sewer systems may help Ecology gauge whether the comprehensive stormwater management programs are making cost-effective progress towards the goal of reducing the amount of pollutants discharged and protecting water quality in the most cost-effective manner.

3.1.1 Driver

Three basic control strategies exist for stormwater. First, prevent pollutants from coming into contact with stormwater by using source control best management practices (BMPs). Second, apply treatment BMPs prior to discharge to surface or ground waters to reduce pollutants in the discharge. Third, control the flow rate of stormwater through flow control BMPs.

The complexity inherent in stormwater discharges and the difficulty of controlling such discharges means that it will take many years for full implementation that adequately mitigates or prevents adverse environmental impacts.

A feedback loop is needed by Ecology for adaptive management of the municipal stormwater permit to determine which strategy, or combination of strategies, is the most cost-effective at managing stormwater.

The permit requires each permittee to select one conveyance within the Municipal Separate Storm Sewer System (MS4) representing residential, industrial, and commercial land uses and collect and analyze samples that represent: (1) stormwater quality during qualified storm events, (2) annual sediment quality, and (3) stormwater toxicity during an annual “first flush” event. The MS4 is defined as a conveyance, or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains). Within the City of Seattle, this includes fully separated and partially separated storm drain systems.

3.1.2 Decision-making

Ecology intends to use the collected data to detect and monitor regional patterns and trends in stormwater quality and to analyze the relations between observed patterns and trends in stormwater program efforts.

3.2 Study Area

Seattle was founded in 1865 and grew rapidly in the following decades forcing the City to develop drainage and wastewater infrastructure to protect the citizens and water supplies. The first systems in Seattle were engineered to combine wastewater and stormwater. As the City grew so did the drainage infrastructure which today includes combined, partially separated, and fully separated systems. Seattle Public Utilities operates and maintains the drainage system within the City of Seattle and adjacent areas, which includes approximately 1,850 miles of combined, partially separated, and separated conveyance structures (Ecology 2005).

As noted above, the permit requires each permittee to select three sites within the stormwater conveyance system based on specific land use designations. The following requirement applies:

- Phase 1 Counties are required to choose three monitoring sites with the following land use designations: commercial, low density residential and high density residential.
- Phase 1 Cities are required to choose three monitoring sites with the following land use designations: commercial, high density residential and industrial.

- Ports of Tacoma and Seattle are to choose one outfall or conveyance.

City of Seattle sites selected to meet these requirements are described below in Table 1 and presented visually in Drawing 1.

Table 1. Stormwater characterization monitoring proposed sites summary.

Land Use Category	Catchment Name	Sewerage System Type
Residential	Venema	Separated, ditch & culvert system
Industrial	Norfolk/Martin Luther King Jr. Way (Norfolk)	Partially separated
Commercial	University District (UD)	Partially separated

The Venema basin was selected as the residential basin for stormwater monitoring because it represents a typical residential area in the separated portion of the City. This basin is located in the north-west portion of Seattle and discharges to Piper's Creek and then Puget Sound.

Industrial uses are concentrated in the Duwamish Valley, the Ballard-Interbay area, and the shoreline area between Ballard and Fremont. Many of these areas are located in combined areas and/or have stormwater systems that are tidally influenced. The Norfolk industrial basin was selected because it is served by the partially separated stormwater system, contains a suitable sampling location, and contains business activities typical of industrial land uses in Seattle. The Norfolk basin is located in southern Seattle on the Seattle Tukwila border and drains under I-5 to the west into the Duwamish waterway.

Commercial land uses vary by type and density in Seattle. The University District basin was selected as the commercial basin for stormwater monitoring. This basin is located in the partially separated portion of the city and represents a mix of commercial uses such as the University of Washington and neighborhood businesses that serve the surrounding residential population. This basin is located north of Lake Union and east of I-5 and drains to Lake Union above the Ballard Locks.

Table 2 summarizes the estimated basin land use distribution for the selected monitoring sites. As Table 2 also displays, residential is a predominant land use category within the City of Seattle.

Table 2. Stormwater characterization monitoring sites basin land use distribution.

Monitoring Site Land Use Category	Catchment Name	Catchment Area (acres) [1]	Land Use Category (%) (estimated from King County Parcel Database)[2]		
			Residential	Industrial	Commercial
Residential	Venema	157	82%	--	18%
Industrial	Norfolk	164	37%	36%	28%
Commercial	UD	187	32%	--	68%

[1] The catchment area is the total land area. The area draining to the storm drain system may be less in a partially separated area. See section 7.1 for details. These areas may be updated as additional information is made available.
[2] Commercial includes commercial, government, and schools. Other/vacant is determined by visual review of GIS. Residential includes single-family, multi-family, and open/parks. Right-of-way allocated to residential, commercial, and industrial proportionally. Includes area draining to the combined system.

3.3 Parameters of Concern

Impacts from stormwater are highly site-specific and vary geographically due to differences in local land use conditions, hydrologic conditions, and the type of receiving water.

There are many pollution sources that may affect stormwater quality, including land use activities, operation and maintenance activities, illicit discharges and spills, atmospheric deposition, and vehicular traffic conditions. Many of these sources are not under the direct control of the municipalities that own or operate the storm sewers. Table 3 lists common stormwater pollutants with related potential sources.

Table 3. Common stormwater pollutants and their sources (Ecology 2006, modified).

Pollutant	Potential Sources
Arsenic	Atmospheric deposition (ASARCO Smelter, fossil fuel combustion)
Cadmium	Tire wear, metal plating, batteries
Chromium	Metal Plating, rocker arms, crank shafts, brake linings, yellow lane strip paint
Copper	Vehicles (brake pads, thrust bearings, bushings), copper pesticides, atmospheric deposition from fuel combustion and industrial processes
Lead	Motor oil, transmission bearings, gasoline
Zinc	Vehicles (motor oil, tire wear), galvanized materials (roofing – flashing, dlown spouts, uncoated galvanized roofs, pipes, fencing)
Bacterial/Viral Agents	Domestic animals, septic systems, animal & manure transport
Nutrients	Sediments, fertilizers, domestic animals, septic systems, vegetative matter
Oil & Grease	Motor vehicles, illegal disposal of used oil
Organic Toxins	Pesticides, combustion products, petroleum products, paints & preservatives, plasticizers, solvents
Oxygen Demanding Organics	Vegetative matter, petroleum products
Sediments	Construction sites, stream channel erosion, poorly vegetated lands, slope failure, vehicular deposition
Temperature	Pavement runoff, loss of shading along streams

Ecology (2006) summarizes the parameters of concern:

> *TSS and turbidity are measures of particulates in the discharges. Particulates in receiving waters can change sediment habitat, disrupt breathing, feeding, and other behaviors in biota, and can be a vehicle for the entrance of toxicants into the ecosystem. TSS sources are eroding soils and organic and inorganic debris.*
>
> *In western Washington, where hardness levels are often very low, metals concentrations in urban stormwater can frequently exceed water quality standards by large amounts.*
>
> *Elevated metals concentrations can impact salmonid behaviors, and can have immediate lethal impacts. Vehicles are a major source of metals. Sources of copper include the wear of brake pads, bearings and bushings and other moving engine parts, and tailpipe emissions. Copper is also included in pesticide formulations. Tires, motor and hydraulic oils are major sources of zinc. Galvanized materials exposed to the weather also contribute high concentrations of zinc to stormwater runoff. Cadmium sources include tires and diesel exhaust.*
>
> *There are many polycyclic aromatic hydrocarbons (PAH's) that are associated with vehicle operation and with road and parking lot construction and maintenance. A recent study by the USGS in Austin, Texas identified coal tar and asphalt emulsion sealcoats as the major source of*

PAH-contaminated sediment in local waterbodies. Water column concentrations of PAH's as low as 1 part per billion (or, 1 microgram per liter) have caused decreased survival of salmonid embryos. Ecology has established marine sediment standards for PAH's. Those standards have been exceeded in various urban embayments around Puget Sound. Stormwater has been implicated as a contributor. Recent surveys of PAH's in sediments through out Puget Sound reveal that background PAH concentrations are increasing virtually everywhere, making PAH's a significant threat to ecosystem health.

The pesticides listed in the permit have all been detected with significant frequency in urban streams around King County based on a study conducted by the USGS, Ecology, and King County (1999). These results are consistent with results obtained in other areas of the country. The data collected in the King County study showed that some in-stream concentrations of insecticides exceed maximum recommended concentration limits for protection of aquatic life established by the National Academy of Sciences and National Academy of Engineering (1973), or the Ministers of Health Canada and Environment Canada (1995). Most instream samples of the insecticide, Diazinon, exceeded chronic aquatic life criteria recommended by USEPA (1998). Surface water runoff is the primary vehicle for transport of pesticides into these waters. Homeowner and commercial applications of these pesticides are the primary sources.

Nutrients, primarily phosphorus and nitrogen compounds, are often present in stormwater in concentrations that make significant contribution to eutrophication of streams, lakes, and estuaries. Stimulation of nuisance algae blooms and reduction in dissolved oxygen levels leading to stresses and sometimes death of sensitive organisms can occur.

Various studies throughout the country, and locally, have documented stormwater toxicity to test organisms such as daphnids, amphipods, bacteria, and fish. The causes of toxicity have included various pesticides and metals. Recently, studies confirming higher rates of pre-spawn mortality of adult salmonids returning to urban streams as compared to mortality rates in rural streams has raised awareness and concern about stormwater toxicity. Performing a toxicity test on the "seasonal first-flush storm" should give generally give us an annual worst case scenario. The build-up of pollutants on the urban landscape during the dry season (July – Sept.) can result in higher concentrations and loads from discharge sites when compared to concentrations and loads from smaller, more frequent storms throughout the winter. Generally, receiving waters have less volume of water available for dilution of those pollutants during this time, and the water is at a warmer temperature. These receiving water conditions increase the potential for toxic conditions to the biota.

The monitoring program includes grab samples for total petroleum hydrocarbons. Grab sampling from the stormwater surface is indicated because of the volatile nature of some of the compounds in this broad class of compounds. The presence of low levels of petroleum hydrocarbons that concentrate at the surface of waters can have impacts on biota that reside in or frequent the surface.

Grab samples for fecal coliform bacteria are also indicated. Fecal coliform bacteria are present in virtually all stormwater discharges. Sources include urban wildlife (birds, rats, mice, raccoons), domestic wildlife (dogs and cats), illegal cross-connections of sanitary sewers from residences and businesses, and onsite sewage disposal system failures. Because the urban landscape is dominated by impervious surfaces and nearly impervious surfaces, defecation on those surfaces is quickly washed into the storm drainage system. Fecal coliform bacteria are

the most common reason for a surface water to be listed as not attaining water quality standards.

The stormwater quality analytes identified as parameters of concern by Ecology are those that have a history of association with stormwater discharges and are found in urban environments. Ecology has identified the following parameters of concern that will be collected using flow-weighted composite sampling procedures (Table 4).

Table 4. Water quality parameters to be analyzed from samples collected by automatic composite sampler.

Analyte Group	Parameter	Stormwater	First-flush Toxicity
Conventional	Biological Oxygen Demand (BOD_5)	√	
	Chloride	√	√
	Conductivity	√	
	Hardness	√	√
	Surfactants (Methylene Blue Activating Substances , MBAS)	√	√
	Total Suspended Solids (TSS)	√	√
	Turbidity	√	
Metals (dissolved & total)	Cadmium	√	√
	Copper	√	√
	Lead	√	√
	Mercury [3]	√	√
	Zinc	√	√
Nutrients	Nitrate-nitrite	√	
	Orthophosphate	√	
	Total kjeldahl nitrogen (TKN)	√	
	Total phosphorus	√	
Semi-Volatile Organic Compounds (SVOCs)	Pentachlorophenol (fungicide) [4]	√	√
	Phthalates	√	√
	Polycyclic aromatic hydrocarbons (PAHs)	√	√
Pesticides, Chlorinated	2,4-D (herbicide)	√	√
	Dichlobenil (herbicide)	√	√
	MCPP (herbicide)	√	√
	Triclopyr (herbicide)	√	√
Pesticides, Nitrogen	Prometon (herbicide)	√	√
Pesticides, Organophosphorus	Diazinon (insecticide)	√	√
	Malathion (insecticide)	√	√
	Chloropyrifos (insecticide)	√	√

[3] Not required at residential sites.
[4] The greatest use of pentachlorophenol is as a wood preservative (fungicide). Though once widely used as an herbicide, it was banned in 1987 for these and other uses, as well as for any over-the-counter sales.

Ecology has identified two parameters of concern that will be collected using manual grab sampling procedures from stormwater (Table 5).

Table 5. Water quality parameters to be analyzed from samples collected by manual grab.

Analyte Group	Parameter
Bacteria	Fecal coliform bacteria
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics (DRO)
	Gas Range Organics (GRO)

The sediment analytes identified as parameters of concern by Ecology are those that have a history of association with stormwater discharges, are found in urban environments, have a marine sediment quality standard, or that provide necessary support information (e.g., total organic carbon). The following table contains the required sediment parameters for laboratory analysis (Table 6).

Table 6. Sediment quality parameters to be collected by sediment trap.

Analyte Group	**Parameter**
Conventional	Total solids
	Grain size
	Total organic carbon
Metals	Cadmium
	Copper
	Lead
	Mercury [3]
	Zinc
Persistent Organic Compounds	Polychlorinated biphenyls (PCBs) [3]
Semi-volatile Organic Compounds	Pentachlorophenol (fungicide)
	Phenolics
	Phthalates
	Polycyclic aromatic hydrocarbons (PAHs)
Pesticides, Organophosphorus	Diazinon (insecticide)
	Malathion (insecticide)
	Chloropyrifos (insecticide)

4 PROJECT DESCRIPTION

This section presents the goals and objectives of the project; describes the boundaries, target populations and practical constraints of the study; and specifies the information and data required to meet the study objectives.

4.1 Study Goals

The goal of the stormwater characterization monitoring study is to meet the requirements of Section S8D of the permit. Ecology's purpose is to obtain knowledge of pollutant loads and average event mean concentrations from representative areas drained by municipal storm sewer systems and to gauge

whether the comprehensive stormwater management programs are making progress towards the goal of reducing the amount of pollutants discharged and protecting water quality.

4.2 Study Objectives

Ecology's two primary objectives of the stormwater characterization monitoring required under Section S8E include:

(1) Estimate concentrations and loads from representative areas or basins to be used in evaluating overall program effectiveness.

(2) Provide a feedback loop for adaptive management of the City of Seattle's stormwater management programs and the municipal stormwater permit. Adaptive management will be implemented through future permits or permit modifications.

Ecology intends this type of monitoring to continue well beyond this permit cycle. Ecology determined the number of samples per year needed coupled with qualifying event criteria to establish a sufficient dataset from which they can discern annual and seasonal loading trends over a long time.

4.3 Information Requirements

The sampling design for stormwater monitoring under S8D contains three primary components that will be conducted at each monitoring site through the remainder of the Phase I Permit cycle:

- Stormwater sampling
- Toxicity sampling
- Sediment sampling

Information required to meet the study objectives is described below.

Stormwater Sampling Automatic flow-weighted composite and manual grab sampling methods will be used to collect stormwater samples from qualifying storm events (Table 18) throughout each water year. Sampling will be distributed throughout the year, approximately reflecting the distribution of rainfall between the wet and dry seasons (a goal of 60 to 80 percent of the samples collected during the wet season). Section 9 includes a list of the parameters to be analyzed and associated volumes.

Manual grab samples will be collected at each stormwater monitoring site during qualifying storm events as early in the storm event as possible. If it is not possible to collect a sample during the same storm event as a composite sample, a grab sample will be collected from a separate event. Information on parameters and volumes for grab samples can be found in Section 9.

Continuous flow data will be collected at each selected site during all storm events and for one year (prior to sampling where feasible) to establish rainfall and runoff relationships at each basin.

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

Event Mean Concentrations (EMCs), total annual pollutant loads for the sampled events, and seasonal pollutant loads for the sample events will be calculated for each required parameter at each monitoring site.

Toxicity Sampling Screening level toxicity sampling representing the seasonal first flush will be conducted using automatic flow-weighted composite sampling equipment at each stormwater monitoring site.

In addition to collecting a stormwater sample for toxicity testing, stormwater must also be collected for associated chemical analyses. The purpose of the chemical analysis for toxicity testing is to provide information on the presence of toxicants or classes of toxicants which affect the toxicity of other chemicals (such as metals). Information on parameters and volumes for toxicity testing can be found in Section 9 Measurement Procedures.

Sediment Sampling Sediments will be collected at each stormwater monitoring site using sediment traps. If sufficient volume is unattainable from these devices, other methods for collection may be approved by Ecology. Collected sediments will be analyzed annually for parameters that have shown to be associated with stormwater discharges and are found in urban environments. Information on parameters and volumes for sediment samples can be found in Section 9 Measurement Procedures.

4.4 Study Boundaries

This section describes spatial and temporal boundaries of the problem, the scale of decision-making when appropriate, the characteristics that define the population of interest, and any practical constraints on data collection.

4.4.1 Spatial Boundary

The spatial boundary defines the geographic area within which all decisions will apply and the physical area to be studied and from where the samples will be collected.

Ecology may apply any decisions resulting from this study within the Phase I permittees' jurisdictions.

Three basins were selected based on the permit criteria that each site must represent a discernible type of land use, but not a single industrial or commercial complex. Ideally, to represent a particular land use, no less than 80 percent of the area served by the conveyance will be classified as having that land use.

Table 7 summarizes the selected monitoring basins. The basins are presented visually in Drawing 1. Each monitoring station has a corresponding receiving water station that may be used to ascertain background hardness for the first flush toxicity test.

4.4.2 Temporal Boundaries

The temporal boundary defines the timeframe to which the decision applies and when data will be collected. Ecology intends that this monitoring program will extend well beyond the current permit cycle (February 2007 – February 2012).

Stormwater flow will be monitored continuously at stations VN001, NF001, and UW001. Sampling will be conducted periodically as indicated in Table T-38. For stormwater characterization monitoring, flow-weighted composite samples will be collected for 67 percent of the qualifying storms throughout the year, up to a maximum of eleven storm events per water year. A goal of 60-80 percent of the samples will be collected during the wet season to reflect rainfall distribution patterns typical in this region (Figure 1).

Table 7. Stormwater characterization monitoring proposed sites

Land Use Category	Catchment Name	Monitoring Station ID[5]	Rain Gage [6]	King County Receiving Water Station[7]
Residential	Venema	R1	RG07	KTHA03[8]
Industrial	Norfolk	I1	RG10	0309[9]
Commercial	University District (UD)	C1	RG03	536

For each individual sampling event, samples will be collected over at least 75 percent of the storm's hydrograph for storm events lasting less than 24 hours and at least 75 percent of the hydrograph of the first 24 hours of the storm event for storms lasting greater than 24 hours. In addition, the automatic flow-weighted composite sampler will be programmed to begin sampling as early in the runoff event as practical and to continue sampling past the longest estimated time of concentration for the tributary area.

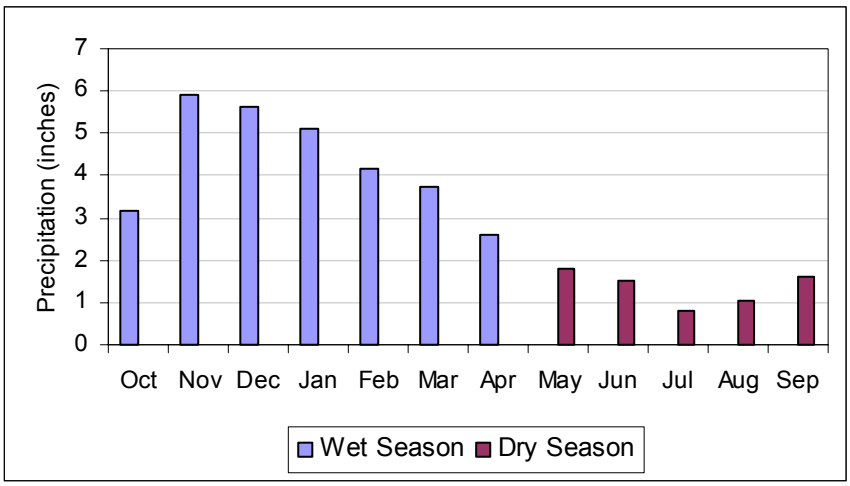


Figure 1. Normal monthly precipitation at SeaTac for the water year.

4.4.3 Target Populations

The characteristics that define the population of interest are wet and dry season and annual pollutant loads in the stormwater conveyance system from selected basins within the City of Seattle.

4.4.4 Practical Constraints

The three primary practical constraints to a successful study are discussed below and include:

[5] Permanent station names will reflect the maintenance hole the sample is collected from. This will not be known until after construction of the sites is complete.
[6] See Drawing 1 for rain gage station locations.
[7] A grab sample for hardness may be collected in the receiving water at the beginning of the first flush event intended to be measured for toxicity. A decision on whether to collect this sample will be made on a case-by-case basis for each storm event at the discretion of the Principle Investigator.
[8] King County has been conducting monthly baseline water quality monitoring at three sites along Piper's Creek since 1988. Station KTHA03 is located at the mouth of Venema Creek.
[9] King County has been conducting monthly baseline water quality monitoring at several sites along the Green-Duwamish River beginning in the early 1970s. Station 0309 is located in the Duwamish River at the bridge on East Marginal Way in Allentown.

1) Sampling design assumptions and requirements;

2) Construction and installation of equipment in time to meet the permit deadline to begin sampling; and

3) Typical logistical challenges associated with the difficult task of monitoring stormwater.

Sampling design – The sampling design is very ambitious and assumes a high success rate. Local experience with flow-weighted composite stormwater sampling indicates that it will be challenging to meet the following:

- Successfully track and sample 11 qualifying storm events per year;
- Distribute successful sample collection between wet season (goal of 60 to 80 percent of samples to be collected) and the dry season; and
- Successfully track and collect a seasonal first flush toxicity sample of the appropriate volume, cool during collection, and deliver to the laboratory within the specified temperature criterion within two attempts.

Construction Schedule – Each selected site has specific construction and equipment installation issues. Equipment installation may include the need to obtain permits, entering into agreements with contractors, closing the street to replace pipe sections, installing new maintenance holes, etc. In particular, the Norfolk and Venema sites are dependent on the completion of scheduled repairs and/or upgrades to accommodate sampling equipment. The monitoring location has been selected and installation plans have been developed.

Monitoring equipment can not be installed at the industrial site until the construction of *Phase II of the Norfolk-MLK Way Subbasin Stormwater Improvements Proposed Storm Drain Connection at SR-5, MP 158.1,* which is scheduled for the summer fall and winter of 2008, is complete. Construction includes replacement of a 36-inch line that has collapsed and is contributing to significant backup of stormwater on Martin Luther King Jr. Way with subsequent overflow to the City of Seattle sanitary sewer Pump Station No. 17 on South Norfolk Street. Phase II would improve conveyance in the trunk storm drain system primarily serving Martin Luther King Jr. Way from Boeing Access Road to Beacon venue South. The purpose of the upgrade is to eliminate street flooding on Martin Luther King Jr. Way for events greater than or equal in magnitude to the 25-year, 24-hour rainfall event. This project would also reduce the volume of stormwater discharge to the City of Seattle sanitary sewer.

Significant upgrades at the Venema site were completed in June to provide for accurate flow and water quality measurements to meet the permit requirements. These include installation of a flume and realignment of the storm drain to reduce the pipe slope.

Logistical challenges - The unpredictable nature of storm events poses the greatest logistical challenge for this study. Only storms of particular depths and intensities will result in qualifying storm events and successful sample collection. However, the location, timing, duration, magnitude, and intensity of storm events cannot be forecast with certainty.

Since long-term forecasts have greater uncertainty, mobilization of field staff and equipment setup for a potential storm sampling event cannot happen more than two days ahead of a forecasted storm. During

an event, staff must be mobilized to collect grab samples on very short notice and must visit a set of sites in a relatively short period (2 to 3 hours) in order to collect samples as early in the event as possible.

Although Standard Operating Procedures (SOPs) will be followed, it is inevitable that during this long duration and intense monitoring study equipment malfunction and human error will result in unsuccessful sample collection of some qualifying storm events.

Although sites are selected to minimize safety concerns, traffic control may be necessary to access the monitoring stations safely. Access may be necessary during high traffic periods, at night, and/ or during severe weather. These access conditions pose additional logistical challenges for sample collection.

Specific logistical considerations for each selected site are described further below.

4.4.4.1 Residential Site – R1 (Venema)

This site is located in a quiet residential area with available parking on the shoulders. The equipment enclosure location has been sited several feet back from the road.

A confined space entry will be needed at each maintenance hole for any installation or maintenance activity (Figure 3). Maintenance holes 2, 3, 4, and 5 will need to be accessed to install the monitoring equipment and maintenance holes 2, 3 and 5 will need to be accessed for routine maintenance and calibration activities (see Section 7.3).

All of these maintenance holes are located near the edge of the road surface on two corners of a four-way intersection. Traffic lanes will need to be narrowed during work in any of the manholes but no lane closures will be needed.

4.4.4.2 Industrial Site – I1 (Norfolk)

This site is located at the end of a busy industrial private parking lot. The City's legal department is currently negotiating with the landowner (Pape) to secure an easement for placement and access to the monitoring equipment. The landowner has verbally indicated he is amenable to the proposed easement. On July 22, 2008, approval was requested from the City Council committee to acquire properties for the project. On July 28, 2008, the legislation was presented to the full Council and passed. After passing, we expect approximately six weeks to secure access.

Confined space will be required at the industrial land use site. While working, an area of the parking lot will likely have to be closed off.

4.4.4.3 Commercial Site – C1 (UD)

The commercial site, located near the University of Washington, is located along a busy road. The equipment enclosure and the maintenance hole are located in the planting strip between the curb and the sidewalk.

Regular street parking at the site is not available and may require partially blocking the northbound lane of Brooklyn Avenue while working at the site.

Confined space entry will be needed to install and maintain the sample line and ultrasonic sensor. A barricade should be placed around the manhole when it is open to prevent any accidents involving pedestrians on the nearby sidewalk.

Crime may be an issue in the area. No permits are likely needed for the site.

5 ORGANIZATION AND SCHEDULE

This section describes the roles & responsibilities of the study team, the study timeline and schedule.

5.1 Roles & Responsibilities

The team consists of representatives from key groups with a role in data collection or use, and often those with a critical interest or stake in the problem. This section includes the names, duties, and responsibilities of all key team participants, including internal and external team members. The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for the field investigation.

The roles of key individuals involved in the study are provided in Table 8. A detailed description of the lines of authority and reporting between these individuals and organizations is presented in Figure 2 and the responsibility associated with each role is outlined in Table 9.

Table 8. Study Team contact information.

Role	Name	Organization	Telephone No.
NPDES Permit Coordinator (Business Area Representative)	Kevin Buckley	SPU	206.733.9195
Study Manager	Sharon Walton	Taylor Associates, Inc.	206.267.1413 Cell: 206.940.3594
NPDES Monitoring Lead (Principle Investigator)	Doug Hutchinson	SPU	206.233.7899
QA Coordinator	Amy Minichillo	SPU	206.684.0974
Field Supervisor	Bryan Berkompas	Taylor Associates, Inc.	206.267.1413
Data Steward	Ann McNally	SPU	206.386.9786
Contract Laboratory (General) PM	Mark Harris	Analytical Resources Inc.	206.695.6200
Contract Laboratory (Toxicity) PM	Mary Ann Rempel-Hester	Nautilus Environmental	253.922.4296

In general, the Principle Investigator (PI), reporting to the Business Area Representative (NPDES Permit Coordinator), is assigned to manage the stormwater characterization monitoring program. In this role, he/she provides technical expertise; coordinates sampling activities with the laboratory and the study manager, who coordinates the field team; and reports the status and results of the study to the Business Area Representative.

The Business Area Representative provides direction to the PI and communicates with the Ecology Regional Representative.

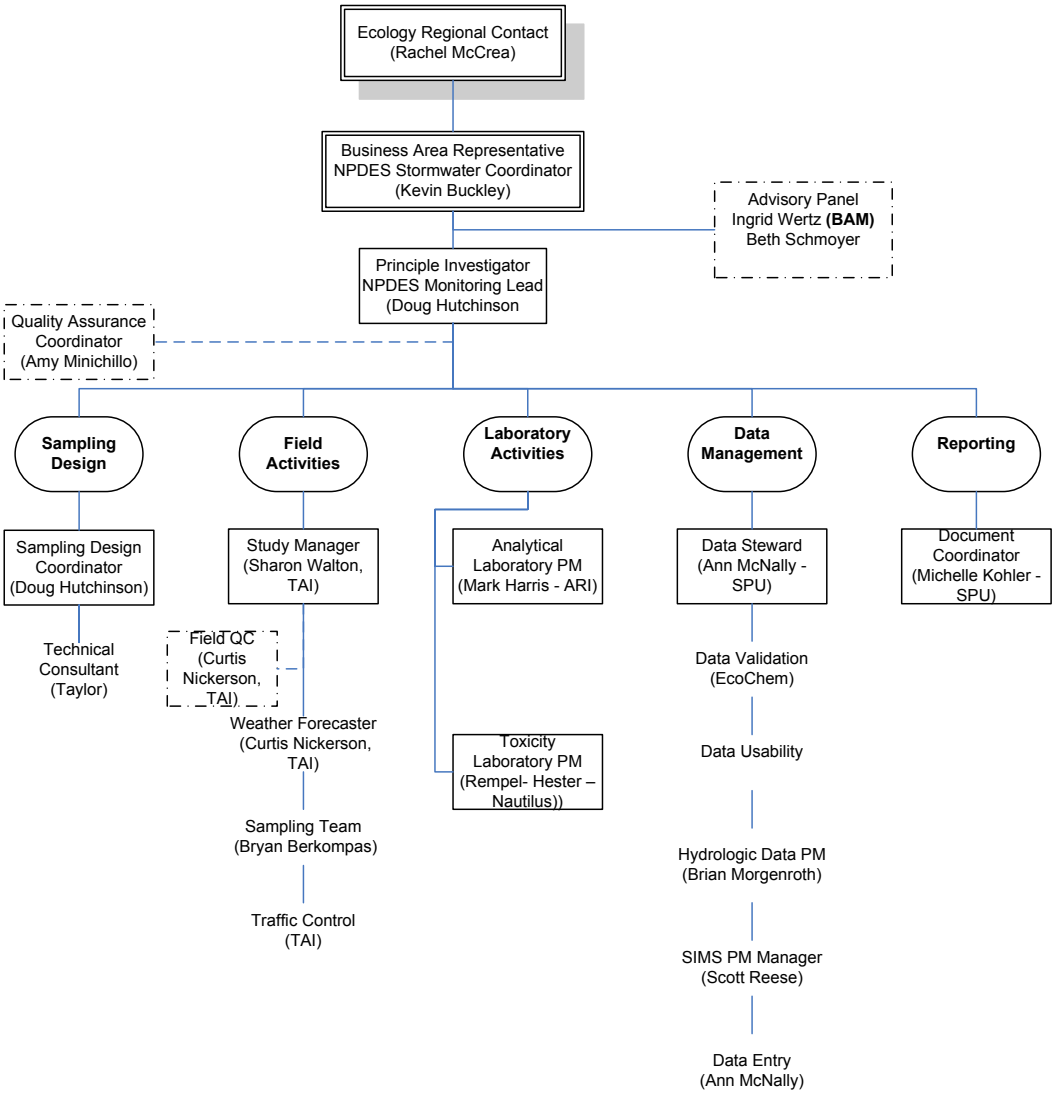


Figure 2. Organization chart illustrating study organization & lines of communication.

A description of the detailed responsibility of each role is outline below in Table 9.

Table 9. Roles & responsibilities

Roles & responsibilities
Advisory Panel The Advisory Panel attends intermittent meetings for review process of the overall program in order to confirm or refute whether the study objectives are being met. The group may make suggestions for changing specific procedure or overall organization in the event that the study design fails to meet the stated goals.
Business Area Manager (BAM) Responsible for overall monitoring program including fiscal resources and personnel. Approves QAPP.
Business Area Representative (BAR) Carries out needs and requirements set by the Business Area Manager. Coordinates with Ecology representative. Provides study/program direction. Ensures that there is sufficient managerial, technical and support staff with the authority and resources (equipment, etc.) to perform their stated duties. Establish procedures to ensure that all personnel are free from any undue internal or external commercial, financial, and other pressures or influences that may adversely affect the performance and quality of their work.
Principle Investigator (PI) Responsible for the development, approval, implementation, and maintenance of the

Roles & responsibilities
QAPP. Acts as a liaison between the analytical laboratory, the study manager, the field team leader, the QAC and the organization. Responsible for: maintaining records of QAPP distribution, including appendices and amendments; maintaining written records of sub-tier commitment to requirements specified in this QAPP; identifying, receiving, and maintaining study quality assurance records; coordinating with the QAC to resolve QA- related issues. Notifies Business Area Representative of particular circumstances which may adversely affect the quality of data derived from the collection and analysis of samples. Ensure that the staff has the necessary education, experience, and/or training to perform their stated duties. Enforces corrective action.
Quality Assurance Coordinator (QAC) Reports to the Principle Investigator indirectly and is independent of the field, laboratory, data, and reporting staff. Major responsibilities include monitoring QC activities to determine conformance, distributing quality related information, training personnel on QC requirements and procedures, reviewing QA/QC plans for completeness and noting inconsistencies, and signing-off on the QA plan and reports.
Study Manager (SM) Responsible for ensuring tasks and other requirements in the contract for field implementation are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance at conference calls, training, meetings, and related study activities. Responsible for verifying the QAPP is followed and the study is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Complies with corrective action requirements. Supervises the assigned study personnel (scientists, technicians, and support staff) in providing for their efficient utilization by directing their efforts either directly or indirectly on study tasks. In general, other specific responsibilities include: coordinate study assignments in establishing priorities and scheduling, ensure the completion of high-quality studies within established budgets and time schedules, provide guidance and technical advice to those assigned to studies by evaluating performance, implement corrective actions and provide professional development to staff, and prepare and/or review preparation of study deliverables, interact with clients, and technical reviewers to assure technical quality requirements are met in accordance with contract specifications.
Sampling Design Coordinator Responsible for completion of the sampling design by coordinating resources from the consultant, statistician, senior contributing personnel, and the needs of the user.
Document Coordinator Responsible for on-schedule completion of assigned writing, editing, and data interpretation work. Directs all reporting activities, including in-house and outside review, editing, printing, copying, and distributing or journal submission.
Field Supervisor Responsible for: supervising all aspects of the sampling and measurement in the field; the acquisition of samples and field data measurements in a timely manner that meet the quality objectives; field scheduling, staffing, and ensuring that staff are appropriately trained.
Data Steward Responsible for the acquisition, verification, and transfer of data to the SPU database. Oversees data management for the study. Ensures data are submitted according to work plan specifications. Responsible for validation and verification of data collected. Provides the point of contact to resolve issues related to the data.
Laboratory Manager Responsible for supervision of laboratory personnel involved in generating analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.
Laboratory QAO Monitors the implementation of the Quality Assurance Manual (QAM) and the QAPP within the laboratory to ensure complete compliance with QA objectives as defined by the contract and in the QAPP. Conducts internal audits to identify potential problems and ensure compliance with written SOPs. Responsible for supervising and verifying all aspects of the QA/QC in the laboratory. Performs validation and verification of data before the report is sent to the contractor. ensures that all QA reviews are conducted in a timely manner from real-time review at the bench during analysis to final pass-off of data to the QA officer.

5.2 Special Training Needs/Certification

This section identifies and describes any specialized training or certifications needed by personnel in order to complete the study or task successfully.

Field personnel will receive training in proper sampling and field analysis for each Standard Operating Procedure they will be using. They will demonstrate to the Field Supervisor (in the field), their ability to properly operate the automatic samplers and retrieve the samples. The Field Supervisor will sign off each field staff in their field logbooks.

Field staff that collect positional data shall undergo a training program to ensure that he or she has the knowledge and skills required to collect data in accordance with SOPs for GIS.

In addition to technical training, field personnel will receive training that addresses stormwater monitoring activities that have the potential to adversely affect their health and safety. Stormwater monitoring field crews often work in wet, cold, and poor visibility conditions. Sampling sites may be located in high traffic areas or remote, poorly lit areas that need to be accessed on a 24-hour basis. Monitoring personnel and workers installing or maintaining equipment may be exposed to traffic hazards, confined spaces, biological hazards (e.g., medical waste and fecal matter), vectors (e.g., snakes and rats), fall hazards, hazardous materials, fast moving stormwater, and slippery conditions. A health and safety plan will be developed for each site. The health and safety plan will include detailed training and procedures to address confined spaces, vehicle traffic, open manholes and manhole lids, open water hazards, biological hazards, and chemical hazards.

The selected laboratory will be accredited or registered under the provisions of Accreditation of Environmental Laboratories, Chapter 173-50 WAC.

5.3 Timeline/study schedule

This section specifies the relevant deadlines for the study. The critical milestones to be met to meet the study implementation deadline of February 16, 2009 are provided below.

Key dates include:

August 25, 2008	Summary description of the monitoring program and Quality Assurance Project Plan (QAPP) submitted to Ecology.
September 26, 2008	Ecology completes review of the QAPP and responds with comments to the City.
February 16, 2009	Final QAPP with revisions submitted to Ecology.
February 16, 2009	Full implementation of the monitoring program begins.
March 31, 2010	First annual report due covering the period from February 16, 2009 through September 30, 2009
March 31, 2011	Second annual report due covering first complete water year, from October 1, 2009 through September 30, 2010.
March 31, 2012	Second annual report due covering first complete water year, from October 1, 2010 through September 30, 2011.

Table 10 outlines the target equipment installation and testing schedule needed to meet the monitoring initiation date of February 16, 2009. This schedule is dependent on receiving review comments from Ecology by May 16, 2008 so equipment can be ordered with some confidence that the specifications will be correct for the final monitoring configuration. Due to the industrial basin scheduled construction upgrades, equipment installation at the industrial site is expected to be complete by the end of March 2009, with flow monitoring to establish pacing needs in April and sampling to begin in May.

Table 10. Target equipment installation and testing schedule.

Activity	Residential	Industrial	Commercial
Finalize QAPP/Equipment List	June 2008	June 2008	June 2008
Order Equipment	December 2008	December 2008	December 2008
Install Equipment	January 2009	March 2009	December/January 2009
Initiate Flow Monitoring	January 2008	March 2009	December 2008
Evaluate Flow Data and Pacing Rates	January/February 2009	March/April 2009	January/February 2008
Test water sample collection	February 2009	March 2009	February 2009

5.3.1 Study Deliverables

This section describes the project deliverables. Section 14.2 provides additional details describing the procedure and method for developing the deliverables. Refer to Section 11 for documentation and records supporting development of the deliverables and Section 15 for a discussion of the content.

Each annual report will include all monitoring data collected during the preceding water year (October 1 – September 30). The first annual monitoring report submitted will include data from a partial water year, February 16, 2009 through September 30, 2009. Each report shall also integrate data from earlier years into the analysis of results, as appropriate. Reports shall be submitted in both paper and electronic form and shall include:

- A summary including the location, land use, drainage area size, and hydrology for each site,
- A comprehensive data and QA/QC report for each component of the monitoring program, with an explanation and discussion of the results of each monitoring study,
- The annual pollutant load based on water year for each site expressed in total pounds, and pounds/acre, and
- The wet and dry season pollutant loads based on water year, expressed in total pounds, and pounds/acre.

The study results will be presented in an annual report. Table 11 presents the study timeline, the number of events to be sampled each season, and the study deliverables schedule.

5.3.2 Study Success Factors

It is anticipated that five additional plans may be developed to support the sampling efforts and increase the chances for a successful outcome (Table 12).

Table 11. Study deliverable schedule and events sampled timeline.

Period	Season	Continuous Flow Recording [10]	Qualified Event Stormwater Sampling [11]	Non-qualified Event Stormwater Sampling [12]	Toxicity Sampling (First flush event) [13]	Sediment Sampling	Deliverable Due Date [14]
Partial Water Year One (2009) [15]	Wet (2/16/2009 to 4/30/2009)	Yes	2	0-2	0	1	03/31/2010
	Dry (5/01/2009 to 9/30/2009)	Yes	2-4		1		
Water Year Two (2010)	Wet (10/01/2009 to 4/30/2010)	Yes	7-9	0-3	0	1	03/31/2011
	Dry (5/01/2010 to 9/30/2010)	NA	2-4		1		
Water Year Three (2011)	Wet (10/01/2010 to 4/30/2011)	NA	7-9	0-3	0	1	03/31/2012
	Dry (5/01/2011 to 9/30/2011)	NA	2-4		1		
Partial Water Year Three (2012)	Wet (10/01/2010 to 3/12/2012)	NA	6-7	0-1	0	1	No deliverable
Permit Cycle	Total Samples (not including QC)	NA	33	0-9	3	4	See above

[10] This data will be used to establish a baseline rainfall runoff relationship. Not required to be submitted to Ecology.
[11] The storm events in this column are based on capturing 11 storms per water year with 60-80 percent of the storms sampled occurring in the wet season. Wet season extends from October 1st through April 30th the next year and dry season extends from May 1st each year through September 30th . For water year 2009, 2.5 months out of 7 months in the wet season are available for sampling, which is 23 percent of the expected wet season precipitation based on monthly normals at SeaTac (Figure 1 http://www.beautifulseattle.com/precsum.asp).
[12] Up to 3 samples collected as a result of attempts to sample the eleven required storm event and do not meet the rainfall volume storm event criteria will be analyzed.
[13] If a successful toxicity sample is not collected within the period from August 1st through September 30 attempts will be made to collect the sample in October. Toxicity samples will be reported in the water year they are taken.
[14] Submitted with Annual Report and includes the Annual Stormwater Monitoring Report and Toxicity Follow-up Actions (if applicable). Toxicity testing follow-up actions (if applicable) will follow the timeline presented in Section 9.2.2. If follow-up actions are completed prior to the calendar year the report is issued in, they will be submitted at that time. If not completed, they will be submitted with the next annual report.
[15] The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

Table 12. Anticipated additional plans to support sampling activities.

Plan	Purpose	Responsible for prepared & Implementation
Communication Plan	Provide anticipated communication between the Principle Investigator, analytical laboratories, Study Manager, and field teams. Includes process to keep the laboratory informed of the schedule for sample delivery. For example, the plan will include the following: the toxicity laboratory will be contacted prior to the forecasted storm event to inquire about gamete (test organism) availability. If the laboratory confirms that gametes of sufficient quantity and quality will not be available for toxicity testing, the first flush sampling will be cancelled.	Study Manager
Construction Plan	Develop construction schedule, identify any permits needed (i.e. Seattle Department of Transportation (SDOT), Seattle City Light, etc.), develop power and communication needs list, etc.	Study Manager
Implementation Plan	Property access, storm event response, equipment availability, back up options as needed, etc.	Study Manager
Traffic Control Plan	SDOT permits, required training, flagging needs, etc.	Study Manager
Health & Safety Plan	Personnel hazards including confined space entry.	Study Manager

Element II. Type, Quality, and Quantity of Data Needed

This element describes the type, quality, and quantity of data needed to meet the study objectives and includes:

Section 6 - Quality Objectives, which describe the type and quality of data needed to meet the study goals and objectives, and

Section 7 - Sampling Process Design, which determines the quantity of data needed.

6 QUALITY OBJECTIVES

This section describes the study data quality and measurement quality objectives, which describe the type and quality of data needed to meet the study goals and objectives.

Data Quality Objectives (DQOs) are qualitative and quantitative statements developed using the data quality objectives process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors. These will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Once established, DQOs become the basis for the measurement quality objectives (MQOs) that are used specifically to address analytical performance.

Measurement Quality Objectives (MQOs) are “acceptance criteria” for the quality attributes measured by the study data quality indicators (DQIs). During study planning, measurement quality objectives are established as quantitative measures of performance against selected data quality indicators, such as precision, bias, representativeness, completeness, comparability, and sensitivity. By extrapolation, data that meets defined MQOs are considered acceptable for use in study decision making.

6.1 Data Quality Objectives

The Data Quality Objectives (DQOs) serve to guide the eventual determination of the data quality that is needed to make good decisions, but do not directly set criteria for the quality of the data or express data quality characteristics. The outputs of a Decision (or Data) Quality Objectives (DQO) Process are needed to determine the number of samples that must be collected and analyzed.

Ecology has specified the number of samples to be collected annually, acknowledging the challenge associated with stormwater monitoring, to meet their objectives and goals over the long-term.

6.2 Measurement Quality Objectives

Measurement quality objectives (MQOs) specify how good the data must be in order to meet the objectives of the study. MQOs are the performance or acceptance thresholds or goals for the study’s data, based primarily on the data quality indicators. Another name for MQOs is measurement performance criteria (MPC). For existing data, these correspond to acceptance criteria. MQOs are used to select procedures for sampling, analysis, and quality control (QC).

Of the six principal data quality indicators, precision, bias, and sensitivity are quantitative measures; representativeness and comparability are qualitative; completeness is a combination of both qualitative and quantitative measures; and accuracy is a combination of precision and bias. Please refer to the

Glossary for definitions of each DQI. Table T-39 summarizes the MQO for each DQI and a short discussion follows.

6.2.1 Precision, Bias, and Accuracy

Precision, bias, and accuracy MQOs for the study are specified in Table T-40.

6.2.2 Representativeness

The representativeness of the data is dependent on 1) the sampling locations, 2) the flow regime during sample collection 3) the number of years sampling is performed, and 4) the sampling procedures. Site selection and sampling of pertinent media (i.e., water) and use of only approved analytical methods will assure that the measurement data represents the population being studied at the site.

6.2.2.1 Stormwater Quality

Stormwater representativeness is achieved by selecting sample locations, methods and times so that the data describe the characteristics of stormwater runoff over a range of rainfall/runoff conditions in the drainage basin, the varying hydrologic conditions within an individual storm event (i.e., rising and falling portions of the hydrograph), and a representative cross-section of storm types. Additional details regarding representativeness of sample location, collection of storm flows, and the criteria used for sampling are presented in Sections 2.1.1 and 3.4.

Representativeness of land use The permit calls for each permittee to select three sites representing different land uses. To "represent" a particular land use, no less than 80 percent of the area served by the conveyance should be classified as having that land use. There is some risk in designating so few numbers and types of sites for this long-term monitoring. The sites selected may not be adequately "representative" of what is being achieved throughout the municipal storm sewer system. Results at these sites can over-estimate or under-estimate what is happening system-wide.

To reduce that error, Ecology intends to pool results from all Phase I permittees and to consider extending this type of monitoring to Phase II municipal stormwater permittees in the second round of their permits. The second round is scheduled for issuance in 2011. The combination of intensive monitoring at a number of sites through out the state may provide a sufficient data set from which Ecology can draw conclusions about the effectiveness of programs on a region-wide basis.

Representativeness of individual storm events – Stormwater (both whole-water and filtered) samples will be flow-weighted composite samples representing at least 75 percent of the hydrograph for storms less than 24 hours. For storms greater than 24 hours, the flow-weighted composite sample will represent at least 75 percent of the hydrograph from the first 24 hours of the storm.

Representativeness of storm types – Storm event criteria have been selected to consider the variation in storm event runoff volume, flow rate, antecedent rainfall conditions, and season. In addition, if monitoring is extended into the next permit cycle, monitoring will be conducted over a sufficient length of time to ensure that data are collected during representative climatic conditions for the region

Representativeness of toxicity results – Toxicity analyses will be performed on stormwater samples collected from the conveyance system. The results will be used for screening purposes as the conveyance system environment does not necessarily represent conditions to which aquatic life may be exposed nor is it effluent characterization or compliance monitoring under WAC 173-205.

6.2.2.2 Sediment Quality

Sediment traps are useful monitoring tools to help identify chemical concentrations in suspended sediments in stormwater. There are several issues relevant to the representativeness of sediment trap samples. It is difficult to predict potential sampling biases that may occur during sample collection, but considering the perturbations in the flow field that the bottle creates, certain grain size fractions in the suspended load could be preferentially trapped.

In addition, the physical characteristics of each sediment trap sampling location vary such that a different range and/or type of flows, and therefore, storm conditions may be sampled. Because there is a minimum height at which the sediment trap is overtopped and starts to collect sample, some sediment traps may not be collecting sample during smaller storms, and the frequency of such occurrence will vary from location to location. Because the sample bottles are approximately 8 inches tall, sample collection will not occur until the depth of flow in the pipe exceeds 8 inches. For small diameter pipes (less than 24-inch) traps may only be effective in sampling runoff during large storm events.

6.2.3 Completeness, and Comparability

The completeness of the data will be maximized by using proven sampling techniques, packaging samples for transport to avoid breakage, and timely processing at the laboratory. The analytical requirements will be met to assure acceptable data. Where possible, excess sample will be archived until the laboratory results can be reviewed by the project manager. A completeness target of 90 percent has been set for this study.

Confidence in the comparability of data sets for this study is based on the commitment of study staff to use only approved sampling and analysis methods and QA/QC protocols in accordance with quality system requirements and as described in this QAPP and in SOPs. Comparability is also guaranteed by reporting data in standard units, by using accepted rules for rounding figures, and by reporting data in a standard format.

6.2.4 Sensitivity (Reporting Limits)

Ecology specified uniform reporting limits and analytical methods intended to meet those reporting limits in Appendix 9 of the permit. Note that the term "reporting limit" in this document refers to the practical quantification limit established by the laboratory, not the method detection limit and is usually 3 to 5 times the method detection limit. Subsequently, Ecology has provided guidance providing alternative analytical methods to the ones listed in Appendix 9. Appendix 9 provides Ecology the authority to approve alternative methods from those listed in Appendix 9 with those listed in the QAPP.

Alternative methods and MQOs for sensitivity are provided in Table T-42, Table T-43, and Table T-44 for parameters in water collected by automatic composite sampler, parameters in water collected by manual grab, and parameters in sediment, respectively.

7 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The sampling design strategy was developed by Ecology to increase the knowledge of pollutant loads and average event mean concentrations from representative land use types drained by the municipal storm sewer system. Ecology will use this information to gauge whether the permittees' comprehensive stormwater management programs may be making progress towards the goal of reducing the amount of pollutants discharged and protecting water quality.

This section describes the overall sampling design for the study to support the program objectives identified in Section 4.2. The general sampling process design is summarized in Table 13.

Table 13. Sampling design summary.

Matrix	Sample Technique/ Type	Analytes	Temporal Boundaries[16]	Annual Frequency per Site[17]
Stormwater	Manual grab	Water chemistry	Qualifying storm event (or as soon as possible thereafter)	11
			Storm event that meets all criteria but rainfall volume	Up to 3
	Automatic flow-weighted composite	Water chemistry	Qualifying storm event	10
			Storm event that meets all criteria but rainfall volume	Up to 3
		Water chemistry	First-flush qualifying storm event	1
		Toxicity		1
	Manual grab	Water chemistry	Base flow qualifying storm event (if applicable)	2[18]
	Automatic time-weighted composite	Water chemistry		2[18]
Sediment	Manual sediment trap	Sediment chemistry	Composite over sample deployment	1

Three steps are generally specified prior to the initiation of any stormwater field collection activities. They include:

- Selection of the monitoring locations,
- Development of the stormwater sampling strategy, and
- Selection of the equipment to meet the study objectives and the site specific needs of the selected locations.

These steps are discussed below.

7.1 Monitoring Location Selection Methodology

Ecology has determined that three basins, each representing a different land use, are to be monitored. The number of locations to be monitored generally depends on specific program objectives, the size and complexity of the drainage watersheds and conveyance system, and the budget allocated to monitoring. In addition, the frequency of sampling at each location should be considered.

To determine locations for stormwater monitoring, the City's geographic information system (GIS) was used to display the stormwater infrastructure and identify possible catchments in the separated areas of the city that represent a discernible type of land use. Field visits were then conducted to evaluate hydrology (base flow, turbulent flow, and tidal influence), the feasibility of monitoring (access, potential for vandalism, safety of monitoring personnel, equipment installation needs), and the suitability of the site for long-term monitoring.

Placement of equipment at elevations sufficient to minimize the potential for tidal influence or backwater effects that would compromise flow data quality, the integrity of the sediment traps, and collection of quality stormwater samples was also evaluated.

[16] See Table 18 for a description of the storm event criteria.
[17] This total does not include QC samples.
[18] These samples are not required and may not be needed. See Section 7.2.3.1.

The results of this investigation and the City's preferred stormwater characterization monitoring sites are presented below (Table 14) and graphically (Drawing 1). Additional details for each site are presented below.

Table 14. Monitoring site characterization summary.

Represented Land Use	Residential	Industrial	Commercial
Basin	**Venema – R1**	**Norfolk – I1**	**University District- C1**
Surface Area Distribution			
Total Area (acres)	157	164	187
Impervious Area estimate (%)	62	55	79
Land Use Distribution Estimate [19]			
Residential (%)	78	32	35
Industrial (%)	0	39	0
Commercial (%)	17	12	62
Open Space (%)	5	17	4
Hydrologic Information			
Time of Concentration (minutes)	<60	<60	<60
Rain Gauge	RG07	RG10	RG03
Rain Gauge Location (latitude/longitude)	47.6961/ 122.3769	47.5000/ 122.2600	47.6481/122.3081
Mean Annual Precipitation (in) [20]	31.4	34.3	35.6

7.1.1 Land Use Estimate Methodology

The method to determine the land use area to meet the goal: "ideally, to represent a particular land use, no less than 80 percent of the area served by the conveyance will be classified as having that land use" is presented below.

Land use data is derived from the King County Parcel Database, which provides data in eight general categories: single family, multi-family, commercial, schools, other/NA, government/public facility, industrial, parks/open space, and vacant. Land that is not classified as a parcel is considered right-of-way.

Land use is generally grouped into four categories: (1) residential which includes single family and multi-family and may include other/NA; (2) commercial which includes commercial, schools, government/public facility and may include other/NA; (3) industrial which includes industrial and may include vacant; and (4) open which includes parks/open space and may include vacant.

The portion of right-of-way that is classified as open, for example the planting strip, is estimated by visually reviewing the GIS photo coverage. The portion of each surface type draining to the MS4 within partially separated areas will be estimated based on a review of selected side-sewer cards. The surface type for each land use category is estimated using citywide averages based on GIS analysis.

For basins that are partially separated, the equivalent area draining to the MS4 is less than the total basin area.

[19] Assumed 20% and 10% of right-of-way is open space for residential and industrial/commercial respectively. These values will be updated as additional information becomes available. Values not adjusted for partial separation.
[20] From Seattle Public Utilities (2003).

7.1.2 Drainage Area Confirmation Methodology

This section describes the methodology used to confirm the tributary conveyance system and drainage areas. The tributary conveyance system and drainage areas were defined using SPU's Geographic Information System (GIS). Mapping and documenting the MS4 is an ongoing project, which was initiated by incorporating preliminary drainage system information using as-built and design drawings, both paper and digital. Field data collection and verification were then conducted with a field-based global positioning system (GPS) that allowed staff to determine locations and collect attribute information regarding the MS4 components.

The drainage areas will be field verified during the project implementation phase with a walking survey of the mapped drainage areas during rainfall to confirm or correct the drainage area maps per observations in the field.

7.1.3 Times of Concentration Methodology

Section S8D, paragraph 2b, requires that automatic flow-weighted composite samplers be programmed to begin sampling as early in the runoff event as practical and to continue sampling past the longest estimated time of concentration, T_c, for the tributary area. Our understanding is that Time of Concentration can be a concern in areas with a short tidal window, very large basin, and a time-composite sampling method. The T_c provides a measure to ensure the time pacing is set to obtain a representative sample and to ascertain whether contributions from the entire basin are represented, (i.e. sampling at or near the T_c may not be representative of the entire basin). All estimated T_c's for the selected basins are less than one hour, which will be the minimum time the automatic sampler will be programmed for sample collection in order to meet this permit requirement.

The times of concentration were estimated using the method described in the City's *Stormwater Treatment Technical Requirements Manual* (Seattle 2000). For the purposes of this document, it is assumed that overland flow is very limited and all pipes are concrete. The Time of Concentration, T_c, is defined as:

$$T_c = L \times k \times s^{1/2}$$

Where:

T_c = time of concentration (minutes)
L = flow length (ft)
k = velocity factor (ft/s) (value of 42 for concrete pipe)
s = slope of flow path (ft/ft)

Estimated flow lengths, in feet, are 3800, 4000, and 4800 for the residential, industrial, and commercial basins respectively.

7.2 Stormwater Monitoring Strategy

A discussion of the stormwater monitoring strategy developed by Ecology is presented below and includes:

- Selection of parameters and analytical methods,
- Selection of sampling techniques and types
- Selection of sampling frequency and criteria to ensure representative samples, and

- Selection of sampling and flow monitoring equipment.

7.2.1 Parameters and Analytical Methods

Ecology selected pollutants to be monitored based upon their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information (see Section 3.3 for additional information).

A significant sampling design concern is the ability to obtain adequate sample volume to complete the selected analyses. This section discusses the selected parameters, the volumes required to analyze those parameters, and the priority order in which analyses will be done. Table 15 summarizes the estimated volumes needed for stormwater analytical chemistry and toxicity samples.

Table 15. Volume requirements for stormwater chemistry and toxicity analyses.

Sample Technique/Type	Analytes	QC Sample Status	First Flush Toxicity Volume (L)	Routine Volume (L)
Manual grab	Water Chemistry	Primary	1.5 -2.5	1.5 - 2.5
		Duplicate		1.5 - 2.5
	Max Volume per Event		**1.5 -2.5**	**3-5**
Automatic flow-weighted composite	Water Chemistry	Primary	10-14	10-14
	Water Chemistry	Duplicate	--	10-14
	Toxicity	Primary	45 [21]	--
	Max Volume per Event		**54 - 59**	**20-28**

Three types of analyses may be conducted on samples collected at each site: (1) stormwater analytical chemistry, (2) stormwater toxicity, and (3) sediment analytical chemistry. Each analysis is discussed further in the following sections.

7.2.1.1 Water Analytical Chemistry

Samples collected using automatic flow-weighted composite samplers will be analyzed for the following parameters:

- Conventionals (BOD_5 , chloride, conductivity, hardness, surfactants (methlyene blue activating dubstances [MBAS]), TSS, turbidity)
- Metals (total and dissolved cadmium, copper, lead, mercury, and zinc. Mercury is required for commercial and industrial land uses only).
- Nutrients (nitrate/nitrite, orthophosphate, total kjeldahl nitrogen, total phosphorus)
- SVOCs (pentachlorophenol, phthalates, polycyclic aromatic hydrocarbons [(PAHs]))
- Pesticides (2,4-D, MCPP, triclopyr, diazinon, malathion, chlorpyrifos, dichlobenil, prometon and pentachlorophenol)

Samples collected using manual grab sampling procedures will be analyzed for the following parameters:

- Fecal coliform bacteria,
- Total petroleum hydrocarbons (TPH) using NWTPH-Dx and NWTPH-Gx.

Table T-42 presents the analytical methods and minimum reporting limits. Adequate volume to perform stormwater analysis of the flow-weighted composite sample will be between 10 to 14 L. If the volume of stormwater sample collected from a qualifying storm is insufficient to allow analysis for all parameters

[21] If 44 liters can not be obtained for the toxicity test then a minimum volume of 24 liters is needed.

listed in Table T-42, the sample shall be analyzed for as many parameters as possible in the following priority order (Table 16):

Table 16. Required composite sample analysis priority order (S8D, paragraph 2c).

Land Use	Site	Priority analysis order
Residential	Venema	1. TSS; 2. Conductivity; 3. Surfactants (MBAS); 4. Metals and hardness ;5. Nutrients; 6. Pesticides; 7. SVOCs (PAH's and phthalates); [22] 8. BOD_5; and 9. Chlorides
Industrial & Commercial	Norfolk & UD	1. TSS; 2. Conductivity; 3. MBAS; 4. Metals and hardness; 5. SVOCs (PAH's and phthalates) [22] 6. Pesticides; 7. Nutrients 8. BOD_5; and 9. Chlorides
Toxicity Sample	All	1. TSS, Chloride, Hardness, Surfactants (MBAS), Metals, SVOCs [22] , Pesticides; 2. Conductivity; 3. Nutrients; 4. BOD_5; 5. Turbidity.

If insufficient sample exists to run the next highest priority pollutant, that analysis should be bypassed and analyses run on lower priority pollutants in accordance with the remaining priority order to the extent possible.

The priority order for the chemistry analysis for the samples that will be collected concurrently with the toxicity sample is slightly different. A minimum volume of 10 L is required to analyze TSS, chloride, hardness, surfactants (MBAS), metals, SVOCs, and pesticides. If additional volume is available then conductivity, nutrients, BOD_5, and turbidity will be analyzed.

7.2.1.2 Toxicity Samples

The "first-flush" toxicity will be tested for screening purposes only. The total volume required for toxicity testing and associated egg analysis is in the range of 24 to 45 liters. In addition, a minimum volume of 10 to 14 liters is needed for the required associated chemical analyses (see Table 4 and Section 7.2.1).

If a minimum volume of 34 liters, 10 liters for chemistry and 24 liters for toxicity, is not collected then the sample will not be analyzed for toxicity. Section 9.2.1 discusses the approach to be taken for toxicity testing if less than 54 liters is collected. Receiving water may be sampled for hardness at the same time as the stormwater. This will be determined on a case-by-case basis by the Principle Investigator.

7.2.1.3 Sediment Samples

The following parameters will be analyzed for in sediments:

- Total solids (% solids)
- Grain size
- Total organic carbon
- PAHs
- Phthalates
- Phenolics
- PCBs[23]
- Pesticides (diazinon, chloropyrifos, malathion, pentachlorophenol)
- Metals (total copper, zinc, cadmium, lead and mercury [23])

Table T-44 presents the required analytical methods and minimum reporting limits. Adequate volume to perform sediment analysis will be approximately 60 ounces. If the volume of sample collected is insufficient to allow analysis for all parameters listed in Table T-44 , the sample shall be analyzed for as

[22] SVOCs are analyzed using the same method. Pentachlorophenol, a fungicide, will be analyzed with the SVOC group. The permit includes pentachlorophenol with the pesticide group.
[23] For monitoring site representing industrial and commercial land uses only.

many parameters as possible in the following priority order (Table 17). Grain size will be characterized qualitatively by field personnel (see section 8.2.3):

Table 17. Required sediment sample analysis priority order (S8D, paragraph 2(f)(iii)).

Land Use	Site	Priority analysis order
Residential	Venema	1) Grain size; 2) Total organic carbon; 3) Metals; 4) Pesticides; 5) PAH's and Phthalates; and 6) Phenolics
Industrial & Commercial	Norfolk & UD	1) Grain size ; 2) Total organic carbon; 3) Metals; 4) PAH's and Phthalates; 5) Phenolics; 6) PCB's; and 7) Pesticides

7.2.2 Sampling Techniques and Types

Ecology has specified the sampling techniques and types to be used. In addition to those specified, automatic time-weighted composite sampling will be used to characterize base flow.

7.2.2.1 Automatic Composite Sampling

Automatic composite sampling is required for all parameters, except those that are likely to transform rapidly (e.g., fecal coliform bacteria) or adsorb to sample containers (e.g., total petroleum hydrocarbons). Automatic flow-weighted composite samples will be collected for water chemistry (Table 4) and toxicity. Automatic time-weighted composite samples will be collected for base-flow chemistry (Table 4).

7.2.2.2 Manual Grab

Manual grab samples will be collected for total petroleum hydrocarbon and fecal coliform bacteria.

7.2.2.3 Manual Sediment Trap

Sediment samples will be collected using inline sediment traps. Sediment traps will be deployed for approximately 12-month intervals. Traps are designed to passivle collect suspended particual present in stormwater that passes by the sampling station. Traps will be installed from October through September to capture a sample representing the annual water year.

7.2.3 Qualifying Sample Criteria

Ecology has defined "representative" storms that must be monitored and the frequency of monitoring. Storm event criteria are established to: (1) ensure that adequate flow will be discharged; (2) allow some build-up of pollutants during the dry weather intervals; and (3) ensure that the storm will be "representative," (i.e., typical for the area in terms of intensity, depth, and duration).

Collection of samples during a storm event meeting these criteria attempts to ensure that the resulting data will accurately portray the most common conditions for each site. Ensuring a representative sample requires two considerations: (1) the storm event must be representative, and (2) the sample collected must represent the storm event.

7.2.3.1 Qualifying Storm Event Criteria and Sampling Frequency

Table 18 lists the qualifying storm event criteria for dry and wet seasons and the seasonal first flush. Ecology determined that 67 percent of forecasted qualifying events that result in actual qualifying storm events, up to a maximum of 11 per water year, is a reasonable requirement to establish a sufficient data set from which to discern annual and seasonal loading trends over a long period. In addition, they are requiring analysis of up to a maximum of three samples collected as a result of attempts to sample the eleven required storm events but do not meet the rainfall volume storm event criterion but do meet the other storm event and sample criteria. In addition, annual stormwater toxicity and sediment sampling are required.

Table 18. Qualifying storm event criteria and sampling frequency.

Criteria	Wet season	Dry season	First Flush (Dry Season)	Base Flow
Period	October 1 through April 30	May 1 through September 30	August or September[24]	October 1 through September 30
Rainfall volume	0.20" minimum, no fixed maximum	0.20" minimum, no fixed maximum	0.20" minimum, no fixed maximum	NA
Rainfall duration	No fixed minimum or maximum	No fixed minimum or maximum	No fixed minimum or maximum	NA
Antecedent dry period	≤ 0.02" rain in the previous 24 hours	≤ 0.02" rain in the previous 72 hours	≤ 0.02" rain in the previous 168 hours	≤ 0.02" rain in the previous 24 hours
Inter-event dry period	6 hours	6 hours	6 hours	NA
No. of annual chemistry samples per site that meet all criteria[25]	7-9	2-4	1	2 (if needed)
No of annual chemistry samples per site that don't meet rainfall volume criteria [26]	0-3		NA	NA
No. of annual toxicity samples per site	NA	NA	1	NA

Collection of flow-weighted composite water samples will be attempted whenever weather conditions present themselves in order to obtain 11 stormwater samples distributed within the wet-weather and dry weather season during storms that meet the acceptable target storm conditions.

Base-flow event criteria is included should base flow sampling be needed. Continuous flow data during the first full water year will be used to determine if base flow is present, and if so, in quantities sufficient enough to warrant sampling to determine the annual base flow pollutant load for future water years. Between storm flow conditions will be observed during the winter-wet season and summer-dry season to determine whether collection of base flow samples will be possible.

7.2.3.2 Qualifying Composite Sampling Criteria

Ecology has defined criteria to ensure the composite sample collected is representative of the storm event sampled (Table 19). For storm events lasting less than 24 hours, samples shall be collected for at least 75 percent of the storm event hydrograph. For storm events lasting longer than 24 hours, samples shall be collected for at least 75 percent of the hydrograph of the first 24 hours of the storm. Each composite sample must consist of at least 10 aliquots. Composite samples with 7 to 9 aliquots are acceptable if they meet the other sampling criteria and help achieve a representative balance of wet season/dry season events and storm sizes.

Table 19. Qualifying sampler collection criteria.

Storm event duration	<24 hours	>24 hours	Base Flow
Minimum storm volume to sample	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm	NA
No. of Aliquots	7 to 9 accepted	7 to 9 accepted	Every 15 minutes

[24] Or October, irrespective of antecedent dry period, if unsuccessful in August or September.

[25] Includes grab and flow –weighted composite samples. Assumes a goal of collecting 60 to 80 percent of the samples during the wet season. Does not include QC samples.

[26] Up to a maximum of three samples that are collected as a result of attempts to sample the 11 required storm events and do not meet the rainfall volume storm event criterion but do meet the other storm events and sample criteria will be analyzed. These samples are not targeted for collection but result from unsuccessful (i.e. missing rain fall volume) targeting of the 11 storm events.

Storm event duration	<24 hours	>24 hours	Base Flow
Minimum duration to program ISCO for sampling (hours) [27]	1	1	24

7.2.4 Equipment Selection Strategy

The general equipment strategy for each site is to employ a modified ISCO Model 6712 composite sampler, which will contain eight 2.5-gallon bottles, Campbell Scientific flow monitoring equipment (for example, sensors and pressure transducers) , and telemetry, a technology that allows the remote control of monitors and reporting of information. When possible telephone lines will be used otherwise the data link will be wireless.

A recommended strategy for collecting the required sample volumes to meet the analytical parameter list, the toxicity sampling requirements, and any field quality control samples such as duplicates and blanks is summarized below.

As described in Section 7.2.1, a range of sample volumes needs to be collected depending upon the site and the target event. This volume ranges from 10 to 59 L excluding grab sample volumes (Table 15). To collect this range of sample volumes, three sampler configurations (Table 20) were considered. The third option (modified 6712) was selected because it provided the greatest flexibility for collecting a range of sample volumes required under the permit as well as provided for easier collection of field quality control duplicate samples.

Table 20. Three proposed sampler configurations.

Sampler Configuration	Maximum Total Sample volume
(1) Single modified ISCO 6712 sampler with four 2.5-gallon bottles	10 gallons or 37.9 Liters
(2) Two modified ISCO 6712 samplers with four 2.5-gallon bottles	20 gallons or 75.7 Liters
(3) Single modified sampler using an ISCO 6712 with eight 2.5-gallon bottles	20 gallons or 75.7 Liters

Option 3 requires modification of an ISCO 6712 sampler to collect water samples into eight discrete 2.5-gallon (9.46 L) glass bottles. The auto-sampler would be configured and programmed to collect eight replicate flow-paced composite samples into eight 2.5-gallon (9.46 L) bottles.

This specific customization of an ISCO 6712 automatic sampler allows for the collection of sufficient sample volume to meet the required permit analyses (see Section 7.2.1). Another benefit of the large volume capacity of the modified sampler is that the design provides flexibility in targeting a range of rainfall depths, thus minimizing labor costs associated with field staff time required to check the bottle capacity status remaining during a storm event.

The modified sampler could also be programmed to collect paired sequential samples over the course of the storm. This sequential program rather than replicate program would allow the possibility of selecting a subset of filled bottles (depending upon total sample volume needed for the targeted event) which represent the targeted hydrograph area and exclusion of a sample bottle largely filled with base flow at the end of an event. Depending upon the compositing approach chosen, additional sample handling may be required to composite the sequential samples. The best programming approach will be fined tuned once actual site flow data is available. Each site will use the same sampler configuration, a modified ISCO 6712 (Table 21).

[27] Paragraph S8D2(b) requires the sampler to be programmed to continue sampling past the longest estimated time of concentration, which is estimated to be less than one hour (see Section 7.1.3).

Table 21. Stormwater quality composite sampler equipment specifications.

Water Quality Sampling Equipment
ISCO model 6712 with modified base
Sixteen 2.5-gallon glass jars with teflon lids (2 complete sets)
10-foot ISCO flow meter to sampler cable
ISCO 913 Power pack

The recommended housing size for each site is 5'W x 4'D x 4'T with a one-foot partition to divide the space into a 1'W x 4'D x 4'T dry side for flow monitoring equipment and a 4'W x 4'D x 4'T wet side to house the sampler for water quality monitoring. This may be modified depending on whether the housing is custom manufactured or off-the-shelf.

The monitoring strategy for each site is described below and includes a discussion of the site characteristics and the equipment strategy. The site characteristics discussion includes:

- Background information,
- Site hydrology,
- Suitability of long-term monitoring, and
- A summary of long-term rainfall/runoff data.

The equipment specification section for each site describes:

- rational for selected equipment strategy,
- monitoring and communication equipment specifications, and
- site configuration.

7.3 Residential Basin – R1 (Venema) Monitoring Strategy

The residential land use site is located in the Piper's Creek drainage basin in the Venema Creek catchment at the intersection of 3rd Avenue Northwest and North 120th Street (Drawing 2). The contributing drainage area is 157 acres in size with 78 percent residential land use.

7.3.1 Monitoring Site Characteristics

The drainage system at the intersection of NW 120th Street and 4th Avenue NW was modified in June 2008 to ensure hydrologic conditions are conducive to monitoring. Upgrades included replacing the storm drain to reduce the slope, installing a 24-inch Palmer-Bowlus flume as a primary flow measurement device, and installing an overflow weir to measure flows that exceed the capacity of the flume (Figure 3 and Figure 5).

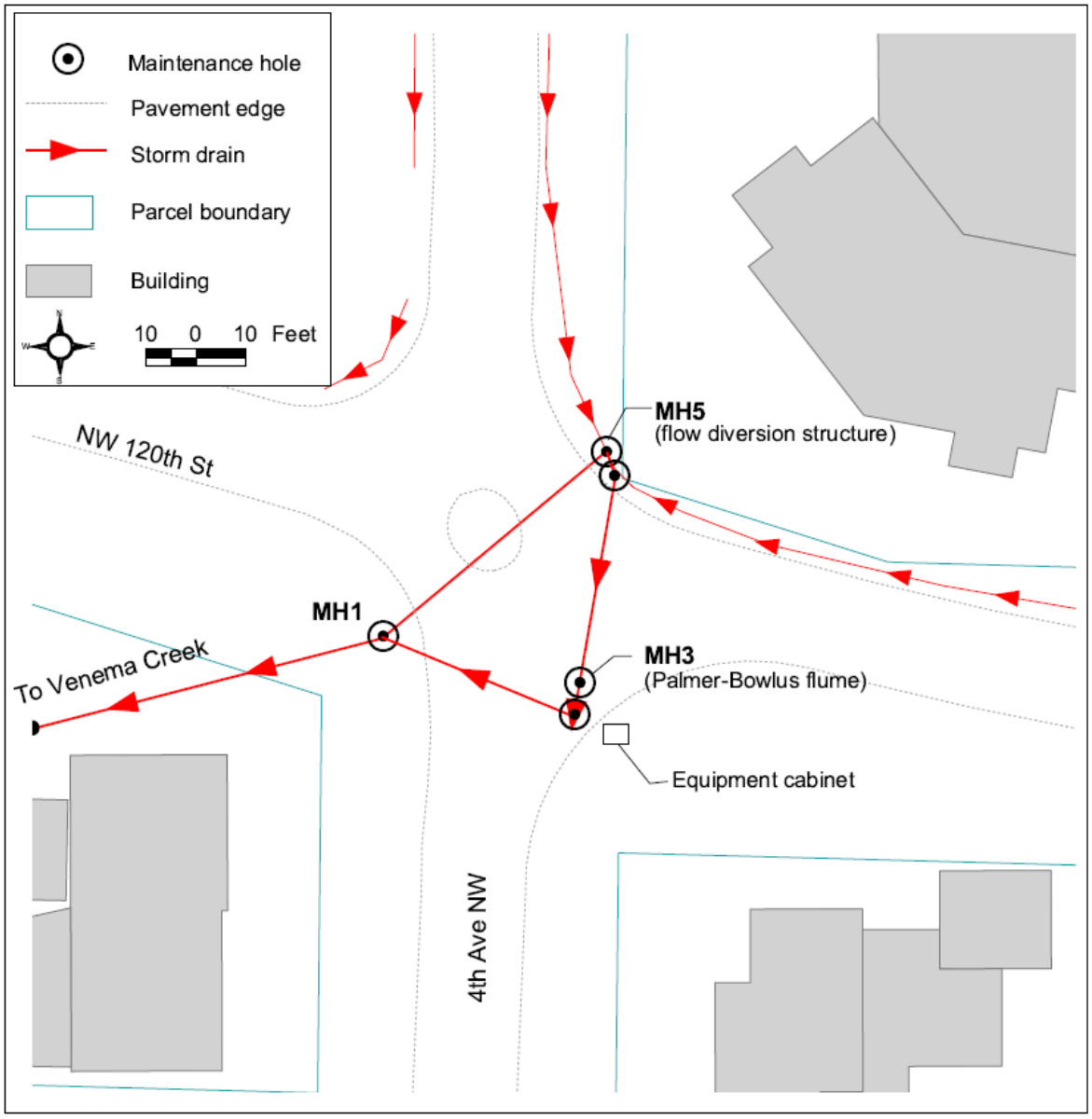


Figure 3. Residential monitoring station configuration.

All stormwater will flow into Maintenance Hole (MH) No. 5 (Figure 3). Most flows will be directed to the 24-inch Palmer-Bowlus flume in MH No. 3 and then flow back to the existing pipe via MH No. 2 and MH No. 1. High flow rates exceeding 14.6 cfs, which is expected with a frequency of less than one percent, will begin to overtop the sharp crested flow-control weir in MH No. 5 and will flow directly to MH No. 1.

The Palmer-Bowlus flume (Figure 4) is a hydraulic structure of rectangular cross-section that constricts and reshapes the flow, developing a hydraulic head proportional to flow. These flumes consist of a converging section at the inlet, a throat and diverging section at the outlet.

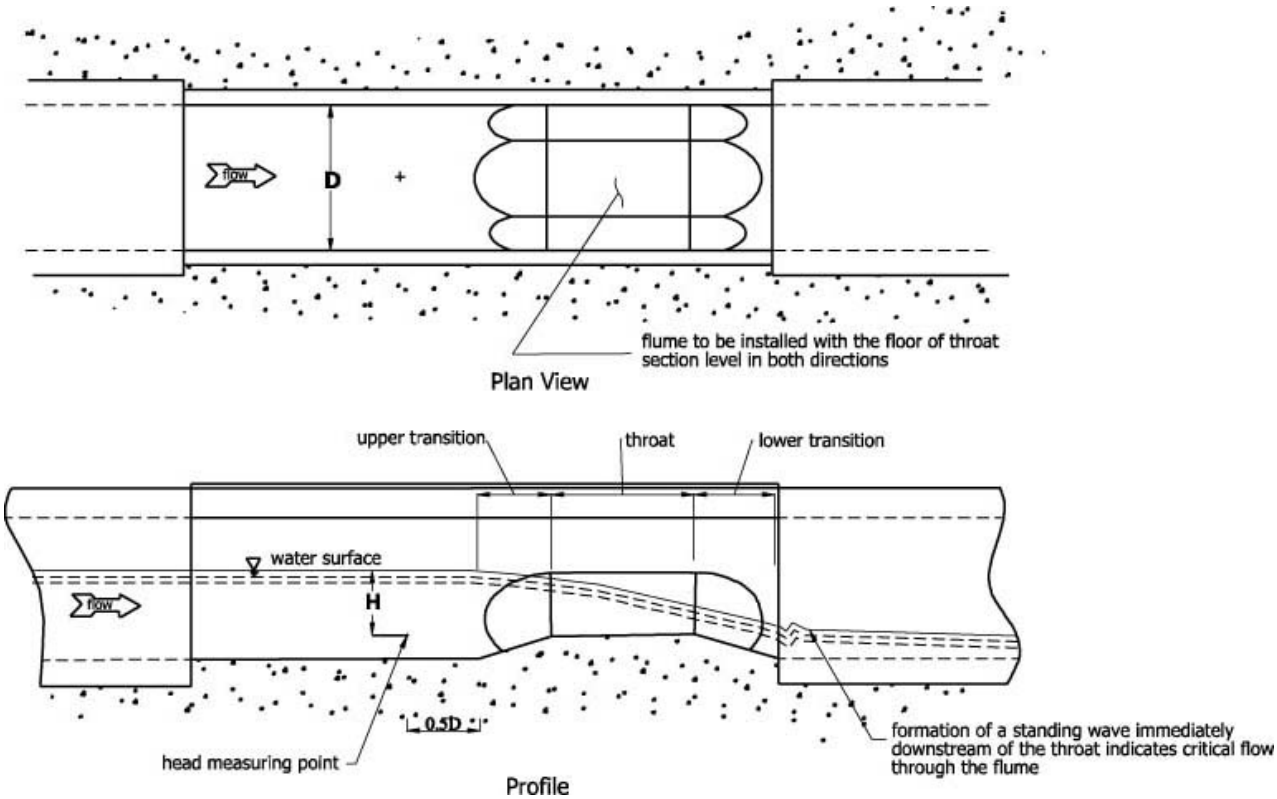


Figure 4. Typical Palmer-Bowlus flume.

Flow will be monitored at two locations (Figure 3):

- The primary flow measurement point will be in a 24-inch Palmer-Bowlus flume installed in MH No. 3. The water level in the flume will be measured using a Campbell Scientific, Inc (CSI) CS408 pressure transducer (sensor).

- The secondary flow measurement point will utilize the weir in MH No. 5. Higher flow rates will flow over the weir, bypassing the flume in MH No.3. The water level behind the weir will be measured using a CSI CS448 pressure transducer.

A CSI CR1000 data logger will combine the flow in the flume and the flow over the weir into the overall flow rate for the residential site. The two pressure transducer cables will be routed into MH No. 3 and MH No. 5, respectively through buried conduits connecting the manholes (Figure 3).

Water quality samples will be collected at a single location, MH No. 2, assuming a well-mixed flow. An ISCO 6712 modified sampler will collect flow-weighted samples controlled by the CR1000. The sampler will be enabled by a change in water level in the flume. The data logger and ISCO sampler will be installed in the enclosure and the sample lines will be run into maintenance hole (MH) No. 2 through the provided conduits (Figure 3). The sample line and strainer will be mounted in MH No.2 and will collect water quality samples from the sump just below the invert of the outlet pipe (Figure 3).

A dedicated phone line or wireless telemetry will provide remote communications with the CR1000, both the data logger and sampler will be powered by AC power with battery backups if necessary.

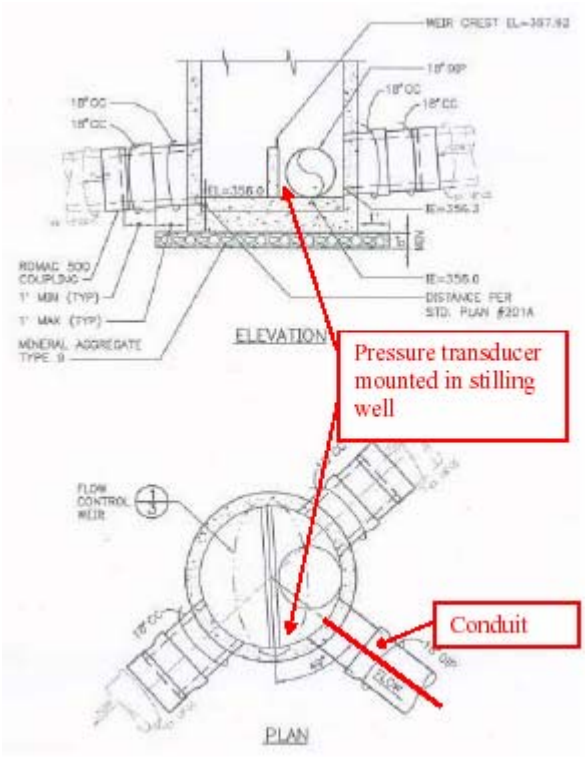


Figure 5. Residential site installation details in MH No. 5.

7.3.1.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site specific conditions that may influence sampling.

The State of the Waters (Seattle 2008) summarizes the Piper's Creek watershed where Venema is a tributary:

> "The Piper's Creek watershed covers 1,604 acres, or 2.5 square miles, in northwest Seattle. It is the third largest watershed in the city, and is just under one-quarter the size of the largest watershed, Thornton Creek. The main stem channel is roughly 2 miles in length, with an additional 3 miles in tributaries, including one major tributary (Venema/Mohlendorph) and 13 minor tributaries. The watershed has three distinct zones: a gently rolling upland plateau, an area of steep-walled ravines, and a low-gradient valley. The headwaters of Piper's Creek originate on the upland plateau, and the watercourse enters Carkeek Park as it drops down from the plateau through a steep ravine. Once on the low-gradient valley, the watercourse discharges to Puget Sound. The lower portion of the watercourse is tidally influenced, with a delta deposition area. The tributaries of Piper's Creek flow through steep ravines, with gradients exceeding 20 percent.

The underlying geology of the watershed includes upland plateau glacial till that is dense, erosion resistant, and nearly impermeable to water, as well as advance outwash deposits that are easily eroded by moving water in the ravines of Piper's Creek and its tributaries (Troost et al. 2003, 2005; Stoker and Perkins 2005). These easily eroded sediments, particularly in the steep tributaries, contribute over 50 percent of the sediment in the watercourse (Stoker and Perkins 2005; Barton 2002). The Piper's Creek watercourse has experienced many erosion problems stemming from watershed development. Erosion control efforts, including bank armoring, grade controls, and tight-lining (i.e., piping) of outfalls, have reduced erosion of the stream banks and valley walls. However, sediment production in the watershed today is about six times greater than predevelopment levels. Venema Creek and other steep tributaries entering Piper's Creek upstream are the largest areas of sediment introduction to the watercourse (Stoker and Perkins 2005).

Gravel is the predominant substrate in the stream and sand covers the stream bed locally in slow-flow areas, particularly within lower and middle Piper's Creek and Venema Creek. Sand dominates the streambed in the upper portions of Piper's Creek, upstream of the twin pipes stormwater outfall. The sand and gravel in the watercourse come from sources in different watershed locations. Gravel is introduced from the gravel-bearing outwash deposits located near the tops of the ravines, while sand is recruited to the stream from outwash deposits in the steep valley walls. In addition, the stream has been filled (with a mixture silt, sand, gravel and concrete) in some places both in the lower valley and in local areas in the headwaters.

Piper's Creek and Venema Creek have year-round flow, while Mohlendorph Creed(a tributary of Venema Creek) and some smaller tributaries can go dry in some years. Average flows are 3 to 9 cubic feet per second (cfs) in the main stem of Piper's Creek (4.7 cfs in water year 2004); 0.1 to 1.3 cfs in Mohlendorph Creek; and 0.5 to 0.3 cfs in Venema Creek (based on SPU data for water year 2004)."

7.3.1.2 Suitability for Long-term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the residential land use site follows.

Pros:

- Capable of collecting very accurate flow measurement using the flume.
- Access to parking and equipment will be easy and street has low traffic.
- Alternating Current (AC) power and telemetry will be brought to site.

Cons:

- Flows greater than 14.6 cfs will bypass the flume, which will result in less accurate load contribution estimates than those estimated for loads contributed from flows greater than 14.6 cfs. However, a duration curve (Figure 6) estimated for the 157-acre basin using the Western Washington Hydrology Model version 3 (WWHM3) indicates flows greater than approximately 6 cfs will be exceeded less than one percent of the time. Should data indicate the potential for less accurate high flows that are bypassed to impact the loading analysis then the accuracy of the bypass weir measurement will be readdressed.

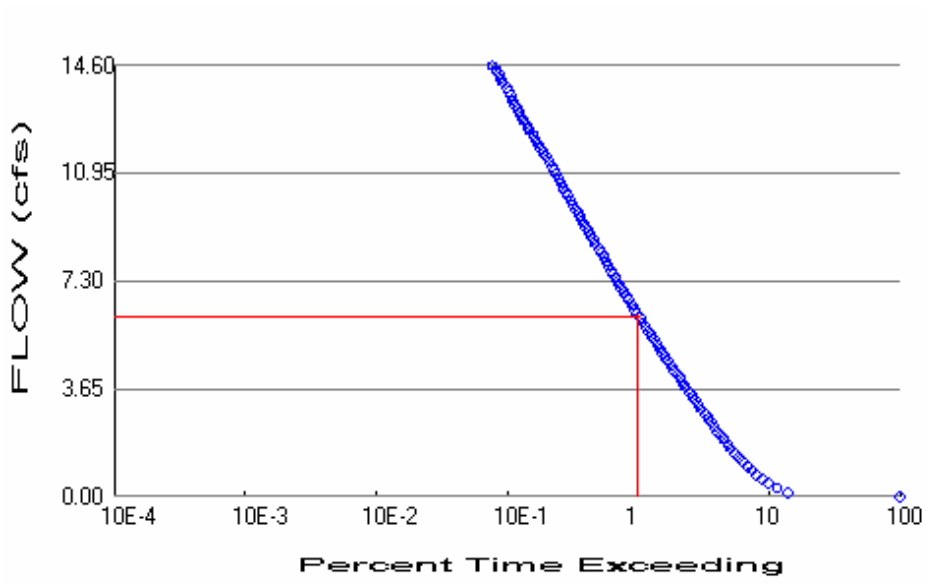


Figure 6. Residential basin site duration curve predicted by WWHM3.

7.3.1.3 Summary of Long-term Rainfall/runoff Data

This section summarizes the collected and in-progress statistical evaluations for long-term rainfall data for rain gage RG07, which is located at Whitman Middle School (45-S007) is located near the corner of 15th Avenue NW and NW 92nd Street roughly 1.5 miles southwest of the monitoring station.

Drawing 1 shows the location of the rain gage, Table 22 provides the location and period of record, Table 23 provides frequency results in table form, and Figure 7 shows frequency curves.

Table 22. Residential basin rain gage RG07 summary information (from SPU 2003).

Basin	Station ID	Station Name	Latitude	Longitude	Year Start	Gage Type
Residential/Venema	45-S007	Whitman Middle School	47.6961	122.3769	1965	TB

Table 23. Residential basin rainfall-frequency results for RG07 through 2003 (from SPU 2003).

Duration (hours)	Precipitation (inches) for Recurrence Interval (years)									
	0.2-YR	0.5-YR	1-YR	2-YR	5-YR	10-YR	20-YR	25-YR	50-YR	100-YR
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.48	1.77	1.97	2.21	2.28	2.51	2.74
24	0.94	1.33	1.63	1.93	2.34	2.63	2.97	3.07	3.41	3.75
48	1.35	1.86	2.24	2.64	3.18	3.57	4.02	4.16	4.62	5.08
72	1.54	2.13	2.56	3.00	3.60	4.03	4.51	4.67	5.15	5.64
168	2.14	3.05	3.68	4.30	5.08	5.61	6.19	6.37	6.91	7.43

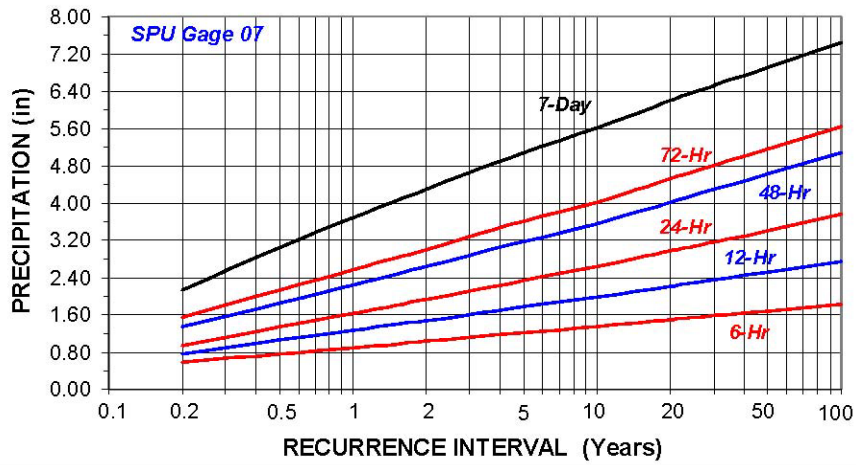


Figure 7. Residential basin rainfall-frequency curves for RG07 (from SPU 2003).

7.3.2 Equipment Monitoring Strategy

A 24-inch Palmer Bowlus flume has been selected as the primary flow device to ensure accurate flow measurements for discharge in the range of 0.096 to 9.47 cubic feet per second (cfs). The flume is fitted with a very accurate pressure transducer to measure low-to-medium high flow rates as accurately as possible. The highest flow rates are measured using the combined flow rates of the flume and the upstream bypass weir. The bypass weir is not as accurate as the flume and it is fitted with a slightly less accurate (but more economical) pressure transducer. The accuracy of the weir is constrained by the need for it to bypass high flows properly within the existing pipe hydraulics. Since the weir is only used during the highest flows, the percent error is expected to be low. This assumption will be verified with flow data.

Flow monitoring equipment for the residential land use site is specified in Table 24. These specifications include equipment manufacturer, model, capacity, and communications needs.

Table 24. Flow equipment specifications for residential site [28].

Flow
CSI CR1000 datalogger
CSI CS408 pressure transducer (for flume)
CSI CS445 pressure transducer (for bypass weir)
Plastifab 2' palmer-bowlus flume
CSI PS100 power supply w/ AC charger
CSI COM220 phone modem

7.4 Industrial Basin – I1 (Norfolk) Monitoring Strategy

The industrial land use site is located in the MLK Way catchment of the Norfolk drainage sub-basin of the Duwamish drainage basin, at approximately 10023 Martin Luther King Jr. Way South (Drawing 3). The

[28] Equipment Sources: ISCO – http://www.isco.com/; Campbell Scientific, Inc. (CSI) – http://www.campbellsci.com; Automated Products Group, Inc. (APG) – http://www.apgsensors.com/

basin area includes portions that are partially separated. The 219-acre basin area is 38 percent residential, 48 percent industrial, 9 percent commercial, and 5 percent open space.

7.4.1 Monitoring Site Characteristics

The monitoring site is located within a flow diversion structure vault that will be constructed as part of an upgrade to the drainage system. The existing 36-inch CMP, which has failed and is scheduled for upgrades in the fall/winter of 2008/2009, is located between Martin Luther King Jr. Way and the WSDOT ditch (Figure 8). This pipeline runs along the south property boundary of the Papé Material Handling property and parallels the boundary between the City of Seattle and the City of Tukwila. The upstream 55-foot long segment of pipeline extends into the Steeler Property and shares the utility easement with sanitary sewer, natural gas, and telecommunication and electric conduits. It is located under asphalt pavement and some limited areas of concrete paving. The easement does not extend to the Papé property.

Figure 8. Industrial site existing conveyance system.

The existing pipe will be replaced with 64-inch, ductile-iron pipe (DIP) to provide the required conveyance capacity. A 6-foot by 10-foot precast vault will be installed at the end of the new 64-inch conveyance pipeline. A high-flow outlet weir will be installed at the downstream end of the vault with a crest elevation

of 11.75 feet NAVD88. The purpose of the weir is to divert low flow to an oil control facility located under the Papé drive north of the pipeline. The weir, which discharges to the WSDOT ditch, will also help to dissipate flow energy of higher flows by spreading flow over the length of the weir (Figure 9).

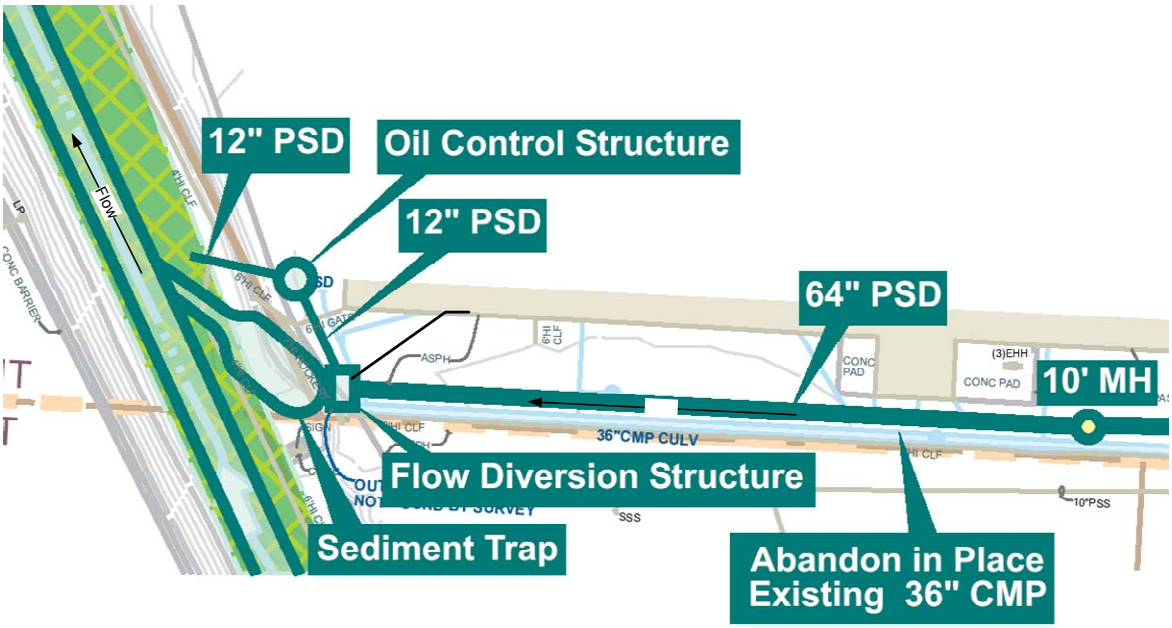


Figure 9. Industrial site schematic.

The upgrade hydraulic structures were designed to convey the peak flow from the 25-year, 24-hour design storm. A design rainfall amount of 3.125 inches used in the hydrologic analysis was based on City of Seattle standard rainfall values distributed according to the City of Seattle modified SCS Type 1A design event hyetograph. The City's modified SCS Type 1A distribution results in a higher intensity during the peak of the storm event. Approximately 10 percent of the total flow occurs during the peak 10-minute period, whereas only about 3.8 percent of the total flow occurs during the same period for the unmodified SCS Type 1A distribution (Figure 10).

Flow & Water Quality Monitorin Location

Hydraulic modeling of the Norfolk Basin was performed using the XP-SWMM model, a dynamic, unsteady flow computer model commonly used to simulate runoff and hydraulic routing in stormwater systems. The XP-SWMM analysis of the existing system showed that the restrictive capacity of conveyance structures downstream of the WSDOT ditch in combination with the flat slope of the ditch would cause stormwater to back up approximately 1,700 feet to the proposed flow diversion structure. The predicted water surface elevation is approximately 15 feet for the 24-hour 25-year event. The invert elevation of the 64-inch pipe is 10.75 feet. The model indicates that backwater conditions will primarily occur on the falling limb of the hydrograph.

The model is based on conservative assumptions and a review of precipitation from RG10 indicates the 24-hour 25-year event was exceeded approximately eight times during the period June 1978 through December 2006. Therefore, the proposed monitoring strategy objective is to obtain water quality samples during all flow events; to obtain accurate flow measurements during non-backwater conditions, which are expected most of the time; to estimate flows during backwater conditions; and to provide redundancy when possible.

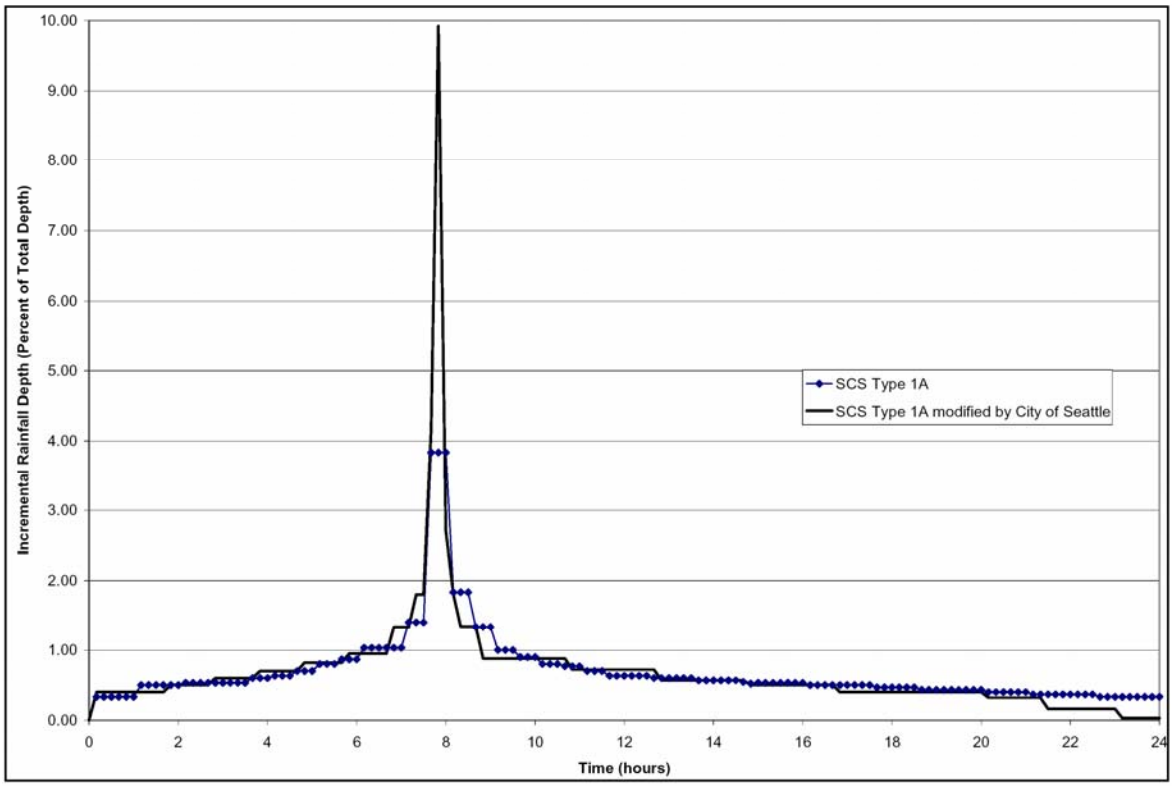


Figure 10. NF/MLK conveyance upgrades design event hyetograph.

Flow will be monitored at two locations at the industrial land use site (Figure 11).

- The primary flow measurement device will be the 10-foot wide high-flow weir, installed in the vault structure. The water level in the vault behind the weir will be measured using a BG FlowShark, an area-velocity device, which provides redundancy by including ultrasonic, peak velocity and pressure depth sensors. Flows will be estimated based on water level measurements using standard hydraulic equations for a rectangular weir.

- The second flow measurement point will be located in the 12-inch ductile iron pipe (DIP) which diverts low flow to the oil control structure, bypassing the weir (Figure 11). A BG FlowShark will also be used to estimate these flows.

- The combined flows will estimate the overall flow rate for the industrial land use site.

Stormwater samples will be collected using an ISCO 6712 modified sampler installed at a single location, within the 64-inch DIP with access from the vault. Sample collection will be controlled by an ADS Spider, a stand-alone, data logging, alarm dialing system that controls and monitors inputs and outputs.

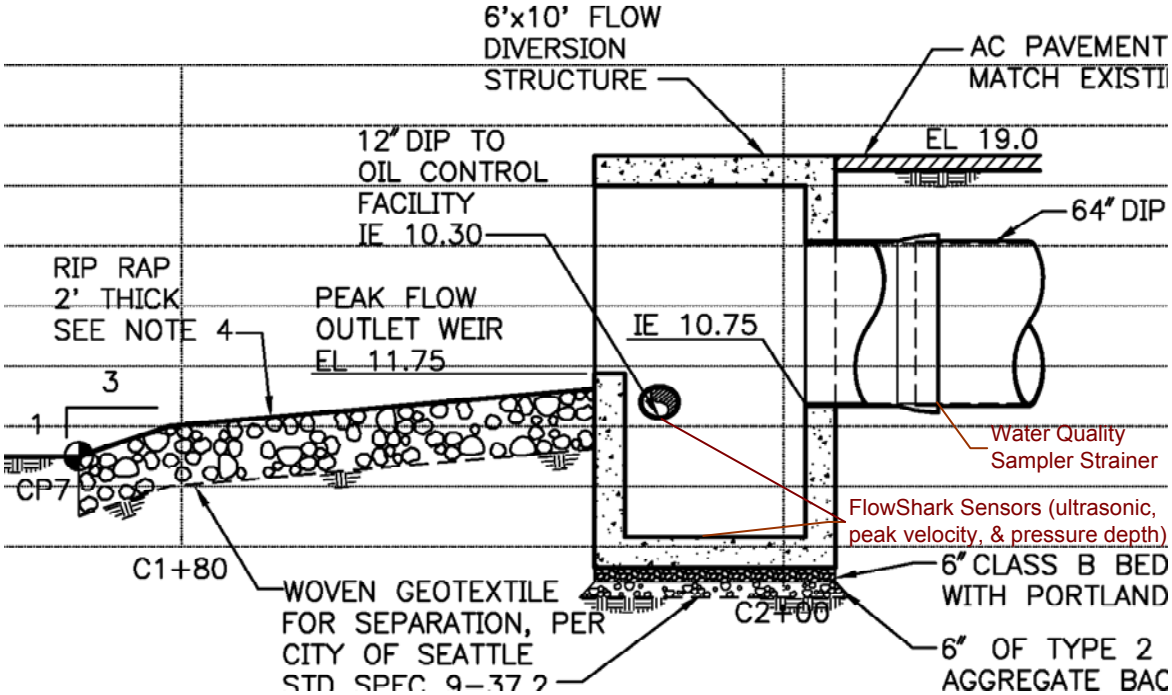


Figure 11. Industrial site water quality sampling equipment layout.

7.4.1.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site specific conditions that may influence sampling.

The industrial sampling site is located at the downstream end of the xx-acre Norfolk/MLK subbasin of the 800-Ac Norfolk drainage basin, which discharges to the Duwamish Waterway (Drawing 1). The Norfolk drainage basin includes residential neighborhoods, industrial areas, and steep undeveloped hillsides. The entire drainage basin is divided into eight different sub-basins, of which one is the Norfolk/MLK Way sub-basin. This basin has two distinct land use zones: a highly industrial area with flat, paved surfaces bisected by MLK Way, and a dense forested area with steep hillsides on both sides of the industrial area.

Runoff in the Norfolk/MLK subbasin is collected and conveyed in a series of ditches and pipes. The main drainage trunk line, consisting of 12- to 48-inch pipes runs from north to south along Martin Luther King, Jr. Way S. Approximately 700 feet north of the Boeing Access Rd, the storm drain line turns west in a 60-inch pipe and crosses private property before discharging to a ditch that runs along the east side of I-5. The ditch crosses under I-5 in 24- and 48-inch culverts where it enters a serpentine swale constructed as part of a WSDOT stormwater treatment system located on the west side of I-5 just south of S Norfolk St. The swale crosses under the BNSF railway and connects to the larger Norfolk drainage system west of Airport Way S.

The pipe between MLK Way and the I-5 ditch is severely damaged, causing stormwater to back up into an adjacent sanitary sewer line. In 2008-2009, SPU intends to replace the damaged line with a new xx-inch pipe and regrade a short section of the I-5 ditch to restore the hydraulic capacity of this system. In

addition, SPU will install a small vault structure at the downstream end of the piped system to control oil spills and trap other floatable materials before discharging to the I-5 ditch. A bypass structure will be installed to route low flows to the spill control structures and allow larger flows to discharge directly to the I-5 ditch. The NPDES monitoring station will be located at the bypass structure.

This site is one of few industrial basins within the City that is not influenced by tidal levels. The lower portion of the basin is relatively flat and highly industrialized and as such, contains a considerable amount of impervious area. The upper portion of the basin contains several steep slopes and runoff concentrates in the lower basin quickly. The proposed sampling location is in a very flat section of pipe. The short time of concentration combined with low pipe slopes may increase the frequency of backwater conditions.

Surficial deposits in the area are typically recent alluvium and peat deposits. The alluvium was deposited by the Duwamish River under moderate to low energy conditions and can be expected to be an inter-bedded unit of sand and silt with organics. The alluvium is found on the west side of I-5. The peat deposits were deposited by vegetation in wetland environments. Because the soils were not overridden by glacial ice during the last glaciation, they tend to be relatively loose/soft. The entire area has been modified by grading activities. Fill soils to a depth of 9 to 10 feet are common.

7.4.1.2 Suitability for Long-term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the industrial land use site follows.

Pros:

- No tidal influence
- An XP-SWMM model is has been developed to support the current storm drain upgrades and could be used to facilitate monitoring.

Cons

- Backwater conditions are predicted at storm events greater than the 25-year 24-hour event.
- Easements are needed to secure site access.

7.4.1.3 Summary of Long-term Rainfall/runoff Data

This section summarizes the collected and in-progress statistical evaluations for long-term rainfall data for rain gage RG10 (SPU 2003). Drawing 1 shows the location of the rain gage, Table 25 provides the location and period of record, Table 26 provides frequency results in table form, and Figure 12 shows frequency curves for rain gauge RG10.

Table 25. Industrial rain gage RG10 summary information (from SPU 2003).

Basin	Station ID	Station Name	Latitude	Longitude	Year Start	Gage Type
Industrial/Norfolk	45-S010	Rainier Ave Elementary	47.5000	122.2600	1968	TB

The rain gauge at Rainier Avenue Elementary is located near the corner of Beacon Avenue South and 56th Avenue South. It is approximately 1.2 miles southeast of the industrial land use monitoring site. Table 26 and Figure 12 show the results of the rainfall-frequency calculations for the Rainier Avenue Elementary rain gauge.

Table 26. Industrial basin rainfall-frequency results for RG10 through 2003 (from SPU 2003).

Duration (hours)	Precipitation (inches) for Recurrence Interval (years)									
	0.2-YR	0.5-YR	1-YR	2-YR	5-YR	10-YR	20-YR	25-YR	50-YR	100-YR
6	0.59	0.77	0.90	1.04	1.22	1.36	1.51	1.55	1.70	1.86
12	0.78	1.07	1.28	1.50	1.79	2.00	2.24	2.31	2.55	2.78
24	0.96	1.37	1.67	1.98	2.40	2.70	3.05	3.16	3.50	3.85
48	1.38	1.91	2.29	2.70	3.25	3.65	4.11	4.26	4.72	5.20
72	1.58	2.18	2.62	3.07	3.68	4.12	4.62	4.78	5.27	5.78
168	2.20	3.14	3.78	4.42	5.23	5.78	6.37	6.55	7.11	7.64

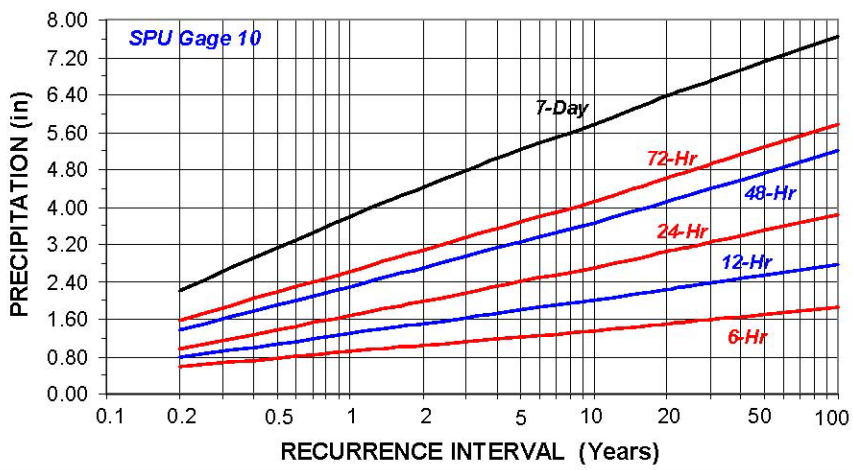


Figure 12. Industrial basin rainfall-frequency curves for RG10 (from SPU 2003).

7.4.2 Equipment Monitoring Strategy

Flow monitoring equipment for the industrial land use site is specified in Table 27. These specifications include equipment manufacturer, model, capacity, and communications needs. An ADS Spider, a stand-alone, data logging, alarm dialing system that controls and monitors inputs and outputs

Table 27. Flow equipment specifications for industrial site. [28]

Flow
BG FlowShark
ADS Spider

7.5 Commercial Basin (UD)

The commercial land use site is located in the Lake Union drainage basin in the University District (UD) catchment located just south of the Burke-Gilman Trail on Brooklyn Avenue Northeast (Drawing 4). The basin area includes portions that are partially separated. The dominant land uses in the 187-acre basin are 62 percent commercial and 35 percent residential. A summary of information collected, reviewed, and/or developed following the review of available technical information follows.

7.5.1 Monitoring Site Characteristics

Maintenance Hole D023-135 was selected as the best alternative for successfully monitoring the UD basin when considering pipe slopes and flow regime. MH D023-0135 is located on a 36-inch diameter concrete reinforced pipe installed in 1972 within a relatively straight section of pipe. The straightness of the pipe produces a relatively linear flow path through the maintenance hole. The upstream pipe slope is approximately 6.4 percent and the downstream pipe slope is approximately 7.6 percent. The sampling equipment will be housed in a separate enclosure installed along the parking strip adjacent to MH D023-135 (Figure 14).

Flow will be measured and recorded using a BG FlowShark area-velocity type meter and an ADS Spider data logger. The AV sensor will be mounted on the upstream, at the bottom of the 36-inch concrete pipe using mounting rings provided by the manufacturer.

A velocity-area measurement method will be employed to estimate flows. Direct measurements will be made of the velocity and area (derived from level and channel geometry). Flow is calculated as the product of velocity times area following the continuity equation. A velocity-area flow measurement system consists of the required set of sensors installed into the channel or conduit at a suitable location and the associated signal-processing instrumentation. The computation of flow from the sensor measurements incorporates the geometrical dimensions of the stream, as well as site-specific velocity correction coefficients.

The flow meter will calculate the flow rate and control a modified ISCO 6712 sampler. The sampler will be activated by a change in level in the pipe and paced according to the flow rate in the pipe.

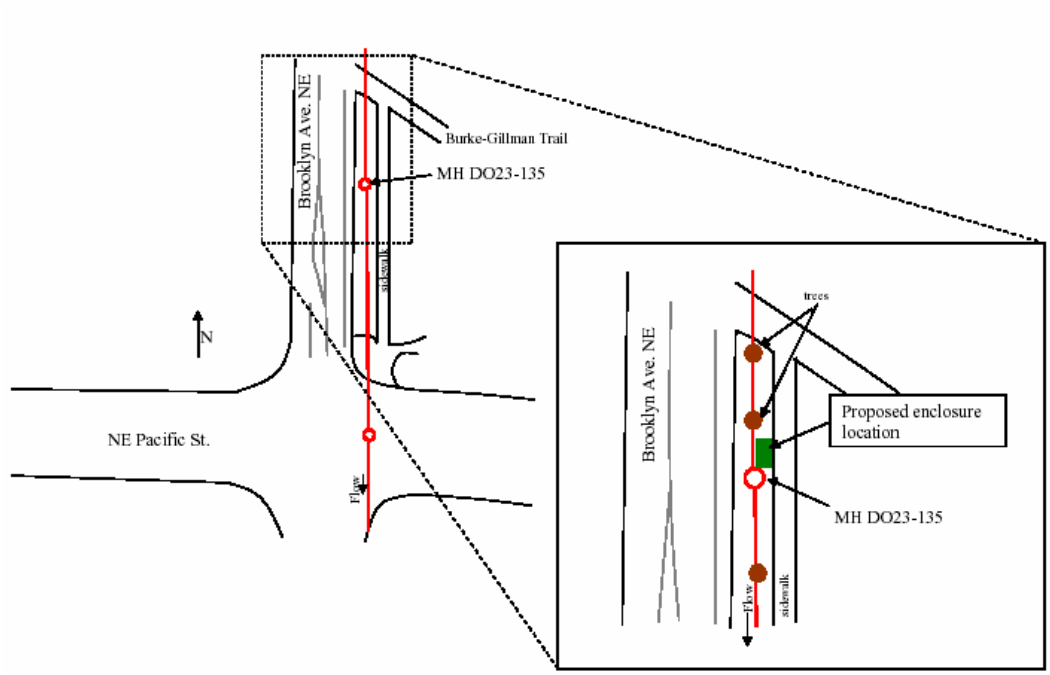


Figure 13. Commercial site sampling location (plan view).

7.5.1.1 Site Hydrology

This section contains a brief description of the site's hydrology including any potential or known back-water conditions, whether or not the site is subject to base flow or tidally influenced, or other site specific conditions that may influence sampling.

7.5.1.2 Suitability for long-term Monitoring

This section includes an assessment of the suitability for permanent installation and operation of flow-weighted composite sampling equipment. A discussion of pros and cons associated with the long-term monitoring of flow and water quality at the industrial land use site follows.

Pros:

- The grass parking strip adjacent to Brooklyn Ave NE provides a safe location to install a storage cabinet to house the necessary monitoring equipment.
- The straight lengths of pipe upstream and downstream of MH D023-135 provide a suitable location for installing the AV sensor.

Cons:

- The pipe slopes along Brooklyn Ave NE are relatively steep (i.e., 6.4 – 7.6 percent), which may affect the accuracy of flow measurements under certain flow conditions:
- Runoff from smaller storm events may not generate adequate water depth in the pipe to accurately measure flow.
- High flow velocities may adversely affect the Isco suction line, causing problems with calibrating sample volumes.

SPU will test the equipment installation and make modifications as necessary (e.g., install small weir in the pipe to raise the water depth in pipe for flow measurement and to improve conditions at the Isco sampler intake).

7.5.1.3 Summary of Long-term Rainfall/runoff Data

This section summarizes the collected and in-progress statistical evaluations for long-term rainfall data for rain gage RG03 (SPU 2003). Drawing 1 shows the location of the rain gage, Table 28 provides the location and period of record, Table 29 provides frequency results in table form, and Figure 14 shows frequency curves for rain gauge RG03.

Table 28. Commercial basin rain gage RG03 summary information (from SPU 2003).).

Basin	Station ID	Station Name	Latitude	Longitude	Year Start	Gage Type
UD	45-S003	UW Hydraulics Lab	47.6481	122.3081	1965	TB

Rain Gauge RG03 (45-S003) is located on the roof of the Harris Hydraulics Laboratory on the University of Washington Campus near Lake Union. It is approximately 0.3 miles southeast of the monitoring site. Table 29 and Figure 14 show the results of the rainfall-frequency calculations for the UW Hydraulics Lab gauge.

Table 29. Commercial basin rainfall-frequency results for RG03 through 2003 (from SPU 2003).

Duration (hours)	Precipitation (inches) for Recurrence Interval (years)									
	0.2-YR	0.5-YR	1-YR	2-YR	5-YR	10-YR	20-YR	25-YR	50-YR	100-YR
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.48	1.77	1.97	2.21	2.28	2.51	2.74

Duration (hours)	Precipitation (inches) for Recurrence Interval (years)									
	0.2-YR	0.5-YR	1-YR	2-YR	5-YR	10-YR	20-YR	25-YR	50-YR	100-YR
24	0.94	1.34	1.64	1.94	2.35	2.65	2.98	3.09	3.43	3.77
48	1.36	1.87	2.25	2.65	3.19	3.58	4.03	4.18	4.63	5.10
72	1.55	2.14	2.57	3.01	3.61	4.04	4.53	4.68	5.17	5.66
168	2.15	3.06	3.69	4.32	5.10	5.64	6.22	6.40	6.94	7.47

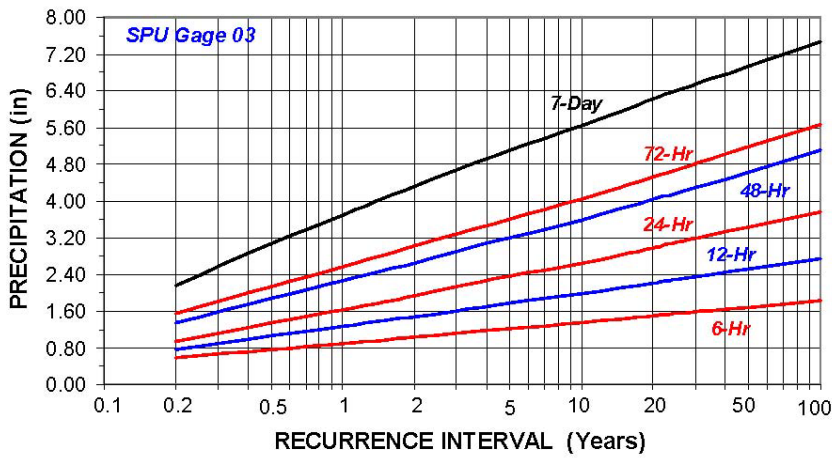


Figure 14 . Commercial basin rainfall-frequency curves for RG03 (from SPU 2003).

7.5.2 Equipment Monitoring Strategy

Flow monitoring equipment for the commercial land use site is specified in Table 30. These specifications include equipment manufacturer, model, capacity, and communications needs.

Table 30. Flow equipment specifications for commercial site. [28]

Flow Equipment
CSI CR1000 data logger
CSI PS100 power supply w/ AC charger
ADS FlowShark
CSI COM220 phone modem

8 SAMPLING (FIELD) PROCEDURES

This section describes field procedures that will be utilized to ensure that samples are collected in a consistent manner and are representative of the matrix being sampled, and the data will be comparable to data collected by other existing and future monitoring programs.

Sampling procedures will generally follow *Recommended Protocols for Measuring Selected* Environmental *Variables in Puget Sound* (PSEP 1997) and the *NPDES Stormwater Sampling Guidance Manual* (U.S. EPA 1992). A modified version of the “Clean Hands” and “Dirty Hands” protocol will be used for stormwater metals sample collection as described in EPA (1996).

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations, practices, and specific sample collection will be well planned and carefully implemented and follow specific Standard Operating Procedures (SOPs) that support the following field activities:

- Monitoring Equipment Installation and Setup
- Storm Tracking and Forecasting
- Automatic flow-weighted composite sampling
- Grab Sampling
- Sediment Sampling
- Equipment Decontamination
- Equipment Maintenance and Calibration

These SOPs will include requirements for training and documentation of activities, collection of field quality control samples, and description of "Clean Handling Techniques" where appropriate. A general description of field activities is provided below.

8.1 Equipment Decontamination Procedures

A brief description of decontamination procedures for each set of Equipment follows. Details of these procedures will be contained in the SOPs.

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

8.1.1 Water Sampling Equipment

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

SOPs will contain detailed procedures and equipment material requirements to avoid potential contamination of samples. The sampler intake tubes and screens will be cleaned once prior to installation of the samplers and prior to each sample event thereafter. The laboratories will provide certified pre-cleaned containers.

8.1.2 Sediment Sampling Equipment

The Teflon sampling bottles will be pre-cleaned by the analytical laboratory. Bottles will be transported to the field and mounted in the inline bracket with caps in place. Caps will be removed as the last step prior to exiting the MH.

8.2 Sample Collection Procedures

A general discussion of sample collections procedures is described below. Specific details will be provided in the SOPs.

8.2.1 Automatic Flow-weighted Composite Samples

Automatic flow-weighted composite samples using the modified ISCO 6712 sampler will be collected for analytical chemistry (Table T-42) and toxicity testing.

The ISCO sampler will be programmed and filled with ice prior to each storm event. In addition, all sample tubing (i.e., sampler pump tubing and the suction line installed in the pipe) will be back flushed with at least three volumes of reagent grade water prior to each sample event. Clean hands sampling protocol will be used at all times to avoid cross-contaminating the samples. ISCO sample jars will be pre-cleaned by the analytical laboratory and transported to the sampling site with the caps in place. Caps will be removed after all sampling preparations are completed.

The standard ISCO 6712 sampler will be modified for collection of flow-weighted composite samples as shown in Figure 15. The modified sampler will contain eight 2.5-gallon (9.46 L) glass bottles. The sampler will be programmed to fill two replicate bottles for each sample aliquot. As shown in Figure 15, the first bottle will be analyzed for metals and conventional parameters, while the second bottle will be analyzed for organic compounds (e.g., SVOC…). The bottles for metals/conventional and organic analyses will be alternated in the bottle carousel.

ISCO samplers will be programmed to activate when the depth of water in the pipe exceeds a specified base level and to de-activate when the water depth drops below the specified level.

8.2.1.1 Collected for Analytical Chemistry

Up to fourteen flow-weighted composite samples at each of three sites will be collected annually to obtain Event Mean Concentrations (EMCs) of chemicals. Flow-weighted, whole water (unfiltered) sample aliquots will be collected over the course of the storm event with ISCO 6712 automatic samplers. Samples will be cooled to ≤ 6 degrees Celcius per 40 CFR 136. The samplers will be located either within the maintenance hole being sampled (above the expected water levels) or at secure sites, on the ground surface. Samples will be analyzed for the list of parameters using the analytical methods as described Table T-42.

8.2.1.2 Collected for Toxicity

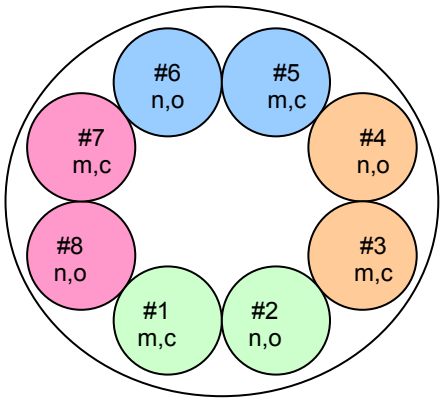
A flow-weighted composite sample of sufficient volume to meet analytical chemistry and toxicity needs (34 to 59 L) will be collected using the procedures described above (Section 8.2.1) to represent the “first flush” during August and September (or October if unsuccessful in August or September). The sample will be split by the laboratory into a subsample for toxicity testing and chemistry analyses.

The Study Manager will contact the toxicity laboratory prior to the forecasted storm event to verify the availability of gametes (test organisms). If the laboratory confirms the gametes of sufficient quantity and quality will not be available for toxicity testing, the sample collection will be postponed.

Despite good faith efforts, the first sampling effort may be deemed unsuccessful, e.g. inadequate sample volume, rainfall volume that did not meet the criteria (Table 18), etc. These efforts will be documented as such and a second sampling attempt will be made if sufficient time remains to meet the toxicity storm event criteria (Table 18).

The first sampling effort may also be deemed unsuccessful due to an invalid or anomalous test result. In this case, Ecology may require an attempt to collect a second sample if they believe sufficient time remains to collect a sample meeting the toxicity storm event criteria (Table 18).

No more than two sample attempts for toxicity testing are required. Documentation of unsuccessful attempts will be reported in the annual stormwater monitoring report.



Legend

#1– bottle number

m,c –bottles receiving nitric acid rinse; contents to be analyzed for metals, and conventionals

n,o–bottles to receive organic solvent rinse; contents to be analyzed for nutrients and organics

–same colored bottles represent bottle pairs that are filled simultaneously. Bottle pairs are filled sequentially over the course of the storm, resulting in four bottle pairs if all bottles are filled.

Sample Compositing Scenario

(1) The contents from all "m,c" bottles are combined to create a single composite sample for analyses of conventionals and metals
(2) The contents of all "n,o" bottles are combined to create a single composite sample for analysis of conventional metals analysis

Figure 15. Flow-weighted composite auto-sampler bottle configuration schematic.

8.2.2 Manual Grab Samples

Manual Grab samples will be collected at each stormwater monitoring site during qualifying storm events as early in the storm event as possible using an extension pole equipped pole swing arm sampler to lower the appropriate sample container, with proper preservative. If it is not possible to collect a manual grab sample due to logistical or safety reasons, a grab sample will be collected at a separate qualifying event.

Because we expect some storm events to occur in the middle of the night, on weekends, or during holidays (and automatic samplers may begin sampling if level enabled), having staff immediately available may be difficult. During these times, it is possible that grab samples may be collected during different storm events when no composite samples are targeted. If the grab sample is collected during storm runoff that meets all qualifying storm event criteria, except for the minimum amount of rainfall, the grab sample will be analyzed and considered a valid sample.

Attempts should be made to have fecal coliform bacteria and TPH analyzed in the same grab sample. However,a grab sample could be collected for fecal coliform and TPH either later in the storm event, or during a future storm event.

8.2.3 Sediment

Sediment samples will be collected using sediment traps, which consist of a stainless steel bracket mounted inside the MS4 that holds a wide-mouth Teflon bottle (Figure 16). Traps are designed to passively collect suspended particulates present in stormwater that passes by the sampling site. Sediment traps were initially designed by Ecology (Wilson and Norton 1996, Barnard and Wilson 1995) and have since been modified by both Tacoma (Norton 1997) and SPU. SPU's modifications permit the use of a wide mouth bottle and expand on Tacoma's changes to enable the sample bottle to be installed in a vertical position in most field conditions (i.e., maintenance holes, vaults, and pipes). Brackets are mounted onto the wall of the pipe, maintenance hole, or other structure using stainless steel screws.

Two traps will be installed at each monitoring location to ensure that an adequate volume of sample is collected for chemical analysis. Wherever possible, traps will be mounted in quiescent areas (e.g., maintenance holes and vaults) to maximize sample collection. In vaults and maintenance holes that are equipped with sumps, the trap will be mounted so that the mouth of the sample bottle is just above the base flow level to sample only storm flows. In pipes and other locations, the trap will be installed at the lowest point in the pipe. Sampling locations will be selected to avoid small diameter pipes (e.g., less than 24-inch diameter) because a large storm event is generally needed in this systems to inundate the approximately 8-inch tall sample bottle. A typical installation is shown in Figure 17.

Traps will be deployed for approximately 12 months, starting in September of each year to capture the winter-wet season. During the first deployment, traps will be checked after about 3 months to evaluate their condition (e.g., damage and sediment volume). If necessary, installations may be modified to improve sample collection and/or repair any damage that may occur. Possible changes include:

- Install more traps (if less than 0.5 inches of sediment deposited after 3 months),
- Install debris deflectors to protect the trap and prevent debris (e.g., plastic bags) from blocking the trap,
- Install a weir or other structure to enhance sediment deposition by ensuring that the sample bottle is inundated under most storm flows, and
- Move traps to a different location.

Figure 16. SPU sediment trap mounting bracket.

Figure 17. Typical sediment trap installation.

Trap samples will be retrieved following PSEP (1997) sample handling guidelines. Gloves will be worn at all times when collecting sediment samples. The sample bottles will be capped in place with a clean Teflon lid, removed from the bracket, stored in a cooler on ice, and transported directly to the analytical laboratory. Clean Teflon bottles will be immediately redeployed for the next 12-month sampling period.

Descriptions of field observations (e.g., potential construction activities that could interfere with sample collection) and sample characteristics (e.g., sheen, odor, color, amount and type of particles being removed, size description) will be included in the field notes recorded during sample collection.

Teflon sample bottles will be cleaned by the analytical laboratory and re-used. The cleaning protocol is summarized below:

- Phosphate-free detergent wash and tap water rinse
- percent ultra-pure hydrochloric acid rinse
- Reagent-grade water rinse
- Ultra-pure methanol rinse
- Air dry.

After cleaning, the bottles will be capped for storage and transport to site.

8.2.4 Flow and Rain Data

Flow will be measured with flow meters that provide the ability to collect flow proportional sample volumes and flow-paced samples. The sampler displays the real time level, velocity, flow rate, and total flow provided by the module. The sampler records this data for later analysis.

The sampler will be programmed to use the customary U.S. measurement units, such as feet (depth), cubic feet per second or gallons per minute (flow, depending on size of the contributing basin), and

gallons or millions of gallons (volume, depending on the size of the contributing basin). The sampler will be programmed to record flow data at 5-minute intervals. These data will be periodically downloaded throughout the course of the sampler deployment (as determined by data storage capacity) and entered into the I-SCADA database.

Rainfall data will be obtained from various existing established rain gauge stations around the Seattle area following established quality assurance/quality control procedures (see Drawing 1). These data will be used to make sampling decisions throughout the course of the sampling and to understand flow results for data reporting.

8.3 Sample Handling & Custody

Sample handling and custody procedures ensure that uniquely identifiable samples are transported to the analytical laboratory with appropriate preservation within prescribed holding times and with proper documentation. Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample is recognized as a vital aspect of an environmental study. The chain-of-custody of the physical sample and its corresponding documentation will be maintained throughout the handling of the sample by following the procedures outlined below.

Table T-45 presents stormwater (both analytical and toxicity analyses) and sediment sample volume, container type, holding time and preservative needed for each required parameter.

8.3.1 Sample Identification

All samples will be clearly labeled in the field with indelible ink. Each sample will be uniquely identified by its sample location identifier (see Table T-38) combined with the sample method (type and technique, i.e. manual grab, automatic flow-weighted composite), the event date and time stamp, and the sample matrix. For composite samples, the date and time stamp will reflect the last aliquot collected.

A field blank will be noted with the addition of a “FB” to the “sample type on the Chain of Custody.

The combination of the sample location identifier-sample method, date and time stamp, and matrix provided on the Electronic Data Deliverable (EDD) by the analytical laboratory will provide the index that links the sample event data and field data, which will identify storm event data and field duplicate samples where applicable. Table T-47 summarizes the sampling identification scheme and indicates what attributes may be tracked in the database.

8.3.2 Sample Transportation

The sample teams will collect the stormwater from the automated samplers or collect grab samples, place the samples on ice, and transport them as soon as possible to the selected analytical laboratory.

8.3.3 Sample Preservation

Other than ice, sample preservation will not be required in the field. Composite samples, for both chemistry and toxicity, will be chilled with ice as they are collected. The modified ISCO sampler configuration has a custom base to contain ice, which will be freshened or placed in the sampler at the start of the sampling event during routine collection of grab samples. The field supervisor will monitor daytime temperatures to ensure ice will be sufficient to last until post-storm sample pick-up occurs. Occasionally, a mid-storm event visit may be needed to add more ice if the air temperatures are warm enough to melt the ice while sample collection is still underway.

Grab samples must be chilled immediately following collection.

Chemical preservatives are added to the samples for certain analyses to prolong the stability of the parameters during transport and storage. Table T-45 lists the required sample preservatives for the analytical parameters. If composite sampling procedures are used, no preservatives are added to the composite container because no single chemical preservative is suitable for all of the parameters to be analyzed. The laboratory must first divide the composite sample into the appropriate bottle for each analysis, and then add chemical preservatives as appropriate for each analysis. If manual grab sampling procedures are used (i.e., monitoring personnel directly fill the containers required for each analysis), the monitoring personnel will add the appropriate preservative to each sample container immediately.

8.3.4 Sample Processing

In general, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere and transported to the analytical laboratory as soon as possible after sample collection. The Study Manager will coordinate with the analytical laboratory to ensure samples can be transported, received, and processed during non-business hours if needed.

Sample filtration is required when collecting samples for dissolved metals determinations. Filtration for metals will be conducted by the analytical laboratory to reduce the potential for contamination in the field, especially during storm conditions.

Once the composite samples have been delivered to the laboratory, the laboratory staff will transfer the composite sample to the appropriate bottles for the required analytical procedures (see Table T-45). During this process, the composite sample bottle will be vigorously agitated to ensure that a representative sample will be transferred to each bottle. In order to minimize exposure of the samples to human, atmospheric, and other potential sources of contamination, laboratory staff will process the samples using “clean” techniques pursuant to protocols developed by the U.S. EPA (1996) for the low-level detection of metals.

8.3.5 Holding Times

Holding times (Table T-45) are short for some parameters, particularly fecal coliform bacteria, nutrients, and BOD (24 to 48 hours). For composite samples, the "sample collection time" used to evaluate holding time limits, is the time that the final sample aliquot is collected. To minimize the risk of exceeding holding times, the Study Manager will coordinate with the analytical laboratory prior to each event to ensure that the laboratory is prepared to begin processing samples as soon as samples are received. In addition, samples will be delivered to the laboratory immediately after retrieval from field samplers.

8.3.6 Chain of Custody

A chain-of custody form will accompany each sample batch that is delivered to the laboratory. The purpose of chain-of-custody (COC) forms is to keep a record of the sample submittal information and to document the transfer of sample custody. Standard COC forms will be prepared for the study that will include sample location identifier, analyses to be requested, and any special considerations, such as analyses priority order and sample filtration needs. At the time of sample collection, the field team will record the sample date and time, sample location, matrix, and analyses requested. Any special instructions for the laboratory will also be noted on the COC form such as specifications of quality control requirements (e.g., duplicate samples). The COC form must be signed by both the person relinquishing the samples and the person receiving the samples every time the samples change hands, thus documenting the chain of custody.

8.4 Non-direct Measurements

Precipitation data will be collected under the existing Seattle Public Utilities hydrological program. This data, which is managed by the Hydrological Project Manager, follows Standard Operating Procedures for data collection, validation, and management to ensure it is of known and documented quality.

9 MEASUREMENT PROCEDURES

The analytical methods for this study were specified by Ecology and have performance characteristics that meet the MQOs for precision, bias, and sensitivity described in Section 6.1 (Tables Table T-42Table T-43Table T-44).

9.1 Water Quality & Sediment Analysis

All parameters will be analyzed in the laboratory from stormwater, sediment, and QC samples collected in the field by a laboratory accredited per Chapter 173-50 WAC. The parameters to be analyzed and their method number and reporting limits for each analysis are provided in Table T-42 and Table T-44 for water and sediment respectively.

A description of each analytical method can be found on the National Water Quality Monitoring Council web site at http://acwi.gov/methods/.

9.2 Toxicity Testing

This section describes the laboratory procedures needed to test the seasonal first-flush sample for toxicity. The laboratory will conduct water quality measurements on all samples and test solutions for toxicity testing as specified in the most recent version of Department of Ecology publication # WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.

9.2.1 Testing Procedures

Testing procedures should follow the E-test (seven day), Environment Canada, Pacific Environmental Science Center, Environmental Toxicology Section, SOP ID: RBTELS11.SOP, 1999. The test procedure may take advantage of the smaller volume modification described in: Canaria, E.C., Elphick, J.R. and Bailey, H.C. 1999. A simplified procedure for conducting small scale short-term embryo toxicity tests with salmonids is found in Environ. Toxicol. 14:301-307.

Toxicity tests must meet quality assurance criteria in the most recent versions of the Environment Canada manual EPS 1/RM/28 and the Department of Ecology Publication #WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria.

If a receiving water sample for hardness is submitted, the toxicity laboratory will be instructed to measure the hardness of the receiving water sample and the stormwater sample and to increase the hardness of the stormwater sample to match the hardness of the receiving water sample prior to beginning the toxicity test. Control water and dilution water must be a moderately hard-reconstituted laboratory water or pristine natural water of sufficient quality for good control performance.

The EC_{50} must be calculated by the trimmed Spearman-Karber procedure. Abbott's correction may be applied to the data before deriving this point estimate. A minimum of five (5) concentrations and a control must be used in the testing.

The test configuration for the 44 liters shall have five concentrations and a control with four replicates at each concentration. An additional seven replicates of 100% sample shall be run in order to provide tissue for yolk/embryo analysis if needed. The test concentration series shall be determined using a 0.5 dilution factor.

If the total sample volume for toxicity analysis, excluding the volume required for associated chemical analysis, is less than 11.6 gallons (44 liters) but greater than 6.3 gallons (24 liters) then the volume that was collected will determine changes in the toxicity-testing configuration described above in accordance with the following:

- 10 gallons (38 liters) of sample – base the concentration series on a 0.3 dilution factor.
- 8.7 gallons (33 liters) of sample – base the concentration series on a 0.3 dilution factor and reduce the number of replicates to three.
- 7.9 gallons (30 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three and the number of replicates in the test itself to three.
- 6.9 gallons (26 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three and base the concentration series on a 0.3 dilution factor.
- 6.3 gallons (24 liters) – reduce the number of extra replicates of 100 percent sample for yolk/embryo analysis from seven to three, base the concentration series on a 0.3 dilution factor, and reduce the number of replicates in the test itself to three.

If the sample volume falls between the values listed above, then the test configuration must match the next lowest volume and the excess sample used for additional replicates of 100 percent sample to improve the detection limit for the egg analysis. If sample volume is less than 6.3 gallons (24 liters), toxicity sample analysis will not be conducted.

9.2.2 Follow Up Actions

If the EC_{50} from any valid and non-anomalous test is 100 percent stormwater or less, the Permittee must implement follow-up actions. Terminated organisms must be preserved for up to six months.

Within sixty (60) days after final validations of the data, the Permittee shall compare the chemical analysis results for the same sample event to a library of toxicity test results complied by the Department and identified for this purpose, using good faith efforts to determine if the presence of an analyzed contaminant is within a range reported in the literature that may adversely affect fish embryos and if so, to review the source literature.

9.2.2.1 Potential Chemical Contaminant of Concern Determination

If a possible chemical contaminant(s) of concern is determined by the library comparison and literature review, the Permittee must prepare and submit a report summarizing the toxicity and chemical analysis results, the library comparison, a review of relevant sources of literature from the Department's library, the possible chemical contaminant(s) of concern, and an explanation of how the Permittee's stormwater management actions are expected to reduce stormwater toxicity. This report will be submitted to the Department within one hundred twenty (120) days after final validation of the toxicity and chemistry data. In addition, the report will be attached as an appendix to the following year's annual stormwater monitoring report.

If a possible chemical contaminant of concern is not determined by library comparison and literature review, a Gas Chromatograph/Mass Spectrometer (GC/MS) analysis of the eggs from the highest ten concentrations must be performed. The GC/MS need not be quantitative but only capable of identifying stormwater contaminants present in the eggs. Within one hundred fifty (150) days after final validation of the toxicity and chemical analysis data, the Permittee must prepare and submit a report summarizing the toxicity and chemical analysis results, the library comparison, a review of relevant sources of literature from the Department's library, the GC/MS results, and an explanation of how the Permittee's stormwater management actions are expected to reduce stormwater toxicity. In addition, the report will be attached as an appendix to the following year's annual stormwater monitoring report.

9.2.2.2 Reporting

The reporting schedule for follow-up actions is summarized below in Table 31. The report will be attached as an appendix to the following year's annual stormwater monitoring report.

Table 31. Toxicity follow-up reporting schedule.

Report	Submittal date to Ecology
Potential chemical contaminant of concern determination	Within one hundred twenty (120) days after final validation of the toxicity and chemistry data
Additional egg chemical analysis	Within one hundred fifty (150) days after final validation of the toxicity and chemical analysis (including additional GC/MS analysis described in Section 9.2.2.1) data.
Appendix to Annual Report	March 31 of year following submittal date of above reports to Ecology

Element IV. Study Implementation QA/QC Procedures

This element describes the procedures to be followed during the study implementation phase and includes:

Section 10 – Quality Control, which discusses measures to be implemented in the analytical laboratory and field,

Section 11 – Data Management and Documentation, a quality assurance (QA) measure to ensure maintenance of accurate and complete records of all study activities, and

Section 12 – Audits and Reports, which ensures the QAPP is implemented as described in this Plan.

10 QUALITY CONTROL

This section discusses the quality control samples needed (i.e. field splits, field blanks, temperature checks, etc.) to be collected in the field and the laboratory. Detailed laboratory QC requirements are contained within the laboratory Quality Assurance Manual, which will be reviewed by the Study Manager. The MQOs or criterion specified for each QC sample result is summarized in Table T-39.

Table 32 and Table 33 specify the frequency of quality control samples and the Glossary provides definitions and explanations of analytical and field quality control samples.

10.1 Analytical Quality Control

Laboratory analytical quality control (QC) procedures involve the use of four basic types of QC samples. QC samples are analyzed within a batch of client samples to provide an indication of the performance of the entire analytical system. Therefore, QC samples go through all sample preparation, clean up, measurement, and data reduction steps in the procedure. In some cases, the laboratory may perform additional tests that check only one part of the analytical system. Please refer to the Glossary for a definition of each laboratory QC sample.

Table 32. Laboratory Quality Control Samples by Matrix.

QC Sample	Matrix	Frequency of Analysis
Matrix Spike (MS)	Water	One of each per batch of 20 or fewer samples of similar matrix.
Laboratory (or Matrix) Duplicate (MSD)	Water Sediment	One of each per batch of 20 or fewer samples of similar matrix.
Method or Preparation Blank (MB)	Water Sediment	One of each per batch of 20 or fewer samples of similar matrix.
Laboratory Control Samples (LCS)	Sediment	One of each per batch of 20 or fewer samples of similar matrix.

10.2 Field Quality Control

Field quality control (QC) procedures involve the use of two basic types of QC samples: duplicates (or field replicates) and blanks. Please refer to the Glossary for a definition of each.

Table 33. Field quality control sample schedule.

QC Sample	Matrix	Frequency of Collection
Duplicate	Water	Collect at a minimum *ten percent* of each reported result (i.e. for each sample container submitted). Collect at least one field duplicate for each reported test result combination each year.
	Sediment	
Blanks	Water	Collect at a minimum *five percent* of each test result. Collect at least one blank for each reported test result for each year. Collect field-cleaned **equipment blanks** if any sample equipment decontamination is performed in the field. If decontamination is not performed in the field, collect precleaned equipment blanks if the equipment is not certified clean by the vendor or the laboratory providing the equipment. Collect **field blanks** if no equipment except the sample container is used to collect the samples or if the sampling equipment is certified clean by the vendor or the laboratory providing the equipment.
	Sediment	Collect at a minimum *five percent* of each test result. Collect at least one blank for each reported test result each year. Collect field-cleaned equipment blanks if any sample equipment decontamination is performed in the field. If decontamination is not performed in the field, collect precleaned equipment blanks if the equipment is not certified clean by the vendor or the laboratory providing the equipment.

11 DATA MANAGEMENT & DOCUMENTATION PROCEDURES

This section discusses data management, which addresses the path of data from recording in the field or laboratory to final use and archiving. The data management and documentation strategy combines the use of Standard Operating Procedures (SOPs) that specify documentation needs and provide for consistency when collecting, assessing, and documenting environmental data and electronic storage of all documents and records on servers that are regularly backed up.

Documents will be archived in portable document format (pdf) on the City of Seattle's Science Information Catalog (SIC), an Oracle Portal-based document library. Data will be managed and archived in the City's Science Information Management System (SIMS), an Oracle-based information management system. The documents described below will be retained for a minimum of 5 years.

11.1 Documents and Records

Four types of documentation will be managed: (1) field operation records; (2) laboratory records; (3) data handling records and (4) Plan revision documentation.

11.1.1 Field Operation Records

Field operation records may include:

- Go/No-go Event Report
- Discharge Measurement Notes (when collected)
- Level Notes (when collected)
- Data sheets and field notes
- Photographs taken of the described activities (when taken)
- Calibration & Maintenance Notes

11.1.2 Laboratory Records

Laboratory records will include a statement of work, data package, and electronic data deliverable, which are described below:

Statement of Work (SOW): A list of specifications and requirements with which analytical laboratories must meet in order to do work.

Data Package: A hardcopy and electronic (pdf format) report from an analytical laboratory on a single set of chemical analyses, which contains the material specified in the SOW and sufficient documentation to allow an appropriate professional, at a substantially different time and location, to ascertain:

- what analyses were performed and what results were obtained,
- that the data had acceptable properties (such as accuracy, precision, method reporting limits),
- where, when, and by whom the analyses were performed,
- that the analyses were done under acceptable conditions (such as calibration, control, custody, using approved procedures, and following generally approved good practices), and
- that the SOW was otherwise followed.

The data package will report the test results clearly and accurately. The test report will include the information necessary for interpretation and validation of data and will include the following:

- Report title,
- Name and address of laboratory,
- Name and address of client and study name,
- Subcontractor results clearly identified,
- Description and unambiguous name of tested sample,
- Date and time of sample collection, date of sample receipt, and date and time of analysis,
- Preservation at time of sample acceptance (temperature, pH, etc.),
- Identification of test method,
- QC results for method blank, MS/MS duplicates, LCS, as appropriate,
- An explanation of failed QC and any non-standard conditions that may have affected quality,
- A signature and title of laboratory director or designee, and.
- Chain of Custody and sample receipt forms.

The Toxicity Data Package will follow the most recent version of Department of Ecology Publication # WQ-R-95-80, Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria and will include in addition to the above:

- Test report,
- Bench sheets, and
- Reference toxicant results for test methods.

Electronic Data Deliverable (EDD): The data will be provided in a computer-compatible file that is delivered from the analytical laboratory in the SOW-specified format via Internet, e-mail, or compact disk from which analytical chemistry data may be uploaded directly into databases.

11.1.3 Data Handling Records

This section describes the approach for record control and storage of each sampling event. All documents associated with a sampling event will be stored electronically. Paper copies will not be archived. Each sampling event will be documented with the following records:

- Field Datasheet,
- Chain of Custody (COC),
- Field QA Report,
- Data Package,
- Data Validation Memo,
- Electronic Data Deliverable (EDD) with Quality & Usability Flags.

All documents will be provided in portable document format (pdf) with the exception of the flow data and the EDD, which will be in Excel® format. These documents will be uploaded to the Science Information Catalog (SIC) and referenced in the Science Information Management System (SIMS). The EDD with quality and usability qualifiers will be uploaded to SIMS. Table T-48 summarizes the data path for each sampling event and outlines the roles and expected timeline.

11.2 Revisions to the QAPP

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

Expedited Changes to the QAPP should be approved before implementation to reflect changes in study organization, tasks, schedules, objectives, and methods, address deficiencies and non-conformance, improve operational efficiency and accommodate unique or unanticipated circumstances. Requests for expedited changes are directed from the Study Manager to the Principle Investigator in writing. They are effective immediately upon approval by the Principle Investigator and Quality Assurance Coordinator, or their designees, and any regulatory authority if needed.

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 Principle Investigator. Expedited changes will be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.

12 AUDITS AND REPORTS

This section discusses assessment, response actions, and corrective actions to ensure all data is being collected as described in this Plan.

12.1 Assessments and Response Actions

Field, analytical, and data management activities are evaluated based on the schedule below.

Table 34. Assessment and response action schedule.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Laboratory Inspections	Dates to be determined	QA Coordinator	Analytical and quality control procedures employed at the laboratory and the contract	30 days to respond in writing to address

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
			laboratory	corrective actions.
Monitoring Systems Audit	Dates to be determined	QA Coordinator	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP and may include: field sampling; handling and measurement; facility review; and data management as they relate to the study.	30 days to respond in writing to address corrective actions.
Site Visit	Dates to be determined	Study Manager	Status of activities. Overall compliance with work plan and QAPP	As needed.

12.2 Deficiencies, Nonconformances and Corrective Action

The Study Manager is responsible for implementing and tracking corrective action procedures because of audit findings. Records of audit findings and corrective actions are maintained by both the QA Coordinator and Study Manager.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in the laboratory's Quality Management Plan (QMP) and in agreements or contracts between participating organizations.

Deficiencies are defined as unauthorized deviation from procedures documented in the QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate.

Deficiencies related to sampling methods requirements include, but are not limited to, such things as sample container, volume, and preservation variations, improper/inadequate storage temperature, holding-time exceedances, and sample site adjustments.

Deficiencies related to chain-of-custody include but are not limited to delays in transfer, resulting in holding time violations; incomplete documentation, including signatures; possible tampering of samples; broken or spilled samples, etc.

Deficiencies related to field and laboratory measurement systems include but are not limited to instrument malfunctions, blank contamination, quality control sample failures, etc.

Deficiencies related to Quality Control include but are not limited to quality control sample failures.

Deficiencies are documented in logbooks, field data sheets, etc. by field or laboratory staff and reported to the cognizant field or laboratory supervisor who will notify the Study Manager. The Study Manager will notify the QA Coordinator of the potential nonconformance within 24 hours, who will then initiate a Nonconformance Report (NCR) to document the deficiency.

The Study Manager, in consultation with QA Coordinator (and other affected individuals/organizations), will determine if the deficiency constitutes a nonconformance. If it is determined that the activity or item in question does not affect data quality and therefore is not a valid nonconformance, the NCR will be completed accordingly, and the NCR closed. If it is determined a nonconformance does exist, the Study Manager in consultation with QA Coordinator will determine the disposition of the nonconforming activity

or item and necessary corrective action(s); results will be documented by the contractor QA Coordinator by completion of a Corrective Action Report.

Corrective Action Reports (CARs) document: root cause(s); programmatic impact(s); specific corrective action(s) to address the deficiency; action(s) prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and, the means by which completion of each corrective action will be documented. CARs will be included with quarterly progress reports. In addition, significant conditions (i.e., situations that, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the Principle Investigator immediately both verbally and in writing.

Element V. Assessment Procedures

This element describes the assessment procedures implemented after data collection is complete to determine if the data conform to the specified criteria and will satisfy the study objectives and if so, the analysis and format for presentation of the results. It includes:

Section 13 - Data Validation & Verification,

Section 14, Data Quality (Usability) Assessment, and

Section 15 – Data Analysis and Presentation.

Sections 13 and 14 describe the procedures used to determine if the MQOs established in Section 6.2 for the six data quality indicators (PARCCS - precision, accuracy (bias), representativeness, completeness, comparability, and sensitivity) have been met.

The result of sections 13 and 14 are data of known and documented quality, we answer the question; *are the data of sufficient quality and quantity to meet the use for which they are intended*.

The quality of the data is indicated by data qualifier codes, notations used by laboratories and data reviewers to briefly describe, or qualify, data and the systems producing data. Table T-49 provides a brief list of data qualifier codes anticipated to be used for this study.

During data review, verification, and validation, results are either accepted or reported with data qualifiers or flags. Data that meet all QC acceptance limits are potentially usable and are not qualified. Data that fail one or more QC criteria are qualified as estimated (with the J flag), tentatively rejected (with the S flag), or rejected (with the R flag). The distinction between estimated, tentatively rejected, and rejected data resides in the degree of the QC failure and is highly dependent upon the reviewer's understanding of the objectives of the study.

During the data usability assessment, data that are believed to be completely unusable with a high degree of confidence (e.g., because of the gross failure of QC criteria) are qualified as rejected and would not normally be used to support decisions for an environmental study.

13 DATA VERIFICATION AND VALIDATION

This section discusses data review, verification, and validation. Data will be reviewed, verified, and validated using a Tier I data review level (Table 35).

13.1 Data Review, Verification, and Validation

This section discusses how data are reviewed and decisions made regarding accepting, rejecting, or qualifying data.

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance of a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in the QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of the study. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

Table 35. Data review levels.

Tier	Description
Tier I – Compliance Screening[29]	Includes evaluation of package completeness; sample chain-of-custody; sample preservation and analytical holding times; blank contamination; precision (replicate analyses); accuracy (compound recovery); target analyte list, and detection limits.
Tier II – Summary Validation[30]	Includes evaluation of all QC elements from Compliance Screening plus instrument performance (initial calibration, continuing calibration, tuning, sensitivity and degradation.
Tier II – Full Validation[31]	Includes evaluation of all QC elements from Summary Validation plus evaluation of compound identification and quantitation (transcription and calculation checks).

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to study requirements, and then validated against the measurement quality objectives, which are listed in Section 6. Only those data that are supported by appropriate quality control data and meet the measurement performance specification defined for this study will be considered acceptable and used in the study.

The procedures for verification and validation of data are described in Section 13.2, below.

13.2 Verification and Validation Methods

Procedures used to validate and verify data will be described in a SOP, which will also include roles, responsibilities, and documentation. Table T-39 summarizes the data verification elements that will be assessed, the criterion to be met, and the action to be taken should the criterion not be met.

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to study specifications. The data verification procedures will generally include:

- Storm event verification (i.e., did the sampling event meet the established storm criteria, Table 18);
- Sampler verification (i.e., did the sampler collect a valid flow-paced sample and capture the appropriate storm volume, Table 19);
- Field QC (did we collect at appropriate frequency and did they meet the established control limits); and
- Laboratory QA/QC (did lab meet established control limits).

14 DATA QUALITY (USABILITY) ASSESSMENT

This section describes the process for determining the data usability, the method for data reduction, and the process for assessing the data quality. The methods and procedures that will be used to determine if the DQO's established in Section 6.1 have been met and to prepare presentation of the study results are discussed. The purpose of this process is to determine: *if the decision (or estimate) can be made with the desired confidence, given the quality of the data set?*

[29] Also referred to as: cursory; verification/CCS (EPA); QA-1 (PSDDA/PSEP);Tier I (EPA Region I).
[30] Also referred to as: Level 3 (EPA CLP); Level C (Navy);Screening (AFCEE)' M-2 (organic EPA Region 3); IM-2 (inorganic EPA Region 3); Tier II (EPA Region 1); CLP summary form review.
[31] Also referred to as: Levels 4 or 5 (EPA CLP); Levels D or E (Navy); QA-2 (PSDDA/PSEP); Definitive (AFCEE); Tier III (EPA Region 1); M-3 (organic EPA Region 3); IM-3 (inorganic EPA Region 3).

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Data reduction is the process of converting raw data to results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form.

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use.

14.1 Data Usability Assessment

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose. Three levels or classes of data quality are used:

- **Accepted** Data conform to all requirements, all quality control criteria are met, methods were followed, and documentation is complete.
- **Qualified** Data conform to most, but not all, requirements, critical QC criteria are met, methods were followed or had only minor deviations, and critical documentation is complete.
- **Rejected** Data do not conform to some or all requirements, critical QC criteria are not met, methods were not followed or had significant deviations, or critical documentation is missing or incomplete. The results are unusable.

Data usability assessment is a more complex and comprehensive activity than data review or validation and is usually performed by the end user (rather than by the data reviewer) because the data user typically possesses a greater understanding of the study's DQOs (e.g., because of a more extensive knowledge of the study's history). Therefore, the end user must ultimately determine the acceptability of the data. However, this does not imply that the end user may apply qualified data in an indiscriminate fashion.

Tentatively rejected data must not be used to support study decisions unless the data user presents (i.e., documents) some technical rationale for doing so. In other words, tentatively rejected data must ultimately be rejected (e.g., using the R flag) in the absence of a scientifically defensible rationale to do otherwise. Furthermore, when data qualified as tentatively rejected are used to support decisions for a study, the data reviewer should be consulted for a consensus unless it is clear that the reviewer did not possess a complete understanding of the objectives of the investigation (e.g., new DQOs were established after the data review was performed).

Ideally, estimated (i.e., J-qualified) data, though presumed to be usable by the data reviewer, should be accepted by the end user only after the reasons for the data qualifications and their impact on the achievement of study DQOs have been examined.

The usability assessment includes assessment of potential outliers, confirmation that the data is comparable and representative, and calculation of the completeness:

- Identification of outliers from the previous quarter's data collection efforts,

- Confirmation of outliers from previous data collection efforts when sufficient data is available to complete the outlier test,
- Confirmation of the comparability of the data,
- Confirmation of the representativeness of the data, and
- Calculation of the completeness for each dry and wet season for the water year to date.

Definitions for each DQI can be found in the Glossary as well as the equation for calculating completeness. Specific methodology for completing the data usability assessment is discussed below.

14.1.1 Data Processing Guidelines

Some additional data processing may be required prior to performing any data usability or data reduction functions. Anticipated data processing needs are described below. Any additional needs will be included in the Quarterly Usability Report (see Section 14.1.4).

Handling of non-detected values. The analytical laboratory will be requested to report an estimated value for all non-detected results as well as identifying each as such. In the event an estimated value below the reporting limit is not provided, the value will be estimated at half of the reporting limit.

Handling of field duplicates The primary field duplicate sample will be used in the data assessment process.

14.1.2 Identification of Outliers

Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.

The evaluation and handling of potential outliers will be performed using the guidance found in the EPA document "Guidance for Data Quality Assessment", EPA/600/R-96/084. Section 4.4 of the EPA document provides guidance on identifying potential outliers, choosing the proper statistical test, evaluating the results and documenting the process.

Documentation of the outlier designation will include:

- The rationale for the choice of the outlier test along with the results,
- the supporting scientific facts to demonstrate that the outlier is not just a statistical anomaly, but was in fact a true outlier, and
- The impact the outlier data point had on the statistical processing of the data.

14.1.3 Descriptive Statistics

At a minimum, the following resistant measures will be developed to describe the measured concentrations for each parameter:

- Measure of location – median,
- Measure of spread – interquartile range (IQR), and
- Measure of skewness - quartile skew coefficient (q_s).

14.1.4 Roles, Responsibility, and Documentation

The Principle Investigator will document the Usability Assessment by preparing a quarterly report, which includes:

(1) Listing of all data collected for the period. Include any usability flags qualifying the data.

(2) Summary for the water year to date including:

- Descriptive statistics, and
- Completeness for each season.

14.2 Data Reduction Methods

Data reduction is the process of converting raw data to results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form. The data generated for this investigation will be used to calculate Event Mean Concentrations (EMCs), total annual pollutant loads, and the seasonal pollutant loads for wet and dry seasons. This section describes the methodology used to calculate these values.

14.2.1 Event Mean Concentration

The event mean concentration (EMC) is the flow-weighted average of a constituent concentration over the duration of a single runoff event. When samples are collected using an automatic flow-weighted composite sampler, there is no calculation necessary. EMC is computed as total constituent mass discharged during an event divided by total volume V of discharge during the event.

Calculation of the average annual and seasonal sampled EMC uses a weighted average approach and is discussed below in Section 14.2.2.

14.2.2 Pollutant Load

The total annual load is the sum of base flow loading and stormwater runoff loading. For the purposes of this analysis, base flow loading is defined as the annual mass of a chemical constituent that infiltrates the MS4 from groundwater and shallow subsurface stormwater flow and enters the MS4 from surface flows such as springs or irrigation. Base flow is determined using the storm event criteria defined in Table 18 and is generally defined as flow contributed from non-storm sources.

Stormwater runoff loading is defined as the annual mass of a chemical constituent exported from flow that is derived from storm events. Because the chemical composition of base flow water is expected to be different from that of stormwater runoff water due to infiltration, biological processes that occur within the ground, or the source of the base flow, separate calculations may need to be performed to determine the annual base and storm flow loadings, respectively.

The loadings will be expressed as total pounds and as pounds per acre draining to the MS4.

For each parameter monitored and each storm event in which a sample was collected, follow the steps below to calculate the annual water year, dry season, and wet season EMC and stormwater loading.

Step 1. Determine representative volumes for each sampled event:

> **Step 1a**. Determine the total event volume for the sampled storms (which includes the entire storm flow period related to the event, not just the period that samples were collected) both stormwater flow and base flow combined, $V_{i,t}$, for each storm event, i.

Step 1b. Determine the base flow volume, $V_{i,b}$, for the sampled storms (which includes the entire storm flow period related to the event, not just the period that samples were collected) for each storm event, i.

Step 1c. Determine the stormwater volume representing the sampled event (which includes the entire storm flow period related to the event, not just the period that samples were collected), V_i, by subtracting the base flow from the total event volume (which includes storm flow and base flow) for each sampled event.

Step 2. Determine representative loads for each sampled event:

Step 2a. Calculate a total load for each sampled storm event, $L_{i,t}$. Multiply each storm event mean concentration, EMC_i by the total event volume for the sampled storm (Step 1a), $V_{i,t}$.

$$L_{i,t} = EMC_i x V_{i,t}$$

Step 2b. If applicable, calculate a base flow load for each sampled event, $L_{i,b}$. Multiply the base flow concentration for the appropriate season, C_d or C_w, by the base flow volume, $V_{i,b}$, for each sampled event (Step 1b).

$$L_{i,b} = C_d x V_{i,b} \quad \text{OR} \quad L_{i,b} = C_w x V_{i,b}$$

Step 2c. Calculate the stormwater load for each sampled event, ℓ_i. Subtract the base flow load (Step 2b), $L_{i,b}$, from the total event load (Step 2a), $L_{i,t}$.

$$\ell_i = L_{i,t} - L_{i,b}$$

Step 3. Sum the sampled event loads, annually and seasonally, for the sampled events:

Step 3a. Calculate the total storm load, L_t, representing each sampled storm event by summing the respective loads from each storm event within each period (i.e., water year, wet season, dry season) (Step 2a), where n is the number of storms sampled.

$$L_t = \sum_{i=1}^{n} L_{i,t}$$

Step 3b. If applicable, calculate the base flow load, L_b , representing each sampled storm event by summing the respective loads from each storm event within each period (i.e., water year, wet season, dry season) (Step 2b), where n is the number of storms sampled.

$$L_b = \sum_{i=1}^{n} L_{i,b}$$

Step 3c. Calculate the stormwater load, L, representing each sampled storm event by summing the respective loads from each storm event within each period (i.e., water year, wet season, dry season) (Step 2c), where n is the number of storms sampled.

$$L = \sum_{i=1}^{n} \ell_i$$

Step 4. Calculate the volume-weighted concentrations, annually and seasonally, representing the sampled events:

Step 4a. Calculate the average annual, dry season, and wet season total volume-weighted concentration (VWC_t), representing the storms sampled. Divide the summed loads for the respective period (Step 3a) by the sum of the total event volumes that were associated with each sampling period (Step 1a).

$$VWC_t = \frac{\sum_{i=1}^{n} L_{i,t}}{\sum_{i=1}^{n} V_i} = \frac{L_t}{\sum_{i=1}^{n} V_i}$$

Step 4b. If applicable, calculate the annual water year, dry season, and wet season base flow volume-weighted concentration (VWC_b), representing the storms sampled. Divide the base flow load for the respective period (Step 3b) by the sum of the volumes that were associated with each sampling period (Step 1b).

$$VWC_b = \frac{\sum_{i=1}^{n} L_{i,b}}{\sum_{i=1}^{n} V_{i,b}} = \frac{L_b}{\sum_{i=1}^{n} V_{i,b}}$$

Step 4c. Calculate the average annual water year, dry season, and wet season stormwater volume-weighted concentration (VWC), representing the storms sampled. Divide the stormwater load for the respective period (Step 3c) by the sum of the volumes that were associated with each sampling period (Step 1c).

$$VWC = \frac{\sum_{i=1}^{n} \ell_i}{\sum_{i=1}^{n} V_i} = \frac{L}{\sum_{i=1}^{n} V_i}$$

Step 5. Calculate the annual water year and seasonal loads representing the entire discharge for each period (i.e., for the entire water year, wet season, dry season) using a ratio estimator:

The basis of ratio estimators is the assumption that the ratio of load to flow for the entire period should be the same as the ratio of load to flow for the sampled events. Therefore:

$$\frac{L_e}{\left(\sum_{i=1}^{m} V_i\right)} = \left(\frac{\sum_{i=1}^{n} \ell_i}{\sum_{i=1}^{n} V_i}\right)$$

Where;

L_e = estimate of annual stormwater load
ℓ_j= estimate of load for storm i (step 2c)
n = number of storms sampled
m = number of storms in the period
V_i = Storm volume of storm event i

And:

$$V_d = \sum_{i=1}^{m} V_i$$

Where:
V_d is the volume discharged during the period and either measured continuously or estimated using rain data.

Step 5a. Estimate an annual water year, dry season, and wet season total (stormwater and base flow) discharge load, L_{et}, representing each period for the total continuous discharge in that period.

$$L_{et} = \frac{\sum_{i=1}^{n} L_{i,t}}{\sum_{i=1}^{n} V_{i,t}} V_{d,t} = VWC_t x V_{d,t}$$

Step 5b. If applicable, estimate an annual water year, dry season, and wet season base flow discharge load, L_{eb}, representing each period for the continuous base flow discharge in that period.

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$$L_{eb} = \frac{\sum_{i=1}^{n} L_{i,b}}{\sum_{i=1}^{n} V_{i,b}} V_{d,b} = VWC_b x V_{d,b}$$

Step 5c. Estimate an annual water year, dry season, and wet season storm flow discharge load, L_e, representing each period for the continuous storm flow discharge in that period.

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$$L_e = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} V_i} V_d = VWCxV_d$$

Step 5d. Assess the assumption that the concentration per sampled storm event was positively related to volume per sampled storm event.

Step 6 Calculate the annual water year and seasonal loads representing the entire discharge for each period (i.e., for the entire water year, wet season, dry season) on an areal basis (i.e., pounds pounds per acre):

Step 6a. Estimate an annual water year, dry season, and wet season total (stormwater and base flow) discharge load in pounds per acre ($L_{et/a}$) by dividing the estimated Total Load for the period (L_{et}) in pounds (Step 5a) by the basin area (A) draining to the monitoring station in acres.

$$L_{et/a} = \frac{L_{et}}{A}$$

Step 6b. Estimate an annual water year, dry season, and wet season base flow discharge load in pounds per acre ($L_{eb/a}$) by dividing the estimated base flow load for the period (L_{eb}) in pounds (Step 5b) by the basin area (A) draining to the monitoring station in acres.

$$L_{eb/a} = \frac{L_{eb}}{A}$$

Step 6c. Estimate an annual water year, dry season, and wet season stormwater flow discharge load in pounds per acre ($L_{e/a}$) by dividing the estimated storm flow load for the period (L_e) in pounds (Step 5c) by the basin area (A) draining to the monitoring station in acres.

$$L_{e/a} = \frac{L_e}{A}$$

14.3 Data Quality Assessment Methodology

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use. This section describes the process for determining whether the data meet study data

quality objectives once the data results are compiled, have been assessed for usability, and reduced following the processes above. The purpose of the DQA is to answer the question:

Can the decision (or estimate) be made with the desired confidence, given the quality of the data set?

As discussed in Section 3.1.2, the results of this study will not be used to make a decision, but rather to provide guidance.

The null hypothesis or baseline condition is that *there is no temporal trend in the seasonal or annual stormwater pollutant load from selected basins within the City of Seattle*, i.e., "H_o: no trend". The alternative condition or hypothesis will be either "H_a: upward trend" or "H_a: downward trend."

Because detecting a statistically significant trend requires a relatively large sample size and the sampling design strategy produces a single value for trend testing annually, the trend determination will be performed in two steps: (1) graphically over the current permit cycle at a minimum, and (2) with a hypothesis test at some future date.

14.3.1 Graphical Trend Testing

The graphical representations below will be implemented as the first step to identify possible trends.

- Scatter plot showing dry season, wet season, and annual load for each parameter measured over time.
- A box plot grouped by dry season, wet season, and annual load for each parameter showing the variation in the results.

14.3.2 Hypothesis Trend Testing

The Mann-Kendall, a non-parametric test that can handle missing data and accommodates trace values or values below the detection limit, has been tentatively identified as the selected statistical test. The test can also be modified to deal with multiple observations per time period and generalized to deal with multiple sampling locations and seasonality.

The basic principle of Mann-Kendall (MK) tests for trend is to examine the sign of all pair-wise differences of observed values.

15 DATA ANALYSIS & PRESENTATION

This section discusses the content of the Annual Stormwater Monitoring Report, which will cover data collected during the previous water year. Each Annual Stormwater Monitoring Report, which is an attachment to the Annual Report under the Phase I Permit, is required to include the following four elements (Permit Section H.1.a):

1) A summary including the location, land use, drainage area size, and hydrology for each site.
2) A comprehensive data and Quality Assurance/Quality Control (QA/QC) report for S8.D Stormwater Monitoring, with an explanation and discussion of the results from each monitoring site.
3) The annual pollutant load based on water year for each monitoring site expressed in total pounds, and pounds/acre
4) The wet and dry season pollutant loads based on water year, expressed in total pounds, and pounds/acre

These requirements are discussed below in three sections that will likely provide the outline for the report; a site summary, a comprehensive data summary, and a QA/QC summary.

15.1 Site Summary

The "summary including the location, land use, drainage area size, and hydrology for each site" is a brief description of the more detailed information presented in this QAPP. Additionally, the following information, if applicable, will be included in this section of the Annual Stormwater Monitoring Report:

- Describe any land use changes in the drainage basin that would potentially affect hydrology or pollutant loading.
- Indicate hydrologic information if a monitoring site is subject to base flow from groundwater or is tidally influenced. Describe backwater conditions or other site-specific conditions if they influence sampling

15.2 Comprehensive Data Summary

The comprehensive data summary will include at a minimum:

- **Stormwater sampling results**
  - A table or descriptive summary indicating whether the sampled storm events met the requirements listed in Section S8.D.2.a & b of the permit.
  - A table or descriptive summary indicating the number of qualifying storm events sampled, additional storm events sampled that may not have met all storm event criteria, the total percentage of forecasted qualifying storms that occurred in each monitoring site, and the ratio of storm events sampled in the wet and dry season.
  - For each storm event at each site, a summary or graph of the following:
    - Time versus precipitation,
    - Time versus flow rate, and
    - Time versus initiation of aliquot collection.
  - Tables showing qualified analytical results from each sampling event.
  - Tables showing annual, wet season, and dry season pollutant loads calculated for whole water for each of the monitored parameters.
- **Toxicity testing results**
  - Documentation of any invalid or anomalous test results, good faith attempts to collect the required volume, and any unsuccessful second attempts.
  - Bench sheets for toxicity 7-day E-tests.
  - An analytical report for the chemistry analysis.
  - A toxicity data analytical report.
  - Reference toxicant results for test methods.
  - If required under Section 9.2.2, a "follow-up report" which will include:
    - A summary of the "library of toxicity test results" comparison findings,
    - A summary review of relevant source literature used from the library of toxicity test results,
    - The GC/MS data analytical results (if applicable),
    - An explanation of how the City of Seattle Stormwater Management Program is expected to reduce stormwater toxicity, and
    - If the follow-up actions for toxicity detections are not complete in time for the Annual Report, the toxicity report will include a description of the status of these activities and an estimated date of completion. The full toxicity report will be submitted to Ecology when complete, and along with the following Annual report.

- **Sediment Sample Results**
  - Tables showing qualified sediment quality data.
- **Program Changes**
  - A description of any changes made to the sampling program. Significant changes must be documented in a revised QAPP.
  - A list of parameters that are below detection limits after two years of data and will be dropped from the analysis. The QAPP will be updated with the revised list without approval from Ecology.
  - When appropriate, the determination that base flow monitoring should or should not be included in the study.

15.3 Quality Assurance/Quality Control Summary

The QA/QC summary will include at a minimum:

- A data validation memo for each sampling event that includes: (a) a narrative analysis of appropriate *field quality control* procedures *data quality indicator results* and of any associated issues and corrections made and (b) a narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discussed, any associated issues and corrections made.
- A summary Quality Assurance Report, which includes:
  - A narrative summarizing the data validation memos that apply to the entire reporting period.
  - An overall assessment of the usability and representativeness of the data.
  - A summary description of any planned changes or deviations from the approved QAPP to address problems encountered during QA/QC.

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List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R0D1	11/5/2007	Draft	Shelly Basketfield	Initial draft.
R0D2	2/2/2008	Draft	Shelly Basketfield	Include site specific information from Taylor.
R0D3	2/10/2008	Draft	Shelly Basketfield	Incorporate reviewer comments.
R0D4	05/10/2008	Draft	Rex Davis	Update with settlement language.
R0D5	05/16/2008	Draft	Rex Davis	Incorporate Ecology's comments of May 13, 2008.
R0D6	08/25/2008	Draft	Shelly Basketfield	Incorporate Ecology's comments of May 13, 2008.
R0D7	09/18/2007	Draft	Shelly Basketfield	Modified analytical methods in Table 43 for nitrate-nitrite, TKN, and orthophosphate.
R0D8	09/29/2008	Draft	Shelly Basketfield	Modified section 14.2.2, stormwater pollutant load estimation procedure, to incorporate Ecology's comments of 09/26/2008. Added Taylor Associates, Inc. personnel.
R1D0	02/12/2009	Final	Doug Hutchinson/ Shelly Basketfield	Added lab information. Modified section 14.2.2 stromwater pollution load estimation procedure to address Ecology's comments in September 26, 2008 letter.

Table T-36. Quality assurance planning document cross-walk.

Washington Department of Ecology	Environmental Protection Agency
1. Title Page with Approvals	A1 Title and Approval Sheet
2. Table of Contents and Distribution List	A2 Table of Contents A3 Distribution List
I. Goals and objectives of the study	
3. Background	A5 Problem Definition/Background
4. Project Description	A6 Project/Task Description
5. Organization and Schedule	A4 Project/Task Organization
II. Type, quality, and quantity of data needed	
6. Quality Objectives	A7 Quality Objectives and Criteria for Measurement Data
7. Sampling Process Design (Experimental Design)	B1 Sampling Process Design (Experimental Design)
III. Sampling and measurement procedures to acquire those data	
8. Sampling Procedures	B2 Sampling Methods B3 Sample Handling and Custody
9. Measurement Procedures	B4 Analytical Methods
IV. Study implementation QA/ QC procedures to ensure Plan is followed	
10. Quality Control	B5 Quality Control B6 Instrument/Equipment Testing, Inspection, and Maintenance B7 Instrument/Equipment Calibration and Frequency B8 Inspection/Acceptance of Supplies and Consumables
11. Data Management Procedures	B10 Data Management
12. Audits and Reports	C1 Assessments and Response Actions C2 Reports to Management
IV. Assessment procedures to ensure that study objectives are met	
13. Data Verification and Validation	D1 Data Review, Verification, and Validation D2 Verification and Validation Methods
14. Data Quality (Usability) Assessment	D3 Reconciliation with User Requirements
15. Data Analysis and Presentation	

Table T-37. Standard Operating Procedure List (draft).

Field Category	SOP No.	Standard Operating Procedure
BK- Background	BK 1000	General
	BK 2000	Laboratory Process
QC – Quality Control	QC 1000	General
	QC 2000	Documentation
	QC 3000	Data Verification and Validations
	QC 4000	Procedure Specific QA/QC
	QC 5000	Alternative Methods
	QC 6000	Data Management
	QC 7000	Data Requests
SD-Sample Design	SD 1000	Site Selection
	SD 2000	Field Plan & Mobilization
DS – Discrete Sampling	DS 1000	Surface Water Sampling
	DS 2000	Stormwater Sampling (includes field cleaning and clean techniques)
FM – Field Measurements	FM 1000	pH
	FM 2000	Specific Conductance
	FM 3000	Temperature
	FM 4000	Dissolved Oxygen
	FM 5000	Turbidity
CM - Continuous Monitoring	CM 1000	Discharge
	CM 2000	Automatic Samplers
	CM 3000	Sediment Traps

Table T-38. Sampling schedule for a complete water year.

Matrix	Temporal Boundaries[32]	Sample Technique/ Type	Measurement(s)	Station	No. of Field QC Samples per Site		No. of Samples per Site		Total
					Blank	Duplicate	Wet[33]	Dry	
Precipitation	Continuous over water year	Continuous Recording	Tips	RG03, RG07, RG10	NA	NA	NA	NA	NA
Stormwater	Continuous over water year	Continuous Recording	Level and/or velocity to estimate discharge	VN001, NF001, UW001	NA	NA	NA	NA	NA
	Qualifying storm event	Manual grab	Water chemistry (Table 5)	VN001, NF001, UW001	1	2	7-9	1-3	39
		Automatic flow-weighted composite	Water chemistry (Table 4)	VN001, NF001, UW001	1	2	7-9	1-3	39
	Non-qualifying storm event	Manual grab	Water chemistry (Table 5)	VN001, NF001, UW001	0	0	0-3		0-9
		Automatic flow-weighted composite	Water chemistry (Table 4)	VN001, NF001, UW001	0	0	0-3		0-9
	First-flush qualifying storm event	Manual grab	Water chemistry (Table 5)	VN001, NF001, UW001	0	0	0	1 (34)	3
			Receiving Water hardness	KTHA03, 0309, 536	0	0	0	1 (34)	3
		Automatic flow-weighted composite	Water chemistry (Table 4)	VN001, NF001, UW001	0	0	0	1 (34)	3
			Toxicity	VN001, NF001, UW001	0	0	0	1 (34)	3
	Base flow qualifying storm event (35)	Manual grab	Water chemistry (Table 5)	VN001, NF001, UW001	0	0	1	1	6
		Automatic time-weighted composite	Water chemistry (Table 4)	VN001, NF001, UW001	0	0	1	1	6
Sediment	Continuous over water year	Manual sediment trap	Sediment chemistry (Table 6).	VN001, NF001, UW001	1	1	1		5

[32] See Table 18 for a description of the storm event criteria.
[33] The dry season is from May 1 through September 30. A wet season is from October 1 through April 30.
[34] The "first flush" sample is scheduled for the dry season, August or September. However, if not successful this sample may be collected in October, during the wet season.
[35] The collection of base flows samples will be at the discretion of the Principle Investigator after visual observation during non-storm flows.

Table T-39. Data Quality Indicators and their MQO criteria

Data Verification Element	Data Quality Indicator (DQI)	Evaluation	MQO (criterion)	Action [36]
Compliance	Bias	Field and Method Blanks	<RL (Table T-42, Table T-43, Table T-44)	If [Field blank] >2x RL or [Method blank]>RL; Apply "J" to all affected samples if the [sample] <5xRL. Apply "B" to all affected samples if the [sample] ≥5xRL.
		Laboratory Control Sample (%R)	Table T-40	Apply "R" to all affected samples if the %R ≥2xMQO. Apply "J" to all affected samples if the MQO > R% <2xMQO.
	Repeatability	Field Duplicate (RPD)	25% water/35% soil	Apply "R" to all affected samples if the RPD ≥ 2 x MQO. Apply "J" to all affected samples if MQO < RPD < 2 x MQO.
	Precision	Laboratory Duplicate (RPD)	Table T-40	Apply "R" to all affected samples if the RPD ≥ 2 x MQO. Apply "J" to all affected samples if MQO < RPD < 2 x MQO.
	Accuracy	Matrix Spike Recovery (%R)	Table T-40	Apply "R" to all non-detected value samples if %R <30%. Apply "J" to all affected samples if MQO < %R < MQO (spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of 4 or greater).
		Discharge	Table T-41	Apply "J" to all affected storm events.
		Water Level	Table T-41	Apply "J" to all affected storm events
		Precipitation	Table T-41	Apply "J" to all affected storm events
	Sensitivity	Reporting Limits (RL)	Table T-42, Table T-43, Table T-44	Apply "J" to all affected samples (reported as <RL) if the reported RL≤ 2 times specified RL. Apply "R" to all affected samples if the reported RL is >2 times the specified RL.
Complete-ness	Completeness	Analytical data	90%	Estimate of the amount of successfully collected data versus the amount intended (based on MQOs) in the experimental design. If percent of useable data collected over a year period (the water-year) < criterion the MQO was not met.
		Hydrologic data	90% of data record is present	Completeness will be assessed on the basis of the occurrence of gaps in the data record for all monitoring equipment.

[36] In the case of laboratory QC samples, the affected samples typically means the batch. See Table T-49 for data qualifier code definitions.

Table T-39 (continued) Data Quality Indicators and their MQO criteria.

Data Verification Element	Data Quality Indicator (DQI)	Evaluation	MQO (criterion)	Action
Correctness	Representativeness	Qualitative Assessment of methodology	Analytical Methods (Table T-42, Table T-43, Table T-44) Field methods (Section 8)	Representativeness is maintained by following procedures such as complying with a statistically-based field sampling design and proper sample homogenization. If sampling and analytical methods did not conform to established plans and methods the MQO for representativeness may not have been met. Any deviations from these methodologies must be approved in writing by the PI in accordance with the procedures outlined in Sections 11.2. Deviations that are deemed unacceptable will result in rejected values (R).
		Qualitative Assessment of Holding time & Preservation	Table T-45 Table T-46	Apply "J" to all samples that exceeded the holding time by <48 hours. Apply "R" to all samples that exceeded the holding time by ≥48 hours
		Qualitative Assessment of storm event sampled	Table 18	Did the sampling event meet the established storm criteria?
		Qualitative Assessment of sampler performance	Table 19	Did the sampler collect a valid flow-paced sample and capture the appropriate storm volume?
		Qualitative Assessment of specified storm event criteria	Table 18	Does the storm event criteria specified represent typical site conditions? See Smoley (1993). Is the monitoring conducted over a sufficient period to represent climatic conditions for the site?
Consistency	Comparability	Qualitative Assessment	Adequate	Expected level of confidence with which data sets from different sources (e.g., related projects, different analytical methods, different sampling locations, or sampling teams) can be compared to one another. If sampling and analytical methods did not conform to established plans and methods, the MQO for comparability may not have been met.

Table T-40. MQOs for analytical precision, accuracy, and bias.

Parameter	Bias	Precision	Accuracy
Field Testing			
Conductivity	+ 5%	± 5%	NA
pH by meter	+ 0.5 units	± 0.5 or 5%	NA
Depth	+ 0.2 meters	not necessary	NA
Laboratory Analyses - Water			
Conventional Constituents in Water	Standard Reference Materials (SRM, CRM, PT) within 95% CI stated by provider of material. If not available then with 80% to 120% of true value	Laboratory duplicate, Blind Field duplicate, or MS/MSD 25% RPD Laboratory duplicate minimum.	Matrix spike 80% - 120% or control limits at ± 3 standard deviations based on actual lab data.
Synthetic Organic Analytes (including PCBs, PAHs, pesticides)	Standard Reference Materials (SRM, CRM, PT) within 95% CI stated by provider of material. If not available then with 50% to 150% of true value	Field replicate or MS/MSD ± 25% RPD. Field replicate minimum.	Matrix spike 50% - 150% or control limits at ± 3 standard deviations based on actual lab data.
Trace metals in water, including mercury	Standard Reference Materials (SRM, CRM, PT) 75% to 125%.	Field replicate, laboratory duplicate, or MS/MSD ± 25% RPD. Laboratory duplicate minimum.	Matrix spike 75% - 125%.
Bacteria/ Pathogens	Laboratory positive and negative cultures – proper positive or negative response. Bacterial PT sample — within the stated acceptance criteria.	R_{log} within 3.27*mean R_{log} (reference is section 9020B of 18th, 19th, or 20th editions of *Standard Methods*	NA
Laboratory Analyses –Sediment			
Organic compounds (PCBs) and semi-volatiles (PAHs, pesticides) & volatiles	Standard Reference Materials (SRM, CRM, PT) within 95% CI stated by provider of material. If not available then with 50% to 150% of true value	Field replicate or MS/MSD ± 25% RPD. Field replicate minimum.	Matrix spike 50% - 150% or control limits at ± 3 standard deviations based on actual lab data.
Trace metals (including mercury)	Standard Reference Materials (SRM, CRM, PT) 75% to 125%.	Field replicate, laboratory duplicate, or MS/MSD ± 25% RPD except Hg in sediment at ± 35%. Laboratory duplicate minimum.	Matrix spike 75% - 125%.
Total organic carbon in sediment and sediment grain size	CRM within the 95% CI stated by the provider. Laboratory Control Material (LCM) ± 20% to 25% of stated value. No accuracy criteria for grain size.	Replicates within ± 20%	Consider ± 25% recovery (75% - 125%)
Laboratory Analyses - Other			
Toxicity testing	Meet all performance criteria in method relative to reference toxicant.	Meet all performance criteria in method relative to sample replication.	NA

Table T-41. MQOs for hydrological accuracy and bias.

Measurement Type	Operational Range	Sensitivity	Accuracy measured as %Bias
Discharge	TBD	TBD	20% when 10% < Q < 90% of operational range 35% when 90% < Q < 10% of operational range
Water Level	TBD	0.01 feet	10%
Precipitation Depth	TBD	TBD	5% tipping bucket volume

Table T-42. Sensitivity MQOs in stormwater collected by automatic sampler [37].

Analyte Group	Parameter	Units	Methodology	Analytical Method [38]	Reporting Limit Target (Appendix 9) [39]	Method Detection Limit [40]	Method Reporting Limit [41]
Conventional	Biological Oxygen Demand (BOD_5)	mg/L	Dissolved oxygen depletion	SM5210-B	2		2
	Chloride	mg/L	Ion chomatography	SM4110-B	0.2		0.2
	Conductivity (Specific conductance)	umho/cm @ 25°C	Wheatstone bridge	SM2510-B	+/- 1		+/- 1
	Hardness (total)	mg/L CaCO3	Titrimetric (EDTA)	SM2340-B or C	1		1
	Surfactants	mg/L	Colorimetric (Methylene Blue Activating Substances [MBAS])	SM 5540-C	0.025		0.025
	Total Suspended Solids (TSS)	mg/L	Non-Filterable Gravimetric, Dried at 103-105°C	SM2540-D	1		1
	Turbidity	NTU	Nephelometric	SM2130-B	+/- 0.2		+/- 0.2
Metals (dissolved & total)	Cadmium	ug/L	ICP/MS	EPA 200.8	0.02 dissolved /0.2 total	0.03 [42]	0.2
	Copper	ug/L	ICP/MS	EPA 200.8	0.1	0.02	0.5
	Lead	ug/L	ICP/MS	EPA 200.8	0.02 dissolved /0.1 total	0.05 [42]	1.0
	Mercury [43]	ug/L	Purge & Trap Cold Vapor atomic fluorescence spectrometry (CVAFS)	EPA 1631E	0.1	0.0005	0.1
	Zinc	ug/L	ICP/MS	EPA 200.8	1.0 dissolved/ 5.0 total	0.1	4.0
Nutrients	Nitrate-nitrite	mg/L	Cadmium reduction, automated	EPA 353.2	0.01		0.01
	Nitrogen, Total Kjeldahl (TKN)	mg/L	Semi-automated block digestor colorimetric	EPA 351.2	0.5		0.6
	Orthophosphate	as P mg/L	Ascorbic acid, manual single reagent	SM4500-P E	0.01		0.01
	Phosphorus, Total	as P mg/L	Persulfate digestion followed by manual or automatic ascorbic acid reduction	Manual (SM 4500-P E) or Automatic (SM 4500-P F)	0.01		0.02
Semi Volatile Organic Compounds (SVOCs)	Pentachlorophenol (fungicide)	ug/L	Selective Ion Monitoring (SIM) by GC/MS	SW-846 8270D SIM	0.5		0.5
	Polycyclic aromatic hydrocarbons (PAHs)	ug/L	SIM by GC/MS	SW-846 8270D SIM	0.1		0.1
	Phthalates	ug/L	GC/MS	SW-846 8270D	1		1
Pesticides, Chlorinated	2,4-D (herbicide)	ug/L	gas chromatographic (GC)	SW-846 8151	1	1.0	1

[37] These parameters will be analyzed by an accredited laboratory per Chapter 173-50 WAC.
[38] A single method will be noted after selection of the analytical laboratory.
[39] Based on method detection limits or method performance.
[40] Results that fall between the MRL and MDL as not quantifiable and results that fall below the MDL are considered non-detects.
[41] The method reporting limit (MRL) is 3 to 10 times the MDL. Or the value the laboratory can meet.
[42] From 200.8, Table 7, selection ion monitoring mode, total recoverable aqueous.
[43] Not required at residential site.

Analyte Group	Parameter	Units	Methodology	Analytical Method [38]	Reporting Limit Target (Appendix 9) [39]	Method Detection Limit [40]	Method Reporting Limit [41]
	MCPP (herbicide)	ug/L	GC	SW-846 8151	0.5	500	250
	Triclopyr (herbicide) [44]	ug/L	GC	SW-846 8151 [45]	0.1-1.0		
Pesticides, Organo-chlorine	Dichlobenil (herbicide) [44]	ug/L	GC	SW-846 8270D SIM	0.3		
Pesticides, Organo-nitrogen	Prometon (herbicide) [44]	ug/L	GC	SW-846 8270D SIM	0.5		
Pesticides, Organo-phosphorus [46]	Chloropyrifos (insecticide)	ug/L	GC/MS	SW-846 8270D	0.01-1		0.04
	Diazinon (insecticide)	ug/L	GC/MS	SW-846 8270D	0.01-1		0.04
	Malathion (insecticide)	ug/L	GC/MS	SW-846 8270D	0.01-1		0.2

[44] A search of Accredited Laboratories last updated on July 17, 2008 indicated there are no accredited laboratories that analyze for this parameter ((http://www.ecy.wa.gov/programs/eap/lab-accreditation.html).
[45] Must request special extraction and analysis for triclopyr.
[46] See http://www.epa.gov/region09/qa/pdfs/8141.pdf.

Table T-43. Sensitivity MQOs in stormwater collected by manual grab sample [37].

Analyte Group	Parameter	Units	Analytical Method	Reporting Limit Target (Appendix 9)
Bacteria	Fecal coliform bacteria	CFU/100 mL	SM 9221E	Minimum of 2 and maximum of 2E6
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics - Diesel	mg/L	NWTPH-Dx - Ecology, 1997, (Publication No. 97-602) or EPA SW-846 method 8015B	0.25
	Diesel Range Organics - Oil			0.50
	Gas Range Organics	mg/L	NWTPH-Gx - Ecology, 1997, (Publication No. 97-602)	0.25

Table T-44. Sensitivity MQOs in sediment [37].

Analyte Group	Parameter	Units	Analytical Method	Reporting Limit Target (Appendix 9)	Method Detection Limit	Method Reporting Limit
Conventional	Total solids	%	EPA160.3 or SM2540B	NA		0.01%
	Grain size		Ecology Method Sieve and Pipet (PSEP 1997) or ASTM F312-97 or ASTM D422			
	Total organic carbon	%	EPA 9060 or SM5310 B,C, or D	0.1%		200 mg/kg
Metals	Cadmium	mg/kg	EPA 200.8 or 6020	0.1	0.2	0.2
	Copper	mg/kg	EPA 200.8 or 6020	0.1	0.2	0.5
	Lead	mg/kg	EPA 200.8 or 6020	0.1	0.3	1.0
	Mercury [43]	mg/kg	SW-846 7471A	--		0.05
	Zinc	mg/kg	EPA 200.8 or 6020	5.0	0.7	4.0
Persistent Organic Compounds	Polychlorinated biphenyls (PCBs) [43]	ug/kg	SW-846 8082	80		100
Semivolatile Organic Compounds	Pentachlorophenol (herbicide)	ug/kg	SW-846 8270	1		100
	Phenols	ug/kg	SW-846 8270	70		20-200
	phthalates	ug/kg	SW-846 8270	70		70
	Polycyclic aromatic hydrocarbons (PAHs)	ug/kg	SW-846 8270	70		20-100
Pesticides, Organophosphorus	Diazinon	ug/kg	SW-846 8270D	50		50
	Malathion	ug/kg	SW-846 8270D	25		25
	chloropyrifos	ug/kg	SW-846 8270D	25		25

Table T-45. Containers, holding time, and preservation for water.

Parameter	Recommended Quantity	Container	Holding Time [47]	Preservation [48]
Total suspended solids (TSS)	1000 mL	1000 mL w/m poly	7 days	
Turbidity	500 mL	500mL w/m poly[2]	48 hours	
Conductivity	300 mL	500 mL w/m poly[49]	28 days	
Chloride	100 mL	500 mL w/m poly[2]	28 days	
Biological Oxygen Demand (BOD5)	2000 mL	1 gallon cubitainer	48 hours	Keep sample in the dark
Hardness (CaCO3)	100 mL	125 mL w/m poly	6 months	H_2SO_4 to pH<2
Surfactants (Methylene Blue Activating Substances, MBAS)	250 mL	1-L Amber glass	48 hours	
Total phosphorus	50 mL	60mL clear n/m poly	28 days	1:1 HCL to pH<2
Orthophosphate	125 mL[2]	125 mL amber w/m poly	48 hours	
Total kjeldahl nitrogen (TKN)	125 mL	125mL clear w/m poly	28 days	H_2SO_4 to pH<2
Nitrate-nitrite (N/N)	125 mL	125mL clear w/m poly	28 days	H_2SO_4 to pH<2
Dissolved Metals (copper, zinc, cadmium, lead)	350 mL	500 mL HDPE bottle	6 months	Filter; then HNO_3 to pH<2 at least 24 hours prior to analysis.
Dissolved Mercury[50]	350 mL	500 mL Teflon FEP bottle	28 days	HNO_3 to pH<2
Total Metals	350 mL	500 mL HDPE bottle	6 months	HNO_3 to pH<2 at least 24 hours prior to analysis.
PAHs	1 gallon	1 gallon glass jar	7 days	
Phthalate-BNA	1 gallon	1 gallon glass jar	7 days	
Herbicides: 2,4-D, MCPP, triclopyr, dichlobenil, prometon, pentachlorophenol	½ gallon	½ gallon glass jar	7 days	
Pesticides: Nitrogen, organophosphate, and/or chlorinated includes: dichlobenil, diazinon, malathion, chlorpyrifos	1 to 4 liters	1 liter to 1 gallon glass jar (volume effects reporting limits)	7 days	
Fecal coliform bacteria	250 mL	250 mL glass/polypropylene auto claved bottle	6 hours	<10°C If chlorine is expected in the sample, then request thiosulfate preservative
Total petroleum hydrocarbons – NWTPH-Dx	1L – 1Gallon + 40 mL	1L or 1 Gallon glass jar (volume affects reporting limit) + 40 mL vial w/ septum	7 days	HCL to pH<2
Total petroleum hydrocarbons – NWTPH-Gx	120 mL	(3) 40-mL vials w/ septum	14 days	HCL
Toxicity	24 to 45 liters	5-gallon Glass	36 hours	Received within 4 hours of sample collection - between 0° and 12°C otherwise between 0° and 6°C

[47] "For a composite sample collected with an automated sampler…the holding time begins at the time of the end of collection of the composite sample." (40 CFR 136, Table II, note 4).
[48] Unless otherwise noted, all samples will be cooled to less than 6°C.
[49] May be able to analyze several general chemistry parameters from the same container.
[50] For low level mercury analysis, contact laboratory prior to sample collection for a specialty cleaned bottle.

Table T-46. Containers, holding time, and preservation for sediments.

Parameter	Recommended Quantity	Container	Holding Time	Preservation
Total solids (% solids)	25 g	2 oz. glass jar	7 days	Refrigerate, 4°C
Grain-size	100g	8 oz. plastic jar	6 months	Refrigerate, 4°C
Total organic carbon	25g	2 oz glass jar	14 days, 6 months if frozen	Refrigerate, 4°C
Total metals: Copper, zinc, cadmium, lead	50g	4 oz. glass jar	6 months 2 years	Refrigerate, 4°C Freeze, -18°C
Mercury	50g	8 oz. glass jar	28 days	Refrigerate, 4°C
PAHs	100g	8 oz glass jar	14 days [51], 12 months if frozen	Refrigerate, 4°C Freeze, -18°C
Phthalates-BNA	250g	8 oz. glass jar	14 days [51], 12 months if frozen	Refrigerate, 4°C Freeze, -18°C
Phenolics - BNA	250g	8 oz. glass jar	14 days [51], 12 months if frozen	Refrigerate, 4°C Freeze, -18°C
PCBs	250g	8 oz. glass jar	14 days, 6 months if frozen	Refrigerate, 4°C Freeze, -18°C
Pesticides: Nitrogen, organophosphate, and/or chlorinated includes: diazinon, malathion, chlorpyrifos	250g	8 oz glass jar	14 days	Refrigerate, 4°C
Herbicides: Pentachlorophenol	250g	8 oz. glass jar	14 days [51], 12 months if frozen	Refrigerate, 4°C Freeze, -18°C

[51] Semi-volatile organic compounds analyzed with method EPA8270 require separate holding times for extraction and analysis of the elutriate for organic compounds. The elutriate must be analyzed within 40 days of extraction.

Table T-47. Unique sample identification scheme.

Database attribute and sample values						Sample Label Example
Source Location	**Matrix (from COC)**	**Sample Technique/ Type**	**Analyses**	**Temporal Scale**	**Flow Conditions**	
MS4(Municipal Separate Sewer System)	Water	MGR (Manual grab)	Water chemistry	Wet/dry season	Qualifying storm event	VN001-MGR NF001-MGR UW001-MGR
		AFC (Automatic flow-weighted composite)			Qualifying storm event	VN001-AFC NF001- AFC UW001- AFC
				Dry season	First-flush qualifying storm event	VN001-AFC NF001- AFC UW001- AFC
			Toxicity			VN001-AFC NF001- AFC UW001- AFC
		MGR (Manual grab)	Water chemistry	Wet/dry season	Base flow	VN001-MGR NF001-MGR UW001-MGR
		ATC (Automatic time-weighted composite)				VN001-ATC NF001- ATC UW001- ATC
	Sediment	MST (Manual sediment trap)	Sediment chemistry	Water year	Composite over sample deployment	VN001-MST NF001- MST UW001- MST
RCV (Receiving water)	Water	MGR (Manual grab)	Water chemistry	Dry season	NA	KTHA03-MGR 0309-MGR 536-MGR

Table T-48. Sample data path.

Activity	Role	Process Duration (days)	Timeline (days) [52]	Document to Data Steward (cc PI)	Document from Data Steward (cc PI)
Target Storm go/no go	Study Manager	7	-7	Forecast Storm Go/No Go Decision	NA
Collect sample & deliver to Lab	Field Lead	2	2	Field Datasheet & COC	NA
Precipitation Data Verification (by 10th of month)	Hydrologic Data PM	Up to 30	32	Storm Event - Precipitation Summary	NA
Flow Data Verification (by 10th of month)	Hydrologic Data PM	Up to 30	32	Storm Event – Discharge Summary	NA
Field Data Verification	Study Manager	7	41	Field QA Report	All data submitted to Data Steward to Date
Laboratory Analyses	Lab PM	60	62	Certified Analytical Report, EDD	NA
Analytical review, verification, validation	Data Validation PM	Up to 21	83	Data Validation Memo, EDD with Quality Flags	Data Package, EDD, Field QA Report
Data entry to SIMs & SIC	Data Entry	Up to 7	90	NA	All data submitted to Data Steward to Date
Verify all data/reports/forms have been entered	Data Steward	Up to 2	92	Status Log	NA
Data Usability Assessment	Principle Investigator	Up to 28	Quarterly	EDD with Usability Flags	All data submitted to Data Steward to Date
Data entry to SIMs & SIC	Data Entry	Up to 2	Quarterly	NA	EDD with Usability Flags

[52] Day 0 of the timeline is the beginning of a storm event.

Table T-49. Study data qualifier flags.

Use	Flag	Description
Example Laboratory Data Indicator Flags	H	Holding time exceeded
	B	Analytes detected in associated method blank at a concentration greater than one half of the reporting limit or 5 percent of the regulatory limit or 5 percent of the analyte concentration in the sample
Verification & Validation Flags	R	The datum is rejected. The qualifier typically indicates that a datum is completely unusable because it is of unknown quality (e.g., missing QC information) or because of gross QC deficiencies (e.g., extremely poor recoveries for the LCS).
	J	The target analyte is positively identified, but the reported numerical result (e.g., analyte concentration) is an estimated value. The flag indicates that a significant quantitative (as opposed to a qualitative) uncertainty exists. The J flag must always be used to report detections below the method quantitation limit (MQL).
	U	Analyte not detected at the listed method reporting limit.
	S	The datum is tentatively rejected (suspect) because study-specific measurement quality objectives (e.g., for sensitivity, accuracy, or precision) were not met or were not demonstrated. When objectives for sensitivity are not met, the S flag typically indicates that a result (a detection or non-detection) is potentially unusable with respect to an action level (e.g., the result does not demonstrate that a target analyte is actually present in an environmental sample at a concentration above or below a risk-based decision limit). Note: When evaluating objectives for sensitivity, the R flag may be more appropriate than the S flag when action levels are fixed and statistical analyses are not being performed. The S flag may be appropriate when action levels are subject to change, a set of data is being evaluated with respect to different action levels, or when statistical analyses are being performed.
Usability Data Qualifiers	NR	Data was requested and not reported.
	J	The Identification of the analyte is acceptable, but quality assurance criteria indicate that the quantitative values may be outside the normal expected range of precision, i.e., the quantitative value is considered estimated.
	Q	Data is considered questionable and shall not be used until the acceptability of the data is confirmed or denied. This flag is usually used to qualify extreme values that are suspected to be outliers. Statistical analysis is used to confirm or deny that the suspected value is or is not an outlier. If the suspected value is confirmed to be an outlier, the data qualifier shall be changed to R.
	R	Data is considered to be rejected and shall not be used. This flag denotes the failure of quality control criteria such that it cannot be determined if the analyte is present or absent from the sample. Resampling and analysis are necessary to confirm or deny the presence of the analyte.

Accuracy - Accuracy is defined as the degree of agreement of a measurement to an accepted reference or true value.

Analytical accuracy will be measured as the percent recovery (percent R) of an analyte in a reference standard or spiked sample. Accuracy (percent R) criteria for matrix spike recoveries and surrogate recoveries will be within limits specified in the QAPP. Accuracy shall be calculated as percent recovery of matrix spikes as follows:

$$R_I(\%) = \frac{Y_i}{X_i} x100\%$$

where:

% Ri	=	percent recovery for compound i
Yi	=	measured spike concentration in sample i (measured - original sample concentration)
Xi	=	known spike concentration in sample i

The resultant percent recoveries will be compared to the criteria specified in the QAPP and deviations from specified limits reported. If the objective criteria are not met, the laboratory will supply a justification of why the acceptability limits were exceeded and implement the appropriate actions. Percent recoveries will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Hydrologic data have no “true” results for comparison. For hydrologic data, accuracy will be assessed by comparison of results to repeat measurements using another instrument, engineering calculations, or to manufacturer specifications and expressed as bias:

$$\%Bias = \frac{\mathrm{M - I}}{\mathrm{I}} \times 100\%$$

where:

M	=	measured value
T	=	Independent (true value).

<u>Discharge data</u> – The independently measured value may be determined by measuring the cross-sectional area of flow at a particular station and the average flow velocity using a portable meter (e.g., Marsh-McBirney Flo-Mate). These data will then be processed in accordance with standard procedures (PSEP 1997) to estimate discharge. Alternatively, the independently measured value may be determined by routing the flow from a particular station to a container with a known volume (e.g. graduated cylinder, bucket, or jerrycan) and measuring the time required to fill this container.

Water level data - The independently measured value will be derived by measuring the water depth in the primary measuring device at a particular station using a staff gauge or ruler.

Precipitation depth - The independently measured value is the theoretical accuracy as specified by the manufacturer. The rain gauge's actual readings will be determined by measuring the volume of water required to initiate one tip of the associated bucket by adding incremental drops of water with a pipette.

Comparability - Comparability is the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision, as these quantities are measures of data reliability. Data are comparable if sample collection techniques, measurement procedures, analytical methods and reporting are equivalent for samples within a sample set.

To assure analytical comparability the laboratory will:

- Use National Bureau of Standards or USEPA - traceable standards
- Use standard methodologies
- Apply an appropriate level of quality control
- Participate in interlaboratory studies to document laboratory performance

As with representativeness, quantitative criteria for data comparability are difficult to establish, hence, a qualitative assessment of data comparability will be made of applicable data sets.

Completeness – An element of the data verification process. Completeness ensures that a sufficient amount of data and information (relative to the prescribed DQOs) are present. A Measurement Quality Objective (MQO), completeness is defined as the percentage of valid analytical results (results not qualified as R, rejected) obtained compared with the total number of analytical results required by the study scope of work. Analytical completeness is defined as the percentage of valid analytical results obtained compared with the total number of analyses requested. Completeness will be calculated as follows:

$$C(\%) = \frac{A}{I} x100\%$$

where:

% C	=	Percent completeness (field / laboratory)
A	=	Actual number of valid samples collected / analyses obtained
I	=	Intended number of samples / analyses requested

Compliance - An element of the data verification process. The extent that adherence to SOPs, QAPP, and/or contractual requirements were followed, achieved, and/or completed successfully, and that conditions under which the data were recorded also met the requirements. Compliance ensures that the data pass numerical quality control tests, including criteria on precision and accuracy, based on parameters or specified limits specified in relevant SOPs and or QAPP.

Composite samples – A composite sample is a mixed or combined sample that is formed by combining a series of individual and discrete samples of specific volumes at specified intervals. Although these intervals can be time-weighted or flow-weighted, the stormwater regulations require the collection of flow-weighted composite samples.

This means that discrete aliquots, or samples, are collected and combined in proportion to flow rather than time. Composite samples characterize the quality of a stormwater discharge over a longer period of time, such as the duration of a storm event.

Consistency - An element of the data verification process. The extent to which data collection procedures were done in a similar manner across different sites (if applicable) and data reporting was done in a similar manner in multiple places. Consistency (also known as comparability) ensures that the reported values are the same when used throughout the study.

Correctness - An element of the data verification process. A mechanical, objective check that data collection plans and protocols have been followed and that basic operations and calculations were performed using properly documented and properly-applied algorithms. Correctness ensures that the reported values are based on properly documented algorithms.

Field Blanks - Field blanks are also commonly called field rinsate blanks, decontamination blanks and equipment blanks. A field blank evaluates the effectiveness of decontamination procedures when equipment is not dedicated to a site or disposed of after one use. If decontamination procedures are effective, there should be no contamination in the field blanks. Field blanks are not required if dedicated sampling equipment or disposable sampling equipment is used. A field blank consists of a sample of the reagent grade water supplied by the laboratory and used in the final rinse step of the equipment decontamination procedure. Process the field blank water through the equipment the same way you process any other final rinse water.

Field Replicates - A field replicate (duplicate) sample is collected to determine the variability of analytical results caused by the sampling equipment and procedures used.

Field replicates are samples collected simultaneously or sequentially from the same sampling location using identical sampling methods. The samples equally represent as nearly as possible the medium being sampled, and may provide information of the variance of chemicals at a sampling location and the consistency of sampling techniques.

Replicate samples will be collected at the time of sample collection. Replicate samples will be sent to the laboratory. The final number of replicate samples collected and submitted for analysis to each laboratory will equal or exceed 10 percent of the total number of primary samples for each analytical method.

Grab Sample - A grab sample is a discrete, individual sample collected within a short period of time (usually less than 15 minutes). Analysis of grab samples characterizes the quality of a storm water discharge at a given time of the discharge.

Interquartile Range (IQR) - The interquartile range (IQR) is the most commonly-used resistant measure of spread. It measures the range of the central 50 percent of the data, and is not influenced at all by the 25 percent on either end. The IQR is defined as the 75th percentile minus the 25th percentile.

The 75th, 50th (median) and 25th percentiles split the data into four equal-sized quarters. The 75th percentile (P.75), also called the upper quartile, is a value which exceeds no more than 75 percent of the data and is exceeded by no more than 25 percent of the data. The 25th percentile (P.25) or lower quartile is a value which exceeds no more than 25 percent of the data and is exceeded by no more than 75 percent.

Interim Minimum Level - The interim minimum level is calculated when a method specified ML does not exist. It is equal to 3.18 times the method specified MDL.

Laboratory Control Samples - Laboratory control samples (LCS) are well-characterized, laboratory-generated samples used to monitor the laboratory's day-to-day performance of routine analytical methods. Certain LCS are used to monitor the precision and accuracy of the analytical process, independent of matrix effects. Other LCS are used to identify any background interference or contamination of the analytical system which may lead to the reporting of elevated concentration levels or false positive measurements.

The results of the LCS are compared to well-defined laboratory acceptance criteria to determine whether the laboratory system is "in control." Controlling lab operations with LCS (as opposed to MS/MSD samples) offers the advantage of being able to differentiate low recoveries due to procedural errors from those due to matrix effects. One LCS should be analyzed for every set of 20 or fewer samples or with each sample preparation lot.

Percent recovery for laboratory controls will be calculated using the following equation:

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

where:

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

Laboratory (or Matrix) Duplicate - A laboratory duplicate is a split of an environmental sample, which is prepared and analyzed in a manner identical to that of the original sample. The results are utilized to evaluate the precision of the laboratory analyses. Results are expressed in Relative Percent Difference (percent RPD) between analytical results for the split and the original sample.

If more than five but less than 20 samples are submitted, at least one laboratory duplicate should be analyzed. A general rule is one laboratory duplicate for every batch of up to 20 samples analyzed together.

Matrix Spike - A matrix spike (MS) is an environmental sample to which known concentrations of analytes have been added. The matrix spike is taken through the entire analytical procedure and the recovery of the analytes is calculated. Results are expressed as percent recovery of the known amount spiked. The matrix spike is used to evaluate the effect of the sample matrix on the accuracy of the analysis.

One matrix spike sample should be analyzed for every set of 20 or fewer samples or with each sample preparation lot. The spike solution is added to samples prior to digestion. The sample that is chosen for spiking should be the same sample used for laboratory duplicate analysis. The amount of spike added to the sample should be 2 to 5 times the expected sample concentration or the IDL, which ever is greater. Matrix spike recovery is calculated using the formula:

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

where:

%R	=	percent recovery
S	=	measured concentration in spike sample
U	=	measured concentration in unspiked sample
C_{sa}	=	actual concentration of spike added.

Method Detection Limit (MDL) – The minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero as determined by a specific laboratory method (40 CFR 136).

Method or Preparation Blank - A method blank consists of analyte-free deionized water. The method blank is carried through each step of the analytical method. The method blank data will be used to detect any laboratory contamination during analysis.

A method blank is required for each batch of samples prepared for analysis, except in the case of volatile organic analyses, which should be analyze at least once every 12 hours.

Method Reporting Limit (MRL) – The concentration at which confidence in the reported value requires no qualifying remarks. The MRL should be 3-5 times the MDL. A standard is run at the MRL to verify acceptable data quality. The MRL may be affected by sample size, sample dilution, and matrix interference.

Minimum Level (ML) - the concentration at which the entire analytical system must give a recognizable signal and acceptable calibration point. The ML is the concentration in a sample that is equivalent to the concentration of the lowest calibration standard analyzed by a specific analytical procedure, assuming that all the method specified sample weights, volumes and processing steps have been followed.

Outlier - Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.

Precision Objectives - Precision is the degree of agreement between a set of replicate measurements. Precision will be measured as the relative percent difference (RPD) between duplicate analyses for matrix spike duplicates, laboratory duplicates, and field duplicates.

Precision RPD for matrix spike duplicates and laboratory duplicates will be within limits specified in the QAPP. Precision will be calculated as the relative percent

$$RPD_i(\%) = \frac{2|O_i - D_i|}{O_i + D_i} x100\%$$

difference (RPD) as follows:

where:

% RPD_i	=	Relative percent difference for compound i
O_i	=	Value of compound i in original sample
D_i	=	Value of compound i in duplicate sample

The resultant %RPDs will be compared to the criteria specified in the QAPP and deviations from specified limits reported. If the objective criteria are not met, the laboratory will supply a justification of why the acceptability limits were exceeded and implement the appropriate actions. The percent RPDs will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Quality control objectives for field replicate precision have not been established by the USEPA. These analyses measure both field and lab precision; therefore, the results may also have more variability than lab duplicates which measure only lab performance. It is also expected that fish tissue replicate results will have a greater variance than water matrices due to the inherent variability in the fish.

Quartile skew coefficient, qs. A resistant measure of skewness. The difference in distances of the upper and lower quartiles from the median, divided by the IQR. A right-skewed distribution again has positive qs; a left-skewed distribution has negative qs. Similar to the IQR, qs uses the central 50 percent of the data.

Representativeness - Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter concentrations at a sampling point, or an environmental condition of a site. Representativeness is a function of sample site selection, sampling methods, and analytical techniques. The rationale for sample site selection and sampling methodology is provided in Section 7. Representativeness will be maintained by performing all sampling, sample handling, and analyses in compliance with the procedures described in this QAPP and the referenced analytical methods.

It is difficult to establish quantitative representativeness criteria. Representativeness of the analytical data may be determined by a comparison of the quality control data for the samples to established criteria, and by affirming that sampling and analytical methods conformed to established plans and methods.

Sample Type – Sample type refers to the king of sample that must be collected – either a grab or composite.

Sample Technique – Sample technique refers to the method by which a grab or composite sample is actually collected – either manually or by automatic sampler.

Standard Reference Material – Standard Reference Materials (SRM's) generall are considered the most useful QC samples for assessing thea ccuracy of a give analysis (i.e., the closeness of a measurement to he "true" value). SRM's can be used to assess accuracy because the have "certified" concentrations of the analystes of interest, as determined through replicate analyses by a reportable certifying agency using two independent measurement techniques for verification. In addition, the certifying agency may provide "non-certified" or "informational" values for other analytes of interest. Such values are determined using a single measurement technique, which may introduce unrecognized bias. Therefore, non-certified values must be used with caution in evaluating the performance of a laboratory using a method which differs from the one used by the certifying agency.

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Drawings

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Drawing 1
Project Locations

Venema

RG07

University District

RG03

Norfolk

RG10

Green Lake

Lake Union

Elliott Bay

Puget Sound

Lake Washington

Legend

WATERBODY

- Duwamish Waterway
- Lake Washington
- Puget Sound
- Ship Canal

- Rain Gage
- Water Hardness Station

- State Highway
- Interstate Highway

- City Limits

Stream Networks

- Culvert
- Open Channel

The City of Seattle

Produced by the City of Seattle

January 2008

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0 2,500 5,000 10,000
Feet

N W E S

Trend Monitoring Basins - Residential

Venema Basin

The City of Seattle

Produced by the City of Seattle

July 2008

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0 250 500 1,000
Feet

Legend

Drainage Basin Boundary

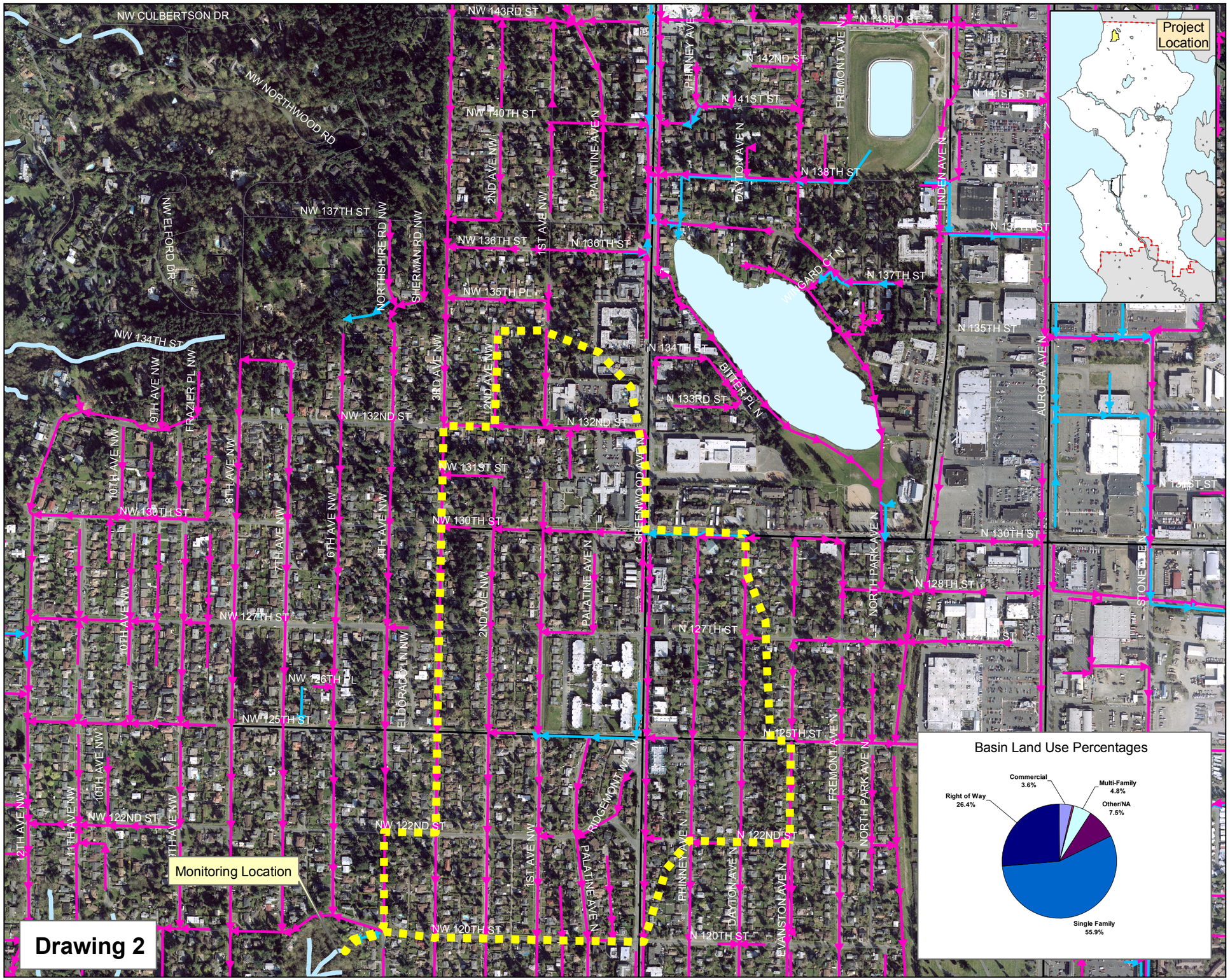
Mainlines
- Drainage Mainline
- Sanitary Mainline
- Combined Mainline
- Metro Mainline

Streets
- Residential
- Arterial
- State Highway
- Interstate Highway

Streams
- Culvert
- Open Channel

Basin Size = 157.3 Acres

Building Outlines = 33.2 Acres



Drawing 2

Trend Monitoring Basin - Industrial

Norfolk/MLK Basin

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July 2008

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0 375 750 1,500
Feet

Legend

Drainage Basin Boundary

Mainlines

- Drainage Mainline
- Sanitary Mainline
- Combined Mainline
- Metro Mainline

Streets

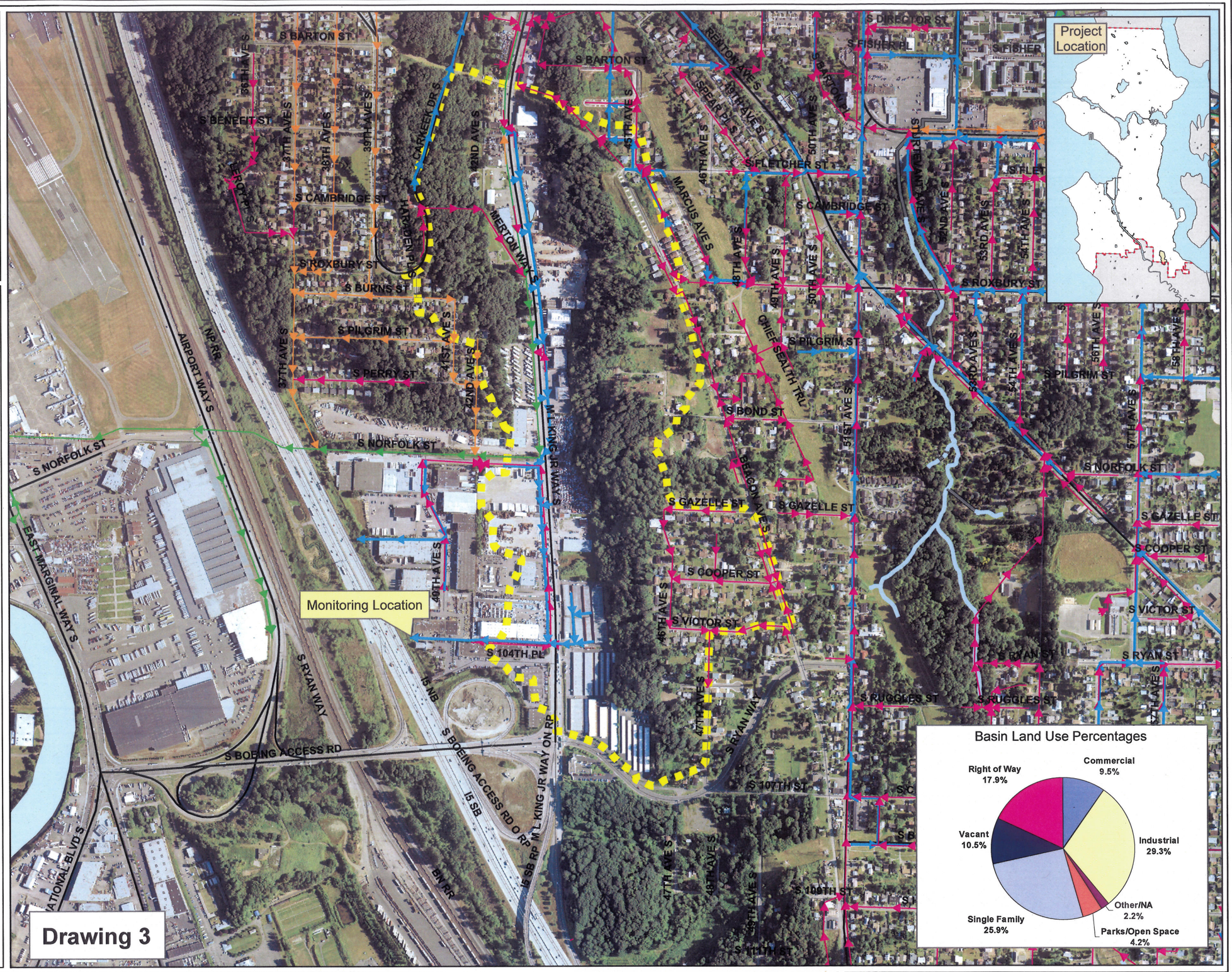
- Residential
- Arterial
- State Highway
- Interstate Highway

Streams

- Culvert
- Open Channel

Basin Size = 163.5 Acres

Building Outlines = 17.2 Acres



Drawing 3

Trend Monitoring Basins - Commercial

University District

The City of Seattle

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0 250 500 1,000
Feet

Legend

Drainage Basin Boundary

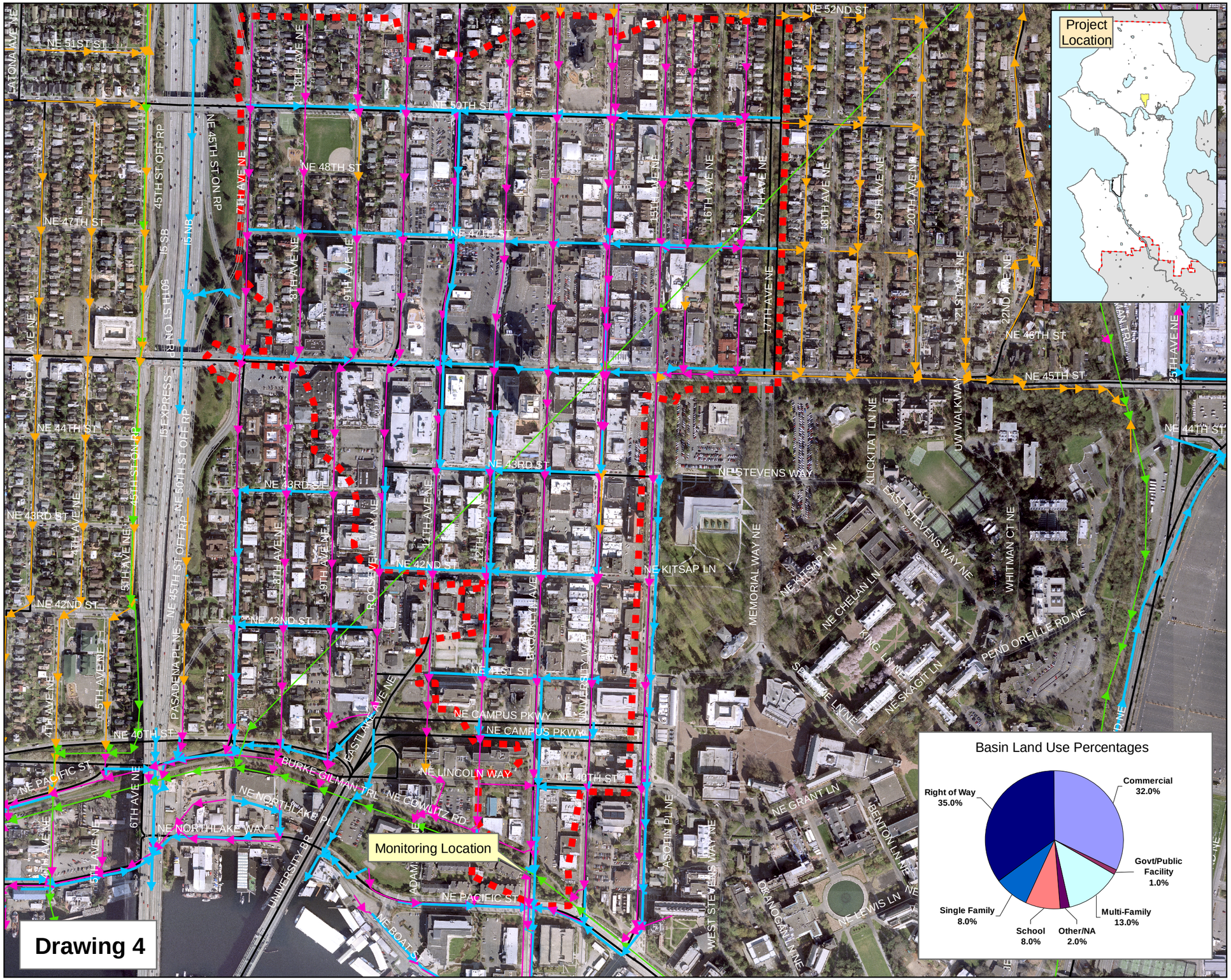
Mainlines

- Drainage Mainline
- Sanitary Mainline
- Combined Mainline
- Metro Mainline

Streets

- Residential
- Arterial
- State Highway
- Interstate Highway

Streams

- Culvert
- Open Channel

Basin Size = 186.6 Acres