DEPARTMENT OF
ECOLOGY
State of Washington

Draft – October 3, 2011

2012 Status and Trends Stormwater Monitoring and Assessment Strategy for Small Streams

An Addendum to

Quality Assurance Monitoring Plan

Status and Trends Monitoring for Wastershed Health and Salmon Recovery

Oct 2011 - DRAFT

Publication No. xx-03-1xx-Addendum

Publication Information

Addendum

This addendum is an addition to an original Quality Assurance Project Plan. The addendum is not a correction (errata) to the original plan.

This addendum is available on the Department of Ecology's website at www.ecy.wa.gov/biblio/0?031??Addendum.html

Original Publication

Quality Assurance Project Plan: Status and Trends Monitoring for Watershed Health and Salmon Recovery.

Publication No. 06-03-203.

The Quality Assurance Project Plan is available on the Department of Ecology's website at www.ecy.wa.gov/biblio/0603203.html.

Authors and Contact Information

Scott Collyard
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

For more information contact:

Communications Consultant
Phone: 360-407-6834

To ask about the availability of this document in a format for the visually impaired,
call 360-407-6834.
Persons with hearing loss can call 711 for Washington Relay Service.
Persons with a speech disability can call 877-833-6341.

Table of Contents

Figures

Tables

Background

In 2002, an independent Monitoring Oversight Committee developed the Washington Comprehensive Monitoring Strategy (CMS) for Watershed Health and Salmon Recovery (MOC, 2002). The CMS describes objectives for various types of coordinated monitoring in the State. To meet CMS objectives for extensive monitoring, the Washington Department of Ecology (ECY), the Washington Conservation Commission, and the Washington Department of Fish and Wildlife, developed a plan (Cusimano et al, 2006). This quality assurance monitoring plan is the foundation of a statewide program: *Status & Trends Monitoring for Watershed Health and Salmon Recovery* (WHSR). This program was modeled after the Environmental Protection Agency's (EPA) national Environmental Monitoring and Assessment Program (EMAP). It uses indicators of stream health and randomly-selected sample sites to make unbiased regional assessments (EPA, 2002). The QAMP for WHSR was developed to help answer questions at several scales: statewide, by Salmon Recovery Region (SRR), and (given adequate participation) by Water Resource Inventory Area (WRIA). The indicators selected for the plan were chosen to address salmonid habitat "limiting factors" identified in Pacific Coastal Salmon Recovery Fund Reports to Congress (www.nwr.noaa.gov/Salmon-Recovery-Planning/PCSRF).

In 2007, a report developed by a Puget Sound advisory committee recommended establishing an integrated monitoring program within municipal stormwater permits (Monitoring Committee, 2007). The report also suggested the program be modeled after WHSR. Following this recommendation the Puget Sound Stormwater Work Group (SWG) was assembled to develop recommendations for a permit- based monitoring and assessment strategy to monitor the effects of stormwater in the Puget Sound Region.

In 2010 the SWG finalized the *2010 Stormwater Monitoring and Assessment Strategy for the Puget Sound Region* (SWG, 2010). These recommendations were submitted to the Washington State Department of Ecology (Ecology) and Puget Sound Partnership for consideration in the development of an integrated Puget Sound municipal stormwater permit. The 2010 Strategy included 55 Key Recommendations for establishing a new Stormwater Assessment and Monitoring Program for Puget Sound. One recommendations of the workgroup was to develop a status and trends probabilistic sampling strategy for assessing impacts of stormwater which is compatible with current statewide status and trends monitoring.

This document is the quality assurance monitoring plan (QAMP) for the Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS). It is an addendum to the existing QAMP for WHSR (Cusimano et al., 2006). WHSR is a separate monitoring effort with similar monitoring components and quality assurance objectives. This addendum provides details regarding sampling locations, parameters, and sampling/analysis schedules for the SWAMPPS associated with the municipal permits. The monitoring design (field indicators, sample design) within this addendum was developed following recommendations of the SWG (SWG, 2010).

Design Characteristics for Assessing Stormwater Impacts

The study design for this stormwater monitoring strategy is based on a random (probabilistic) site selection process which includes a five year rotating sampling design. Stream health is assessed at each sampling site within the study areas (populations) by measuring biological condition using macrionivertebrate and periphyton indicators. Biological condition is determined using multi-metric models (e.g., Karr, 1991) or multi-variate models (e.g., Wright, 1995). Both types of empirical models classify stream health based on comparison to reference conditions. Stressors effecting biological conditions are estimated using concurrent habitat and chemical measurements.

The "status" of each stream population is determined by estimating the percentage of stream length with impaired biological conditions and their associated stressors (Figure 1). The "trends" within stream populations are estimated by comparing measurements between five- year periods. Estimates for status and trends monitoring are made using statistical evaluations of the data using protocols developed for EMAP (EPA, 2005). For the purposes of assessing stormwater impacts, the study design characteristics will take into account the desire for Puget Sound scale estimates at a 90% confidence level and potential for stratification of samples into other categories (e.g., landuses).

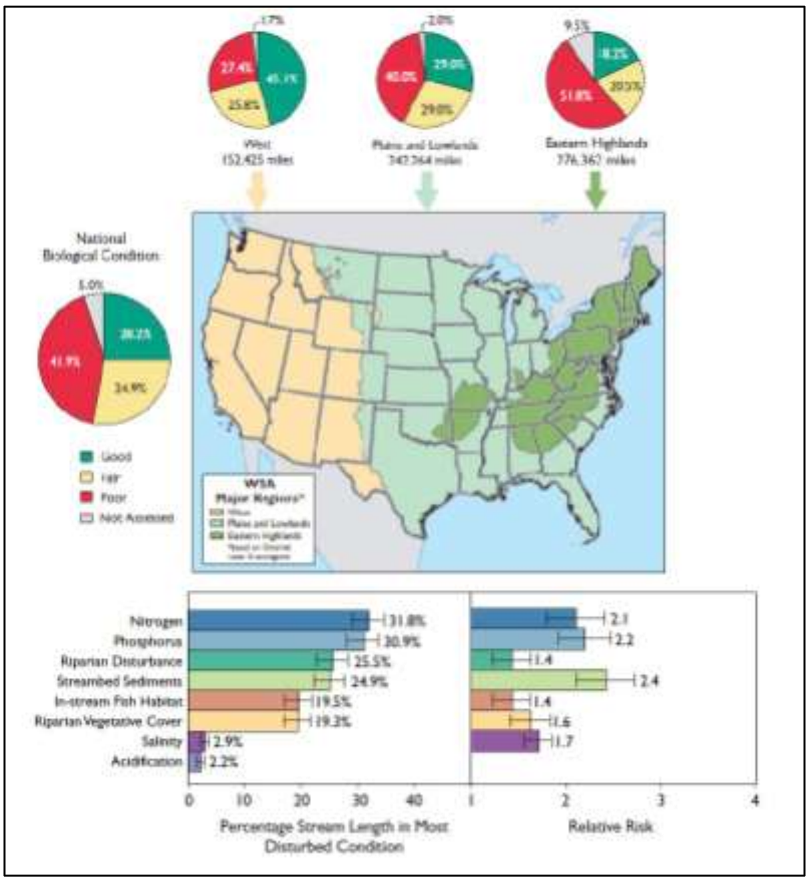

Figure 1. Biological condition of wadeable streams and Extent of stressors and their relative risk to the biological condition of the nations stream (U.S. EPA, 2007).

The 90% confidence level is determined by the variance of the indicator variable and the sample size within populations (http://www.epa.gov/nheerl/arm/surdesignfaqs.htm. Several evaluations have been conducted by EPA and Ecology scientists to determine the physical, chemical, and biological variables and their "signal/noise" properties. These evaluations determine the magnitude of change that occurs in a single variable when some sort of human-induced influence is present. Variables can change over the short-term or the long-term depending on how much artificial change is necessary to measure a response.

Replicated sampling helps to provide descriptions of signal to noise ratios for individual variables (e.g. Kaufmann et al., 1999). Variability between sites indicates signal. Variability across time or samples at identical sites indicates noise.

Scale and Site Selection

For the purposes of this stormwater monitoring strategy, a probabilistic status and trends study design is meaningful at the Puget Sound region scale by identifying stream sub-populations within the Puget Lowlands Ecoregion that are influenced by stormwater runoff. A combined region (incorporated City boundaries and unincorporated Urban Growth Areas (City/UGA)) is presumed to contain sub-populations where streams are most influenced by stormwater runoff. Areas outside of the City/UGA boundaries are presumed to be less influenced. Statistical estimates of stream health between these two sub-populations are only possible at this scale using a probabilistic sample design.

The SWG recommended stratifying sampling sites within the study regions based on stream order (Strahler, 1957). Only 1st, 2nd, and 3rd order streams within the study areas were considered because of limitation of sampling protocols (SWG, 2010).

Indicators

Although a number of stormwater indicators were suggested by the SWG, only those that have been previously used in other regional Status and Trends study designs are presented here. To the extent that resources become available additional indicators should be consider. A serial autocorrelation should be conducted on existing data (e.g., toxics) collected over time at the same place in order to calculate the minimum frequency that the indicator should be measured. This could result in saving money by not over-sampling in order to be successful at trend detection. Also, evaluating properties of each indicator variable like the "signal/noise" variance assists with determining the length of time sampling is needed in order to detect a trend.

Two categories can be established that describe the utility of variables; those useful in indicating change over the broad spatial scale (e.g., Ecoregion or City/UGA) and those that change at the "stream-reach" level. Some variables integrate the characteristics of streams over the broad spatial scale while others are sensitive to small changes from place-to-place in a stream. Each can make effective evaluations that answer objectives for monitoring that includes status of habitat for aquatic biological communities and examine variables that respond to site specific changes.

Puget Sound Status and Trends

Goals and Objectives

The following description is a list of goals and objectives for a Puget Sound wide Status and Trends monitoring program. These statements summarize the goal for initiating monitoring efforts over a large spatial scale and enabling participation of numerous groups that can assemble similar information so that cost is reduced and timeliness enhanced.

The Status and Trend Monitoring program goal is to provide quantitative, statistically valid estimates of the status and trends in the physical, chemical, and biological conditions of Washington's rivers and streams. This information about habitat and water quality can be used to inform policy and management decisions.

The Status and Trend Monitoring program objectives are as follows:

- Provide a probability-based sampling framework that can be used at multiple scales by all levels of government and volunteers to assess the conditions of the state's aquatic resources.
- Determine a sampling site selection process that provides a minimum of 90% confidence in the estimated status.
- Identify specific metrics or indicators that will be monitored and the protocols used to measure them.
- Incorporate existing information and monitoring data, where possible, into the status and trends assessment.
- Develop partnerships with other agencies, local governments, and volunteer groups to implement the monitoring plan or share data.

Scale for Monitoring

Status and Trends is intended to report at a high level of statistical confidence (at least 90%). Precision is defined by the statistics of the EPA-designed framework, and the number of sites sampled. An explanation on calculating the precision for the sample survey can be found at the EPA website (EPA 2009): http://www.epa.gov/nheerl/arm/surdesignfaqs.htm#manysamples. Use of consistent protocols with training among as many sites as possible ensures precise status estimates.

Monitoring for this addendum is focused at three landscape scales:

- Wadable streams which flow into the Puget Sound.
- Wadable streams within City and Urban Growth Areas (City/UGA) that flow into the Puget Sound.
- Wadable streams outside City/UGA that flow in the Puget Sound.

These areas are the focus of important resource conservation and protection efforts. Information generated for each of these regions can be useful for agencies in managing aquatic resources that are impacted by stormwater.

Monitoring Questions

The intent of producing this monitoring framework is to support efforts of the Stormwater Assessment and Monitoring Program for Puget Sound (SWAMPPS) by answering the following core broad-scale monitoring questions:

- What are the status and trends of instream biological and habitat conditions for 1^{st}, 2^{nd}, and 3^{rd} order streams flowing into the Puget Sound?
- What are the status and trends of the biological and habitat conditions for 1^{st}, 2^{nd}, and 3^{rd} order streams flowing into Puget Sound both inside and outside of City/UGAs?

In addition to core questions, numerous others queries can be extrapolated from individual indicators and corresponding metrics (e.g., biological metal tolerance index inside and outside City/UGAs). Also, site specific evaluations of data can be useful for answering questions at local scale and can give local governments an idea of stream condition and stressors.

Since management for water quality improvements usually occurs at a local scale, the framework design provides for answering habitat and water quality questions at smaller, watershed scales (e.g., sub-watershed). Provided local partners wish to contribute to funding and sampling at this scale. At smaller scales, estimates of stream condition are more closely related to the causes of aquatic resource impairments. In addition, the focus on sub-watersheds is understood and readily used by local governments such that they are likely to participate in data collection efforts and become users of data generated by the monitoring program.

Sampling Methods

Methods are from those already broadly applied in the Northwest. They all are derivatives or closely related to the EPA's Environmental Monitoring and Assessment Program (EMAP). The source programs include The Pacific Northwest Aquatic Monitoring Partnership (PNAMP), the Aquatic and Riparian Effectiveness Monitoring Program (AREMP), and the Integrated Status and Effectiveness Monitoring Program (ISEMP). Chemical, biological, and habitat assessment protocols for wadeable streams are well-documented.

The data from wadeable stream survey is collected at a stream reach scale and is most efficiently and safely collected by a crew of at least three persons and can be parsed into tasks to be accomplished by one or more persons at a given time. Sampling at wadeable streams will be performed along a reach that extends 20 bankfull widths and at least 150 meters (Figure 2).

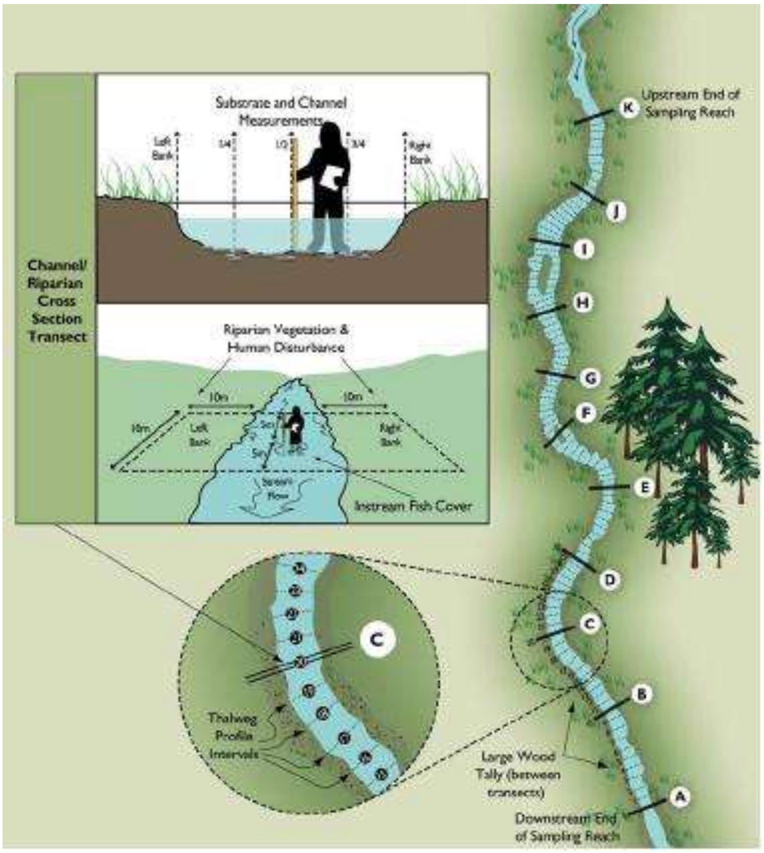

Figure 2. Stream reach layout for sampling (from EPA, 2007).

Site Selection

Overview

Each of the 387,237 points contained in the study areas on the Washington Master Sample shapefile (http://www.ecy.wa.gov/services/gis/data/enviro/mastersample.htm) were evaluated to generate a list of candidate sampling sites within the assessment regions. Master sample sites were statistically chosen from the lines on a 1:24,000-scale hydrography frame (*WDNR watercourses, February 2005).*

Site evaluations determine the suitability of each site for monitoring at the region of interest. This addendum pertains to proposed work within only 1^{st}, 2^{nd}, and 3^{rd} order streams which flow into the Puget Sound. Sites were selected from assessment regions that were created using existing geographic information system (GIS) maps that were modified to the appropriate scale (Table 1.)

Table 1. Assessment Regions for Stormwater Assessment and Monitoring Program for Puget Sound.

Assessment Region	Definition	Map Source
Puget Lowlands Ecoregion[1] within the Puget Sound Salmon Recovery Region[2] (PLSRR).	The portion of the Puget Lowlands Ecoregion that is contained within the Puget Sound Salmon Recovery Region (i.e., streams that flow into the Puget Sound.	1) www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm#Level%20III 2) www.rco.wa.gov/salmon_recovery/regions/regional_orgs_map.shtml
City/UGA regions within the PLSRR.	Within combined incorporated City boundaries and unincorporated Urban Growth Areas (as defined by the Growth Management Act) within the PLSRR	http://www.ecy.wa.gov/services/gis/data/polsub/cityuga.htm
Regions within the PLSRR outside City/UGA.	External to combined incorporated City boundaries and unincorporated Urban Growth Areas (as defined by the Growth Management Act) within the PLSRR	

There are selection criteria for each site's statistical *target* status and for *accessibility* status. Once the Master Sample site list is generated for each assessment region, sites are evaluated in sequence from lowest to highest SITE_ID on the list. Evaluation for some sites on the list will not be complete until a crew can make on-site observations during the July-October sampling index period (Adams, 2010).

Target Status

The assessment regions are

1. The area within the overlap of the Puget Lowlands Ecoregion and Puget Sound Salmon Recovery Region. For this document we will call this the Puget Sound Lowlands Salmon Recovery Region (PLSRR). (seeking 100 sample sites, including those described below).

    a. City and Urban Growth Areas (UGAs) within the PLSRR. (seeking 50 sample sites)

    b. The portion of the PLSRR that is external to the City and Urban Growth Areas (seeking 50 sample sites).

The goal is to identify at least 50 sampling sites in each component assessment region (Table 1) that meet target criteria. A preliminary site list will then be provided to each field crew so they can determine:

1. Whether the streams can be safely accessed and sampled during the designated field season, and
2. If on-site conditions reflect target status (e.g. some streams might be found to be intermittent).

If crews disqualify sites upon visitation, alternates sites should be available for replacement. The procedure is to be started about 6 months prior to the sampling season and continues through the sample season.

Non-Federal status

Exclude sites on federal lands using reconnaissance and parcel research.

Size

Strahler order

Only 1st, 2nd and 3rd order streams following the definitions in Strahler (1952) will be considered for the 50 sites allocated within each component assessment region. This size designation is based on a hierarchy of tributaries. Headwaters are considered 1st order. For this purpose, the Strahler order is based on attributes of a 1:100,000-scale National Hydrography Dataset (Horizon-Systems, 2006). Since the sample frame is at 1:24,000-scale, some streams are too small to appear on the map that defines Strahler order. These streams will not be considered.

For each component assessment region, sampling sites are determined by working down the Master Sample list in ascending order of SITE_ID until 50 sites are sampled for each component assessment region (100 sites total).

National Hydrography Dataset

Target sites must be on streams that are represented in the National Hydrography Dataset at 1:24,000-scale (available here http://www.ecy.wa.gov/services/gis/data/data.htm).

Flow

Lotic

The stream or river must have lotic flow. Lotic means an aquatic system with flowing water such as a brook, stream, or river where the net flow of water is unidirectional (Armantrout, 1998). For this protocol, crews must also be able to see defined left and right banks to discern lotic from wetland systems. Lentic systems are discerned from lotic systems if they have a holding time of more than 15 days. If the point represents a watercourse that is actually a lentic system (i.e., lake, pond, reservoir, or wetland) it is disqualified.

Continuous

If the point represents a water course that is interrupted (subsurface) for more that 50% of the site length, it is disqualified. Site length is 20 bankfull widths surrounding the coordinates (minimum of 150 meters).

Perennial

If the point represents a water course that stops flowing on a seasonal basis, it is disqualified.

Natural Channel

A natural channel is one that was *not* constructed, although it might have been highly modified. Any constructed channel is non-target. This includes canals, ditches, or pipelines.

Freshwater

We want to exclude points that are associated with water that is not fresh. Freshwater means that the water is estimated to have more than 95% of its water column with < 1 ppt salinity at any time during the index period (July 1-October 15). Multiple lines of evidence may be used to make this estimation (e.g., vegetation and proximity to a known estuary).

Access Status

Safety

Safety consideration can be estimated prior to the season, based on state and federal law and organizational policy. But it is ultimately the responsibility of individual crew members at the time of arrival to decide if the stream is safe to enter.

Physical barriers

A site can be disqualified from sampling if it takes more than a day to sample, including transit. Barriers that would disqualify a site may include extreme distances from parking.

Permission

Property owners and tenants will be contacted prior to sampling. This requires researching the parcel information in the preceding months and a good faith effort to contact owners or tenants. A site should be disqualified from sampling if permission has been denied by land-owners, tenants, or resource managers. The Washington Department of Natural Resources describes how to discern public and state-owned waters (WDNR, 2010).

Candidate Sample Locations

Assessment regions and the initial 50 candidate sites within each component assessment region are presented in Figure 1. Sample site attribute data for initial candidate sites are present in table A-1 and A-2. A complete list of all allocated sample sites, as well as site attributes can be found here: *(Link to permit web site).*

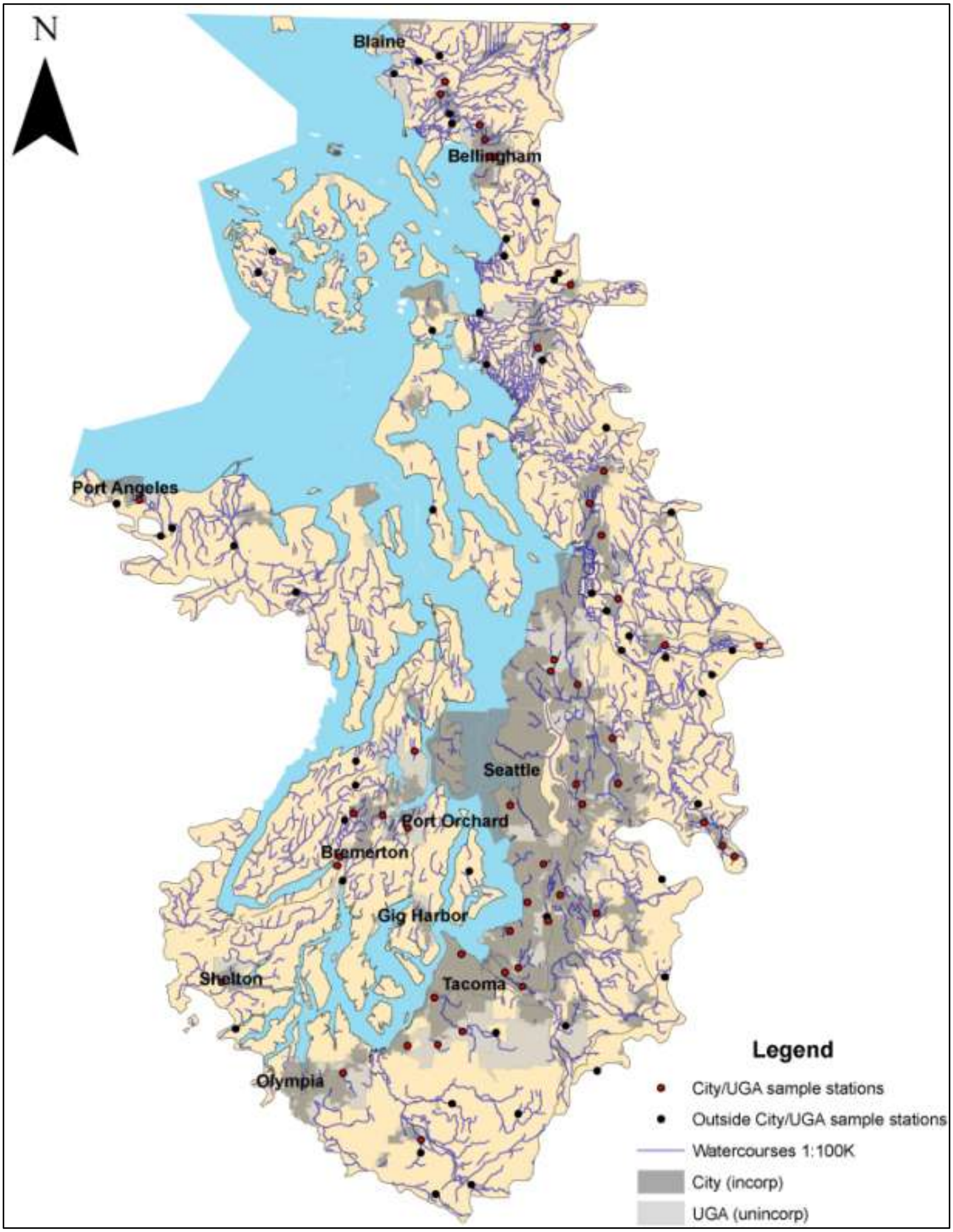

Figure 3. Initial 100 candidate site locations for the Puget Sound assessment region with 50 sites in each of its component assessment regions

Biological and Habitat Parameters

Biological, physical habitat and sediment chemistry parameters are presented in Table 2. Field data collection protocols, quality control procedures and data sheets are summarized in a Quality Assurance Monitoring Plan (QAPP) developed for Ecology's ambient biological monitoring program are located here: (http://www.ecy.wa.gov/biblio/1003109.html)

For additional information a link to Ecology's Status and Trends protocols for Salmon Recovery effort are located here: http://www.ecy.wa.gov/programs/eap/stsmf/index.html

Table 2. Biological and habitat and sediment chemistry parameters .

Parameter	Rationale
Aquatic macroinvertebrates	Integrates water quality and habitat impacts from stormwater over time (Karr 1998; Karr and Rossano 2001; Fore et al., 2001).
Periphyton	Valuable indicators of short-term impacts. Directly affected by physical and chemical factors. Sensitive to some pollutants which may not visibly affect other aquatic assemblages, or may only affect other organisms at higher concentrations (e.g., metals).
Physical Habitat (Slope and bearing, wetted width, bankfull width, bar width, substrate size, substrate depth, shade, human influence, riparian vegetation, large woody debris).	Urban development can alter basin hydrology and adversely affect stream channels (e.g., accelerated bank erosion, loss of LWD, reduced baseflow). Will aid in trend detection, interpretation of biological parameters, and stressor identification.
Sediment Chemistry	
Sediment metals	A group of ecologically consequential heavy metals with defined sediment management standards in WA. Heavy metals contribute to toxic effects on aquatic life and impact the beneficial use of a water body.
Sediment polynuclear aromatic hydrocarbons	Associated with urban runoff and characteristic ensure for roadway impacts. Can accumulate in aquatic organisms and are known to be toxic at low concentrations. Can be persistent in sediments for long periods, resulting in adverse impacts on benthic community diversity and abundance.
Sediment Total Organic Carbon	Will aid in interpretation of sediment chemistry data.
Sediment Grain size	Will aid in interpretation of sediment chemistry data.

Water Quality Index (WQI) Parameters

Water quality parameters that will be used to calculate a Water Quality Index (WQI) at each sampling site are presented in Table 3. Protocols for collecting water parameters are located here: http://www.ecy.wa.gov/biblio/0303200add1.html. Methods for calculating WQIs for each parameter are located here: http://www.ecy.wa.gov/biblio/0203052.html

Table 3. Water quality index parameters.

Parameter	Rationale
Total phosphorus	High concentrations can lead to accelerated plant growth, algal blooms, low dissolved oxygen, decreases in aquatic diversity, and eutrophication in freshwater systems.
Total nitrogen	TN is a concern in the Puget Sound, since nitrogen is typically the limiting nutrient in marine systems.
Turbidity	Primary indicator of water quality and metric of stormwater management systems. Subject to state water quality criteria.
Total suspended solids	Key indicator used to measure the basic treatment effectiveness of a stormwater treatment technology. Can reduce light penetration and lead to a smothering effect on fish spawning and benthic biota. Associated with other pollutants that adsorb to particles such as nutrients, bacteria, metals, and organic compounds. Inexpensive to monitor, minimal field and QA problems, and a reliable indicator.
Specific Conductance	Easily measured and correlates to the total dissolved solids.
pH	Principal driver of aqueous chemical reactions including effects on ammonia volatilization, nitrification, and the precipitation of metals. Subject to state water quality criteria.
Chloride	Elevated levels of chloride usually indicate the presence of other chemicals. Road salt application can result in chloride concentrations in stormwater at levels that may harm aquatic life.
Fecal coliform	A common indicator of urban stormwater pollution or failing septic systems. Subject to state water quality criteria.
Temperature	Key parameter affecting the health and survival of biological communities. Subject to state water quality criteria.
Dissolved oxygen	Key parameter affecting the health and survival of biological communities that is affected by biological and chemical oxygen demand. Subject to state water quality criteria.

Additional Parameters

To the extent that funding becomes available, the framework design provides for the inclusion of additional sample parameters that would help complete the record but are not considered appropriate for funding through municipal NPDES stormwater permits. A list of additional parameters recommended by the SWG is presented in table 4.

Table 4. Additional parameters recommended by the Stormwater Workgroup.

Parameter	Rationale	Sampling Protocols
Biological		
Fish diversity, abundance	Species diversity and relative abundance directly correlate to the stress of an ecosystem.	http://www.ecy.wa.gov/programs/eap/stsmf/docs/01SnTWadeableManA-Vv3bhfl.pdf
Water Quality/Sediment		
Pesticides	Common in residential and agricultural runoff.	http://www.ecy.wa.gov/biblio/0903013.html
Phthalates	Pervasive sediment contaminant in the Puget Sound region.	
PCBs	Corollary to industrial/urban stormwater impacts. Salmonid fish are highly susceptible to PCB accumulation (fatty tissue deposition/accumulation).	http://www.ecy.wa.gov/biblio/0903013.html
PBDEs	Correlates to urban impacts. Growing evidence of PBDE persistence and accumulation in the environment.	http://www.ecy.wa.gov/biblio/0903013.html
Hormone disrupting chemicals	A broad indicator of pollution from urban development. Commonly detected in Puget Sound sediments, with some monitoring stations observing increases in concentrations over recent years.	http://www.ecy.wa.gov/biblio/1103103.html

Sampling Schedule

Table 5. Monitoring activities and frequency of activities to be conducted in the PLSRR assessment region.

Monitoring Activity	Description	Timeline
Biological, sediment chemistry and habitat parameters (Table 2)	One sampling event (each of 100 sites).	One sample event/per permit cycle conducted between July 1 and October.
Water quality Index Monitoring (Table 3)	Twelve water quality sampling events for development of a WQI (each of 100 sites).	12 sampling events per permit cycle conducted monthly.

Reference (Sentinel) Locations

The Puget Sound scale monitoring spreads a limited number of sites across a broad area resulting in sparse distribution of sites. Although variability of population estimates are unaffected by the size of the area surveyed (www.epa.gov/nheerl/arm/) broad-scale surveys are less likely to have a complete description of reference conditions for all assessment regions considered. Broad-scale surveys should therefore be built with enough data collection from known reference sites to allow for rating the conditions of indicators among the randomized survey sites.

A list of eight reference locations surveyed annually for local status and trends efforts within the Puget Sound study area is presented in Table 5. Additional reference stations within each assessment region should be identified. A minimum of 10 reference locations sampled annual are recommended for each assessment region (Cusimano, 2006).

Table 5. Status and Trends reference stations sampled annually by Ecology or EPA.

SITE_ID	Description	Latitude	Longitude
EPA06600-BATT01	Battle Creek	48.05936	-122.26612
EPA06600-CHUC01	Chuckanut Creek	48.70195	-122.48190
EPA06600-DEWA01	Dewatto River	47.46906	-123.02571
WAM06600-299887	Glendale Creek	47.94019	-122.36454
SEN06600-GRIFF01	Griffin Creek	47.60376	-121.88494
EPA06600-OYST01	Oyster Creek	48.61868	-122.43948
EPA06600-TULA01	Tulalip Creek	48.07433	-122.28455
WAM06600-001639	Big Beef Creek	47.62877	-122.79157

Quality Control

The Department of Ecology relies on Quality Assurance (QA) to monitor, improve, and assess its scientific practices, especially those involving generation and assessment of environmental data. Ecology's QA system is based on requirements established by the U.S. Environmental Protection Agency and incorporates guidance and methodology from many standards-setting organizations world-wide. Ecology uses established QA principles to plan execute and assess all of its data-generation projects. Additionally, QA planning is often required for businesses or agencies submitting data to Ecology.

Data quality assurances for biological, sediment chemistry and habitat parameters are summarized in Ecology’s quality assurance monitoring plan for status and trends monitoring for watershed health and salmon recovery (Cusimano, et.al., 2006). Data quality assurances for status and trend monitoring have also been outlined in Ecology’s QAPP for ambient biological monitoring in river and streams (Adams, 2010). Data quality assurances for water quality parameters collected for the WQI are outlined in a QAPP developed for Ecology’s ambient water quality monitoring program (Hallock and Ehinger 2003, Hallock, 2007).

Data Analysis and Reporting

Compiling/Disseminating Reports and Results Data collection is completed by the middle of October in each calendar year. Analysis of water samples and biological samples will extend by three months the period that summary reports can be written. The reporting can be completed by providing information on a web site and providing brief summary interpretations for each monitoring year. A larger and more complete report should be published in the fifth year of a four-year sampling rotation plan. Results need to directly address the questions and statements outlined in the objectives regarding the status of important biological resources, physical habitat conditions, and water quality.

Included with the summary of status are likely causes for impairment. Information generated from the status and trends program can use results from other monitoring programs. Standard analyses have been developed for EMAP program data (EPA, 2005). The EPA has provided on-line tools as well as routines that run on freeware (free software) that analyze and present summary information for habitat and chemical data. Biological information has a few more steps included in its analysis, but provides index-based expressions as well as predictive model-based evaluations of biological condition (see links to resources section below).

Coordination

To the maximum extending possible data collection efforts within the Puget Sound region should be indentified and leveraged for purposes of reporting and interpreting results. For example, Ecology’s Status and Trends Monitoring effort for Watershed Health and Salmon Recovery

Collected base-level monitoring in the Puget Sound SRR in 2009 and is expected to return in 2013. Assessment data collected during these periods can be incorporated into data analysis and reporting efforts for this stormwater QAPP. Ecology's Puget Sound status and trends sample locations (2009) that are within PLSRR presented in figure 4. Sample site attribute data for sites are present in table B-1.

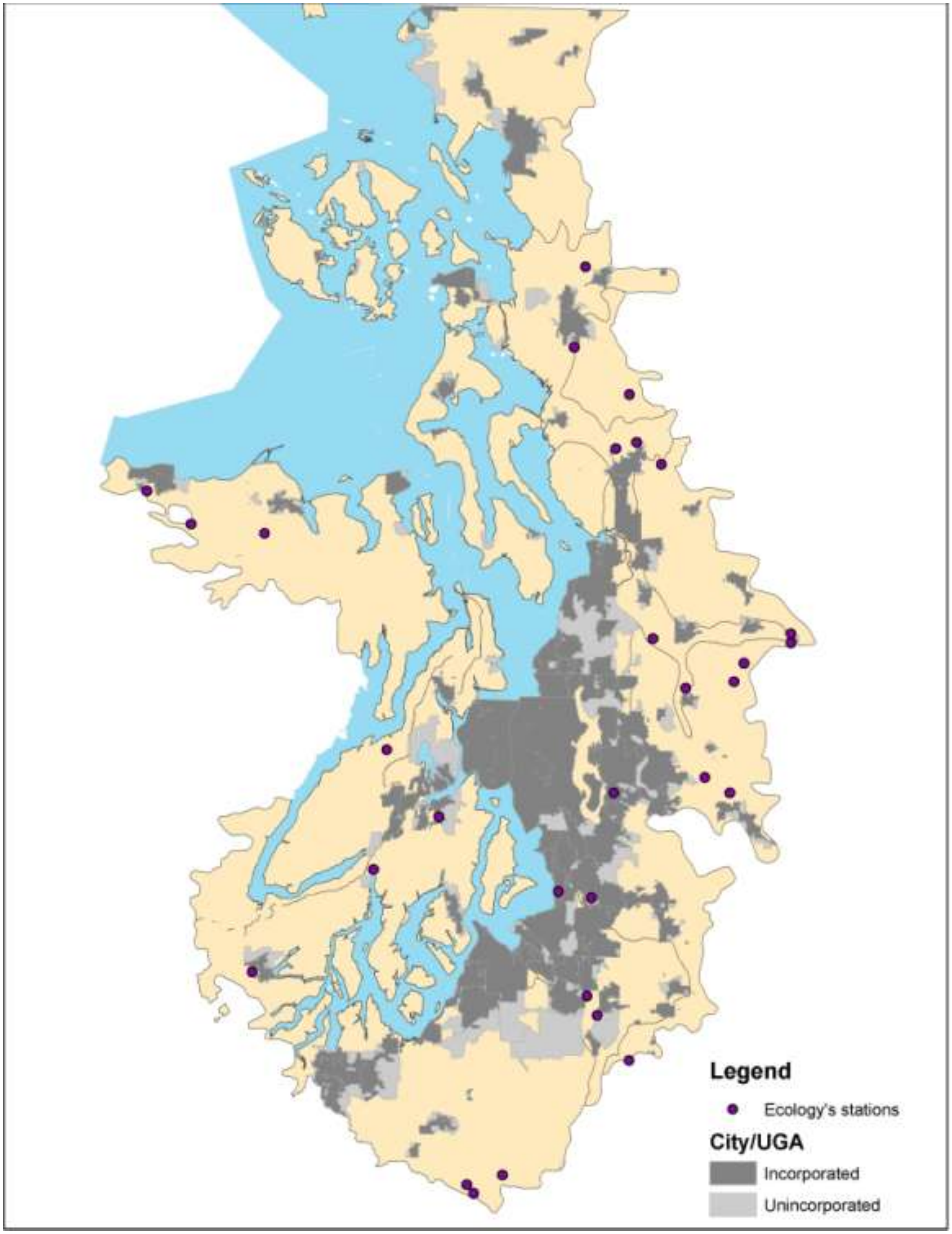

Figure 4. WHSR 2009 sampling stations within the PLSRR.

Links to resources

EPA's Aquatic Resource Monitoring - frequently asked questions

Survey sampling: http://www.epa.gov/nheerl/arm/sursampfaqs.htm
Survey design: http://www.epa.gov/nheerl/arm/surdesignfaqs.htm
Data analysis: http://www.epa.gov/nheerl/arm/dataanalysisfaqs.htm

EPA data analysis resources and tools for surveys

General statistical books on survey designs:
http://www.epa.gov/nheerl/arm/bibliography.htm#generalsurveydesignbooks

Monitoring data analysis and reporting:
http://www.epa.gov/nheerl/arm/analysispages/monitanalysisinfo.htm

Presentations on statistical analysis processes:
http://www.epa.gov/nheerl/arm/presents.htm

Statistical tools for data analysis (Software for R):
http://www.epa.gov/nheerl/arm/analysispages/software.htm

Data analysis resources for sites specific data interpretation

Stressor Identification Guidance:
http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/stressors_index.cfm

Biological Indicators of Watershed Health:
http://www.epa.gov/bioindicators/

Ecology's relevant resources for biological and habitat sampling

Status and Trends Statewide Monitoring web site:
http://www.ecy.wa.gov/programs/eap/stsmf/index.html

Stream Biological Monitoring web site:
http://www.ecy.wa.gov/programs/eap/fw_benth/index.htm

Ecology's relevant resources for water quality sampling

River and Stream Water Quality Monitoring web site:
http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html

2003 Quality Assurance Monitoring Plan: Stream Ambient Water Quality Monitoring:
http://www.ecy.wa.gov/biblio/0303200.html

2007 Addendum to Quality Assurance Monitoring Plan: Stream Ambient Water Quality Monitoring:
http://www.ecy.wa.gov/biblio/0303200add1.html

References

Adams, K., 2010. Quality Assurance Monitoring Plan. Ambient biological monitoring in river and streams: benthic macroinertebrates and periphyton. Washington Department of Ecology. Publication No. 10-03-109. http://www.ecy.wa.gov/biblio/1003109.html

Armantrout, N.B., compiler, 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Cusimano, R., G. Merritt, R. Plotnikoff, C. Wiseman, C. Smith, and WDFW, 2006. Status and Trends Monitoring for Watershed Health and Salmon Recovery: Quality Assurance Monitoring Plan. http://www.ecy.wa.gov/biblio/0603203.html

Ecology (Washington State Dept of Ecology). 2005a. Stormwater Management Manual for Western Washington. Ecology Publication No. 05-10-029.

EPA, 2002. Research Strategy Environmental Monitoring and Assessment Program (EMAP). U.S. Environmental Protection Agency Office of Research and Development National Health and Environmental Effects Research Laboratory Research Triangle Park, NC 27711. EPA 620/R-02/002. http://www.epa.gov/emap/html/pubs/docs/resdocs/resstrat02.html

EPA, 2005. Environmental Monitoring and Assessment Program (EMAP): Western Streams and River Statistical Summary. U.S. Environmental Protection Agency, Office of Research and Development. EPA 620/R-05/006. http://www.epa.gov/emap2/west/html/docs/wstream.html

EPA, 2007. Wadeable Streams Assessment. A collaborative Survey of the Nation's Streams. U.S. Environmental Protection Agency, Office of Research and Development, Office of Water. Washington DC. Publication No. EPA 8-41-B-06-002. http://www.epa.gov/owow/streamsurvey

EPA, 2009. Aquatic Resources Monitoring - Frequently Asked Questions - Survey Design. http://www.epa.gov/nheerl/arm/surdesignfaqs.htm#manysamples.

EPA, 2011. Level III Ecoregions of the Continental United States National Health and Environmental Effects Research Laboratory U.S. Environmental Protection Agency. http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm#Level%20III

Fore, L. S., K. Paulsen, and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. Freshwater Biology 46:109–23.

GSRO. 2011. Regional Organizations: Salmon Regions Map Information from the Governor's Salmon Recovery Office presented by the Washington State Recreation and Conservation Office. http://www.rco.wa.gov/salmon_recovery/regions/regional_orgs_map.shtml

Hallock. D. and W. Ehinger. 2003. Quality Assurance Monitoring Plan: Stream ambient water quality monitoring (Revision of 1995 Version). Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-200. www.ecy.wa.gov/biblio/0303200.html

Hallock, D. 2007. Addendum to Quality Assurance Monitoring Plan: Stream ambient water quality monitoring: corrections of responsibilities and addition of analytes. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-200ADD1 http://www.ecy.wa.gov/biblio/0303200add1.html

Horizons-Systems, Inc. 2006. NHDPlus - The National Hydrography Dataset Plus. http://www.horizon-systems.com/nhdplus/

Karr, J.R., 1991. Biological Integrity: A long-neglected aspect of water resource management. Ecological Applications, 1:66-84.

Karr, J. R. 1998. Rivers as sentinels: using the biology of rivers to guide landscape management. Pages 502-528 in RJ Naiman, RE Bilby (eds.), River Ecology and Management: Lessons from the Pacific Coastal Ecosystems. Springer, New York.

Karr, J. R., and E. Morishita Rossano. 2001. Applying public health lessons to protect river health. Ecol. Civil Eng. 4:3-18.

Kaufmann, P., 1999. Quantifying Physical Habitat in Wadeable Streams. U.S. Environmental Protection Agency, Western Ecology Division, Corvallis, OR. 102 pp.

Strahler, A.N., 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913-920.

Wright, J.F., 1995. Development and use of a system for predicting the macroinvertebrate fauna in flowing waters. Australian Journal of Ecology 20: 181- 197.

WDNR. 2010. Boundaries of State-owned Aquatic Lands. Washington Department of Natural Resources, Olympia, WA
http://www.dnr.wa.gov/Publications/aqr_aquatic_land_boundaries.pdf

Appendix A: Status and Trends site attributes

Table A-1. Attributes for initial 50 candidate sites inside the City/UGA assessment region.

Site Id	Longitude	Latitude	County	Stream Name	lStream Order
WAM06600-000222	47.2122	-123.1388	Mason	Goldsborough Creek	3
WAM06600-000391	47.5599	-122.1701	King	Coal Creek	1
WAM06600-000451	47.3758	-122.3149	King	McSorley Creek	1
WAM06600-000859	47.7804	-122.1894	Snohomish	North Creek	2
WAM06600-001246	47.2192	-122.3226	Pierce	Wapato Creek	2
WAM06600-001454	47.2543	-122.3341	Pierce	West Hylebos Creek	2
WAM06600-001715	47.5082	-122.6446	Kitsap	Blackjack Creek	2
WAM06600-001790	47.3428	-122.2568	King	-	1
WAM06600-001879	47.5966	-122.1877	King	Mercer Slough	2
WAM06600-003691	47.8256	-122.2553	Snohomish	Swamp Creek	1
WAM06600-004026	47.1087	-122.5473	Pierce	Murray Creek	-999
WAM06600-004383	47.9409	-122.0842	Snohomish	-	1
WAM06600-004528	48.8893	-122.5980	Whatcom	California Creek	1
WAM06600-005099	47.8567	-121.9531	Snohomish	-	1
WAM06600-005216	48.8114	-122.4970	Whatcom	-	1
WAM06600-005324	48.5202	-122.2328	Skagit	-	1
WAM06600-005456	48.7533	-122.4679	Whatcom	Whatcom Creek	3
WAM06600-005652	48.0986	-123.4101	Clallam	White Creek	1
WAM06600-006123	47.8591	-121.6933	Snohomish	May Creek	2
WAM06600-006407	47.5318	-122.7946	Kitsap	-	2
WAM06600-007306	46.9311	-122.5861	Thurston	Yelm Creek	2
WAM06600-007424	48.9969	-122.2642	Whatcom	Johnson Creek	3
WAM06600-007518	47.1953	-122.5604	Pierce	Chambers Creek	3
WAM06600-007726	47.2453	-122.3705	Pierce	Wapato Creek	2
WAM06600-007914	47.0508	-122.8022	Thurston	Woodland Creek	2
WAM06600-007971	47.4347	-122.8348	Mason	-	1
WAM06600-008254	47.2772	-122.4901	Pierce	-	1
WAM06600-009168	48.7847	-122.4820	Whatcom	-	1
WAM06600-009443	47.4680	-121.7529	King	SF Snoqualmie River	3
WAM06600-009552	48.7533	-122.4531	Whatcom	-	2
WAM06600-009831	47.6503	-122.6325	Kitsap	-	1
WAM06600-010071	47.5996	-122.0733	King	Pine Lake Creek	1
WAM06600-010147	47.4512	-122.8268	Mason	-	1
WAM06600-010503	47.5307	-122.7142	Kitsap	Gorst Creek	2
WAM06600-010563	47.3581	-122.1253	King	Little Soos Creek	2
WAM06600-011059	47.4881	-121.7853	King	SF Snoqualmie River	3
WAM06600-011399	47.5548	-	King		-999
WAM06600-012080	48.8669	-122.6094	Whatcom		1
WAM06600-012223	48.0579	-122.1336	Snohomish	Munson Creek	1
WAM06600-012387	47.4472	-122.2727	King		-999
WAM06600-012807	47.5307	-121.8370	King	Kimball Creek	2
WAM06600-013031	47.6831	-122.0911	King	Bear Creek	3
WAM06600-013054	47.3225	-122.3600	King		1

Site Id	Longitude	Latitude	County	Stream Name	lStream Order
WAM06600-013838	47.1341	-122.4819	Pierce	Clover Creek	3
WAM06600-013860	48.1770	-122.1301	Snohomish	Stillaguamish River	1
WAM06600-014056	48.4017	-122.3185	Skagit	-	-999
WAM06600-014419	47.3912	-122.2247	King	-	2
WAM06600-014868	48.1167	-122.1684	Snohomish	-	2
WAM06600-015067	47.8040	-122.2641	Snohomish	-	1
WAM06600-015290	47.1054	-122.6300	Pierce	Sequalitchew Creek	1

Table A-2. Attributes for initial 50 candidate sites outside the City/UGA assessment region .but still within the PLSRR.

Site Id	Longitude	Latitude	County	Stream Name	Stream Order
WAM06600-000143	47.9180	-122.1153	Snohomish	-	1
WAM06600-000211	47.4073	-122.8186	Mason	-	1
WAM06600-000287	47.9507	-122.1566	Snohomish	Ebey Slough	1
WAM06600-000398	47.1487	-122.2026	Pierce	Fennel Creek	2
WAM06600-000432	48.9019	-122.7410	Whatcom	Terrell Creek	2
WAM06600-000474	47.0000	-122.5050	Pierce	Lacamas Creek	2
WAM06600-000540	48.5266	-123.1033	San Juan	-	1
WAM06600-000636	48.6713	-122.3354	Whatcom	-	1
WAM06600-000814	47.2428	-121.9368	King County	-	1
WAM06600-000831	48.0203	-123.1449	Clallam	Canyon Creek	2
WAM06600-000855	47.5843	-122.7901	Kitsap	-	1
WAM06600-000875	47.8345	-121.9508	Snohomish	-	1
WAM06600-000891	47.8727	-122.0508	Snohomish	-	1
WAM06600-000900	48.0978	-122.5990	Island	-	-999
WAM06600-000987	47.8035	-121.8213	Snohomish	Crandall Creek	1
WAM06600-001002	47.0670	-122.1140	Pierce	Voight Creek	3
WAM06600-001003	47.8455	-122.0720	Snohomish	-	-999
WAM06600-001120	48.8123	-122.5753	Whatcom	-	2
WAM06600-001180	48.5699	-122.4198	Skagit	-	-999
WAM06600-001192	48.3794	-122.3066	Skagit	-	2
WAM06600-001228	48.5282	-122.2789	Skagit	-	1
WAM06600-001235	47.4309	-122.4742	King County	-	1
WAM06600-001290	46.9077	-122.5856	Thurston	Yelm Creek	2
WAM06600-001320	48.3683	-122.4611	Skagit	-	-999
WAM06600-001415	47.5643	-121.8539	King	Mud Creek	1
WAM06600-001550	47.1261	-123.0969	Mason	Skookum Creek	2
WAM06600-001556	48.0907	-123.4726	Clallam	Tumwater Creek	-999
WAM06600-001564	48.5412	-122.2679	Skagit	Thomas Creek	1
WAM06600-001590	46.8508	-122.4478	Thurston	-	2
WAM06600-001639	47.6288	-122.7916	Kitsap	Big Beef Creek	2
WAM06600-001702	46.8316	-122.5430	Thurston	Deschutes River	3
WAM06600-001756	48.5661	-123.0663	San Juan	-	2
WAM06600-001776	48.9260	-122.6733	Whatcom	California Creek	2
WAM06600-001796	48.0482	-123.3171	Clallam	Bagley Creek	1

Site Id	Longitude	Latitude	County	Stream Name	Stream Order
WAM06600-001856	48.9375	-122.6153	Whatcom	-	1
WAM06600-001882	46.9843	-122.3255	Pierce	-	2
WAM06600-001924	48.1028	-121.9414	Snohomish	SF Stillaguamish River	3
WAM06600-001983	48.0332	-123.3480	Clallam	Surveyor Creek	1
WAM06600-001995	47.7694	-121.8483	King	Cherry Creek	1
WAM06600-002027	47.8493	-121.7663	Snohomish	-	1
WAM06600-002036	48.2570	-122.1267	Snohomish	-	1
WAM06600-002060	48.4647	-122.4838	Skagit	-	-999
WAM06600-002079	47.9382	-122.9702	Clallam	Snow Creek	2
WAM06600-002156	48.6025	-122.4143	Skagit	Whitehall Creek	1
WAM06600-002168	48.4287	-122.6146	Skagit	-	1
WAM06600-002259	47.4232	-121.9484	King	Carey Creek	1
WAM06600-002311	47.5189	-122.8173	Mason	Bear Creek	1
WAM06600-002371	47.3502	-122.2602	King	-	1
WAM06600-002464	48.8304	-122.5833	Whatcom	-	1
WAM06600-002574	47.1335	-122.3910	Pierce	North Fork Clover Creek	1

Appendix B: Ecology's Status and Trends Site Attributes

Table B-1. Attribute data for WHSR 2009Status and Trends sampling stations within the SWAMPPS PLSRR assessment region. Revised Strahler order is based on visual inspection of NHD+ (1:100,000) watercourse attributes relative to frame watercourse geometry.

Site Id	Longitude	Latitude	Count y	Stream Name	Stream Order
WAM06600-000211	-122.819	47.40731	Mason	Coulter Creek tributary	1√
WAM06600-000222	-123.139	47.21224	Mason	Goldsborough Creek	3√
WAM06600-000308	-122.128	48.20669	Snoho	Stillaguamish River-N Fk mouth	4
WAM06600-000391	-122.17	47.55987	King	Coal Creek	1√
WAM06600-000398	-122.203	47.14873	Pierce	Fennel Creek	2√
WAM06600-000451	-122.315	47.37583	King	McSorley Creek tributary	0
WAM06600-000676	-122.185	48.19432	Snoho	Stillaguamish River	5√
WAM06600-000831	-123.145	48.02029	Clalla	Canyon Creek	2√
WAM06600-000987	-121.821	47.80354	Snoho	Crandall Creek	1√
WAM06600-001002	-122.114	47.06698	Pierce	Voight Creek	3√
WAM06600-001003	-122.072	47.84551	Snoho	Snohomish River	6
WAM06600-001047	-121.923	47.59189	King	Snoqualmie River	5√
WAM06600-001192	-122.307	48.37945	Skagit	Carpenter Creek	2√
WAM06600-001228	-122.279	48.52819	Skagit	Willard Creek	1√
WAM06600-001415	-121.854	47.56428	King	Mud Creek	1√
WAM06600-001480	-122.15	48.29512	Snoho	Pilchuck Creek tributary	0√
WAM06600-001556	-123.473	48.09074	Clalla	Tumwater Creek	0
WAM06600-001590	-122.448	46.85075	Thurst	Powell Creek	2√
WAM06600-001639	-122.792	47.62877	Kitsap	Big Beef Creek	2√
WAM06600-001702	-122.543	46.83163	Thurst	Deschutes River	3√
WAM06600-001715	-122.645	47.50819	Kitsap	Blackjack Creek	2√
WAM06600-001899	-121.693	47.84226	Snoho	Skykomish River	5√
WAM06600-001983	-123.348	48.03322	Clalla	Surveyor Creek	1√
WAM06600-001995	-121.848	47.76936	King	Cherry Creek	1√
WAM06600-002596	-122.059	48.16767	Snoho	Jim Creek	3√
WAM06600-003366	-122.524	46.81618	Thurst	Deschutes River	3√
WAM06600-005067	-121.98	47.75554	King	Snoqualmie River	5√
WAM06600-006123	-121.693	47.85907	Snoho	May Creek	1
WAM06600-006467	-122.224	47.36614	King	Green River	5√