Status and Trends Monitoring for Watershed Health and Salmon Recovery

Quality Assurance Monitoring Plan

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For more information contact:
Publications Coordinator
Environmental Assessment Program
Washington State
Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600
E-mail: *jlet461@ecy.wa.gov*
Phone: (360) 407-6764

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Front cover photo:
Brian Engeness taking thalweg measurements on Nason Creek, Chelan County, 2006.
Photo by Dylan Monahan

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Quality Assurance Monitoring Plan

by

Washington State
Department of Ecology:
Robert Cusimano, Project Manager
Glenn Merritt, Technical Lead
Robert Plotnikoff
Chad Wiseman

Washington State Conservation
Commission:
Carol Smith

Washington Department
of Fish and Wildlife

List of Acronyms

This list contains acronyms used frequently in this document. Other acronyms are used infrequently and defined only in the text.

EMAP	Environmental Monitoring and Assessment Program (*EPA*)
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily significant units
ISEMP	Integrated Status and Effectiveness Monitoring Program
LWD	Large woody debris
MQO	Measurement quality objectives
NOAA	National Oceanic and Atmospheric Administration
PSRR	Puget Sound Salmon Recovery Region
QA	Quality assurance
QC	Quality control
RSD	Relative standard deviation
RIVPACS	River InVertebrate Prediction and Classification System
SRR	Salmon Recovery Region
SSHIAP	Salmon and Steelhead Habitat Inventory and Assessment Program (*WDFW*)
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

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Abstract

This document describes a quality assurance monitoring plan for conducting a statewide, probability-based sampling program. The goal of the monitoring is to provide quantitative, statistically valid, and consistent estimates of the status and trends in the physical, chemical, and biological conditions of Washington's rivers and streams. The data collected under this plan can be used to report on the health of salmonid habitat.

Jill Lemmon and Brian Engeness collecting habitat data on Nason Creek, Chelan County, 2006.
Photo by Dylan Monahan

Introduction and Needs Statement

Recent and historical degradation of Washington's rivers and streams has contributed to the decline of salmon, steelhead, and trout populations, resulting in Endangered Species Act (ESA) listings throughout most of the state. In response to ESA listings, the state, the federal government, private industry, and the tribes have invested substantial resources to restore and protect the ecological function of these rivers and streams.

The fate of salmon in the Northwest is dependent on coordinated, long-term monitoring at the regional scale (*Spence et al., 1996*). In 2005 the Governor's Forum on Monitoring sponsored a workshop to determine whether high-level indicators of salmon recovery and watershed health reported biennially in the Washington *State of Salmon in Watersheds* report could be improved. One of the major conclusions from the workshop was that the indicators could not be improved using existing monitoring information.

At this time, there are a number of independent habitat and water quality monitoring efforts occurring throughout Washington (*Monitoring Oversight Committee, 2002c*). Many of these efforts have documented status and trends relevant to their specific project objectives and geographic areas. However, these monitoring efforts cannot be combined and evaluated collectively because they are based on different objectives, designs, and inconsistent methods for measurement; and the monitoring focuses on different geographic scales.

In addition, the statewide limiting factors report estimated that 43% of the Water Resource Inventory Area (WRIA)-scale habitat ratings were either data gaps or unknown conditions (*Smith, 2005*).

Without a program to monitor habitat conditions across the state, most of the existing and current monitoring information cannot be updated, and many of the identified data gaps will continue to be unfilled, decreasing the certainty of success of salmonid habitat restoration actions. At this time, there is no new quantitative monitoring information to assemble future *State of Salmon in Watersheds* reports.

In response to recommendations from the Governor's Forum on Monitoring, the Washington Salmon Recovery Funding Board funded the development of this quality assurance monitoring plan (*Status and Trends Monitoring Plan*). This plan describes a monitoring program that will provide a consistent, objective picture of the health of stream and river corridor habitat and will detect trends. It will also help policy makers in each region prioritize the environmental features and limiting factors that are in most need of being addressed for protection of watershed health and salmon recovery.

This plan was prepared by the Washington State Department of Ecology, Washington State Conservation Commission, and Washington Department of Fish and Wildlife in collaboration with representatives of federal, state, and local governments; and tribes and private groups.

The fate of salmon in the Northwest is dependent on coordinated, long-term monitoring at the regional scale

Summary

Required Elements:

✓ A common set of protocols

✓ Aquatic assessments

✓ A sustainable monitoring program

✓ Funding for local partners

✓ Quality assurance and training

✓ Common data management system

Brian Engeness collecting thalweg readings (and avoiding mosquitoes) on the upper Chiwawa River, Chelan County, 2006.
Photo by Jim Garner

The Status and Trends Monitoring Plan describes a probabilistic sampling design (or framework,) as well as standardized monitoring protocols for assessing the water quality and habitat of the rivers, streams, and watersheds in Washington State.

The indicators under this plan will address the salmonid habitat "limiting factors" identified by the U.S. Department of Commerce National Marine Fisheries Service for each of the Endangered Species Act evolutionarily significant units (ESUs) for salmon and steelhead. These indicators can also address factors affecting distinct population segments (DPSs) of bull trout. Without implementing this plan, there is little prospect of collecting the needed information for reporting on the water quality and habitat status of our river and stream resources.

The organizations that participated in developing the plan identified the following as required elements:

◆ A common set of protocols that can be used by those interested in assessing water quality and habitat conditions.

◆ Aquatic assessments that answer key questions needed to make resource and regulatory decisions for salmon population recovery.

◆ A sustainable monitoring program that can be maintained for a reasonable period of time.

◆ Funding for local partners to maintain their participation.

◆ Paid scientists who can provide overall quality assurance for the program as well as train volunteer groups who can contribute meaningful information to this monitoring effort.

- A common data management system, maintained by a designated agency or consortium, that can be used for data analysis and preparing reports detailing watershed health.

The framework is based on the target population of streams and rivers present on a 1:24,000 scale hydrography coverage. The overall monitoring protocol is based on sampling techniques that have been broadly applied across the Northwest:

- Pacific Northwest Aquatic Monitoring Partnership (PNAMP)
- Environmental Monitoring and Assessment Program (EMAP)
- Aquatic and Riparian Effectiveness Monitoring Program (AREMP)
- Integrated Status and Effectiveness Monitoring Program (ISEMP)

The sampling methods are taken from each of these closely-related efforts. Specific protocols are those that we believe to be the simplest, least expensive, reliable, and therefore the best for training persons at any level of experience, including volunteers. We limited the basic reporting metrics to a small but powerful set. These basic (minimum required) metrics include:

(1) Metrics that have "poor" values extensively, due to human effects, and

(2) metrics that indicate risk to instream biology.

In addition to this basic set, metrics for each WRIA (or smaller region) can be added to determine local needs.

The framework will allow estimates to be made about the water quality and habitat conditions of the target population with +/-10% precision and 80% confidence in the estimates. Data required to make these estimates will be collected over a four-year period.

Sampling sites are selected from a master sample of site locations developed for this framework. The plan covers sampling on non-federal lands, but it also allows for anyone, including federal land managers, to use the same master list and protocols for comparable monitoring that would strengthen the assessment. We propose selecting sampling sites that will represent three significant scales:

- The Salmon Recovery Regions (SRRs)
- Water Resource Inventory Areas (WRIAs)
- Statewide

Information collected at these scales can be used to determine the overall effectiveness of efforts to improve watershed health and recover salmon populations. By adding results from federal monitoring with the conditions to be reported from this plan, we can provide an assessment that covers the state.

As part of this plan, a pilot project is proposed (*Appendix B*) to detect habitat characteristics by testing aerial photographic sampling.

Specific protocols are those that we believe to be the simplest, least expensive, reliable, and therefore the best for training persons at any level of experience, including volunteers.

PART 1: Project Planning and Management

Background

Salmon Habitat Limiting Factors

The *Salmon Habitat Limiting Factors in Washington State* report estimated that 38% of the WRIA-scale habitat ratings were poor, followed by 7% fair and 13% good conditions. Perhaps even more notable is that the remaining 43% of the ratings were either data gaps or unknown conditions (*Smith, 2005*).

The Governor's Salmon Recovery Office (GSRO) and the National Marine Fisheries Service (NOAA-Fisheries) reported criteria necessary for official coast-wide recovery of salmonid species listed under the ESA. The details for riparian and instream habitat factors that limit survival of salmon populations were further discussed at the Governor's Forum on Monitoring (2005). The limiting factors (*Table 1*) are addressed in the State's Limiting Factors Analysis (*GSRO, 2004*) and in the Pacific Coastal Salmon Recovery Fund 2005 Report to Congress (*PCSRF, 2005*).

Information Needs and Approach

A major gap in monitoring watershed health and salmon recovery is measuring the status and trends of streams, rivers, and nearshore estuaries, including landscape-forming processes at spatially contiguous scales that are useful to policy makers. Salmon recovery plans are required by the ESA. NOAA-Fisheries has determined that the plans should be developed based on evolutionary significant units (ESUs), or on a regional basis. Regional recovery organizations or Salmon Recovery Regions (SRRs) have been formed as part of the Governor's salmon recovery strategy. In addition, water issues are managed in the state using Water Resource Inventory Areas (WRIAs) that are defined in Chapter 173-500 WAC as it existed on January 1, 1997. *Figure 1* shows SRR and WRIA geographic boundaries.

Table 1: Limiting factors identified by the state and federal government for Pacific salmonid species that are listed under the Endangered Species Act (ESA).

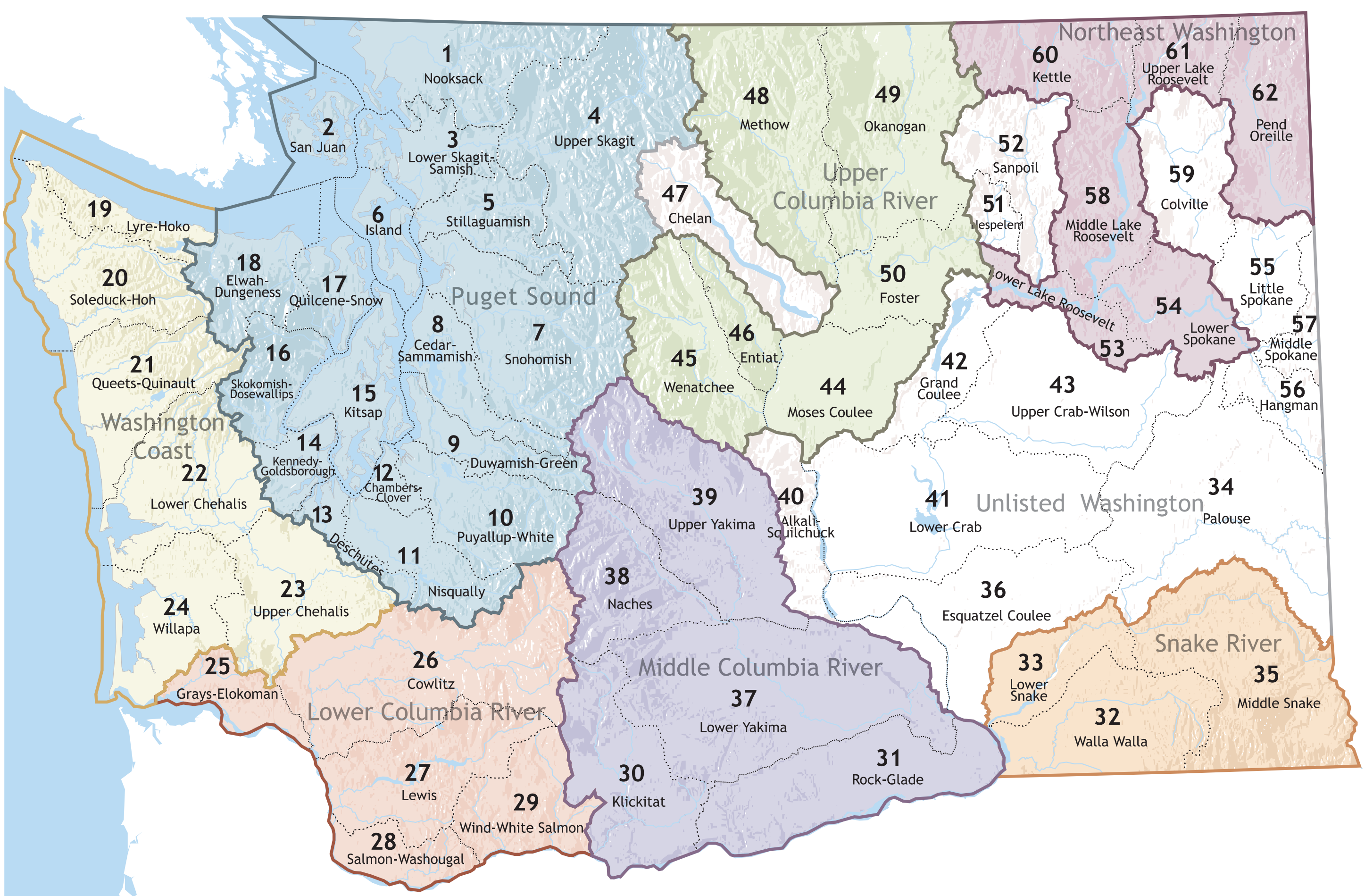
Organization (reference)	Limiting Factors Identified
GSRO (2004)	Access (e.g., dams, hanging culverts), floodplain, sediment, in-stream processes, riparian conditions, water quality, flow
PCSRF (2005)	Floodplain/channel structure, estuaries, riparian conditions, large woody debris, sediment, water quality, flow, and predation

GSRO - Governor's Salmon Recovery Office
PCSRF - Pacific Coastal Salmon Recovery Fund

One of the important needs for determining salmon recovery is the ability to describe, with known certainty, what changes have occurred in the status and trends of habitat conditions affecting watershed health and salmon recovery statewide. The status and trends program described in this document proposes to address these information needs by implementing a monitoring design using a randomized, site-selection approach modeled after the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) at the SRR and WRIA geographic scales.

EMAP has been developed and used to report on the state of the waters in the United States. EPA has partnered with state agencies in order to pass on the technology to state and local governments. Extensive work with the EMAP experimental design, protocol development, data management, and development of indicators has been completed. This site-selection and sampling approach had been examined and endorsed in the *Comprehensive Monitoring Strategy* (*Monitoring Oversight Committee, 2002a, 2002b, 2002c*). Other, related programs (AREMP, ISEMP) sample in similar ways, and we can draw from these also.

Figure 1: Eight large monitoring regions based on Salmon Recovery Regions (SRRs); and 62 smaller monitoring regions: Water Resource Inventory Areas (WRIAs). This plan addresses non-federal portions of these regions. Names and information for WRIAs are available at this Internet link: www.ecy.wa.gov/services/gis/maps/wria/wria.htm.



Participation in the Program

Many monitoring participants have a potential interest in becoming a part of a statewide effort. However, most of the groups currently involved in monitoring programs need to collect site-specific information to support their local management decisions and funding requirements.

The list of participants who attended the workshops used to develop this plan might provide a beginning list of organizations that could contribute to the sampling effort. These include members of counties, municipalities, volunteer groups, tribes, and federal and state agencies.

Although there is interest in participating in a status and trends program, local governments and volunteer groups would require sufficient funding to maintain a minimal program.

A limited number of entities have been assessing fish and habitat conditions using probabilistic site identification and unique sampling methodologies (*Table 2*).

Table 2: Some of the historical and ongoing probability surveys in Washington State

Survey	Region	Lead	Link
ISEMP	Wenatchee Basin	NOAA-Fisheries	*www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm*
OBMEP	Okanogan Basin	Colville Tribes	*http://nrd.colvilletribes.com/obmep/*
REMAP	Coast Range Ecoregion	Dept. of Ecology	*www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*
REMAP	Cascades Ecoregion	Dept. of Ecology	*www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*
REMAP	Yakima Basin	Dept. of Ecology	*www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*
REMAP	Upper Chehalis Basin	Dept. of Ecology	*www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*
EMAP-W	Streams of WA, Western U.S.	Dept. of Ecology/ EPA	*www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*
EMAP-W	Estuaries of WA, Western U.S.	EPA	*http://tinyurl.com/nqh7r*
WSA	U.S. Streams	EPA/States	*www.epa.gov/owow/streamsurvey/index.html*
SHMP	Skagit County	Skagit County Public Works	*http://tinyurl.com/nsc9s*
AREMP	Northwest Forest Plan-Federal Lands	USDA Forest Service	*www.reo.gov/monitoring/watershed/index.htm*
PIBO	Upper Columbia-Federal Lands	USDA Forest Service	*www.fs.fed.us/biology/fishecology/emp/*
WLS	Low-alkalinity Lakes of West	EPA	*www.epa.gov/emap/html/datal/surfwatr/data/napap/wls.html*
NLFTS	U.S. Lakes	EPA/States	*www.epa.gov/waterscience/fishstudy/*
PSAMP	Puget Sound	PSAT	*www.psat.wa.gov/Programs/PSAMP.htm*

AREMP *Aquatic and Riparian Effectiveness Monitoring Program*
EMAP *Environmental Monitoring and Assessment Program*
ISEMP *Integrated Status and Effectiveness Monitoring Program*
NLFTS *National Lake Fish Tissue Study*
OBMEP *Okanogan Basin Monitoring and Evaluation Program*
PIBO *PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program*
PSAMP *Puget Sound Assessment and Monitoring Program (previously the Puget Sound Ambient Monitoring Program)*
PSAT *Puget Sound Action Team*
REMAP *Regional Environmental Monitoring and Assessment Program*
SHMP *Salmon Habitat Monitoring Program*
WLS *Western Lakes Survey*
WSA *Wadeable Streams Assessment*

Program Description

Program Goals

The goal of this status and trends monitoring program is to provide quantitative, statistically valid estimates of status and trends in the physical, chemical, and biological conditions of Washington's rivers and streams. This includes status and trends of limiting factors identified for listed salmonid fishes.

Program Objectives

The objectives of the status and trends program are as follows:

- Provide a probability-based sampling framework that can be used at the state, SRR, and WRIA 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 80% confidence in the estimated status of wadeable and non-wadeable rivers and streams.
- Identify specific metrics or indicators that will be monitored as well as 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.

Benefits

The "status" of a river or stream system is the condition of its physical, chemical, and biological characteristics at a single point in time. These measurements made at different time intervals into the future can be used for "trend" analysis.

The specific indicator (or limiting factor) results will be useful for discerning whether the cumulative effects of all habitat restoration and pollutant reduction efforts in each region are beneficial. If some aspects of cumulative restoration activities are not responding as desired, then knowledge of specific indicators will allow for making changes through adaptive management.

A status and trends framework (i.e., broad-scale evaluation with consistent/comparable protocols) is the only way to realistically determine regional effects of management actions.

Status and trends monitoring can inform decisions for prioritizing salmon recovery projects and other state and local actions. This can be done by demonstrating, on a regional basis, which limiting factors are the most widely impacted (have the largest percentage of stream length with poor metric scores). Efforts to improve conditions should be guided through assessing the status and the trends of physical, chemical, and biological indicators (e.g., salmon limiting factors).

The goal is to provide quantitative, statistically valid estimates of status and trends in the physical, chemical, and biological conditions of Washington's rivers and streams.

Scales, Indicators, and Protocols

One of the purposes of this monitoring plan is to promote the use of a "core" set of indicators and protocols.

Spatial Scales

Status and trends will be estimated at three spatial scales (size of area): (1) statewide, (2) SRR, and (3) WRIA. Monitoring at each scale generates unique information that can be used for different purposes, such as *State of Salmon* reports, EPA-required reporting, as well as SRR and WRIA specific management.

1. The statewide monitoring scale spreads a limited number of sites across a broad area. This results 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 strata considered. Broad-scale surveys should therefore be built with enough data collection from known reference sites (not necessarily random) to allow for rating the conditions of indicators among the randomized survey sites. We recommend sampling at least 10 reference sites for each ecoregion/size strata.

2. Focus on the SRR scale results in an increased density of sites compared to the same number of sites spread across a larger region. Assessments or monitoring at the SRR scale can be useful for comparisons between different ecoregions and ESUs. Also, past assessments at this scale served as the foundation for the previous *State of Salmon* reports (*GSRO, 2004*). Lastly, individual restoration efforts have limited effectiveness, but these projects produce a cumulative effect in the region. Estimates of the condition and evaluations of trend at the SRR scale will inform the adaptive management processes of the cumulative effects of these restoration efforts.

3. Monitoring site locations by WRIA is the finest level of the proposed monitoring framework. Management for water quality improvements usually occurs at a WRIA scale which makes it a desirable scale for monitoring. At the WRIA scale, estimates of stream condition may be indirectly related to cause of aquatic resource impairments. Trend analysis using the WRIA data set can detect changes in stream conditions over the shortest time period if an adequate number of sites are visited. In addition, the focus on WRIAs is more useful to local entities by providing an unbiased overview of basin conditions and a perspective on how well management actions work by comparing adjacent watersheds. Local groups are also more likely to participate in WRIA-scale data collection efforts, given the availability of monetary resources, and become users of data generated by the monitoring program.

Indicators and Protocols

In the short-term, it would be helpful to use existing data from multiple monitoring programs for making a unified assessment. Scientists who contributed to the development of this plan suggested that one means to do this is by "binning" data under common categories (even though the sampling or laboratory protocols might be slightly different). In the short-term and longer-term, monitoring will benefit from a convergence of methods. One of the purposes of this monitoring plan is to promote the use of a "core" set of indicators and protocols.

Major status and trends monitoring programs across the Northwest already use protocols (*e.g., Peck et al., 2003; AREMP, 2006; Moberg, 2006*) that are very similar to each other. The Pacific Northwest Aquatic Monitoring Partnership (*PNAMP; John Day Comparison Study*) may help provide some information on how and what can be compared across programs. For example, preliminary data suggest that, given appropriate training, slope measurements are comparable, regardless of instruments or programs used to collect them. Results of field comparison tests (*Roper, 2005*) are in production.

Program Constraints

This monitoring effort will be limited to perennial rivers and streams (except the mainstem Columbia River) that are present on a 1:24,000-scale stream map coverage (*WDNR, 2006*). Data described in this plan will only be collected from Washington's rivers and streams on non-federal lands (*Figure 2*).

Watershed evaluations may cross into federal lands but only when they are part of catchments for stream locations on non-federal lands. Data from this status and trends plan will complement data collected from federal lands by other agencies such as the U.S. Forest Service and the U.S. Bureau of Land Management.

Figure 2: Non-federal lands of Washington State (in dark gray).

Organization and Schedule

Organization

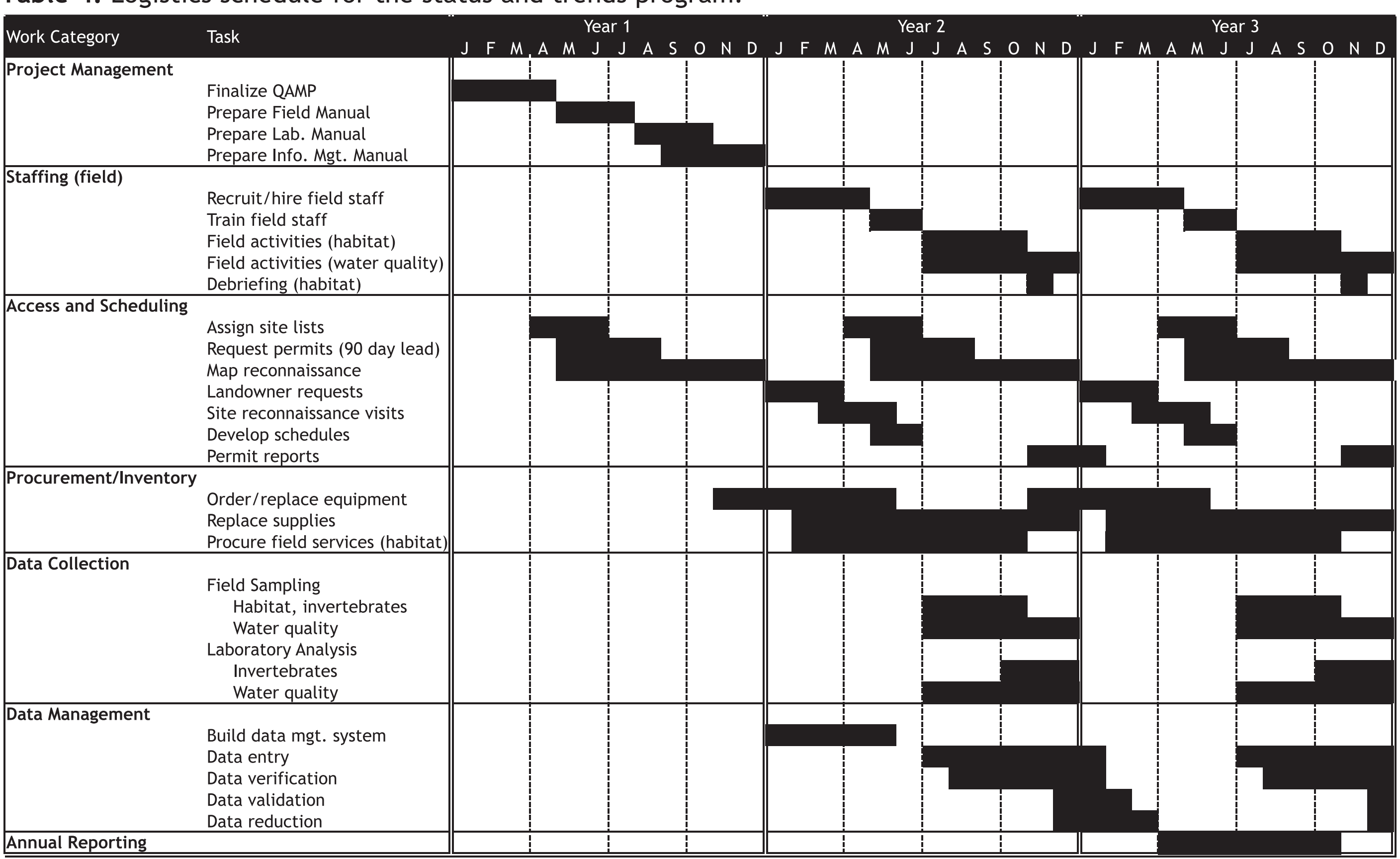
Table 3: Organizations involved, contacts, and duties.

Organization	Contact	Phone	Organization's Duties
Washington State Department of Ecology (Ecology)	Appointed	360-407-6000 (reception)	Project management, data collection, data analysis, and reporting.
U.S. Environmental Protection Agency (EPA)	Appointed	541-754-4600 (reception)	Monitoring design, data integration, and sample draw.
Washington State Conservation Commission	Appointed	360-407-6200 (reception)	Communicate status and trends monitoring procedures to conservation districts, and supply appropriate data to managing agency.
Washington Department of Fish and Wildlife (WDFW)	Appointed	360-902-2200 (reception)	Coordination and summary of fisheries status and trends in Water Resource Inventory Areas (WRIAs) and Salmon Recovery Regions (SRRs).
Participating agencies and volunteer groups	NA		Data collection.

Schedule

A schedule has been developed for implementing the framework, once funded (*Table 4*). The schedule is based on experience from past surveys and on planning elements identified by Baker and Merritt (*1991*).

Table 4: Logistics schedule for the status and trends program.



QAMP - quality assurance monitoring plan

Sampling Design Objectives

The following are objectives for a status and trends framework for Salmon Recovery Regions (SRRs) and for the entire state:

1. Estimate the status of Washington's rivers and streams based on selected habitat and water quality indicators (i.e., estimate the proportion of the streams/rivers that is at or below some threshold value for each indicator), with 80% confidence intervals that are within ±10% of the estimate (from *Paulsen, 1997*).

2. Determine an average change (trend) in condition of Washington's rivers and streams (based on the same indicators) of 20% over eight years with 80% confidence and a statistical power of 0.8 (from *Paulsen, 1997*).

Meeting these objectives by implementing the Status and Trends Monitoring Plan will answer the following questions:

1. Have habitat-limiting factors identified by the National Marine Fisheries Services (NMFS) under the federal Endangered Species Act been improving within the SRRs and the Watershed Resource Inventory Areas (WRIAs)?

2. Has water quality been improving within the SRRs and the WRIAs?

3. Has fish distribution been improving?

The status and trends framework will also help to answer the following questions that were presented in past outlines for largescale monitoring:

Questions from the *Comprehensive Monitoring Strategy* (CMS)

Habitat

◆ What are the overall impacts of human activities on freshwater habitat and landscape processes?
Measure status and trends of freshwater habitat indicators in agricultural, forest, and urban lands:

a. What are the status and trends in habitat quality and quantity within each SRR and WRIA?

b. What is the nature of those trends in urban, agricultural, and forested lands?

c. To what extent are trends in freshwater habitat conditions reflected in trends in fish abundance, distribution, and diversity?

Water

◆ What is the quality of surface water?

◆ How are surface water quality conditions changing over time?

◆ Where do water quality conditions not support aquatic life and recreational uses?

◆ How effective are clean water programs at meeting water quality criteria?

Questions from the Northwest Forest Plan (*Gallo et al., 2005*)

◆ What are the status and trends of identified freshwater habitat and landscape-forming indicators identified in the Aquatic Riparian Effectiveness Monitoring Program (AREMP) and PacFish/InFish (PIBO)?

◆ How effective are treatments at improving the status of habitat and landscape-forming indicators?

Sampling Design

Determining the status and trends of a resource over large geographic regions can be accomplished with a census or random sampling.

Probability-Based Sampling Design and Site Selection

A site-selection method that is based on a randomized sampling approach eliminates bias by randomly selecting sites from the target population. For example, a target population could be the number and area of lakes that are acidic in potentially sensitive areas of the northeastern United States (*Landers et al., 1988*). Lakes randomly selected from this target population will provide unbiased information that can be extrapolated to the population with known certainty.

Determining the status and trends of a resource over large geographic regions can be accomplished with a census or random sampling. A census, by definition, requires every unit of a population to be sampled. Since this approach is often impractical, random samples of the population are taken (i.e., a sample survey) to make statistical inferences about a population with known confidence. In this case, our population is a linear stream network, with results being expressed in terms of length (miles, kilometers) or percent population length.

Target Population and Design Requirements

The survey design is the plan for selecting samples so that they provide the data necessary for developing accurate estimates of the target population. The objectives are to measure the status and trends of selected attributes of Washington's rivers and streams. The target population is Washington's continuous linear network of streams and rivers. We intend to make estimates about the target populations with +/- 10% precision and 80% confidence. Data required to make these inferences would be collected over a four-year sampling period. Design experts from EPA's Western Ecology Division have assisted in developing the design frame and selecting random sampling reaches.

A detailed example for the rotating panel design can be found in Appendix A. Randomly selected sampling points have been identified using the 2006 Washington State Department of Natural Resources (DNR) Hydrography Data Layer (*WDNR, 2006*). The stream line work has been described using a map scale of 1:24,000. The master sample list contains 350,000 stream reaches one kilometer in length. The development of the sampling frame and master sample list is described below.

Sample Frame and Survey Design

To select random reaches, a design frame was constructed: the Washington Master Sample (found at *www.ecy.wa.gov/programs/eap/stsmf/*). DNR, WRIA, and county Geographical Information System (GIS) shapefiles were used to develop this sampling frame. They were obtained from web sites. Data for western Washington were downloaded by county (*http://www3.wadnr.gov/dnrapp6/dataweb/dmmatrix.html*). Data for eastern Washington were downloaded by WRIA (*ftp://198.187.3.44/fp/watertyping/*). They were downloaded on February 22, 2005 and represent the stream network at that point in time. Note that the sample frame has streams mapped at different densities across the state. Densities are greater in "sections" of interest to DNR. A grid system (1 km hexagons) was applied to this network to force geographic spacing (to avoid bunching).

We worked with these spatial data using ArcGIS software. The extent of the GIS coverage is limited to Washington State. The grid system and the 1:24,000 hydrography layer define the reach units. The continuous stream network from which a sample was drawn consists of the intersections of watercourses in the 1:24,000 hydrography layer with the cells in the overlain grid system. Using the Generalized Random Tessellation Stratified (GRTS) survey design, a random sample was drawn from the statewide continuous stream network. This process resulted in a statewide list of sites with equal weight. To obtain the desired sample size, stratification variables can be applied, and stream weights should be adjusted accordingly. Stratification of the sampling sites is meant to account for the variability of stream types in each extent. This is an important step because large sampling extents often have many different stream types with unique physical, chemical, and biological expectations.

Sites can be stratified by the following variables:

- Salmon Recovery Region (SRR)
- Water Resource Inventory Area (WRIA)
- Stream order at 1:100,000 scale (*Strahler, 1957*)
- Level III Ecoregion (*EPA, 2003*)
- Slope
- Others, as necessary

Based on the need for monitoring at two landscape scales, a method for "nesting" sites from the smaller WRIA level needs to occur within the larger SRR level. One four-year period can be compared with the following four-year period for monitoring in a specific landscape area. An annual assessment is possible by using moving averages from data collected during the year. Data can be partitioned based on the large-scale SRR or the smaller-area WRIA for general description of stream conditions. The SRR and WRIA information can be combined to provide statewide level estimates (i.e., a third, larger scale).

If funding is provided to implement this sampling plan, a monitoring rotation including an evaluation of all the SRRs is planned to be completed on a four-year rotation (*Table 5*), so that information is available on a timely basis and assessments do not become outdated. Initial monitoring begins with sites selected to describe conditions in SRRs. Densification of sites in each SRR enables descriptions to be made for WRIAs or smaller landscape areas. This additional monitoring effort is achieved by developing local partnerships with cities, counties, tribes, as well as state and federal agencies.

Table 5: The site sampling rotation in Salmon Recovery Regions (SRRs).

SRR	Yr1	Yr2	Yr3	Yr4
Puget Sound	30	1	1	1
Washington Coastal	30	1	1	1
Lower Columbia	1	30	1	1
Mid-Columbia	1	30	1	1
Upper Columbia	1	1	30	1
Northeast Washington	1	1	30	1
Snake River	1	1	1	30
Unlisted Washington	1	1	1	30
Total	66	66	66	66

Site Selection

We decided to stratify within SRRs using stream order, so that each order would be equally represented (*Table 6*). There are many more kilometers of small streams than large; therefore, the weighting will need to be adjusted. Although ecoregion and slope are not being used for SRR-scale site selection, these factors can be used during the analysis of collected data, so that comparisons can be made with appropriate reference conditions. These factors can also be used to stratify in the WRIA-scale selections, should that be required.

Specific sampling sites will be selected from the EPA-generated "Master Sample" until there are enough sites within each stratum to satisfy acceptable variance requirements for each of the primary regions for monitoring: at least 240 sites statewide (four-year cycle), at least 30 sites per SRR, and locally-determined needs at WRIA scales. This process will continue through the site reconnaissance phase, so that the list contains locations that can safely be sampled with the permission of landowners and permitting agencies. Part of the reconnaissance effort will require coordination amongst all sampling entities, so that no unique site needs to be sampled more than once if it is selected at multiple scales (e.g., SRR and WRIA).

Table 6: Allocation of randomized sample sites within any given Salmon Recovery Region (SRR). Stratification is by Strahler stream order (Strahler, 1957) as on 1:100,000-scale maps.

Stream Order*	Random sample sites per SRR
0	20%
1	20%
2	20%
3	20%
≥4	20%

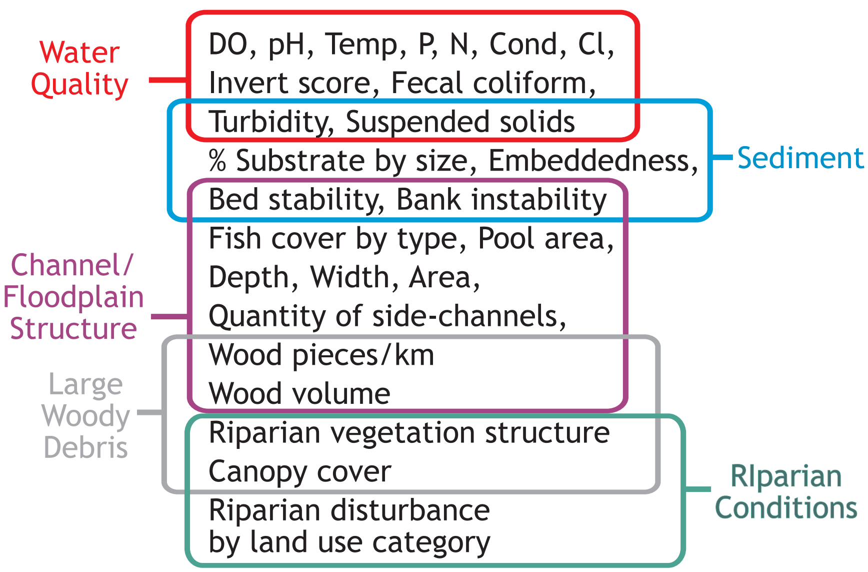
** Stream orders are based on the 1:100,000 scale.*

0 - order streams are those that do not appear on 1:100,000-scale maps but do appear on 1:24,000-scale maps.

Parameters to be Measured

The monitoring protocol is based on sampling techniques that have been broadly applied across the Northwest: those of the Pacific Northwest Aquatic Monitoring Partnership (PNAMP), the Environmental Monitoring and Assessment Program (EMAP), the Aquatic and Riparian Effectiveness Monitoring Program (AREMP), and the Integrated Status and Effectiveness Monitoring Program (ISEMP). The sampling methods are taken from each of these closely-related efforts. Specific protocols are those that we believe to be the simplest, least expensive, and reliable. We therefore believe that these are the best methods for training persons at any level of experience, including volunteers.

Figure 3: The relationship of field-sampled metrics to limiting factors.



We have also proposed to limit the set of basic reporting metrics, based on recent monitoring results from across Washington State (*Merritt, 2006*) and across the Northwest (*Stoddard et al., 2005(2): EPA 620/R-05/005 and EPA 620/R-05/006*). These basic (minimum required) metrics include those with extensive human-caused impairment and metrics that show Relative Risk to instream biology. The list also includes the components of the Washington State Water Quality Index (*Ecology, 2004*). WRIA-level (or smaller) monitoring efforts will be able to add locally appropriate metrics to the basic set to meet locally determined needs.

Human disturbance and alterations to stream regulating processes (characteristics of the riparian zone and upslope) can decrease the amount of high-quality habitat in a region and disrupt the natural processes that regenerate future habitat. We will include attributes that represent landscape-forming processes and are closely related to causes rather than the effects of channel alterations.

Riparian and upslope (catchment) conditions are important to monitor because poor riparian or upslope conditions are often causes of various effects such as low levels of large woody debris (LWD), warm water temperatures, and bank erosion. Also, the time scale of recovery is important. Progress in riparian and upslope recovery can likely be noted in a much shorter timeframe compared to instream LWD conditions. A major purpose of this monitoring program is to report on recovery progress to federal and state administrators, Congress, the State Legislature, and the public; therefore, it is essential that we choose parameters that can accurately portray progress. Metrics that can be measured in either the upslope or riparian areas include those describing land use/land cover categories, vegetation, road density, human density, impervious surfaces, and geology.

The status and trends program will collect data on stream attributes that are directly or indirectly related to salmon and trout environmental requirements. The Pacific Coastal Salmon Recovery Fund (*PCSRF, 2005*) recently identified the major limiting habitat factors that are potentially limiting salmon and trout survival and recovery in Washington State. These are generalized below:

- water quality
- sediment
- riparian conditions
- channel/floodplain structure
- large woody debris
- flow
- estuaries
- predation

We believe that we can address most of these with this monitoring plan. The relationship of metrics to limiting factors is shown in *Figure 3*. Metric descriptions are listed in *Table 7*.

Table 7: Metric descriptions for habitat and water quality monitoring.

Metric	Description	Extensive[2]	Indicates Risk[3]
DO[1]	Dissolved oxygen concentration	●	
pH[1]	pH		
Temp[1]	Water temperature		
P[1]	Total phosphorus concentration		■
N[1]	Total persulfate nitrogen concentration		■
Cond	The electrical conductivity of water		■
Cl	Chloride concentration		■
Invert score	Invertebrate community (e.g., an O/E or MMI score)		
Fecal coliform[1]	Fecal coliform bacteria		
Turbidity[1]	Water turbidity		■
Suspended solids[1]	Total suspended solids concentration		■
% Substrate by size	e.g., % fines or % sand/fines	●	■
Embeddedness	% bottom particles' surfaces that are surrounded by sand/fines		■
Bed stability	Relative bed stability = observed diameter vs. predicted (see: *http://tinyurl.com/nwc8c*)	●	■
Bank instability	% of bank that is unstable (with actively eroding banks)		
Fish cover by type	% of wetted channel with cover	●	■
Pool area	Mean residual pool vertical profile area		■
Depth	Thalweg depth; bankfull depth		
Width	Wetted width; bankfull width		
Area	Bankfull or wetted cross-sectional area (channel capacity)		
Length of side channels	Sum of length of side channels		
Large woody debris (LWD)	Pieces, by length, diameter, and position - standardized to km reach; large wood volume estimated from size class tally		■
Riparian vegetation structure	Riparian vegetation structure (% cover in 3 layers, by type, size)		■
Canopy cover	Percent canopy as measured with a densiometer		■
Riparian disturbance by land use type	Riparian disturbance by humans. This can also be broken down into types of human activities (e.g., agriculture, forestry-related, residential)	●	■

[1] DO, pH, temp, P, N, turbidity, suspended solids, and sometimes fecal coliform are components of the state Water Quality Index (WQI)
[2] Extensive: parameters for which more than 18% of wadeable stream miles of Washington are estimated to be impaired (Merritt, 2006)
[3] Indicates Risk: parameters for which "not good" scores have been associated with poor macroinvertebrate community scores (Merritt, 2006) or which are part of measures that have been associated with "poor" biological scores in ecoregions that enter Washington (Stoddard, 2005a, 2005b)

We expect that the results of the status and trends program will be related to other monitoring efforts that are focused on estuarine and marine monitoring

The PCSRF has also discussed impairment to fish passage as a general limiting factor. We believe that "presence" (distribution) for each aquatic vertebrate species should be a basic metric to help address this limiting factor. This will be compared to the latest mapped distributions as reported by SalmonScape (*http://wdfw.wa.gov/mapping/salmonscape/index.html*) or the Priority Habitats and Species (*http://wdfw.wa.gov/hab/phspage.htm*). Species observations can also be compared to modeled distributions (e.g., *Conrad et al., 2003*, and the *Washington Gap Project, 1997*). The presence of invasive species and predators of salmon (e.g., smallmouth bass or northern pikeminnow) will also be noted.

We will not collect information on habitat access (e.g., dams, hanging culverts), continuous discharge, and estuarine conditions. Habitat access is being inventoried by the Washington Department of Fish and Wildlife (*Table 8*), and inventories of barriers provide a much more complete picture of access conditions than random sampling.

Although the status and trends program will take discharge measurements to help classify sample events during each survey, continuous discharge data from Ecology's Stream Hydrology Unit and the U.S. Geological Survey (*Table 8*) will most likely be used to supplement status and trends results.

Estuarine and marine monitoring is beyond the scope of the status and trends program, even though conditions in these habitats are very relevant to anadromous (sea-run) salmon and trout production. We expect that the results of the status and trends program will be related to other monitoring efforts that are focused on estuarine and marine monitoring (*Table 8*) when the scope of the reporting warrants this type of habitat integration. For example, Ecology and the Washington State Department of Natural Resources have implemented status and trends monitoring of nearshore systems as part of the Puget Sound Assessment and Monitoring Program. Sampling has been conducted following the spatially balanced, random sampling protocol developed by EPA. Samples were collected using both traditional methods as well as remotely sensed data, including LANDSAT and aerial photography.

Table 8: Environmental monitoring programs from which the status and trends program will draw results for periodic reporting.

Program	Acronym	Habitat/Attribute	Website
WDFW Salmon and Steelhead Habitat Inventory and Assessment Program	SSHIAP	Salmonid stock inventory by WRIA	*http://wdfw.wa.gov/hab/sshiap/*
WDFW Salmon and Steelhead Habitat Inventory and Assessment Program	SSHIAP	Fish passage barriers	*http://wdfw.wa.gov/hab/sshiap/*
Ecology Stream Hydrology Unit	SHU	River discharge	*www.ecy.wa.gov/programs/eap/flow/shu_main.html*
U.S. Geological Survey	USGS	River discharge	*http://wa.water.usgs.gov/*
Puget Sound Nearshore Estuarine Restoration Program	PSNERP	Nearshore restoration	*http://sal.ocean.washington.edu/nst/*
Puget Sound Assessment and Monitoring Program*	PSAMP	Marine benthos	*www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html*
Ecology Marine Water Quality Monitoring	(NA)	Marine water quality	*www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html*

WDFW – Washington Department of Fish and Wildlife
Ecology – Washington State Department of Ecology
WRIA – Water Resource Inventory Area
**- previously the Puget Sound Ambient Monitoring Program*

Remote Sensing Parameters

The *Comprehensive Monitoring Strategy* listed remote sensing as a means for determining landscape characteristics such as: (1) road density, (2) percentage of surfaces that are impervious to rain and snow, and (3) quantity of landslide attributes. To approximate these, techniques used in EMAP [e.g., ATtILA metrics (*Wade and Ebert*, *2005*) or other metrics (*Comeleo, 2005, personal communication*)] can be employed based on evaluation of watersheds or stream buffers above each sample point. These include metrics describing land use/land cover characteristics, human stressors, and physical characteristics (*Figure 4*). These landscape metrics can be important in classifying sites according to natural gradients and for describing reference (e.g., "least disturbed") conditions for each natural setting (*Whittier et al., 2006*).

The National Land Cover Data Set (*www.mrlc.gov*) is one basic source for many of these data. Other sources include digital elevation models (DEM) and GIS layers for geology and ecoregions. Input information such as satellite imagery is infrequently generated, so these data are not likely to be useful for rapid trend detection unless imagery is updated more frequently than has been done in the past. The Washington Department of Fish and Wildlife is proposing to acquire high-altitude satellite imagery to be able to compare changes through time.

In the time since the *Comprehensive Monitoring Strategy* recommendation was made, further advances in the technology have expanded what can be evaluated in aquatic and riparian ecosystems. The resolution of remotely sensed images has become greater, and the quality of reach-level characterizations might therefore be possible. However, the ability to apply these techniques to a statewide program needs to be demonstrated. Continual testing of remote sensing technologies will enhance efficiency of evaluations by making a portion of data gathering a desk-top exercise. An experiment to test aerial photography among non-wadeable river and stream sites is provided in Apppendix B of this plan.

The Washington Department of Fish and Wildlife is proposing to use aerial photography to monitor riparian vegetation and other mid-level parameters among 15 watersheds where primary populations of Major Population Groups are concurrently monitored for fish production (number of adults entering freshwater relative to the number of smolts heading seaward). In this way habitat conditions could be directly tied to fish production.

Other imaging techniques, including Light Detection and Ranging (LiDAR), provide spectral images with higher resolution. The "green" version of LiDAR" (*NASA, 2006*) will penetrate water surfaces but presently-available equipment is dedicated almost exclusively to evaluation of hurricane effects in the southeastern United States. LiDAR is advantageous in characterizing stream reaches and not just larger landscape areas. Images generated from LiDAR are related to on-the-ground measurements so that other areas within a drainage or waterbody can be categorized and used to estimate overall condition for aquatic ecosystems.

The USDA Forest Service, Boise Aquatic Sciences Laboratory, is testing green LiDAR to map stream channel bedforms and vegetation and topography in the surrounding floodplain. Their progress should be closely followed. Monitoring efforts in Washington should also try to adapt to new developments in remote sensing technology that are promoted by regional coordination efforts such as the Pacific Northwest Monitoring Partnership (PNAMP).

Figure 4: Example upslope and riparian landscape metrics from Comeleo (2005), Wade and Ebert (2005), and NLDC (2006). Land cover data can be expressed as area or percent area.

- Urban imperviousness
- Road density
- Tree canopy
- Pasture
- Agricultural land (by type)
- Barren land
- Forest land (by types)
- Human land use
- Natural land use
- Natural grassland (by type)
- Shrubland
- Urban
- Wetland (by type)
- Residential (various densities)
- Open water
- Perennial ice/Snow
- Commercial/Industrial /Transportation
- Mining (by types)
- Range
- Level III Ecoregion membership
- Transitional
- Shrubland
- Grasslands/Herbaceous
- Annual runoff
- Annual precipitation
- Population density
- Surficial geologic class
- Estimated aspect of watershed
- Distance to ocean
- Elevation (site, and catchment)
- Watershed slope
- Terrain roughness
- Cattle density on rangeland
- Proportion of ag on >5% slope
- Sample reach slope
- Slope of stream network
- Mode aspect
- Mean aspect
- South aspect

EMAP-style monitoring projects have been conducted in Washington since 1994.

Completeness

A minimum number of samples must be collected for each parameter in order to make inferences about a population or sub-population with a specified level of precision. Generally speaking, 50 sites are required, with an absolute minimum of 30 sites (*Paulsen, 1997*). For within-season and inter-annual repeat visits, we expect to acquire valid data from at least 90% of the cumulative number of sites during a four-year cycle.

Measurements within each indicator may have different completeness requirements, due to variable methodological and logistical rigor. Specific completeness objectives can be found in their respective measurement quality objectives (MQOs) tables in *Part 2* of this document.

Comparability

We will have several field crews collecting data during a given field season. In addition, local agencies and volunteer monitoring groups will likely conduct surveys when sites are located in their jurisdictions. To maintain comparability among these field crews, standard protocols and methods will be used. It will also be important to conduct concurrent training on an annual basis. Water chemistry and biological samples will be evaluated in laboratories with clearly prescribed methods and performance requirements (see *Part 2* of this document). Prior to each field season, within-agency and inter-agency field crews will meet for field method instruction.

EMAP-style monitoring projects have been conducted in Washington since 1994 to characterize stream conditions in watersheds, ecoregions, and statewide. However, each project has had minor modifications in sampling protocols. The challenge will be to determine the usability of some of these data in a standardized statewide monitoring effort. Determination for this inclusion will be evaluated based on making sure that:

- Project field and laboratory protocols overlap with this plan.
- Project performance measures (e.g., accuracy, precision, and sensitivity) are adequate.
- Project design allows for inclusion of comparable resources (e.g., stream types, locations). that provide information for assessment and/or trend detection.

The workgroup identified several sets of habitat and water quality metrics that should be described for status and trends monitoring. These include metrics to describe riparian condition, channel morphology (widening), and sediment condition. In some cases, several protocols exist for the same metric. These methods should be examined and tested to determine their comparability. Results of some comparison tests (*Roper, 2005*) are in production. Eventually, each monitoring effort (statewide, SRR, and WRIA) needs to use the same set of protocols for describing habitat and water quality conditions. The presently planned protocols are described in Part 2 of this document. Results of comparison tests might lead to slight changes that can be described in protocol documents.

Dylan Monahan and Dustin Bilhimer measuring habitat on Copper Creek, Skamania County, 2000.

Representativeness

Representativeness can be expressed in terms of the region being assessed and the parameter being measured. The probabilistic sampling design assures a statistically valid spatial representation at the statewide, SRR, and WRIA scales. We are limiting our surveys to a summer-fall index period to minimize natural variability (i.e., maximize sensitivity to human disturbance), so conclusions from our survey need to be understood in this context. Water quality varies with season, but the summer-fall season is when we expect water quality conditions to be the most deleterious to aquatic life. Many habitat variables, such as channel complexity and shape, are driven by storm events during the winter. However, summer-fall sampling is representative of what channel-forming processes have occurred in past years. In addition, summer-fall sampling at baseflow conditions allows field crews to safely collect information.

Field collection is also more uniform in the sense that measurements are not affected by rising or falling hydrographs. Macroinvertebrate samples are most efficiently collected in the summer-fall index period. Regional biological criteria using macroinvertebrates are based on this index period (*Ostermiller and Hawkins, 2004*; *Wiseman, 2003; Kerans and Karr, 1994; Fore et al., 1996; Barbour et al., 1995, 1996*; and *Karr and Chu, 1999*). Most benthic macroinvertebrates in the Pacific Northwest live for at least one year. As a result, their presence or absence is indicative of year-round conditions at that site.

Measurements and samples taken in the field need to be representative of what they were intended to characterize. To ensure that samples being measured in the laboratory are representative of field conditions, we will follow sample holding-time requirements. We will monitor for accuracy and systematic bias by calibrating equipment properly and checking for meter drift with reference solutions. Finally, precision of our field measurements and samples will be generally evaluated with field duplicates and repeat visits.

Fecal Coliform Monitoring

Bacteriological sampling is normally associated with water quality monitoring programs. Bacteria sampling that measures concentrations of fecal coliform bacteria in surface waters is commonly used to evaluate impairments from agricultural or stormwater runoff. Inclusion of this type of monitoring may be important depending on the monitoring information needs.

There are some logistical problems in combining this type of monitoring with the other water quality monitoring activities. The holding time for fecal coliform samples is sufficiently short (24 hours) so that collection during the habitat and general water quality characterization activities would not be possible. Transport and shipping of time-sensitive bacteriological samples requires additional effort by using independent sampling crews to meet sample holding-time deadlines. There will likely be some sites (e.g., in remote areas) that are inaccessible to fecal coliform sampling.

Chad Brown preparing to sample Dry Creek, Walla Walla County, 2002.
Photo by Jim Garner

Sampling Procedures

Field Sampling

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). A portion of methods from these programs are being tested by PNAMP in comparison studies (*Roper, 2005*). Results of these comparison tests will be used in preparing the final field protocols.

Chemical, biological, and habitat assessment protocols for wadeable streams are well-documented. Many of the wadeable stream protocols are used in large rivers, but logistical constraints arise when water depth increases and river width is broad. Therefore, separate field sampling procedures for non-wadeable rivers and streams were developed.

The following documents are the primary literature for field protocols:

1. For wadeable streams (EMAP): Peck et al.(2003)

2. For non-wadeable rivers and streams (EMAP): Lazorchak et al. (2000)

3. For state fecal coliform methods: Ward et al. (2001)

4. For macroinvertebrate sampling: PNAMP (2006)

5. For aquatic vertebrate distribution in wadeable streams: AREMP (2006)

6. Refinements to habitat sampling by ISEMP: Moberg (2006)

Wadeable Streams

The data from wadeable stream surveys (exclusive of fecal coliform sampling) can be 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 (*Table 9*). Sampling at wadeable streams will be performed along a reach that extends 20 bankfull widths and at least 150 meters (*Figure 5*). Fecal coliform sampling must be performed by a separate two-person crew due to fecal coliform holding time requirements.

Non-wadeable Rivers and Streams

The data collected in non-wadeable river and stream surveys can also be parsed (*Table 10*). However, the individual indicator survey data are collected concurrently as the boat crew works its way down the river. Sampling at non-wadeable rivers and streams will be performed along a reach that extends 100 wetted widths (*Figure 6*).

Table 9: Typical timing of on-site field activities for wadeable streams. This includes all activities except fecal coliform sampling, which must be performed by a separate crew.

Activity	Persons	Hours since arrival				
		1	2	3	4	5
Site verification and layout	A,B	■				
Chemistry samples	C	■				
In situ chemistry	C	■				
Invertebrates and electrofishing	C		■	■		
Physical habitat	A,B,C		■	■	■	■

Table 10: Range of times for non-wadeable rivers/streams field activities (modified from *Lazorchak et al., 2000*).

Activity	Est. Time (hours)
Scout access locations	0 to 1.5
Unload rafts and all equipment	0.5
Shuttle vehicles and set up for float	0.5 to 1.5
Row or float from put-in to start of reach	0 to 1
Conduct field sampling activities	5 to 8
Row or float from end of reach to take-out	0 to 1
Load rafts and shuttle vehicles	0.5 to 1
Sample processing	0.5
Sample tracking and packing	1
Summary	8 to 16

Figure 5: Wadeable stream sampling reach features (modified from AREMP, 2006; Moberg, 2006; and Peck et al., 2003).

At F Transect (middle or "X")
- Water samples
- In situ chemistry
- Flow
- GPS coordinates

At Main transects (solid red)
- Slope and bearing
- Widths (wetted and bankfull)
- Bank heights
- Substrate size, embeddedness, water depth, bankfull depth
- x-section depths (water depth, bankfull depth)
- Bar width
- Bank undercut distance
- Bank instability
- Canopy (shade)
- Fish cover assessment
- Ripanan human disturbance
- Riparian vegetation structure

At Mid-transects (dashed blue)
- Widths (wetted and bankfull)
- Substrate size. embeddedness
- x-section depths (water depth. bankfull depth)

From entire reach length
- Large woody debris by size, position
- Pool habitat assessment
- Thalweg depths (100 points)
- Presence of side channels
- Presence/absence of bars
- Presence/absence of side channels
- Presence/absence of edge habitat (alcoves, etc.)
- Macroinvertebrate composite
- Vertebrate assemblage (fish distribution)

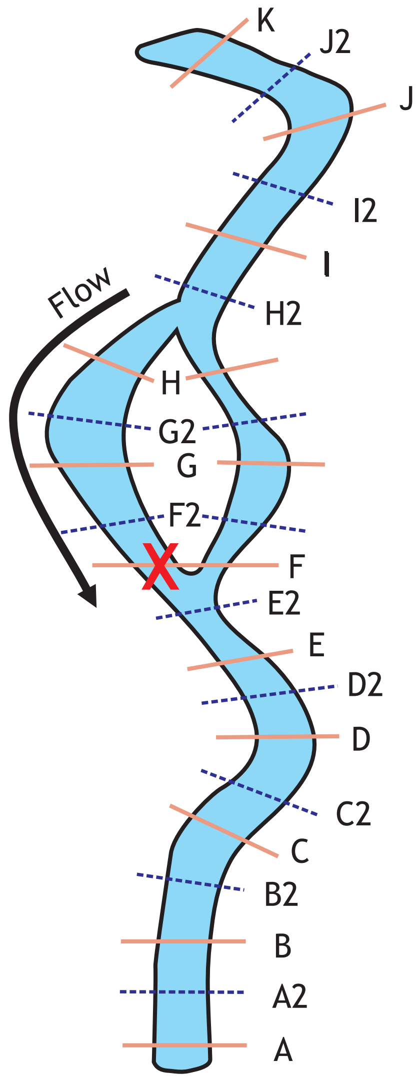
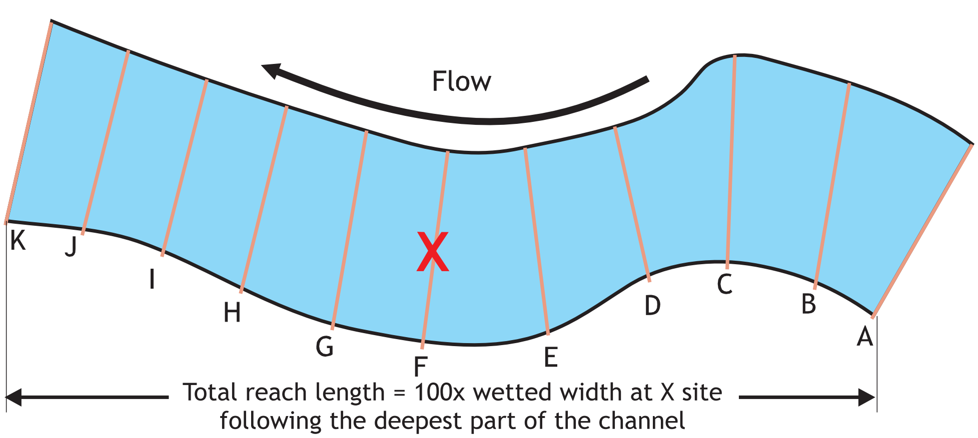


Figure 6: Non-wadeable river/stream sampling reach features (modified from Lazorchak et al., 2000). The distance between each transect along the deepest part of the channel is 10 times the wetted width at the X site (Transect F).



Sample Containers, Identification, Transportation, and Chain of Custody

The generic EMAP sample collection methods are listed here because we believe they would be the easiest for volunteers or occasional field staff to learn. This is because the number of containers, labels, and handling requirements has been kept to a minimum.

There are three containers for water sampling: a 4-L bulk "cubitainer" sample, a 60-ml syringe with Leur-Lok® valve, and an autoclaved microbiology jar. The bulk sample is used to sample for nearly all parameters. The syringe is used for pH. These samples have a 48-hour holding time until processing by the laboratory. Therefore, these samples should be delivered to the laboratory on ice, overnight. If using a courier service, the shipping airbills can be used for tracking. Tracking should also be accomplished with assigned sample identification codes and tracking forms. Samples should not be collected on days prior to laboratory weekends or holidays. Containers for water quality sampling are listed in *Table 11*.

An autoclaved jar is used to sample for fecal coliform bacteria. These have a 24-hour holding time. Where fecal coliform samples are collected, staff should hand-carry the samples to the nearest laboratory or to a commercial airline cargo facility. The shipping airbills can be used to assist for tracking, along with assigned sample identification codes and tracking forms. Timing for fecal coliform collections should be based on how long it takes a laboratory to prepare for processing during the following day. This might mean collecting the sample after 10 a.m. if the laboratory cannot work on the sample prior to 10 a.m. the following day.

Each stream site has one container for a macroinvertebrate composite sample. Gallon-sized zipper bags (about 5) are available at each site, for fish voucher specimens. Each fish species at each site has its specimens separately bagged for freezing.

Table 11: Methods, containers, and treatments for water quality parameters.

Parameter	Method*		Container**	Field Handling	Holding Time***
	Field	Lab.			
Dissolved oxygen	1	n/a	n/a	Measure	n/a
pH (closed system)	1	3	B	Chill	72 hours
Temperature	2	n/a	n/a	Measure	n/a
Fecal coliform (MF)	2	4	C	Chill	24 hrs
Total suspended solids	1	3	A	Chill	48 hrs (then 4 days)
Total nitrogen	1	3	A	Chill	48 hrs (then 28 days)
Total phosphorus	1	3	A	Chill	48 hrs (then 28 days)
Turbidity	1	3	A	Chill	48 hrs (then 3 days)
Chloride	1	3	A	Chill	48 hrs (then 7 days)

** 1 = Peck et al. (2003); 2 = Ward et al. (2001); 3 = EPA (2004); 4 = Ecology (2005).*
*** A = 4-L cubitainer; B = 60-ml syringe with Leur-Lok; C = 250-ml autoclaved.*
**** Holding times in parentheses are after receipt and processing by the laboratory.*
MF = membrane filter method.

Measurement Procedures

Procedures for analyzing water samples and biological samples are recorded in the quality assurance (QA) project plans prepared by Holdsworth (*2004*) and Paulsen (*1997*). The method for field collection of water samples is described in *Figure 7*. Field collection of biological samples according to PNAMP (*2006*) methods is described in *Figure 8*.

Laboratory procedures for chemistry are described in detail in the *Wadeable Streams Assessment Water Chemistry Laboratory Manual* (*EPA, 2004*). We recommend that a field sampling manual be developed for the status and trends program, based on the existing documents cited within this QA monitoring plan. Also, individual QA project plans have been prepared for each of Ecology's projects funded by EPA. These plans provide important documentation to determine comparability of individual projects before combining data sets.

Citations for the specific procedures and protocols are found in the documents listed from EPA, AREMP, PNAMP, ISEMP, and the Department of Ecology (under the *Field Sampling* section in this document). The QA project plans for Ecology's five EMAP projects are available in electronic form. All of the standard operating procedures, final reports, and data can be found at Ecology's web site for Stream Biological Monitoring: *www.ecy.wa.gov/programs/eap/fw_benth/emap-remap.html*. Field procedures and QA project plans for fecal coliform sampling can be found at Ecology's web site for River and Stream Water Quality Monitoring: *www.ecy.wa.gov/programs/eap/fw_riv/rv_methods.html*

Figure 7: Water sampling (modified from *Paulsen, 1997*). Fecal coliform sampling will require another autoclaved jar, not depicted here. The water sample for fecal coliform analysis will be collected from the top of the reach.

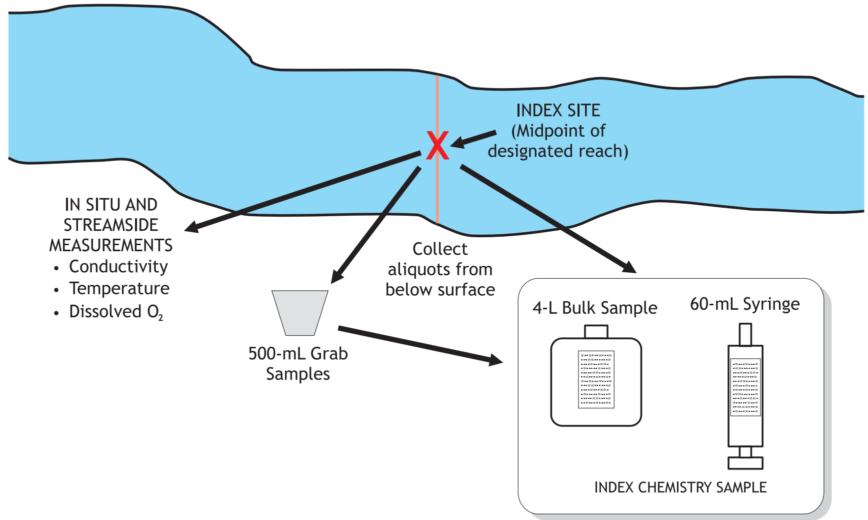
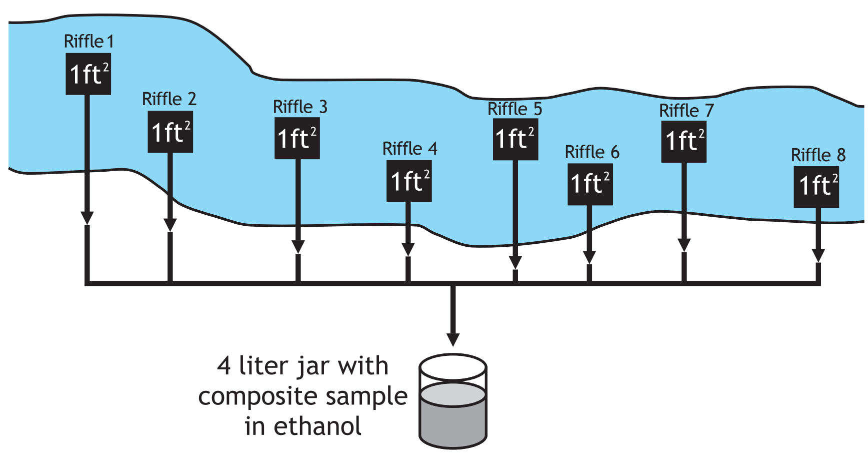


Figure 8: Macroinvertebrate sampling with a 500-μm mesh kick net. In streams without riffles, sampling will be from fast-water locations spread across the reach. In non-wadeable rivers and streams, the sample locations will need to be in wadeable margins.



Quality Control Procedures

Field

Several documents have been prepared that describe the quality assurance (QA) elements for the proposed status and trends monitoring program, including EPA documents for their Western EMAP Rivers and Streams Program and the National Wadeable Streams Program. Each of these documents provides the necessary detail for preparing a QA monitoring plan that would be developed in later phases of the status and trends program planning process. Training of field crews is also an important element for implementing a large-scale program. EPA has historically taken on this role and will be consulted to develop our training program.

Chad Brown and Jim Garner collecting thalweg data on upper French Creek, Wenatchee National Forest, 2001.
Photo by Aspen Madrone

Water Quality Indicator

Quality control procedures are described in the *Water Quality Indicator* section, under Field Quality Control, in Part 2 of this document.

Physical Habitat Indicator

Quality control procedures are described in the *Physical Habitat Indicator* section in Part 2 of this document.

Biological Indicators

Quality control procedures are described in the *Biological Indicators* section in Part 2 of this document.

Laboratory

Laboratory performances are evaluated for data quality using the quality control samples noted below. Results indicate whether the measurement system is functioning properly and whether the measurement quality objectives (MQOs) have been met.

Water Quality Indicator

Quality control samples are described in the *Water Quality Indicator* section, under *Laboratory Quality Control*, in Part 2 of this document.

Biological Indicators

Quality control samples are described in the *Biological Indicators* section in Part 2 of this document.

Data Management Procedures

Database Design

A data management system is one of the most important considerations for successfully achieving and analyzing data collected under this large-scale monitoring program. We have examined some examples for data management for large monitoring programs.

Two examples that were reviewed use approaches that had either free-form or fixed-entry requirements:

1. *The Northwest Fisheries Science Center* (NWFSC; NOAA-Fisheries) has shown one data management system currently under development. The goal of the NWFSC system is to aggregate assessment data from different sources that have different formats. This data management strategy allows for data sets to be stored in the same location, but in their unique formats. Any two data sets will not have the same information, and individual data records from the different sources will not be completely comparable. This strategy allows for access to any existing information stored in electronic form. However, knowing the difference between any two sets of stored data relies on adequate metadata documentation. The developers cautioned that determining data quality is the user's responsibility.

2. *The Surface Waters Information Management* (SWIM) system was developed by an on-site contractor for the EPA Wadeable Streams Assessment (WSA) project completed for the western United States. The scale of this WSA demanded a data management system that could store large quantities of physical habitat, water quality, and biological information. The SWIM system uses a fixed-field format where all information entered uses the same protocols and measures the same variables at each sampling location. Because standardized data collection is the goal of the Status and Trends Monitoring Plan, SWIM appears to be an appropriate data management system template.

This plan proposes that Washington State maintain a master database that incorporates variables measured under the Status and Trends Monitoring Plan. Existing data management systems include Ecology's EIM (Environmental Information Management) and the Washington Department of Fish and Wildlife's SSHIAP (Salmon and Steelhead Habitat Inventory Assessment Program). However, these data management systems currently will not accommodate all of the information generated in the status and trends program.

The content under the following *Data Compilation* section will be developed further, pending the final selection of a data management system for this monitoring program. Each of these three sections under *Data Compilation* will contain the following information categories: Metadata, Parameter Formats, and Standard Coding Systems. For now, these cannot be described in detail:

Crayfish collected during invertebrate sampling, 2000.
Photo by Glenn Merritt

Data Compilation

Site and Geographic Data

Sampling sites are identified by positioning coordinates and by their geographic setting. There are several standard descriptors that will be recorded with sites visited in this monitoring program. The companion information will be compatible with data storage and reporting requirements of those who develop reports from this status and trends information.

(Specific information will be recorded here based on the data management system selected for this monitoring program)

Colchuck Glacier feeding Colchuck Lake, Wenatchee National Forest, 2003.
Photo by Jim Garner

Field Data Collection and Transfer

Examples for collection and transfer of field information differ based on the selection of a data management system. An automated system is described later in this document, in the section titled *Data Management, Review, and Validation*. The system uses scanning technology and electronic transfer. The method for transfer of information will be decided based on the usability and affordability for a data management system adopted by the status and trends program monitoring partnership.

(Specific information will be recorded here based on the data management system selected for this monitoring program)

Laboratory Analyses and Data Transfer

Accredited laboratories will offer reporting of water quality data in electronic form. These data will be reported using a standard set of information that addresses the needs for quality assurance checks, verification, and other auditing requirements. The format for reporting and recording of water quality information will follow a similar design to that of the Environmental Information Management system developed by Ecology. In this way, data generated in this monitoring program can be recorded simultaneously in Ecology's data management system.

(Specific information will be recorded here based on the data management system selected for this monitoring program.)

Audits and Reports

Audits

Audits ensure that quality assurance (QA) monitoring plan elements are implemented correctly. The quality of the data must be determined to be acceptable, and corrective actions must be implemented in a timely manner. There are two components of the auditing process:

1. The *Technical Systems Audit* is a qualitative audit of conformance to the QA monitoring plan. The audit will be conducted soon after work has commenced so that corrective actions can be implemented early in the project. These evaluations include field collection activities, sample transport, laboratory processing, and data management components of the program.

2. *Proficiency Testing* is the quantitative determination of an analyte in a blind standard to evaluate the proficiency of the analyst or laboratory. This audit is included for analysis of water quality samples as a routine procedure in the accredited laboratory. This type of testing is not possible for measurement of physical habitat variables using the suggested protocols in this QA monitoring plan.

Reports

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.

Audits ensure that quality assurance (QA) monitoring plan elements are implemented correctly.

Brian Engeness taking Global Positioning System (GPS) readings on Mill Creek, Chelan County, 2006.
Photo by Jim Garner

Data Analysis and Evaluation of Results

Standard analyses have been developed for EMAP program data. 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.

Ecology staff are trained in the use of on-line data analysis tools and, if needed, can get assistance from the EPA analysts who originally developed them. We have a strong partnership with the EPA in developing and describing results from several monitoring projects in Washington where EMAP monitoring has been completed. Recent developments for analyzing data include determination of habitat and water quality characteristics that are causes for degradation in biological communities (e.g., fish, aquatic invertebrates, amphibians, algae). These results can be used as "high level indicators" in the *State of Salmon* report and sources for pollution identified to explain watershed health and salmon condition evaluations.

Information generated from status and trends monitoring should consider the needs of the *State of Salmon* and NOAA-Fisheries (limiting-factors) reports. The *State of Salmon* report provides information for the following categories: water quality status, water quantity status, habitat quality status, and barriers to fish passage. NOAA-Fisheries must know the status and trends of habitat needed for specific populations of salmon before they can make decisions to list or de-list these populations as threatened or endangered under the Endangered Species Act.

Bull trout from Leland Creek, Chelan County, 2002.
Photo by Glenn Merritt

Data Verification and Validation

The environmental laboratory should verify data prior to issuance of a report to the project leader. This includes a continuous evaluation of laboratory performance through quality control (QC) results (e.g., using control charts).

A manual inspection and evaluation of each datum should be conducted at pre-determined intervals once received from the laboratory. Both field and laboratory data records should be verified against field forms and laboratory reports prior to final validation in the electronic database. At least two personnel should be involved in the verification process to avoid errors from fatigue or oversight. Missing data are identified to ensure that values were not mistakenly overlooked during the data entry process. Printed copies of all stored environmental data should be made to ensure permanent records are available. The printed copy of results can be arranged in a "report" format so that information is useful for browsing.

The following verification and validation steps are the responsibility of the data manager:

Data Verification

- Examine data for errors or omissions as well as compliance with QC acceptance criteria; put laboratory QC results in a case narrative.
- Assign data qualifiers where necessary.
- Verify that the sampling design, methods, and protocols were followed.

Data Validation

Determine whether the measurement quality objectives (MQOs) for precision, bias, and sensitivity were met. Compare QC results to MQO targets.

Missing Data

Missing data are rare. The majority of "missing" data are due to mechanical breakdown, inaccessible sample sites, and samples lost or misplaced during transport by commercial carriers. The effect of sample size, n, can alter interpretations derived from statistical evaluations of the data. Acceptable limits for missing data can be determined, in part, from data requirements of a statistical evaluation. Strict adherence to standard operating procedures and clear communication between field and laboratory personnel are the best measures to prevent lost or misplaced samples.

Loss of a small percentage of data from a long-term monitoring effort will have little impact on the resulting interpretations, but this is not true for sites where a limited amount of information is collected and each data point has a larger influence on the description of water quality conditions.

Jim Garner scouting a sampling site on the Wenatchee River, 2006.
Photo Brian Engeness

Data Quality (Usability) Assessment

Result-level data validation procedures are conducted on a routine basis and prescribed prior to beginning the environmental study. Quality assurance (QA) assessments are made by comparing calculated percent relative standard deviations (RSD) (*see equation below*) to those specified in the measurement quality objectives.

$$RSD = \frac{s}{\overline{X}} \times 100$$

Where

"s" is the standard deviation
"$\overline{X}$" is the sample mean

Duplicate measurements of environmental samples may also be used to estimate precision of the analytical method, but this can include error due to matrix effects. (RSD is also known as the coefficient of variation.)

The results of the analysis of blank samples and known standards will be used to determine overall bias of the results. If a consistent "method bias" is discovered, immediate notification should be made to all data users so that these changes, however small, do not result in poor interpretations from statistical evaluations. Bias due to time of day of collection should be addressed on a site-specific and variable-specific basis as described previously (see the *Representativeness* section in this document).

Project-level QA assessments should be conducted as part of the interim reporting process. Sources of error (e.g., laboratory, field technique, instream spatial) are identified to the extent possible. For water quality parameters that fail data quality objectives, an evaluation of central tendency in variance of sample pairs may be compared by station, season, or sampler in order to identify stations, time periods, or part of the monitoring effort that are the focus for diminished precision.

Ecology staff recording data on the upper Nisqually River, Pierce County, 2000.
Photo by Glenn Merritt

PART 2: Indicators

Water Quality Indicator

Poor water quality can limit salmon and trout presence and production. Excessive sedimentation is probably the most significant water quality issue in streams of Washington (*Merritt, 2006*). A review of the effects on fish and other stream biota can be found in Waters (*1995*). Mobilization of fine sediment into the water column during high-flow events can clog the gill filaments of migrating salmon (*Rand and Petrocelli, 1985*). It can also jeopardize salmonid survival in the wild by disrupting cover-seeking behavior (*Korstrom and Birtwell, 2006*). Subsequent deposition and embedding of cobbles and gravels can cause salmon to avoid otherwise good habitat (*Hillman et al., 1987*). Sedimentation can diminish the quality of spawning gravels, limiting salmon egg incubation success (*Harrison, 1923; Hobbs, 1937; Shapovalov and Berrian, 1940; Shaw and Maga, 1943*; and *Koski, 1966*).

Turbidity and *total suspended sediments* are measures of sediments in the water column.

Other water quality issues include:

◆ **Temperature**: High water temperature is a common seasonal problem in some locations. Chronic and acute high temperatures can effectively block salmonid migration or have sub-lethal effects on aquatic life, limiting the number of young fish joining the stock each year (*Spence et al.*, 1996).

◆ **Total nitrogen and total phosphorus:** Nutrient depletion is a regional problem. Reduced spawning runs across the Northwest have led to diminished levels of marine-derived nutrients and to lower production in stream corridors (*Stockner, 2003*, Scheuerell et al., 2005). The total nitrogen and total phosphorus metrics help to assess nutrient conditions.

◆ **Dissolved oxygen and pH:** Locally elevated nutrients (from human input) and exposure to sunlight can increase algal production, and thereby increase the diel fluctuations of dissolved oxygen and pH. When dissolved oxygen and pH are beyond their normal ranges, they can stress aquatic life.

◆ **Conductivity:** The conductivity metric provides a general indication of dissolved pollutants in the water column, and is typically associated with urban and agricultural land use.

◆ **Chloride:** Chloride has been shown to indicate human-caused impairment to stream biota (*Merritt, 2006*; *Herlihy et al., 1998*).

◆ **Fecal coliform:** The fecal coliform metric provides a general indication of coliform bacteria, which is harmful to human health. Fecal coliform is not related to salmonid environmental requirements, but fecal coliform data should be collected because the state has responsibility for assessing impairments to human recreational uses of our surface waters.

The following sections document the procedures Ecology will follow as a participant in the status and trends program. As such, Ecology's Manchester Environmental Laboratory is cited as the analysis laboratory. However, other groups participating in the sampling effort can follow the same procedures and substitute an accredited laboratory for the references to Manchester Laboratory.

Sampling Procedures

Water quality measurements and samples are the first samples/data collected at each stream. They should be taken in a well-mixed location at mid-reach, also known as the "index site".

Table 12: Preservation requirements: Water quality indicator.

Parameter	Container Type	Sample Volume (ml)	Preservation	Holding Time
Fecal coliform*	Autoclaved Polypropylene	250	Cool to 4°C	1 day
Chloride	Polyethylene	500	Cool to 4°C	28 days
Suspended solids	Polypropylene	1000	Cool to 4°C	7 days
Total nitrogen	Polypropylene	125	Adjust to pH<2 w/ H_2SO_4 and cool to 4°C	28 days
Total phosphorus	Polypropylene	125	Adjust to pH<2 w/ H_2SO_4 and cool to 4°C	28 days
Turbidity	Polypropylene	500	Cool to 4°C	2 days
pH	Syringe with valve	60	Cool to 4°C	2 days

** Sampled by a separate 2-person crew due to its holding time requirements.*

◆ Dissolved oxygen, temperature, and conductivity are each measured once, *in situ*. Temperature and dissolved oxygen can also be measured a second time, before leaving the site, to help calibrate measurements relative to concurrent times on a regional diurnal curve for each parameter.

◆ Turbidity, total suspended solids, and fecal coliform samples are taken below the surface, tagged, and kept cool.

◆ For pH measurement, a 60-cc syringe is collected and sealed without headspace using a Leur-Lok© valve.

◆ A 1000 ml acid-washed polypropylene bottle is used to collect water from the stream for all nutrient samples. Unfiltered nutrient sample bottles are filled from the 1000 ml bottle, acidified (acid already in the bottle), and kept cool.

◆ All samples are transported to Manchester Laboratory for analyses within 24 hours of sample collection.

◆ Fecal coliform will need to be sampled by a separate two-person crew, due to fecal coliform holding time requirements. Therefore the sample date for fecal coliform sampling will likely be different from that of all other parameters.

Preservation requirements for all water samples are listed in *Table 12*.

Measurement Procedures

Table 13 outlines water chemistry analytical methods. All methods are widely accepted and standardized (*APHA, 1998; EPA, 1983; EPA, 1987, EPA 1989*).

Table 13: Methods: Water quality indicator

Analyte	Method	Reference[1 2 3]
Field Constituents		
Oxygen	Membrane electrode, *in situ*	EPA360.1 (EPA, 1983)
Temperature	Thermistor, *in situ*	EPA150.6 (EPA, 1989)
Conductivity	Electrode, *in situ*	EPA 120.6 (EPA, 1989)
Lab Constituents		
pH (closed system)	Glass electrode	EPA150.6 (modified) (EPA, 1987)
Suspended solids	Gravimetric	EPA160.2 (EPA, 1983)
Total nitrogen	Persulfate digestion, cadmium reduction	SM4500NB (APHA, 1998)
Total phosphorus	Persulfate digestion, ascorbic acid	SM4500PI (APHA, 1998)
Turbidity	Nephelometric	SM2130 (APHA, 1998)

1 - EPA 1983 is accessible at this Internet link: http://tinyurl.com/fdzlc
2 - EPA 1987 is accessible at this Internet link: http://tinyurl.com/pznnv
3 - EPA 1989 is accessible at this Internet link: http://tinyurl.com/gphz3

Measurement Quality Objectives

Measurement quality objectives (MQOs) are outlined in *Table 14*. General requirements for comparability and representativeness are addressed in the *Sampling Design* section of this document. Completeness objectives are 95% for each measurement per site type (e.g., EMAP probability sites, revisit sites). Failure to achieve the minimum requirements for a particular site type (e.g., Water Resource Inventory Area, Salmon Recovery Region) results in regional population estimates having wider confidence intervals (*Paulsen, 1997*).

Failure to achieve requirements for repeat and annual revisit samples reduces the precision of estimates of the index period and annual variance components (*Paulsen, 1997*). Precision is assessed by the analysis of field or laboratory duplicates or check standard replicates. Bias is assessed by comparing the measurements of standard solutions to their known values. Seasonal variation will also be assessed by sampling 5% of sites (= 3 sites/year) twice each year. Inter-annual variation is assessed through measures conducted at eight sites that are visited every year.

Quality Control

Field Quality Control

Quality control (QC) of water chemistry in the field consists of performance evaluation (PE) measurements, instrumentation calibration, QC sample measurements, and duplicate measurements (*Table 15* and *Figure 9*). Performance evaluations are checks against the most reliable standards, and are carried out in the laboratory. The dissolved oxygen meters are calibrated daily during each survey, according to the manufacturer's directions. QC checks are done daily, immediately before conducting the in situ measurements.

Table 14: Measurement quality objectives:
Water quality indicator precision reported here is based on within-visit replicates.

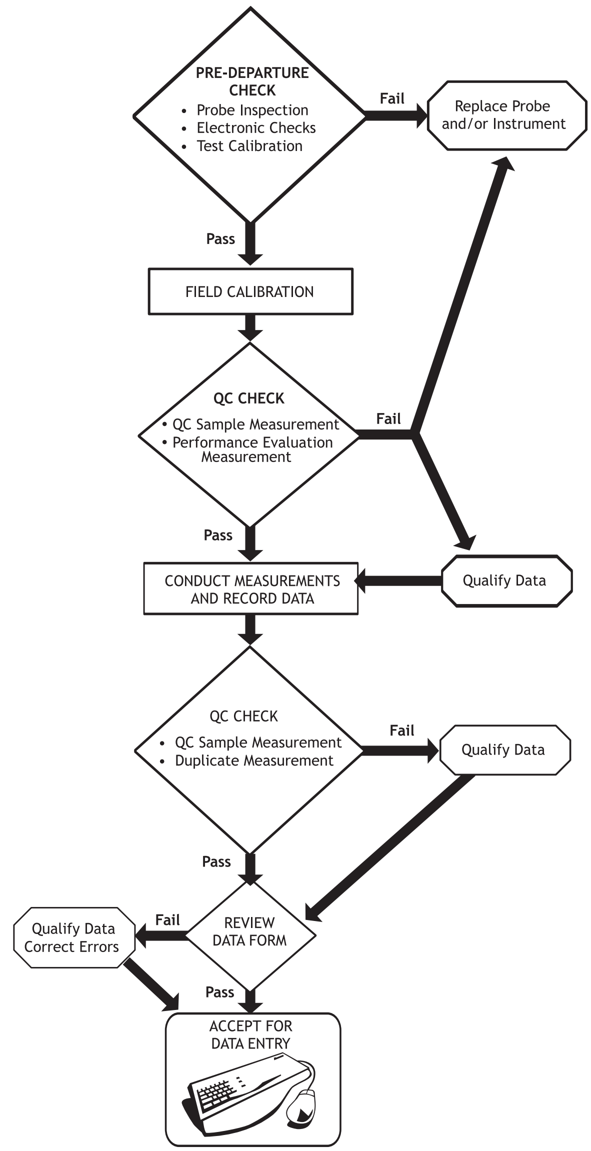
Analyte	**Accuracy** (deviation or % deviation from true value)	**Precision** (% relative standard deviation)	**Bias** (% deviation from true value)	**Lower Reporting Limit**
Field Constituents				
Oxygen	+/- 0.5 mg/L	+/- 0.5 mg/L	NA	NA
Temperature	+/- 1 deg C	+/- 1 deg C	NA	NA
Conductivity	+/- 10 us/cm	+/- 10 us/cm	NA	NA
Lab Constituents				
Fecal coliform	NA	28% RSD	NA	1 colony/ 100 ml
Suspended solids	20%	7% RSD	5%	1 mg/L
Total nitrogen	20%	7% RSD	5%	0.025 mg/L
Total phosphorus	20%	7% RSD	5%	0.01 mg/L
Turbidity	20%	7% RSD	5%	0.5 NTU
pH	+/- 0.075 units (pH < 5.75) +/- 0.15 units (pH > 5.75)	+/- 0.075 units (pH < 5.75) +/- 0.15 units (pH > 5.75)	NA	NA

Table 15: Field quality control measurements: Water quality indicator. (Modified from Paulsen 1997).

Measurement	QC Sample Type	Description	Frequency	Acceptance Criteria	Corrective Action
Dissolved oxygen	PE Sample	Concurrent determination of sample by Winkler titration	Once per meter	Measured oxygen within ± 1 mg/L of oxygen estimated by Winkler titration	Replace meter and/or probe
	QC Check Sample	Water-saturated air	Daily	Instrument can be calibrated to theoretical value	Replace meter and/or probe
Temperature	PE Sample	Concurrent measurement of 0 °C and 25 °C solutions with NIST-traceable thermometer	Once per meter	Within ± 1 °C of thermometer reading	Replace meter and/or probe
	QC Check Sample	Concurrent measurement of sample with field thermometer	Weekly	Within ± 1 °C of thermometer reading	Replace meter and/or probe
Conductivity	QC Check Sample	Solution of known conductivity	Weekly	Within 10 µS/cm of theoretical value	Re-calibrate meter using NIST-traceable standards; replace probe and/or meter

QC - quality control
PE - performance evaluation
NIST - National Institute of Standards and Technology

Figure 9: Field quality control (from Paulsen, 1997).



Laboratory Quality Control

This section has been adapted from the quality assurance (QA) project plan for Ecology's targeted ambient monitoring program (*Hallock and Ehinger, 2003*). The status and trends program will collect a nearly identical array of sample types and will use the same laboratory, Ecology's Manchester Environmental Laboratory, for sample processing. Manchester Laboratory operates a QC program (*Ecology, 2001*). They follow standard operating procedures for individual analyses (*Ecology, 2005*). Manchester Laboratory's QC program includes the analysis of reference materials, check standards, duplicates, matrix spikes, and blanks.

Check Standards

Precision is addressed by the analysis of check standards (water with a known concentration of analyte) equal to about 10% of the total number of analyses. The mean value for a statistically significant number of check standard results may be used to judge whether there is any bias due to calibration. If the 95% confidence limit on the mean value does not include the true or reference value, then bias due to calibration may be present. Generally, calibration standards are set by Manchester Laboratory as needed to bracket the concentration in particular samples. The check standards should equitably span the range of the expected results, ideally approximately 0.2 and 0.9 of the upper value for the range of calibration.

Analytical Duplicates

Laboratory sample splits are analyzed on one of each pair of field-split samples. Using the same sample that was split in the field allows us to better partition sources of error between the laboratory and field. Frequently, Manchester Laboratory will split additional samples as well.

Matrix Spikes

Matrix interference leading to bias is assessed by analyzing river water that has been spiked with a known quantity of the analyte. The quantity of analyte added should not produce a final concentration that is excessively high when compared to the historic range of data (*Table 16*). Spike amounts should approximately double the concentration in the sample prior to spiking.

Blanks

Manchester Laboratory's QC program includes analyzing blank samples according to their internal protocols.

Table 16: Range and 90th percentile of historical ambient water quality samples in Washington State (from *Hallock and Ehinger, 2003*).

Analyte	Units	Expected Range of Results	Approximate 90th percentile
Fecal coliform bacteria	(colonies/100 ml)	<1 to 17,000	120
Suspended solids	(mg/L)	<1 to 1970	41
Total nitrogen	(mg/L)	<0.025 to 16.5	1.2
Total phosphorus	(mg/L)	<0.01 to 2.44	0.104
Turbidity	(NTU)	<1 to 1,900	22

Data Management, Review, and Validation

Field forms will be designed and produced with Teleform software. In the field, each completed form is reviewed for completion and legibility by its respective field team. After the field season, completed field forms are returned to a central location. Each form is scanned, saved as a TIF file, and uploaded into the Teleform program. The software recognizes the field form structure, the expected range, significant figures, etc. of each cell in the field form. The software recognizes suspect values, and flags it for review by the data manager. This software has been thoroughly tested by the EMAP, among others. Field data digitized by Teleform is exported as text files in a format ready for upload by the database. Laboratory data and ancillary QC results will be sent to the data manager in electronic form and uploaded into the database.

Data review and validation checks are outlined in *Table 17*. Data reporting units and significant figures are given in *Table 18*.

Table 17: Data validation: Water quality indicator.

Activity or Procedure	Requirements and Corrective Action
Check data formats and types	Correct reporting errors or qualify as suspect or invalid.
Missing values checks	Verify that the suspected missing value is not zero. If actually missing, determine if there is a substitute alternative that is equal, or if the missing value can be calculated from related data.
Range checks, summary statistics, graphics	Correct reporting errors or qualify as suspect or invalid.
Review holding times	Qualify as appropriate.
Review data from quality assurance (QA) results	Compare with measurement quality objectives (MQOs). Determine impact and possible limitations on overall usability of data.
Illegal value checks	Correct for “inventive coding”.
Logic checks, internal consistency (i.e., if...then...)	Correct reporting errors or qualify as suspect or invalid.

Table 18: Data reporting criteria: Water quality indicator.

Measurement	Units	Number of Significant Figures	Maximum Number of Decimal Places
Conductivity	us/cm	2-3	0
Oxygen	mg/L	2-3	1
pH	Units	3	2
Temperature	°C	2-3	1
Fecal coliform	colonies/100 ml	2-4	0
Suspended solids	mg/L	2-4	0
Total nitrogen	mg/L	2-3	3
Total phosphorus	mg/L	3	4
Turbidity	NTU	2	1

Physical Habitat Indicator

Physical habitat structure and hydraulic characteristics are major drivers of biological integrity and fish production. The natural complexity of these aquatic habitats and the diversity of stream types within a drainage provide the overall conditions necessary to support multiple populations of anadromous (sea-run) salmonids. Salmon benefit from a complex habitat of pools, riffles, and microhabitat variability within these habitat types. The amount of total aquatic habitat and habitat types (e.g., pool distribution) can be quantified. Although the spatial distribution of these quality habitats may shift naturally over time, a stable proportion of these high-quality habitats should be present in large geographic areas in the absence of human disturbance.

This status and trends program is interested in the overall composition of these habitat types over time. Human disturbance and alterations to stream channels, instream processes, the riparian zone, and floodplain characteristics can decrease the amount of high-quality habitat in a region and disrupt the natural processes that regenerate future habitat.

This program will collect stream habitat data that are directly or indirectly related to salmon and trout requirements. The Washington State Conservation Commission (*Smith, 2005*) and the NOAA Pacific Coastal Salmon Recovery Fund (*PCSRF, 2005*) have recently identified attributes that are potentially limiting salmon and trout survival in Washington State (*Table 1* and *Figure 3*). Out of the seven

Table 19: Relevance of measured attributes to salmon and trout habitat requirements: physical habitat indicator.

General Attributes	Variable or Measurement	Relevance to Salmon Habitat Requirements
Channel gradient	Slope	Surface water gradient is used to calculate stream power and bed shear stress. These attributes are required to estimate expectations for spawning gravels and fine sediment pollution.
Channel substrate size and type	Substrate size, embeddedness	Substrate size, distribution, and embeddedness can be evaluated for suitability for spawning, egg incubation, etc. Altered sediment transport from channel and upland erosion can also simplify the channel habitat, affecting juvenile fish habitat.
Habitat complexity, quantity, and cover	Depths, widths, large woody debris, in-channel cover, sinuosity, discharge	Channel dimensions, pool distribution, width variance, and large woody debris distribution are important measures of the complexity of fish habitat. Undercut banks, overhanging vegetation, large woody debris, and boulders provide cover for juvenile fish.
Riparian vegetation cover and structure	Canopy cover at mid-stream and banks, visual estimates of riparian vegetation type, and amount in 3 layers	Canopy moderates water temperature. Roots prevent bank erosion. Riparian trees provide a source of large woody debris. The quality, quantity, and timing of allochthonous leaf material delivered into streams affects food web dynamics that affect fish food sources.
Anthropogenic alterations	Estimated presence/absence of defined types of anthropogenic features in the stream channel and the riparian zone	Channel revetment, pipes, straightening, bridges, culverts, trash, etc. may simplify or eliminate fish habitat. Near-channel alterations may also be diagnostic of instream fish stressors such as altered water quality, fine sediments, etc.
Channel-riparian/ floodplain interaction	Channel sinuosity, incision, and morphometric complexity (based on the spatial pattern and variability in channel width and depth profile data). Length of side channels. Quantity of edge habitat such as alcoves, side pools, and backwaters.	Grazing, farming, flood control, channel revetment, and urbanization can result in the separation of streams from their floodplains and riparian zones. This separation can result in habitat simplification, reduced summer streamflows, and reduced water quality.

limiting factors outlined by Smith (*2005*), there is a critical need for regular ambient monitoring on floodplain, sediment, instream, and riparian processes (*Smith, 2005*).

The physical habitat data collected under the EMAP protocol include the physical habitat limiting factors identified by the Conservation Commission and the PCSRF. Exceptions include access, continuous flow, and estuarine monitoring. As described in the *Sampling Design* section, these parameters are already being monitored by other programs. Another benefit of using EMAP physical habitat protocols is that the components of variability have already been estimated (*Kaufmann, 1999*). *A priori* variance estimates are useful because they indicate how repeatable different measurements are and how they vary across the landscape. Therefore, the status and trends program will use EMAP methods that address the limiting factors identified by the Conservation Commission and the PCSRF. *Table 19* identifies EMAP measurements and relevance to salmon and trout environmental requirements.

The primary categories that should be addressed according to the Status and Trends Workshop participants are the following: *upland processes, riparian condition, floodplain, connectivity, instream features*, and *streamflow.* These appear under categories listed in *Table 19*. These categories will be the "bins" in which protocols are sorted for measuring habitat condition when data are derived from different sources and data are generated using a variety of protocols intended to measure the same physical feature.

Table 20: Precision of physical habitat metrics (Kaufmann 1999, Oregon data).

Variable or Measurement	Metric	S/N = $\sigma^2_{st(yr)} / \sigma^2_{rep}$
Thalweg Profile		
Thalweg depth	Thalweg mean depth	6.9
Wetted width	Mean wetted width	14
Thalweg depth, wetted width	Residual pool vertical profile Area (m2/reach)	17
	Mean residual depth (m2/100 m = cm)	9
	Number of residual pools with depth > 73 cm (number/reach)	8.2
	Mean residual pool vertical profile area (m2/pool)	6.8
Woody Debris Tally		
Large woody debris	Log10(C1WM100) – LWD, all sizes (pieces/100 m)	7
	Log10(V1WM100) – LWD volume, all sizes (m3/100 m)	12
Channel and Riparian Cross-Sections		
Slope	Mean channel gradient (%)	24
Substrate size	% Substrate – by size class	Up to 16
	Mean substrate size class (0 to 6)	23
Bank undercut	Mean bankfull lateral undercut distance (m)	*
Bankfull width	Mean bankfull width (m)	24
Bankfull height	Mean bankfull height (m)	3.5
Canopy cover	Canopy cover midstream - densiometer (%)	15
	Canopy cover at bank - densiometer (%)	17
Riparian vegetation structure	Both canopy and mid-layer present (proportion of riparian)	7.9
	3-Layers of vegetation present (proportion of riparian)	8
Fish cover areal proportion	Different types	Up to 6.2
Human influence	Riparian human disturbance (proximity-weighted) by type	Up to 18

** Refined method. There are no signal-to-noise data available yet.*

Sampling Procedures

Physical habitat methods are summarized in *Table 20*. Detailed method descriptions can be found in the references. All measurements and observations are recorded on standardized forms and entered into a centralized database. All data are collected in the field. No laboratory analyses are required, but detailed computations are required to derive metrics. Precision estimates are listed in *Table 21*.

Measurement Procedures

Physical habitat data are collected with the sampling procedures outlined in *Table 20*.

Table 21: Methods: Physical habitat indicator.

Variable or Measurement	Units	Summary of Method	References
Thalweg Profile			
Thalweg depth	cm	Measure maximum depth at 100-150 points along reach with surveyor's rod and meter stick.	Peck et al., 2003 Lazorchak et al., 2000
Pool depth	cm	Maximum depth and crest depth of each pool.	Hillman, 2004 Moberg, 2006
Pool type	class	Visually estimate channel habitat using defined class descriptions, and estimate pool forming characters.	Hillman, 2004 Moberg, 2006
Side channel length,	0.5 m	Length of side channel as determined from thalweg station positions.	Hillman, 2004 Moberg, 2006
Edge habitat	count	Count the number and position of each: alcoves, backwaters, and side pools.	Moberg, 2006
Woody Debris Tally			
Large woody debris	number of pieces	Visually estimate amount of woody debris in bankfull channel using defined class descriptions.	Hillman, 2004 Moberg, 2006
Channel and Riparian Cross-Sections			
Slope	percent slope	Sight between cross-section stations using clinometer (or hand level), monopod, and surveyor's rod.	Peck et al., 2003 Lazorchak et al., 2000 Moberg, 2006
Sinuosity (bearing + distance)	compass degrees	Sight between cross-section stations using a compass.	Peck et al., 2003 Lazorchak et al., 2000 Moberg, 2006
Substrate Size	mm	At each of at least 11 points on each of 21 cross sections, estimate size class of one selected particle using defined class descriptions.	Moberg, 2006
Embeddedness	percent	At each of at least 11 points on each of 21 cross sections, estimate embeddedness of one selected particle.	Moberg, 2006
Bank undercut	cm	Measure horizontal distance of undercut at bankfull surface	Moberg, 2006
Bankfull width Wetted width	0.1 m	Measure width at top of bankfull height. Measure width of water surface.	Peck et al., 2003 Lazorchak et al., 2000
Bankfull height Bankfull depth	cm	Measure height from water surface to estimated water surface during bankfull flow. Add thalweg depth to obtain bankfull depth.	Peck et al., 2003 Lazorchak et al., 2000
Canopy cover	points of intersection	Count points of intersection on densiometer at specific points and directions on cross-sections.	Peck et al., 2003 Lazorchak et al., 2000
Riparian vegetation structure	percent	Observations of ground cover, under story, and canopy types and coverage of area 5 m on either side of cross section and 10 m back from bank.	Peck et al., 2003 Lazorchak et al., 2000
Fish cover	percent	Visually estimate in-channel features 5 m on either side of cross section.	Peck et al., 2003 Lazorchak et al., 2000
Human influence	none	Estimate presence/absence of defined types of anthropogenic features such as bank hardening, levees, straightening bridges, pipes, and other impairments.	Peck et al., 2003 Lazorchak et al., 2000
Discharge	cubic meters per second	Velocity-Area method, *or* Portable Weir method, *or* Timed bucket discharge method.	Peck et al., 2003

Measurement Quality Objectives

Measurement quality objectives are outlined in *Table 22*. General requirements for comparability and representativeness are addressed in the *Sampling Design* section.

Precision will be assessed by within-season replicates (six sites annually or 10%) and between-season replicates (eight sites annually: representing each SRR-based monitoring region).

Table 22: Measurement quality objectives: Physical habitat.

Variable or Measurement	Precision	Accuracy	Completeness
Field measurements and observations	+/- 10%	NA	90%
Map-based measurements	+/- 10%	NA	100%

Table 23: Field quality control measures: Physical habitat.

Check Description	Frequency	Acceptance Criteria	Corrective Action
Check totals for cover class categories (vegetation type, fish cover)	Each transect	Sum must be reasonable	Repeat observations
Check completeness of thalweg depth measurements	Each site	Depth measurements for all sampling points	Obtain best estimate of depth where actual measurement not possible
Check calibration of current velocity meter	Prior to each use	Specific to instrument	Adjust and recalibrate, use alternative method

Table 24: Data review and validation checks.

Check Description	Frequency	Acceptance Criteria	Corrective Action
Compare field estimates to those determined from recent aerial photographs	Each stream for which aerial photograph is available	Estimates should be within 10%	Flag data
Estimate precision of measurements based on repeat visits by different crews	Each revisit stream	Measurements should be within 10%	Review data for reasonableness; determine if acceptance criteria need to be modified

Completeness objectives are 90% for field measurements and 100% for map-based measurements. The completeness objectives are established for each measurement per site type (e.g., probability sites, revisit sites). Failure to achieve the minimum requirements for a particular site type (e.g., Water Resource Inventory Area, Salmon Recovery Region) results in regional population estimates having wider confidence intervals (*Paulsen, 1997*). Failure to achieve requirements for repeat and annual revisit samples reduces the precision of estimates of index period and annual variance components (*Paulsen, 1997*).

Quality Control

Field Quality Control

Field quality control measures are listed in *Table 23*

Data Management, Review, and Validation

Field forms will be designed and produced with Teleform software. In the field, each completed form is reviewed by its respective field team for completion and legibility. After the field season, completed field forms are returned to a central location. Each form is scanned, saved as a TIF file, and uploaded into the Teleform program. The software recognizes the field form structure, the expected range, and significant figures of each cell in the field form. The software recognizes suspect values and flags them for review by the data manager. This software has been thoroughly tested by the EMAP, among others. Field data digitized by Teleform are exported as text files in a format ready for upload by the database. Data review and validation checks are outlined in *Table 24*.

Biological Indicators

Benthic macroinvertebrate assemblages (e.g., aquatic insects, crustaceans) are found in the bottom sediments of streams and rivers. They are a critical food source for trout and salmon, and also share many of their environmental requirements. Thus, benthic macroinvertebrates serve as a representative indicator of aquatic life use. The macroinvertebrate assemblage indicator is used primarily to assess the cumulative effects of environmental stressors on aquatic life and to monitor trends. However, since benthic macroinvertebrate communities respond in predictable ways to many physical and chemical stressors, they can often be used to determine and prioritize stressors (*Klemm et al., 1990*).

Aquatic vertebrate assemblage descriptions are important for determining the extent of distribution and migratory patterns over time. Therefore we will calculate the length of stream in which species are found outside of their known/estimated range.

Indices of Biotic Integrity (IBI; e.g., Whittier et al., in press) can serve to indicate environmental (e.g., water quality/physical) conditions and provide a direct measure of stream health. For example, Hughes et al. (*2004*) found that low IBI scores in the Coast Range Ecoregion of Oregon and Washington were associated with low values for bed stability, instream cover, riparian cover, and structural complexity but high values for percent fine substrate, road density, and human disturbances of riparian areas.

Few fish species naturally inhabit Washington's streams that are far from the ocean or that have been recently glaciated (*Hocutt and Wiley, 1986*); this might limit the effectiveness of applying an IBI in some areas of the state. Whittier et al. (*2006*) suggest that it might be a challenge to apply IBI-type assessments of mountain streams in the Northwest based on just fish assemblages. We will try to develop and apply an IBI based on the aquatic vertebrate assemblage, including fish and amphibians.

Sampling Procedures

Macroinvertebrate Community

Macroinvertebrate sampling procedures follow the procedures for wadeable streams outlined by PNAMP *(2006)*, ISEMP (*Moberg, 2006*), and EMAP (*Peck et al., 2003; targeted habitat procedure*). Eight 1-ft^2 (929-cm^2) samples are collected in the reach. Within the reach, at least one macroinvertebrate sample is collected per riffle. Each riffle is mentally subdivided into 9ths in order to locate the sampling location (*Figure 10*). If less than eight riffles are present in the reach, additional samples are allocated to riffles at random. The eight samples are combined into a composite, and preserved with 95% ethanol (*Figure 8*). In flowing water where distinct riffles are not present, eight separate kicks will be collected from locations spread across the reach. For non-wadeable rivers and streams, kick samples will need to be taken from margins that can be waded.

Figure 10: Possible sampling locations within each riffle. Divide the riffle into 9ths and then randomly select a number between 1 and 9. In the case pictured, staff selected number 6 and would therefore collect a sample from the middle-right portion of the riffle. This process is repeated for each of eight riffles in the stream reach.

1	2	3
4	5	6
7	8	9

Aquatic Vertebrate Assemblage

Note: This sampling can only occur if work can be accomplished under Section 4(d) rules of the Endangered Species Act (ESA).

Methods for sampling aquatic vertebrate species assemblages are fully described in AREMP (*2006*) and Lazorchak et al. (*2000*). Sampling fish communities is conducted using a single pass with an electrofishing apparatus across the stream reach. Electrofisher settings will be adjusted to meet conductivity, substrate, and permit conditions. Specimens will be handled as little as possible. Representative members of all species will be photographed. Fish species that are difficult to identify in the field will be sampled for voucher specimens (excluding species listed under the ESA). Up to five individuals will be sampled for each select species at each stream reach. Specimens will be placed on ice and delivered frozen to an in-state museum for identification and cataloging. Freezing allows for subsequent genetic analysis.

Table 25: Methods: *Benthic macroinvertebrates.*

Variable or Measurement	Summary of Method	References
Sample collection	One-man D-frame kick net (500 micron mesh) used to collect benthos from 8 sq. ft. of stream bottom (targeted)	PNAMP (2006) Peck et al. (2003)
Sorting and enumeration	Random systematic selection of grids with target of 500+ organisms from the sample	PNAMP (2006) Plotnikoff and Wiseman (2001)
Identification	Lowest practical level	NBAW (2002) *www.xerces.org/aquatic/standard.htm*

Table 26: Methods: *Aquatic vertebrates.*

Variable or Measurement	Summary of Method	References
Sample collection	Single-pass electrofishing: Streams - backpack; Rivers - raft mounted	*Streams* - AREMP, 2006 *Rivers* - Lazorchak et al., 2000
Vouchers	Freeze up to 5 specimens for hard-to-identify (unlisted) fishes (allows for genetic analysis). Send to an in-state museum for verification and cataloging. Photos of all species.	Katherine P. Maslenikov, Collections Manager, University of Washington Fish Collection (personal communication)
Identification	Species	Wydoski and Whitney, 2003 Pollard et al, 1997 Corkran and Thoms, 2006

Measurement Procedures

Macroinvertebrate Community

In the laboratory, at least 500 macroinvertebrates will be sorted out of each composite sample in a random systematic fashion (*Table 25*). The macroinvertebrates will be identified to the lowest practical level, typically genus. This level of identification has been adopted by the Pacific Northwest Taxonomic Workgroup as a reasonable standard.

Aquatic Vertebrate Assemblage

The vertebrate assemblage will be sampled according to methods outlined in *Table 26*. We will resolve discrepancies between field and museum identifications. Then using GIS, we will calculate the length of stream (km) for which vertebrates extend beyond their current known range. The given site coordinates from the master sample list will be used as the location of species occurrence.

The Washington Department of Fish and Wildlife (WDFW) SalmonScape web application describes the status of existing maps for distribution of salmon, steelhead, and bull trout/Dolly Varden. Maps have been drawn at the 1:24,000 scale. See: *http://wdfw.wa.gov/mapping/salmonscape/index.html*; see "help," and then "data availability." Data for other vertebrates may be available from the WDFW Priority Habitats and Species program (WDFW-PHS, 2004; *www.wdfw.wa.gov/hab/release.htm*).

We can also calculate the length of stream (km) where species occur above species distribution boundaries that have been defined by models (e.g., *Conrad et al., 2003*; *Washington Gap Project, 1997*).

Measurement Quality Objectives

Measurement quality objectives (MQOs) for the biological indicators represent the maximum allowable criteria for statistical control purposes (*Table 27*). The general comparability and representativeness requirements are given in the *Sampling Design* section.

Sorting precision is calculated as percent sorting efficiency. At least 10% of our sample residues (i.e., sample material remaining after initial sort) are examined for overlooked organisms. If more than 5% of the organisms in the original sort are found in the residues, the entire sample is resorted. Sorting accuracy is measured by having another technician completely resort random residues. The number of organisms should be within 10% of the original number of organisms sorted.

Taxonomic precision is calculated by percent agreement between two taxonomists in the contract laboratory. When different taxonomic identifications are made for the same organism, the difference is either reconciled in-house or, if necessary, sent to another laboratory to reconcile the problem.

Taxonomic accuracy is measured by having another experienced taxonomist conduct independent identifications of a subset of the samples. Overall accuracy in identifications is estimated with the approach developed by EMAP:

$$Accuracy(\%) = \frac{N_t - (n_i + |n_c|)}{N_t} \times 100$$

where N_t is the sum of the number of specimens counted in the original sample and the number of additional specimens found during the repeat enumeration, n_i is the number of specimens incorrectly identified in the initial analysis, and n_c is the number of specimens that were mis-counted in the original analysis.

Precision requirements for our biological endpoint are based on model performance characteristics. RIVPACS (River InVertebrate Prediction and Classification System) is a model that predicts probabilities of aquatic invertebrates occurring in western streams (*Ostermiller and Hawkins, 2004*). The number of observed taxa (O) at a test site is divided by the expected taxa (E), yielding a ratio. A ratio of 1.0 indicates that all expected taxa are present. As a site becomes more degraded, fewer expected taxa are observed, yielding a smaller ratio. The EPA (*Stoddard et al., 2005a, 2005b*) set a threshold of 0.8 for western streams. Scores below 0.8 were considered to be disturbed, having lost 20% or more of their expected taxa.

Completeness objectives apply to each site type (delineated by stratification scheme). Loss of samples results in population estimates with wider confidence intervals.

Table 27: Measurement quality objectives: Biological communities.

Variable or Measurement	Accuracy	Precision	Completeness
Sort and pick (macroinvertebrates)	90%	95% (sorting efficiency)	99%
Identification	90%	95% (internal agreement)	99%
Analytical endpoint (RIVPACS; Multimetric Indices)	NA	Compare to previous EMAP variance estimates	99%

Benthic invertebrate sample from the Chiwawa River, Chelan County, 2006.
Photo by Brian Engeness

Quality Control

Specific quality control measures for field and laboratory operations are listed in *Tables 28* and *29*.

Table 28: Field quality control: Biological communities.

Check or Sample Description	Frequency	Acceptance Criteria	Corrective Action
Inspect kick net	Prior to each use	No holes or tears, no foreign matter on nets	Repair, clean, or replace net as necessary
Time collection with stopwatch	20 seconds kicking, and 60 seconds picking	Required time ± 3 seconds to ensure consistency of collection at each site	Add time or repeat sample
Check net	Each collection site	No clinging organisms	Remove any clinging organisms and add to sample
Inspect electrofishing equipment	Prior to each use	Electrical equipment working. Nets without holes.	Repair or replace
Inspect photographic equipment	Prior to each use	Equipment working including time/date stamp	Repair or replace
Verify field ID of vertebrate species	As needed	Confident agreement between separate field staff using certified keys	Record tentative IDs until resolved by vouchers, photographs

Table 29: Laboratory and analytical quality control: Biological communities.

Variable or Measurement	Check or Sample Description	Frequency	Acceptance Criteria	Corrective Action
Sorting of invertebrates	Sample residuals examined by different analyst within lab	10% of all samples completed	Efficiency of sorting > 95%	If efficiency 90-95%, examine all residuals from future samples picked by that analyst until 95% efficiency gained. If <90%, examine all residuals of samples by that analyst and retrain analyst.
Identification of invertebrates	Duplicate identification by different taxonomist within lab	10% of all samples completed per taxonomist	Agreement > 95%	If efficiency 90-95%, retrain taxonomist. If less than 90%, re-identify all samples completed by that taxonomist.
Sort and identification of invertebrates	Re-sort and identify	One of each within-season revisit pair	Accuracy of sorting and identification >90%	If picking or taxonomic accuracy <90%, all samples in batch will be re-analyzed.
Identification of uncertain taxa	Independent identification	All uncertain taxa	Uncertain identifications to be confirmed by expert in particular taxa	Record both tentative and independent IDs until resolved.
Identification	Use standard references	For all identifications	All keys and references used must be in a bibliography prepared by lab manager or museum	If other references desired, verify with professional taxonomists and record the citation.
Identification of invertebrates	Prepare reference collection	All taxa in first batch, all new taxa encountered thereafter	Complete reference collection to be maintained by laboratory manager	Lab manager periodically reviews data and reference collection to ensure reference collection is complete and identifications are accurate.
Analytical endpoint score	Inter-annual panel sites	8 same sites every year	Compare to previous EMAP estimates of inter-annual variance	Have sampling crews review protocols and determine if any different procedures occurred.
	Within-season duplicate surveys	10% of surveys each year	Compare to previous EMAP estimates of error variance	

Data Management, Review, and Validation

Taxonomic data will be delivered from the taxonomic laboratory in electronic record format, with site name, sample ID, and Integrated Taxonomic Information System (ITIS) Taxonomic Serial Numbers (TSNs). For invertebrate data, this should also include raw count and the proportion of the sample that was sorted. Quality control information associated with each batch of samples will be attached in a separate spreadsheet. A biologist with contract oversight will check the taxonomic files for "reasonableness" (*Table 30*). Taxonomic data should be comprised of taxa known to occur in the geographic area in which the sample was taken, and in the target habitat from which the sample was collected. TSNs should be valid and verified by cross-checking against the ITIS standard, available online at *www.itis.usda.gov/index.html*

Table 30: Data validation quality control: Biological communities.

Check or Sample Description	Frequency	Acceptance Criteria	Corrective Action
Taxonomic "reasonableness" checks	All data sets	Species or genera known to occur in given stream conditions or geographic areas	Second or third identification by expert for that taxa. Genetic analysis of vertebrates where necessary.

Dylan Monahan collecting habitat data on Jack Creek, Chelan County, 2006.
Photo by Jim Garner.

Riparian and Upland Landscape Indicators

Uplands describe the land area contributing water, nutrients, energy, and sediment to streams. Uplands are often referred to as watersheds, catchments, basins, and hydrologic units. A riparian zone is a defined buffer surrounding each stream. Landscape characteristics and land use/land cover information of uplands and riparian zones can be used to make correlations with instream habitat and biology.

This plan for status and trends monitoring is not intended to describe cause and effect relationships, but only to be descriptive and provide clues to process relationships that can be explored more fully through effectiveness and validation monitoring studies (e.g. the Intensively Monitored Watersheds (IMW) studies).

Upland/riparian metrics to be recorded for the status and trends framework are listed in *Figure 4*, most of which are derived from satellite imagery. Of the metrics listed in *Figure 4*, we believe that the most important to capture are in *Table 31*.

Table 31: Important landscape metrics and source data.

Metric	Source Data
Urban imperviousness	National Land Cover Data[1]
Road density	U.S. Geological Survey digital line graph data[2]
Percent human land use	National Land Cover Data[1]
Population density (human)	U.S. Census Bureau cartographic boundary files[3]
Percent agricultural land use	National Land Cover Data[1]
Percent urban land use	National Land Cover Data[1]
Level III Ecoregion	EPA Ecoregion layer[4]
Site elevation	Digital elevation model[5]
Surficial geologic class	Geology of Washington State[6]

Links to data sources:
1 - *www.mrlc.gov/index.asp*; 2 - *http://eros.usgs.gov/guides/dlg.html*; 3 - *www.census.gov/geo/www/cob/*
4 - *www.epa.gov/wed/pages/ecoregions/level_iii.htm*; 5 - *http://eros.usgs.gov/guides/dem.html*
6 - *www.dnr.wa.gov/geology/dig100k.htm*

Pacific tree frog near the Chiwawa River, Chelan County 2006.
Photo by Brian Engeness

References

APHA, 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington, D.C.

AREMP, 2006. Field Protocols Manual, Aquatic and Riparian Effectiveness Monitoring Program. Regional Interagency Monitoring for the Pacific Northwest Forest Plan, 2006 Field Season.

Baker, J.R. and G.D. Merritt, 1991. Environmental Monitoring and Assessment Program: Guidelines for Preparing Logistics Plans. U.S. Environmental Protection Agency, Las Vegas, NV. EPA 600/4-91-001.

Barbour, M.T., J.B. Stribling, and J.R. Karr, 1995. Multimetric approach for establishing biocriteria and measuring biological condition. Pages 63-77 in W.S. Davis and T.P. Simon (editors). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White, and M.L. Bastian, 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. Journal of the North American Benthological Society 15(2):185-211.

Comeleo, 2005. Personal communication (10/11/05) from Randy L. Comeleo, Senior GIS Analyst, Indus Corporation, contracted to U.S. EPA, Corvallis, OR.

Conrad, R., B. Fransen, S. Duke, M. Liermann, and S. Needham, 2003. The Development and Assessment of the Preliminary Model for Identifying Fish Habitat in Western Washington. Washington State Department of Natural Resources, Olympia, WA.

Corkran, C.C. and Thoms, C., 2006. Amphibians of Oregon, Washington and British Columbia - A Field Identification Guide. Lone Pine Publishing, Redmond, WA.

Ecology, 2001. Quality Assurance Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Ecology, 2004. A Water Quality Index for Washington State Streams (Version 3a, 25 Jun 04). *www.ecy.wa.gov/programs/eap/fw_riv/docs/WQIOverview.html*

Ecology, 2005. Manchester Environmental Laboratory Lab Users Manual, 8th Edition. Washington State Department of Ecology, Manchester, WA.

EPA, 1983. Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency. EPA/600/4-79/020. *http://tinyurl.com/fdzlc*

EPA, 1987. Handbook of Methods for Acid Deposition Studies: Laboratory Analyses for Surface Water Chemistry. U.S. Environmental Protection Agency. EPA/600/4-87/026. *http://tinyurl.com/pznnv*

EPA, 1989. Handbook of Methods for Acid Deposition Studies: Field Methods for Surface Water Chemistry. U.S. Environmental Protection Agency. EPA/600/4-89/020. *http://tinyurl.com/gphz3*

EPA, 2003. Revision to Omernik, J.M. 1987. Ecoregions of the United States: Map at a scale of 1:7,500,000. Suppl. Annals American Assoc. Geogr. 77(1). U.S. Environmental Protection Agency. *www.epa.gov/wed/pages/ecoregions/level_iii.htm*

EPA, 2004. National Wadeable Streams Assessment: Water Chemistry Laboratory Manual. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C. EPA/841-B-04-008. *http://tinyurl.com/8zdbf*

Fore, L.S., J.R. Karr, and R.W. Wisseman, 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of the North American Benthological Society. 15: 212-231.

Gallo, Kirsten, Steven H. Lanigan, Peter Eldred, Sean N. Gordon, and Chris Moyer, 2005. Northwest Forest Plan – The first 10 years (1994-2003): Preliminary Assessment of the Condition of Watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 133 pp. *www.fs.fed.us/pnw/publications/pnw_gtr647/.*

Governor's Forum on Monitoring, 2005. April 14, 2005 Meeting of the Governor's Forum on Monitoring Salmon Recovery and Watershed Health. *www.iac.wa.gov/monitoring/minutes.htm*

GSRO, 2004. Governor's Salmon Recovery Office, 2004 State of Salmon in Watersheds Report. *www.governor.wa.gov/gsro/publications/sosreport/2004/default.htm*

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 28 pp*.

Harrison, C.W., 1923. Planting eyed salmon and trout eggs. Transactions of the American Fisheries Society 53:191-200.

Herlihy, A.T., John L. Stoddard, and Colleen Burch Johnson, 1998. The relationship between stream chemistry and watershed land cover data in the Mid-Atlantic region, U.S. Water, Air, and Soil Pollution 105:377-386.

Hillman, T.W. J.S. Griffith, and W.S. Platts, 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream. Transactions of the American Fisheries Society 116:185-195.

Hillman, T.W., 2004 (February). Draft Monitoring Strategy For The Upper Columbia Basin, Prepared for the Upper Columbia Regional Technical Team and the Upper Columbia Salmon Recovery Board. BioAnalysts, Inc., Eagle, Idaho. *http://tinyurl.com/6bmwb*

Hobbs, D.F., 1937. Natural Reproduction of Quinnat Salmon, Brown and Rainbow Trout in Certain New Zealand Waters. Fisheries Bulletin 6. New Zealand Marine Department, Wellington.

Hocutt, Charles H., and E O. Wiley (editors), 1986. The Zoogeography of North American Freshwater Fishes. Wiley-Interscience, 880 pages.

Holdsworth, S., 2004. Wadeable Streams Assessment: Quality Assurance Project Plan. U.S. Environmental Protection Agency, Office of Water, Office of Environmental Information. Washington, D.C. EPA 841-B-04-005. 71 pp.

Hughes, R.M., S. Howlin, and P.R. Kaufmann, 2004. A biointegrity index for coldwater streams of western Oregon and Washington. Transactions of the American Fisheries Society 133:1497-1515. WED-00-036.

Karr, J.R. and E.W. Chu, 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington, D.C.

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

Kerans, B.L. and J.R. Karr, 1994. A benthic index of biological integrity (B-IBI) for rivers of the Tennessee Valley. Ecological Applications 4:768- 785.

Klemm, D.J., P.A. Lewis, F. Fulk., and J.M. Lazorchak, 1990. Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters. U.S. Environmental Protection Agency. EPA/600-4-90/030. *http://tinyurl.com/jbnzz*

Korstrom, J.S. and I.K. Birtwell, 2006. Effects of suspended sediment on the escape behavior and cover-seeking response of juvenile chinook salmon in freshwater. Transactions of the American Fisheries Society, Vol. 135 (4): 1006–1016.

Koski, K.V., 1966. The Survival of Coho Salmon (Oncorhynchus kisutch) from Egg Deposition to Emergence in Three Oregon Coastal Streams. M.S. thesis. Oregon State University, Corvallis, OR.

Landers, D.H., W.S. Overton, R.A. Linthurst, and D.F. Brakke, 1988. Eastern Lake Survey: Regional estimates of lake chemistry. Environmental Science and Technology 22:128-135.

Lazorchak, J.M, B.H. Hill, D.K. Averill, D.V. Peck, and D.J. Klemm (editors), 2000. Environmental Monitoring and Assessment Program-Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Non-wadeable Rivers and Streams. Cincinnati (OH): U.S. Environmental Protection Agency. Report nr EPA/620/R-00/007. 204 pp. *www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/nonws1.html*

Merritt, Glenn D., 2006. Status of Washington's Wadeable Streams. Presented at the 17th Northwest Biological Assessment Workgroup Meeting, Post Falls, Idaho. November 1-3, 2006.

Moberg, Jeremy, 2006. A Field Manual for the Habitat Protocols of the Upper Columbia Monitoring Strategy. Final Draft of the 2006 Working Version. Terraqua, Inc. Wauconda, WA. 31 pp. June 7, 2006.

Monitoring Oversight Committee, 2002a. The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery. Volume 1, Executive Report. *www.iac.wa.gov/monitoring/docs.htm*

Monitoring Oversight Committee, 2002b. The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery. Volume 2, Comprehensive Strategy. *www.iac.wa.gov/monitoring/docs.htm*

Monitoring Oversight Committee, 2002c. The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery. Volume 3, Action Plan. *www.iac.wa.gov/monitoring/docs.htm*

NASA, 2006. EAARL: Experimental Advanced Airborne Research LiDAR. National Aeronautic and Space Administration. *http://inst.wff.nasa.gov/eaarl/*.

NBAW, 2002. Northwest Biological Assessment Workgroup, Taxonomic Work Group. Draft Standard Taxonomic List for the Northwest (northern California, Idaho, Oregon, and Washington). *www.xerces.org/aquatic/standard.htm*

NLDC, 2006. National Landcover Data Set, Downloads for Zone 1. *www.mrlc.gov/zones/show_data.asp?szone=1*

Ostermiller, Jeffrey D. and Charles P. Hawkins, 2004. Effects of sampling error on bioassessments of stream ecosystems: application to RIVPACS-type models. Journal of the North American Benthological Society: Vol. 23, No. 2, pp. 363–382.

Paulsen, S., 1997. Environmental Monitoring and Assessment Program: Integrated Quality Assurance Project Plan for Surface Waters Research Activities. U.S. Environmental Protection Agency, Office of Research and Development, Corvallis, OR. 129 pp.

PCSRF, 2005. Pacific Coastal Salmon Recovery Fund FY2000-2004: 2005 Report to Congress. National Marine Fisheries Service, Seattle, WA. *www.nwr.noaa.gov/Salmon-Recovery-Planning/PCSRF/index.cfm*

Peck, D., J.M. Lazorchak, and D.J. Klemm (editors), 2003. Environmental Monitoring and Assessment Program – Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. U.S. Environmental Protection Agency, Western Ecology Division, Corvallis, OR. *www.epa.gov/r10earth/offices/oea/ieu/WADEABLE_MANUAL_APR_2003.pdf*

Plotnikoff, R. and C. Wiseman, 2001. Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams: 2001 Revision. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-028. *www.ecy.wa.gov/biblio/0103028.html*

PNAMP, 2006. Draft Field and Laboratory Methods for the Collection of Benthic Macroinvertebrates in Wadeable Streams of the Pacific Northwest. Pacific Northwest Aquatic Monitoring Partnership.

Pollard, W.R., G.F. Hartman, C. Groot, and P. Edgell, 1997. Field Identification of Coastal Juvenile Salmonids. Harbour Publishing, Madeira Park, B.C., Canada. 32 pp.

Rand, G.M. and S.R. Petrocelli (editors), 1985. Fundamentals of Aquatic Toxicology: Methods and Applications. Hemisphere Publishing Corporation, Washington, D.C.

Roper, B., 2005. Overview: 2005 Protocol Comparison Test. *www.nwcouncil.org/news/2006_01/4.pdf.*

Scheuerell, M.D., P.S. Levin, R.W. Zabel, J.G. Williams, and B.L. Sanderson, 2005. A new perspective on the importance of marine-derived nutrients to threatened stocks of Pacific salmon (Oncorhynchus spp.). Canadian Journal of Fisheries and Aquatic Sciences 62: 961-964.

Shapovalov, L. and W. Berrian, 1940. An experiment in hatching silver salmon Oncorhynchus kisutch eggs in gravel. Transactions of the American Fisheries Society 69:135-140.

Shaw, P.A. and J.A. Maga, 1943. The effect of mining silt on yield of fry from salmon spawning beds. California Fish and Game 2929-41.

Smith, C.J., 2005. Salmon Habitat Limiting Factors in Washington State. Washington State Conservation Commission, Olympia, WA. 222 pp. *http://filecab.scc.wa.gov/index.html?DIR=Special_Programs/Limiting_Factors*

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki, 1996. An Ecosystem Approach to Salmonid Conservation. 21TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR. Available from the National Marine Fisheries Service, Portland, OR. *www.nwr.noaa.gov/Publications/Guidance-Documents/ManTech-Report*.cfm

Stockner, J.G. (editor), 2003. Nutrients in salmonid ecosystems: sustaining production and biodiversity. American Fisheries Society, Symposium 34, Bethesda, Maryland.

Stoddard, J.L., D.V. Peck, A.R. Olsen, D.P. Larsen, J. Van Sickle, C.P. Hawkins, R.M. Hughes, T.R. Whittier, G. Lomnicky, A.T. Herlihy, P.R. Kaufmann, S.A. Peterson, P.L. Ringold, S.G. Paulsen, and R. Blair, 2005a. Environmental Monitoring and Assessment Program (EMAP) Western Streams and Rivers Statistical Summary. U.S. Environmental Protection Agency, Washington, D.C. EPA620/R-05/006. *www.epa.gov/nheerl/arm/documents/EMAP.W.Statistical.Summary.Final.pd*f

Stoddard, J.L., D.V. Peck, A.R. Olsen, S.G. Paulsen, J. Van Sickle, A.T. Herlihy, P.R. Kaufmann, R.M. Hughes, T.R. Whittier, G. Lomnicky, D.P. Larsen, S.A. Peterson, and P.L. Ringold, 2005b. Ecological Assessment of Western Streams and Rivers. U.S. Environmental Protection Agency, Washington, D.C. EPA620/R-05/005. *www.epa.gov/nheerl/arm/documents/EMAP.W.Assessment.final.pdf*

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

Wade, T.G. and D.W. Ebert, 2005. Analytical Tools Interface For Landscape Assessments (ATtILA) User Manual. U.S. Environmental Protection Agency, Washington, D.C. EPA/600/R-04/083. *www.epa.gov/esd/land-sci/attila/manual/userman.htm*

Ward, W., B. Hopkins, D. Hallock, C. Wiseman, R. Plotnikoff, and W. Ehinger, 2001. Stream Sampling Protocols for the Environmental Monitoring and Trends Section. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-036. *www.ecy.wa.gov/biblio/0103036.html*

Washington Gap Project, 1997. Washington Department of Fish and Wildlife. Gap Data Products. Vertebrate distribution models for reptiles & amphibians. *www.wdfw.wa.gov/wlm/gap/herps.htm*.

Waters, T.F., 1995. Sediment in Streams, Sources, Biological Effects and Control. American Fisheries Society Monograph 7.

WDFW-PHS, 2004. Washington Department of Fish and Wildlife Priority Habitats and Species GIS Database. Olympia, WA. *http://wdfw.wa.gov/hab/phspage.htm*

WDNR, 2006. Statewide Watercourse Layer (WC.AAT). Washington State Department of Natural Resources, Forest Practices Division, Olympia, WA. August, 2006. *http://www3.wadnr.gov/dnrapp6/dataweb/dmmatrix.html.*

Whittier, T. R., J. L. Stoddard, R. M. Hughes, and G. A. Lomnicky, 2006. Associations among catchment- and site-scale disturbance indicators and biological assemblages at least- and most-disturbed stream and river sites in the Western United States. Pages 641-664 in R.M. Hughes, L. Wang, and P.W. Seelbach (editors). Landscape influences on stream habitats and biological assemblages. American Fisheries Society, Symposium 48, Bethesda, Maryland.

Whittier, T.R., R.M. Hughes, J.L. Stoddard, G.A. Lomnicky, D.V. Peck and A.T. Herlihy, (In press). A structured approach for developing indices of biotic integrity: three examples from western USA streams and rivers. Transactions of the American Fisheries Society.

Wiseman, C.D., 2003. Multi-Metric Index Development for Biological Monitoring in Washington State Streams. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-035. *www.ecy.wa.gov/biblio/0303035.html*

Wydoski, R.S. and R.R. Whitney, 2003. Inland Fishes of Washington, Second Edition. American Fisheries Society, Bethesda, Maryland.

Waterfall in the
William O. Douglas Wilderness,
2000.
Photo by Glenn Merritt

Appendices

Appendix A
A Rotating Panel Design

Table A-1 shows an example of how sites are sampled on a rotating panel design through a five-year period and a sample size of 50. The landscape area is represented by Salmon Recovery Region (SRR), Major Population Group (MPG), Ecoregion, Water Resource Inventory Area (WRIA), or Hydrologic Unit Code (HUC) 12.

The design will be based on the objectives of the monitoring program and questions developed for the monitoring program.

Table A-1: Number of sites sampled in each landscape area (by year).

Landscape Area*	2007	2008	2009	2010	2011
Area 1	50	1	1	1	1
Area 2	1	50	1	1	1
Area 3	1	1	50	1	1
Area 4	1	1	1	50	1
Area 5	1	1	1	1	50

* Landscape Area *is determined from the focus of the monitoring program (e.g., anadromous salmon populations, water quality conditions, cumulative improvements in small watersheds)*

Dark panels - *unique sites for regional assessment*

Light panels - *inter-annual replicate sites (an identical site per Landscape Area is sampled each year)*

Sites are randomly selected within each landscape area. At least 30-50 sites should be selected for sampling within the SRR, WRIA, or HUC 12.

Sites are identified through the Washington "Master Sample" draw described earlier in this document. This draw represents an oversampling in order to be used for multiple landscape areas and over several years.

Appendix B
Method Development: Aerial Photographic Sampling of Non-wadeable Rivers and Streams

We are proposing a study to develop methods and expertise in the use of low-level, high-resolution aerial photographs to collect data in order to monitor the status and trends of the condition of non-wadeable rivers and streams in Washington. Non-wadeable rivers and streams are important to salmon.

These larger, non-wadeable streams are much less numerous than small streams. The non-wadeable streams are mostly located on non-federal lands.

It might be possible to efficiently and precisely measure many of their physical attributes using low-level, large-scale aerial photography. Attributes amenable to sampling via aerial photography include wetted width, channel migration zone width, off-channel habitat measurement, riparian zone area, and large wood counts. Aerial photographs also provide historical records of attribute conditions, and can be re-analyzed as better methods are developed and the importance of different attributes is determined.

Although the use of aerial photography to sample non-wadeable rivers and streams has been suggested (*Beechie et al., 2002*), its use for status and trends monitoring has not yet been demonstrated. Possible advantages are listed below:

- Photographs of a set of sites can be taken in a short time span reducing temporal variability.
- Site access is more certain.
- Photographs provide a permanent record of the site that allows for development of new evaluation methods at a later date.

Table B-1: Attributes and associated statistics proposed for testing by aerial photography in non-wadeable rivers and streams.

Attribute	Statistic
Channel width	Mean width, variation in width
Off-channel pools	Off-channel pool area
Side channels	Side channel area
Floodplain width	Mean width, variation in width
Large wood count	Wood abundance
Emergent vegetation	% estimated fish cover from emergent vegetation
Riparian roads	Crossing, density
Riparian use	Land use type, density
Riparian width	Mean width, variation in width
Riparian cover	% area vegetated

If suitable aerial photography methods are developed, they can be used to implement status and trends monitoring possibly at a low cost. The aerial photographic sampling will be accompanied by field data to make comparisons for precision and effort.

For the proposed study, ten streams from the Master Sample list will be delineated. Locations will be selected to represent a range of environmental conditions for non-wadeable rivers and streams. Samples will consist of one (or a few) digital orthographic, true color photographs taken at low elevations to provide sub 1-foot resolution. Photographic samples will include an area approximately 1.2 km wide and 2.5 km long. Photographs will be taken parallel to streamflow and be positioned to include the streambank and riparian zone because these include the attributes of primary interest. The width of some non-wadeable rivers and streams may be greater than the width of a photographic sample. In such cases additional photographic samples will be taken.

Attributes will be measured manually using a GIS. Attributes will include riparian zone structure and size, off-channel pool and channel area, large wood abundance, proximity to roads or human land uses, bank armoring, and floodplain connectivity (*Table B-1*). These are attributes that could help describe *State of the Salmon Report* limiting factors such as floodplain/channel structure, riparian conditions, and large woody debris.

Reference:

Beechie, T.J., G.R. Pess, E. Beamer, G. Luchetti, and R. Bilby, 2002. Role of watershed assessments in recovery planning for salmon. Chapter 8 in Montgomery, D.R., S. Bolton, L. Wall, and D. Booth (editors). Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA. 512 pp.

Steep hike back after EMAP sampling in the William O. Douglas Wilderness.