7 MONITORING AND RESEARCH

7.1 Overview

As noted repeatedly in this plan, our knowledge and understanding of the biology, complex life histories, and ecosystem relationships varies considerably among the fish and wildlife species of interest. Some species, such as Chinook salmon, have been studied and researched extensively. Others, such as Pacific lamprey, have received relatively little attention. For no species is our knowledge and understanding complete, nor is it ever likely to be so. In short, this plan requests actions from fish managers, agency administrators, tribal leaders, elected officials, and the public based on imperfect and incomplete information. However, to delay all action until more studies and research can be completed risks further deterioration of the species and ecosystems upon which they depend. For some species, such a delay could substantially increase the risk of extinction.

This plan attempts to make the best use of our current knowledge of the fish and wildlife species and ecosystem processes and conditions to chart a course to recovery or viability that can be implemented now with reasonable confidence that it will achieve its stated goals and objectives. In this regard, a recovery program is fundamentally an experiment. Based on our acquired knowledge and understanding, the plan has constructed working hypotheses regarding focal species and their response to changes in ecosystem conditions or management practices.

While science can identify a reasonable course of action, it will never be able to predict with precise certainty whether a prescribed set of actions will be sufficient to meet objectives. Uncertainties exist and must be managed. Working hypotheses provide a sound basis for identifying and scaling a suite of appropriate recovery actions but substantial refinements in the scope and focus of measures will be needed as the recovery effort unfolds. Some measures may not produce the desired effects. Other measures will exceed expectations. Unexpected events will occur. A robust and adaptive monitoring, research, and evaluation framework will be critical for weighing progress toward recovery and making appropriate course adjustments along the way.

Monitoring, research, and evaluation elements of this plan were adapted from and are consistent with other regional strategies and plans developed by the ISAB (2003), SRFB (2002), NOAA (2003), and UCRIT (2004), and PNAMP (2004). The various programs describe monitoring in slightly different terms but generally address the same goal (UCRIT 2004). The ISAB described an integrated 3-tier monitoring program for assessing recovery of tributary habitat based on trend or routine monitoring, statistical monitoring, and experimental research monitoring. The SFRB program identified five purposes for monitoring including status and trend (extensive) monitoring, implementation monitoring, project effectiveness monitoring, validation monitoring, and compliance monitoring. NOAA working with the Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation, developed a detailed and intensive research, monitoring, and evaluation plan for implementing the 2000 Federal Columbia River Power System Biological Opinion (FCRPS). The FCRPS plan included six principle components; population and environmental status monitoring, action effectiveness research, critical uncertainty research, implementation/compliance monitoring, data management, regional coordination. UCRIT draws from existing strategies to develop a monitoring approach specific to the upper Columbia Basin. PNAMP developed guidance for subbasin planners based on a synthesis of existing strategies and plans. This guidance included a series of considerations regarding monitoring objectives, monitoring indicators, data and information archiving, coordination and implementation, and logic paths.

The measures in this plan are based on a series of strategies that provide overarching approaches for achieving plan objectives and working hypotheses or assumptions that underlie selection and definition of strategies. This plan identifies specific measures for monitoring of biological status, habitat status, action effectiveness, and implementation/compliance. Biological status monitoring describes progress toward ESU recovery objectives and also establishes a baseline for evaluating causal relationships between limiting factors and a population response. Habitat status monitoring identifies the cumulative effect of human activity trends and recovery measures on critical limiting factors. Action effectiveness monitoring determines if specific habitat, hydropower, hatchery, harvest, and ecological interaction measures produce the specific intended effect. Implementation/compliance monitoring evaluates whether actions were implemented as planned or meet established laws, rules, or benchmarks.

This plan also identifies potential topics for critical uncertainty research that target specific issues that constrain effective recovery plan implementation. Critical uncertainty research includes evaluations of cause and effect relationships between fish, limiting factors, and actions that address specific threats related to limiting factors.

Evaluation measures describe a process for interpreting results of monitoring and research, assessing the deviation from particular target goals or anticipated results, and recommending appropriate modifications to strategies, measures, and actions identified in this recovery plan.

Coordination and data management measures are included to ensure efficient implementation of a comprehensive and complementary program as well as accessibility and effective application of the associated data.

Monitoring, research, and evaluation measures detailed in this plan provide the key elements of a coordinated regional program supporting the plan's salmon recovery and fish and wildlife management efforts. Included are objectives, indicators, sampling approaches, and methods of analysis. Also included are an inventory of existing programs and new elements. This plan provides the framework for a systematic regional approach. It generally identifies what needs to be done and how to do it. It does not drill down into specific implementation details such as desired confidence levels, statistical power, data collection protocols, sample sizes, etc. These details will depend on additional refinements to the monitoring, research, and evaluation elements of this plan that will be developed as implementation planning proceeds. Refinements will be predicated on the availability of resources for conducting an integrated monitoring, research, and evaluation program.

7.2 Working Hypotheses

1. ***Successful implementation of this recovery/subbasin plan is predicated on an effective monitoring, research, and evaluation plan. Working hypotheses upon which this plan is based provide clear direction but many hypotheses are uncertain. Future course corrections will be required based on MR&E.***
2. ***Programmatic "top-down" and project "bottom up" monitoring, research, and evaluation approaches each provide useful guidance and an effective plan will incorporate elements of both approaches.***
3. ***Existing programs meet many but not all MR&E needs of this plan.***
4. ***There are direct tradeoffs in time and resource costs between MR&E and recovery actions that more directly affect species of interest.***
5. ***It is not feasible to fund and implement projects to monitor, research, or evaluate every focal fish population, uncertainty or action.***

7.3 Strategies

1. ***Develop a programmatic regional framework for monitoring, research and evaluation to address Ecosystem and ESU-wide concerns of fish recovery.***
2. ***Recognize different spatial and temporal scales appropriate to a variety of programmatic and project-specific applications of monitoring, research, and evaluation with a framework that incorporates routine and statistical status monitoring, action effectiveness monitoring, implementation monitoring, and critical uncertainty research.***
3. ***Optimize efficiencies by incorporating and adapting existing monitoring, research, and evaluation activities into the plan.***
4. ***Utilize other Columbia Basin ecosystem and oceanographic monitoring, research, and evaluation efforts.***
5. ***Identify information gaps that need to be addressed with new monitoring and evaluation activities while also balancing a recognition that the available resources limit implementation to the highest priorities and that tradeoffs exist between MR&E activities and measures that more directly contribute to fish recovery.***
6. ***Focus selected monitoring and research activities in intensively monitored watersheds (IWAs) to optimize opportunities for identifying cause and effect relationships while also providing cost efficiencies.***
7. ***Focus research on the effective implementation of recovery measures rather than detailed mechanistic studies of relationships between fish and limiting factors.***
8. ***Incorporate provisions for regional coordination and data distribution to maximize accessibility and applicability.***
9. ***Incorporate an adaptive evaluation framework with clear decisions points and direction to guide future actions.***

7.4 Biological Status Monitoring

Biological status monitoring describes progress toward ESU recovery objectives and also establishes a baseline for evaluating causal relationships between limiting factors and a population response. Status monitoring involves routine and in-depth efforts. ISAB (2003) defines routine monitoring as repeated measurements of a selected series of units over a period of time to quantify and distinguish changes from background noise. For the purpose of this plan, in-depth monitoring is defined as an extension of routine monitoring with repeated measurements over a broader series of units with greater frequency and duration.

The following section presents an overview of routine and in-depth biological monitoring, followed by a graphical monitoring summary by species. Objectives, indicators, sampling strategies and analysis for each type of monitoring have been identified along with the logic trail used to select monitored populations. Rather than prescribing one monitoring strategy, three scenarios are proposed ranging in level of effort and cost from high to low (Level 1-3 respectively). Given the fact that routine monitoring is ongoing, only in-depth monitoring varies between each level. Preliminary cost estimates and funding considerations are included for relative points of comparison between the various monitoring levels.

7.4.1 Routine Monitoring

Routine monitoring for Washington lower Columbia basin consists of adult spawning escapement estimates collected annually as part of ongoing monitoring efforts. Table 1 provides a summary of current monitoring by species, basin and data type. Additional efforts will be required to achieve minimum goals for routine monitoring. The primary objective of routine monitoring can be summarized as follows:

1. ***Monitor trends and variation in annual adult spawning abundance and distribution of representative populations of Chinook, chum, coho, and steelhead in all watersheds.***

   Objective: Current population size and changes relative to objectives
   Indicator: Estimates of absolute or relative abundance from counts of live fish, carcasses, or redds
   Sampling: Representative long term index sites (dams, weirs, snorkel, ground or aerial surveys)
   Analysis: Annualized population growth rate and persistence probabilities

The goal of routine monitoring will be to produce annual adult abundance estimates for all populations included in Table 1 where those species are present. The purpose of the routine monitoring program would be to track abundance status of listed stocks for the purposes of determining if actions taken as a result of this plan are achieving their desired results and if abundance of listed stocks is progressing towards recovery. Routine monitoring is currently being conducted in a majority of watersheds for most species; however, current effort levels for coho are not adequate for the purposes of monitoring the status of an ESA listed stock. Additional adult coho surveys will be required in some streams, especially Washington tributaries. Additional sampling efforts will also be required to adequately monitor chum salmon populations for ESA recovery purposes. Many adult spawning surveys are currently funded with "soft funds" and continued funding will need to be solidified. Moreover, the current funding provides the minimum resources needed to count fish and redds and does not include monies to conduct a thorough investigation of the accuracy of the methods used to estimate total adult spawning escapement.

Table 1. Current biological status monitoring activities by subbasin and species.

		Fall Chinook (tule)	Fall Chinook (bright)	Spring Chinook	Chum	Winter steelhead[7]	Summer steelhead	Coho[11]
COAST[1]	Grays/Chinook	AA	--	--	AA/JM[5]	AA	--	PA
	Elochoman/Skamokawa	AA	--	--	AA	AA	--	PA
	Mill/Abernathy/Germany	AA	--	--	AA	AA/JI[8]	--	PA/JA
	Youngs Bay	AA	--	--	AA		--	AI
	Big Creek	AA	--	--	AA		--	AI
	Clatskanie	AA	--	--	AA		--	AI
	Scappoose	AA	--	--	AA		--	AI
CASCADE	Lower Cowlitz	AA	--	AA	AA	AA	--	PA
	Upper Cowlitz		--	AA/JA[3]		AA/JA	--	AA/JA
	Cispus		--	AA/JA[3]		AA/JA	--	AA/JA
	Tilton		--				--	AA/JA
	SF Toutle	AA	--	--		AA	--	PA
	NF Toutle	AA	--	--		AA/AI[9]	--	PA
	Coweeman	AA[1]	--	--	AI	AA	--	PA
	Kalama	AA	--	AA/JI	AI	AA/JA/BR	AA/JA/BR	PA
	Lewis NF		AA/JA/JT	AA[4]	AA	AI/JI[10]	AA	AI/JI[10]
	Lewis EF	AA[1]	AA	--	AA	AA	AA	PA
	Salmon		--	--	AI			PA
	Washougal	AA	--	--	AA	AA	AA	PA
	Sandy	AA	AA	AA		AA/JI	--	AI/JI
	Clackamas	PA	--	AA/JI		AA/JI	--	AI/JI
GORGE	Lower Gorge	AA	AA[2]	--	AA/JI			PA
	Upper Gorge	AA	AA[2]	AA	AA/JI[6]		AA/JI	PA
	White Salmon	AA	AA[2]	AA	AA	--		--
	Hood	AM	--	AA/JA/BR	--	AA/JA/BR	AA/JA/BR	--

AA = Annual adult abundance (weir counts or an estimate of absolute abundance based on the expansion of index counts) , AI = Annual adult index monitoring (a relative measure of species presence typically reported as redds/mile for the sample area), PA = Periodic adult abundance indices. JA = Annual juvenile abundance, JI = Juvenile index monitoring, JT = Juvenile coded-wire tagging. BR = Biological research, JM =Juvenile presence/absence

[1] *Adult abundance estimates may not include entire spawning area.*

[2] *Not part of lower Columbia ESU.*

[3] *Juvenile accounting at Cowlitz Falls Dam. Does not separate Upper Cowlitz and Cispus production.*

[4] *Juvenile abundance monitoring will likely begin in new license period*

[5] *Juvenile migration timing only*

[6] *Juvenile abundance monitoring for Hamilton, Hardy, and Duncan Creeks. Juvenile index monitoring for mainstem Columbia near Ives Island.*

[8] *Adult monitoring does not include Mill Creek. Juveniles monitored in all three streams.*

[9] *Adult monitoring for NF Toutle. Adult index for Green River.*

[10] *Includes Cedar Creek only. Adult and juvenile monitoring will likely begin in new license period*

[11] *Coho adult monitoring is incidental to Chinook and chum monitoring.*

Since adult spawning escapement is the bottom line currency in which to evaluate progress to recovery, we have proposed two steps to assuring the data is gathered annually for each population and the accuracy of the spawning escapement estimates are adequate to use as a measurement of recovery status.

1) Inventory current funding levels and solidify long-term commitment to provide adequate funding to survey adult spawning returns for all populations

2) Additional funding of $50,000 per year provided to investigate accuracy of spawning escapement estimates

7.4.2 In-depth Monitoring

In-depth monitoring for Washington lower Columbia basin consists of life-cycle population assessments, juvenile and adult abundance estimates and adult run-reconstruction. In-depth monitoring occurs in index watersheds and includes acquisition of juvenile and adult quantifiable data to provide life cycle analysis and enable productivity data to be generated. Such monitoring is critical to connecting habitat measures with fish productivity response and can be generally categorized as follows:

2. ***Monitor distribution/spatial structure of representative populations of Chinook, chum, coho, steelhead and bull trout in each recovery strata.***

    Objective: Distribution and relative abundance of spawning and/or rearing by stream reach throughout potentially-accessible areas as an indicator of population viability and a basis for identifying or refining selection of routine monitoring sites.
    Indicator: Indices of relative abundance of adults from counts of live fish, carcasses or redds and/or juveniles based on snorkel, electrofishing, or seining surveys.
    Sampling: Replicate random samples stratified by time period and area in one or more years, repeated at periodic intervals.
    Analysis: Relative abundance, range, patchiness, used vs. available area, representativeness of index sites identified in routine sampling.

3. ***Monitoring trends and variation in annual juvenile production of representative populations of Chinook, chum, coho, steelhead and bull trout in each recovery strata.***

    Objective: Current freshwater production and changes relative to objectives.
    Indicator: Juvenile migrant population estimates or indices of abundance, size, age, migration dates.
    Sampling: Collect outmigrating juveniles at representative index sites.
    Analysis: Annualized population growth rate, juveniles per spawner.

4. ***Monitoring trends and variation in productivity of representative populations of Chinook, chum, coho, steelhead and bull trout in each recovery strata.***

    Objective: Estimate natural recruits per spawner and hatchery contributions.
    Indicator: Age structure, hatchery/wild origin, sex, biological condition.
    Sampling: Size, age, marks, tags from trapped fish, carcasses, and juvenile tagging in conjunction with adult escapement data.
    Analysis: Run reconstruction.

In-depth Monitoring will include annual monitoring of juveniles and adults in watersheds were annual monitoring is currently being conducted and funded through existing programs. This strategy minimizes cost by capitalizing on information being gathered as part of a FERC license agreement, BPA funds, Salmon Recovery funds, or Mitchell Act research funds. These projects are on-going for all species or are expected to be included in license agreements. These funded projects provide some level of representation for all species and are located in each stratum.

The existing annual projects provide opportunity for long-term assessments and some projects have long-term data bases that can be utilized to assess status trends (e.g. Kalama steelhead), however, these existing programs fall far short of covering sufficient numbers of key populations in watersheds to acquire the productivity data needed to connect and evaluate the adequacy of measures to achieve recovery objectives.

This Monitoring, Research and Evaluation strategy strives for efficiency in monitoring by intensively monitoring populations in watersheds with multiple key species and where information on more than one species can be gathered with the same equipment in the same area. For example, sampling steelhead and coho in upper watershed areas and Chinook and chum in the lower watershed areas. The watershed efficiency strategy is combined with focus on populations with higher biological objectives, as improvement in the populations which must become viable is the most critical and biggest challenge to achieving ESU scale recovery criteria.

In-depth monitoring is rotated between watersheds to provide more geographical coverage across strata, to include more critical watersheds, provide time for the populations to respond to recovery measures, and to save cost. The following criteria were used to select watersheds for in-depth monitoring:

1. Inventory existing monitoring
2. Identify gaps for basic monitoring
3. Develop criteria for In-depth monitoring
    - Indicator populations and watersheds
4. Prioritize In-depth monitoring areas
    - Build on existing programs, including habitat monitoring
    - Compare different biological strategies (hatchery vs. refuge areas)
    - Priority populations emphasized
    - Consider costs and logistics
    - Consider strata representation
5. Process for managing monitoring strategy
    - Funding
    - Coordination
    - Data management
    - Report mechanisms/distribution
    - Adaptive Management

7.4.3 Level of Effort

In-depth monitoring was prescribed according to three levels – Levels 1, 2, and 3. Level 1 reflects the highest level of effort and Level 3 reflects the lowest. Each level identifies the population to be sampled, the area to be sampled and an initial estimate of average annual cost. The following text and summary tables (Table 2 and Table 7) present level-specific sampling strategies and justification for monitoring particular populations and areas. The sampling activities described above do not vary between levels, simply the number of species and basins sampled.

Table 2. In-depth biological monitoring strategies by basin and level of effort.

BASIN	Level 1	Level 2	Level 3
Grays	F. Chinook Chum W. steelhead Coho	Chum*	Chum*
Skamokawa	Chum		
Elochoman	F. Chinook W. steelhead Coho	F. Chinook W. steelhead Coho	F. Chinook
MAG	Chum* W. steelhead* Coho*	Chum* W.steelhead* Coho*	Chum* W.steelhead* Coho*
L. Cowlitz	Coho	Coho	
U. Cowlitz	Spr. Chinook* W.steelhead* Coho*	Spr. Chinook* W.steelhead* Coho*	Spr. Chinook* W.steelhead* Coho*
SF Toutle	W. steelhead Coho	W. steelhead Coho	
NF Toutle	W. steelhead Coho		
Coweeman	F. Chinook W. steelhead Coho	F. Chinook	F. Chinook
Kalama	F. Chinook Spr. Chinook W. steelhead* S. steelhead*	W. steelhead* S. steelhead*	W. steelhead* S. steelhead*
NF Lewis	F. Chinook* W.steelhead* Coho*	F. Chinook* W.steelhead* Coho*	F. Chinook* W.Steelhead* Coho*
U. Lewis	Spr. Chinook* W.steelhead* Coho*	Spr. Chinook* W.steelhead* Coho*	Spr. Chinook* W. Steelhead* Coho*
EF Lewis	F. Chinook Chum W. steelhead S. steelhead Coho	F. Chinook Chum W. steelhead S. steelhead Coho	F. Chinook Chum W. steelhead S. steelhead Coho
Washougal	F. Chinook Chum S. Steelhead	Chum S.Steelhead	Chum
L. Gorge	Chum*	Chum*	Chum*
Wind	S. steelhead*	S.steelhead*	S.steelhead*
# populations/ # basins	42/16	32/16	25/16
Projected Cost/yr	$780,000	$610,000	$325,000

* annual in-depth monitoring program

Table 2 presents the basin-specific species considered at each of the three in-depth monitoring strategies. Included in the table is an initial cost estimate for the various monitoring levels. A breakdown by species for the monitoring costs are included in section 7.4.5. The annual cost was derived according to professional judgment and consists of personnel time, capital investments, data management, and an assessment of adult spawning ground survey accuracy. Given the preliminary nature of these costs estimates, they should only be relied upon for comparative ranking between the three levels.

Level 1 In-depth Monitoring

Level 1 provides the most in-depth in-depth monitoring and is summarized according to species in the following table:

Table 3. Level 1 in-depth biological monitoring by species.

Fall Chinook	Spring Chinook	Chum	Winter steelhead	Summer steelhead	Coho
Grays	U. Cowlitz*	Grays*	Grays	Kalama*	Grays
Elochoman	U. Lewis*	Skamokawa	Elochoman	EF Lewis	Elochoman
Coweeman	Kalama	MAG[3]	SF Toutle	Washougal	L. Cowlitz
Kalama		EF Lewis	NF Toutle	Wind*	SF Toutle
EF Lewis		Washougal	Coweeman		NF Toutle
Washougal		L. Gorge*	Kalama*		Coweeman
NF Lewis*			EF Lewis		EF Lewis
			NF Lewis* [1]		U. Lewis*
			MAG*[2]		U. Cowlitz*
			U. Lewis*		NF Lewis* [1]
			U.Cowlitz*		MAG*[2]

* annual in-depth monitoring program
1 Cedar Creek
2 Mill, Abernathy, Germany

Level 1 in-depth monitoring candidates include populations that are targeted for high viability recovery levels and/or have annual monitoring programs in place. Not all populations targeted for high viable levels are included in the Level 1 in-depth monitoring plan. A graphic representation of routine and in-depth monitoring by basins and species is presented in Figure 1.

All populations designated for annual in-depth monitoring have, or are expected to have in the future, annual monitoring programs with funding. (e.g. FERC Agreements, BPA, State Salmon Recovery, Mitchell Act). The one exception is Grays River chum which are targeted for annual in-depth monitoring because of the existing long-term adult abundance data base. There are a total of 15 populations that are expected to be funded for in-depth monitoring under current plans.

In-depth monitoring for remaining (not annually monitored) Level 1 populations would occur in three-year sampling periods and rotated to begin again every 9 years (Table 8).

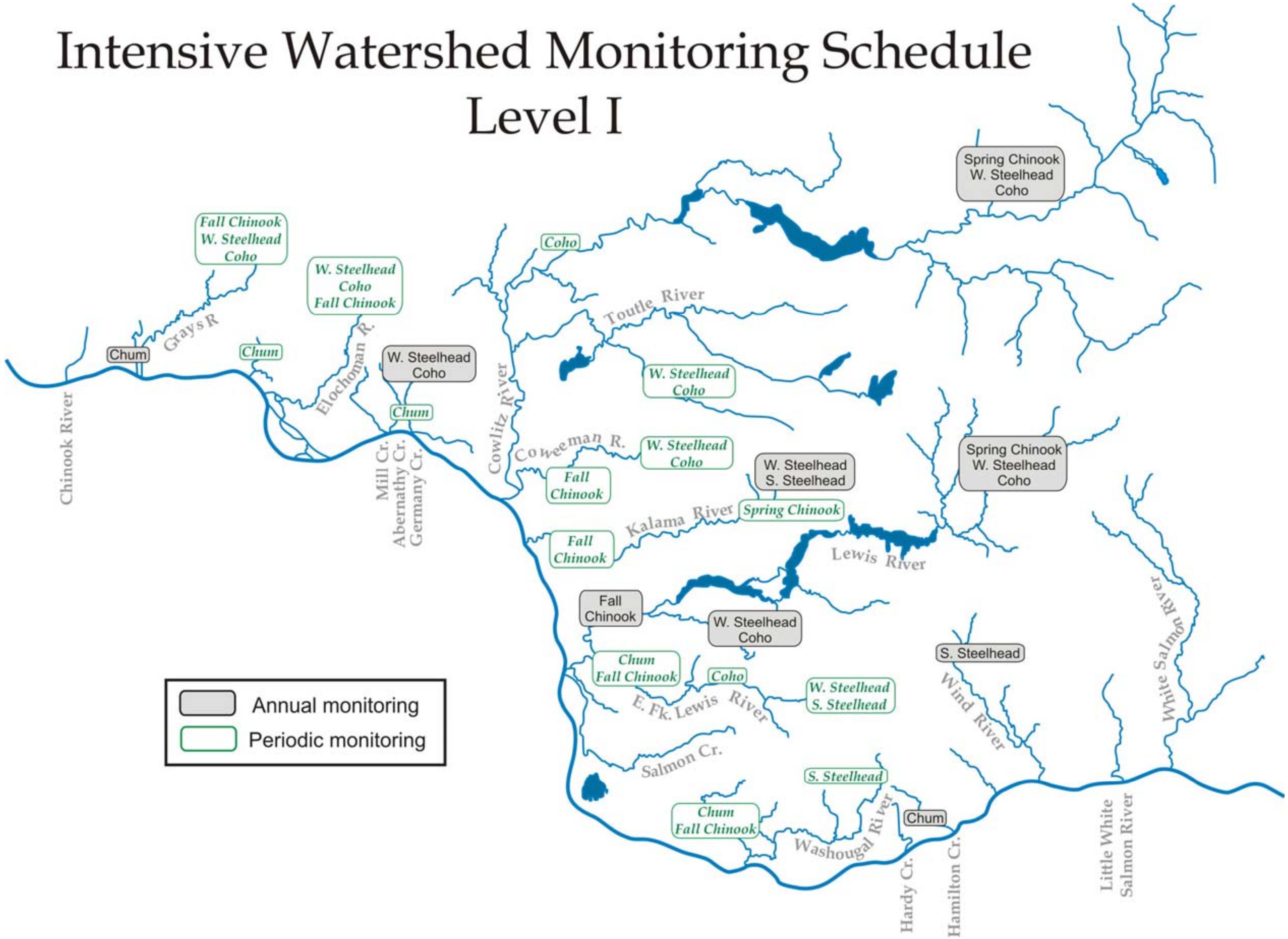

Figure 1. In-depth Biological Monitoring Level 1.

Level 2 In-depth Monitoring

Level 2 provides a moderate level of in-depth monitoring and is summarized according to species in the following table:

Table 4. Level 2 in-depth biological monitoring by species.

Fall Chinook	Spring Chinook	Chum	Winter steelhead	Summer steelhead	Coho
Coweeman NF Lewis* Kalama EF Lewis Elochoman	U. Cowlitz* U. Lewis*	Grays* L. Gorge* Washougal MAG[2] EF Lewis	Kalama* SF Toutle EF Lewis MAG*[2] Elochoman U. Lewis* U. Cowlitz* NF Lewis*[1]	Wind* Kalama* Washougal EF Lewis	Elochoman L. Cowitz SF Toutle EF Lewis NF Lewis*[1] U. Cowlitz* U. Lewis* MAG*[2]

* annual in-depth monitoring program
1 Cedar Creek
2 Mill, Abernathy, Germany

Table 5. Populations removed from Level 1 in order to establish Level 2

Species	Population removed	Justification
Fall Chinook	Grays	There is no weir in the mainstem Grays which would entail a costly investment. Given that expense and the retention of coastal sampling in the Elochoman, Grays Fall Chinook were removed from the Level 2 monitoring strategy
	Washougal	There is no lower river weir in the Washougal which would entail a costly investment. However the Kalama has an operating weir so the Washougal was removed from Level 2 sampling.
Spring Chinook	Kalama	The Upper Cowlitz and the Upper Lewis are the main focus for recovery, so the Kalama was removed from the Level 2 monitoring strategy
Chum	Skamokawa Cr	The Grays and MAG reflect Skamokawa population status
	Coweeman	The Kalama and Toutle represent Coweeman population status
	NF Toutle	The South Fork Toutle represent NF Toutle population status
Summer steelhead	No change	
Coho	Grays	Skamokawa and Elochoman represent Grays population status
	Coweeman	SF Toutle and Lower Cowlitz information remains in Cowlitz basin
	NF Toutle	SF Toutle info remains in Toutle basin
Other Cuts	Capital investments reduced by approximately 20%	

Level 3 In-depth Monitoring

Level 3 provides the lowest level in-depth monitoring and is summarized according to species in the following table:

Table 6. Level 3 in-depth biological monitoring by species.

Fall Chinook	Spring Chinook	Chum	Winter steelhead	Summer steelhead	Coho
Coweeman NF Lewis* Elochoman EF Lewis	U. Cowlitz* U. Lewis*	Grays* L. Gorge* Washougal MAG[2] EF Lewis	Kalama* U. Lewis* U. Cowlitz* EF Lewis* MAG*[2] NF Lewis*[1]	Wind* Kalama* EF Lewis*	EF Lewis* U. Cowlitz* U. Lewis* NF Lewis*[1] MAG*[2]

* annual in-depth monitoring program
[1] Cedar Creek
[2] Mill, Abernathy, Germany

Table 7. Populations removed from Level 2 in order to establish Level 3:

Species	Population removed	Justification
Fall Chinook	Kalama	Use Elochoman to represent hatchery/natural area. Retain Coweeman as the wild index stock for harvest and EF Lewis for long-term habitat monitoring
Spring Chinook	No change	No unfunded watershed remain
Chum	No change	MAG and EF Lewis selected for long-term habitat monitoring, Grays targeted for greater than high viability, and Washougal area chum critical for recovery. Chum are the least expensive species to monitor in-depth
Winter steelhead	SF Toutle	Cover with EF Lewis in Cascade
	Elochoman	Cover with MAG in Coast
Summer steelhead	Washougal	Cover with EF Lewis in Cascade
Coho	SF Toutle	Cover with EF Lewis in Cascade
	L. Cowlitz	Cover with EF Lewis in Cascade
	Elochoman	Cover with MAG
Other Cuts	Capital investments reduced by approximately 50 percent	
	Data management reduced by approximately 20 percent	
	Spawning survey accuracy investigations reduced by 50 percent	

7.4.4 Site Rotation Schedule for In-depth Monitoring

The following discussion presents the recommended monitoring by species. In-depth monitoring for a given population and level-of-effort occurs for 3 consecutive years, a sampling regime that is repeated every 9 years. The specific schedule is documented in Table 8.

Chum - Annual in-depth monitoring will occur in the Lower Gorge tributaries and Grays River. There is currently adult and juvenile accounting in the lower Gorge tributaries but only adult accounting in the Grays River. Periodic in-depth monitoring will occur for 3-year intervals on a rotation schedule in MAG creeks, Skamokawa Creek, EF Lewis, and the Washougal area. There are no juvenile monitoring programs in these sub-basins.

Fall Chinook Tule - All in-depth monitoring for fall Chinook tules would be conducted periodically in 3-year sampling intervals. Elochoman, Kalama, and Washougal basins would represent watersheds that have both natural and hatchery fall Chinook populations, Grays basin would represent an area where fall Chinook hatchery production occurred for many years, but was recently eliminated, and the East Fork Lewis and Coweeman would represent watersheds with only natural fall Chinook populations. There are no existing juvenile monitoring programs in these sub-basins

Winter Steelhead - In-depth monitoring would occur annually under existing programs with no additional cost in the Kalama, Upper Cowlitz, NF Lewis (Cedar creek), Upper Lewis and Cedar Creek), and MAG creeks. Periodic sampling would occur in 3-year intervals, with 2 tributaries annually, with a rotation schedule between Elochoman, Grays, EF Lewis, Coweeman, NF Toutle and SF Toutle. There are no existing juvenile programs in the tributaries included in the proposed rotation schedule.

Summer Steelhead - In-depth monitoring would occur annually with existing programs in the Wind and Kalama. Periodic sampling would occur in 3-year intervals in the EF Lewis and Washougal sub-basin on a rotation schedule and beginning every nine years. Annual cost is calculated as an addition to winter steelhead sampling in the East Fork Lewis and would occur in the same years. Annual cost is a new cost in the Washougal as there is no in-depth winter steelhead monitoring proposed in the Washougal sub-basin.

Coho - In-depth monitoring would occur annually with existing programs in the Upper Cowlitz, NF Lewis (Cedar Creek), upper Lewis and MAG creeks. Periodic monitoring would occur in 3-year intervals in the other basins, with a rotation between Elochoman, Grays, EF Lewis, Coweeman, SF Toutle, NF Toutle and Lower Cowlitz. This rotation schedule would be coordinated with the winter steelhead rotation schedule to enable sampling efficiency and reduced cost. Coho monitoring cost is represented at a reduced rate to represent the benefits of monitoring in the same watersheds as winter steelhead. Coho sampling will need to be extended in some watersheds, however, to include lower river tributaries as necessary.

Spring Chinook - In-depth monitoring would occur annually with existing programs in the Upper Cowlitz and NF Lewis. Periodic sampling would be included with steelhead sampling in the Kalama in 3-year intervals beginning every nine years. Big White Salmon In-depth spring Chinook monitoring would be implemented if passage is restored over Condit Dam or the dam is breached.

Fall Chinook Brights - NF Lewis Bright fall Chinook are intensively monitored with an existing WDFW/Pacificorp program. No additional costs are assumed for monitoring bright fall Chinook.

Table 8. Monitoring Rotation Schedule

Subbasin	Annual/Periodic Sampling	YR 1-3	YR 4-6	Yr 7-9
Grays	Annual Periodic	Chum Fall Chinook	Chum	Chum Winter steelhead Coho
Elochoman	Annual Periodic	Fall Chinook		Winter steelhead Coho
Skamokawa	Annual Periodic	Chum		
MAG	Annual Periodic	Winter steelhead Coho Chum	Winter steelhead Coho	Winter steelhead Coho
L. Cowlitz	Annual Periodic		W.Sthd Coho	
U. Cowlitz	Annual Periodic	Sp. Chinook Winter steelhead Coho	Sp. Chinook Winter steelhead Coho	Sp. Chinook Winter steelhead Coho
Toutle (SF&NF)	Annual Periodic		Winter steelhead Coho	
Coweeman	Annual Periodic	Winter steelhead Coho Fall Chinook		
Kalama	Annual Periodic	Winter steelhead Summer steelhead	Winter steelhead Summer steelhead Sp. Chinook	Winter steelhead Summer steelhead
L. Lewis	Annual Periodic	Fall Chinook Winter steelhead Coho	Fall Chinook Winter steelhead Coho	Fall Chinook Winter steelhead Coho
U. Lewis	Annual Periodic	Sp. Chinook Winter steelhead Coho	Sp. Chinook Winter steelhead Coho	Sp. Chinook Winter steelhead Coho
E.Fall Lewis	Annual Periodic	Winter steelhead Summer steelhead Coho	Fall Chinook Chum	
Washougal	Annual Periodic	Summer steelhead	Fall Chinook Chum	
L. Gorge	Annual Periodic	Chum	Chum	Chum
Wind	Annual Periodic	Summer steelhead	Summer steelhead	Summer steelhead

7.4.5 Cost

Whenever possible, sampling efficiencies were reflected in the site monitoring rationale. The following sections presents cost considerations for biological monitoring, capital investment, data management and adult spawning enumeration.

Biological monitoring - Costs for biological monitoring consist primarily of full time employees (FTE) and travel-related expenses. Monitoring for steelhead and coho is more costly than for fall Chinook or chum because of their extended freshwater life history. Annual base cost for a species is reduced if sampling occurs for another species at the same time

Projected annual cost of biological monitoring per population was estimated as follows:

- Winter steelhead- $100,000
- Summer steelhead-$100,000 (reduced to $25,000 if conducted with winter steelhead)
- Spring Chinook- $100,000 (reduced to $25,000 if conducted with steelhead)
- Coho- $100,000 (reduced to $50,000 if conducted with steelhead)
- Fall Chinook- $60,000
- Chum- $40,000 (reduced to $20,000 if conducted with fall Chinook/ except Washougal reduced to $30,000 because of vicinity chum areas)

Capital Investments (Weirs, Traps, vehicles, boats, sampling equipment) - Projected costs assume a one time purchase of traps and weirs to be rotated between watersheds every three years. The preliminary investment to cover watersheds sampled in years 1-3 will not need to be duplicated for other watersheds in the following years. Maintenance of equipment is projected as a $10,000 per year cost. Vehicles and water craft can be shared between watersheds in the same 3-year period and schedules were arranged geographically to minimize the number of vehicles, craft, and crew that would need to engage in a given day (e.g. sampling in the Elochoman and Grays rivers in the same three-year period). Estimated capital cost break down is:

- Fall Chinook/Chum sampling-$25,000 per watershed
- Steelhead/Coho sampling-$50,000 per watershed
- Vehicles- $90,000
- Water craft-$40,000

Data management - A significant amount of data will be collected and need to be entered, organized and summarized to fit the demands of evaluation. This cost estimates assumes 1 biologist and 1 technician FTE with benefits at a cost of $100,000 per year.

Adult spawning enumeration - This cost includes annual projects to verify the accuracy of spawning population estimates. Adult live and dead counts on spawning grounds would be supported with live adult tagging and recovery, or carcass tagging methods to determine if the count expansions used are appropriate. The studies may also involve confirmation of appropriate index count areas. The cost for adult spawning enumeration is estimated at $25,000 per population, with 2 projects conducted per year at a cost of $50,000 per year.

7.4.6 Funding Sources

Given the importance of funding, the following discussion outlines current annual coverage as well as options for alternative sources of funding. Currently the Bonneville Power Authority provides funding for adult spawning estimates, tag recovery, and biological data. In addition the Mitchell Act (16 USC 755-757; 52 Stat. 345) is responsible for funding in-depth monitoring of steelhead in the Kalama. Lastly, the Federal Energy Regulatory Commission supports spring Chinook, coho, winter steelhead monitoring as part of dam relicensing efforts in the Upper Lewis and Upper Cowlitz

Additional funds may be obtained from the following sources:

Bonneville Power Administration - expand coverage to include adult and juvenile monitoring. The proposed data could provide reference information for biological comparison to areas not impacted by impoundments. Furthermore it could be useful in estuary mitigation and as part of off-site verification under the Federal Hydro Biological Opinion (FCRPS 2000).

Salmon Recovery Federal funds - monitor salmon recovery investments.

State Dollars- Washington Department of Fish and Wildlife, Natural Resources, and Ecology. Each has a budget for monitoring

Mitchell Act- may provide additional monitoring below Bonneville to address harvest mitigation.

Federal Action agency funds- Army Corp. of Engineers, Forest Service, NOAA Fisheries

Local Funds- counties, cities, ports, private industry

Regional Enhancement Groups - work collaboratively with local, federal, and state governments to secure funding

7.5 Habitat Status Monitoring

Habitat monitoring provides a physical baseline upon which evaluate biological health. Habitat data ranges from watershed-scale characteristics such as road density to site-specific conditions such as channel substrate. The following table cites commonly considered habitat attributes useful in characterizing the overall condition of the ecosystem.

Table 9. Habitat attributes

Habitat Characteristics			
Watershed	**Stream Habitat**	**Water Quality**	**Water Quantity**
Geology Topography Road density • paved • unpaved Subwatershed Attributes • area • slope Mass Wasting Land cover Land Use Impervious Surfaces Stream and Wetland Mapping	Migration Barriers Channel Morphology • Stream classification • Habitat unit types • Substrate and sediment • Depth, width, gradient, confinement • Channel stability (incision/bank erosion) Instream structure • LWD • Boulders • Overhanging Banks Riparian Function • Vegetation • Riparian Disturbance (i.e. logging, roads) • Invasive species Floodplain Function • Connectivity • Hydrologic modifications	Temperature Turbidity/Suspended Sediments Dissolved Oxygen Conductivity Contaminants (point and nonpoint source) Nutrients (i.e. nitrogen, phosphorus) Additional Risk Factors (i.e. septic systems, grazing)	Stream gauging Stormwater management Withdrawls Instream Flow Assessment Groundwater / Surfacewater connectivity

Habitat status monitoring will occur in conjunction with biological status monitoring. The first step in establishing useful monitoring data is to develop an on-line, standardized database for the various basin attributes. With such a database, information can be input in a predetermined format and accessed by a wide audience. The next step is to analyze the available data and determine where and to what extend additional data would be useful. Cost estimates for the proposed habitat status monitoring require additional development and will be addressed in plan development.

7.5.1 Watershed Conditions

Of the categories cited in Table 9, watershed attributes are the slowest to change. Once baseline conditions are characterized, they require only need to be updated in the case of substantial land use change or natural events such as mass wasting. Each basin has been characterized in Volume II of this subbasin planning process and should be comprehensively updated every 10 years, unless conditions dictate otherwise. Annual sampling is not feasible for all locations and thus suite of possible statistical analyses are reduced. Nevertheless, the proposed sampling scale and strata is sufficient to reflect watershed changes on the instream habitat condition.

1. ***Conduct comprehensive survey of watershed conditions and processes across the Washington lower Columbia Region - completed.***

   Objective: Establish baseline conditions and use to stratify area for routine monitoring in a representative subset of areas. Also identifies priority areas for protection and restoration.

   Indicators: Geomorphology, land use, vegetation cover, riparian vegetative cover, road density, landslides, wetlands.

   Sampling: Primarily remote sensing and available GIS information.

   Analysis: Spatial and categorical summaries.

2. ***Monitor trends in watershed conditions and processes through periodic sampling of representative and indicator sites.***

   Objective: Detect broad changes in watershed conditions and processes that affect stream habitat forming processes. The changes can be small scale and extensive or large scale and intensive.

   Indicators: Geomorphology, land use, vegetation cover, road density, landslides, wetlands.

   Sampling: Remote sensing with ground validation. Long term index areas to identify temporal changes on a decadal scale; stratified selection of sample areas based on statistical surveys described above to identify sites representative of watershed types, stream types, and uses (forest, agriculture, urban); inclusion of non-randomly selected indicator sites expected to be most sensitive to trends in conditions. Sites should be sampled every 10 years unless changes to physical conditions warrant an increase in sampling frequency (i.e. mass wasting events, removal of impassible barriers).

   Analysis: Within and among site differences, changes over time. Although the frequency and extent of sampling will limit statistical inferences, the proposed monitoring will provide a quantitative as well as qualitative evaluation of watershed trends and processes.

The remaining categories require varying levels of monitoring. Existing monitoring data by basin are summarized in Table 10. The entities conducting ongoing monitoring and dates of sampling are included along with a coarse assessment of the depth of monitoring coverage.

7.5.2 Water Quality

As displayed in Table 10, water quality is extensively monitored by Washington's Department of Ecology, as well as the US Geological Survey. Data pertaining to each basin should be obtained from existing surveys and updated according to established monitoring schedules. Data gaps and regions prone to non-point source pollution may warrant additional monitoring. Furthermore refinement of the sampling plan will be implemented as needed:

1. ***Conduct comprehensive survey of water quality and quantity across the Washington lower Columbia Region.***

   Objective: Establish baseline conditions based on WDOE and USGS sampling. Identify priority areas for protection and restoration.
   Indicator: Stream flow, water temperature, turbidity, dissolved oxygen, conductivity, pH, nitrogen, phosphorous.
   Sampling: Stratified random sampling with replicates based on strata identified based on watershed and stream habitat assessments. Incorporate and supplement existing datasets.
   Analysis: Spatial and categorical summaries.

2. ***Monitor trends in water quantity and quality through periodic sampling of representative and indicator sites (includes USGS gauge sites and additional sites).***

   Objective: Detect changes in local stream conditions that affect the quantity and quantity of habitat provided for fish (i.e. the upstream extent of summer surface water).
   Indicator: Stream flow, water temperature, turbidity, dissolved oxygen, conductivity, pH, nitrogen, phosphorous
   Sampling: Long term index sites to factor out among-site variability and maximize statistical power to identify temporal changes; periodic sampling depending on indicator with replicates to distinguish temporal changes in conditions from inherent sampling variability and background noise; stratified selection of sample sites based on statistical surveys described above to identify sites representative of watershed types, stream types, and uses (forest, agriculture, urban); inclusion of non-randomly selected indicator sites expected to be most sensitive to trends in conditions.
   Analysis: Within and among site differences, changes over time.

Table 10. **Existing monitoring data**

		Stream / Riparian Habitat Surveys			WDOE[1] Water Quality		USGS[2] Water Quality		Continuous Temperature			USGS Stream Gaging			
Strata	Basin	Entity	Date	Level of coverage	Date	Level of coverage	Date	Level of coverage	Entity	Date	Level of coverage	Date	Real-time	Level of coverage	Entity
Coast	Grays/Grays Bay	WCD	1996	good	1973, 1976-7, 1998	moderate	1972-77	moderate	WCD/CCD	2002-present	good	1949-1975		moderate	WDOE
	Skamokawa	WCD, WDFW	1996-2003	moderate		poor	1980	poor	WCD/CCD	2002-present	good			poor	
	Elochoman	WCD, WDFW	1996-2003	moderate	1960, 1973, 1976-7, 1998	moderate	1972-77	moderate	WCD/CCD	2002-present	good	1940-1971		moderate	WDOE
	Mill	CCD, WDFW	1999-2003	poor		poor		poor	WCD/CCD	2002-present	good	1949-1956		poor	WDOE
	Abernathy	CCD, WDFW	1997-2003	moderate		poor		poor	WCD/CCD	2002-present	good	1949-1957		poor	WDOE
	Germany	CCD, WDFW	1997-2003	moderate		poor		poor	WCD/CCD	2002-present	good			poor	WDOE
Cascade	Lower Cowlitz	CCD, LCCD	1996-2001	poor	1960-present	good	1961-86	good	WCD/CCD	1999-present	poor	1926-present	✓	good	WDOE, PacifiCorp, Conservation Groups
	Coweeman	Weyerhaeuser, WDFW	1995-2000	poor		poor	1961-75	moderate	WCD/CCD	2002-present	poor	1950-1982		moderate	WDOE
	Toutle	USFS	1993	poor		poor	1960-2002	good			poor	1909-present	✓	good	
	Upper Cowlitz	USFS	1987-present	good		poor	1964-85, 2002	good	USFS	1996-present	good	1911-present	✓	good	WDOE
	Cispus	USFS	1987-present	good		poor	1971-72, 1980-81	moderate	USFS	1996-present	good	1910-present	✓	good	
	Tilton	USFS	1993	poor		poor	1968	poor			poor	1941-present	✓	good	
	Kalama	USFS, WDFW	1990, 2002-2003	poor	1972-present	good	1961-70, 1972-80	moderate	WDFW, USGS	1984-present	poor	1911-1982		good	WDOE
	Lower NF Lewis	PacifiCorp, WDFW	1999-2003	poor		poor	1962-73, 1976-86, 1994	good	PacifiCorps	1999-2000	poor	1909-present	✓	good	WDOE
	Upper Lewis	PacifiCorp, USFS	1989-present	good		poor	1970-71, 1976, 1980-2002	good	USFS, PacifiCorp	1994-present	moderate	1927-1970		moderate	WDOE
	EF Lewis	USFS, WDFW	1991-present	moderate	1977-present	good	1976-80, 1980	moderate	USFS	1996-present	moderate	1929-present	✓	good	WDOE
	Salmon	WDFW	2002-2003	poor	1973, 2004 (Burnt Br. Cr)	moderate	1968-73, 1978, 1980, 1997-98	moderate	Clark County	1998-present	good	1943-1990		good	WDOE
	Washougal	WDFW	2002-2003	poor		poor	1964-70, 1974-77, 1981	moderate	WDFW, CSF	unknown	good	1944-1981		moderate	WDOE
Gorge	Lower Gorge			poor	1992, 2002 (Campen & Gibbons Cr)	moderate	1981	poor	USFWS, WDFW	unknown	good			poor	WDOE
	Upper Gorge	USFS	1997	poor		poor		poor			poor			poor	WDOE
	Wind	USFS, WDFW	1988-present	good	1973, 1976-83, 1995	moderate	1972-1980	moderate	USFS, WDFW, USGS, UCD, WDOE	1998-present	good	1934-present		good	
	Little White Salmon	USFS	1991-present	moderate		poor		poor	USFS	1998-present	good	1944-1977		moderate	

poor coverage
moderate coverage
good coverage

[1]WDOE collects data on fecal coliform bacteria, oxygen, pH, suspended solids, temperature, total persulf nitrogen, total phosphorous, turbidity

[2]USGS WQ collects some or all of the following: temperature, conductivity, oxygen, pH, hardness, acid neutralizing capacity, nitrogen, calcium, magnesium, sodium, potassium, chloride, sulfate, flouride, silica, arsenic, cadmium, chromium, copper, lead, zinc, selenium, mercury, organic carbon

IFIM - Instream Flow Incremental Methodology

RVA - Range of Variability Approach

7.5.3 Stream Habitat

Stream/riparian habitat data and water quantity records require focused attention to fully characterize the evolving health of the aquatic ecosystem. In parallel with the biological monitoring, there is ongoing routine monitoring (Table 10) which can be expanded with in-depth monitoring efforts. Table 11 shows three levels of proposed surveys by type and location – Level 1 reflecting the highest degree of monitoring and Level 3 reflecting the lowest. Unless otherwise noted, stream/riparian habitat surveys should be conducted every 3 years. The starting year should be coordinated with year 1 and year 9 biological monitoring for a given basin. Given the previously planned sampling effort, it is efficient and biologically beneficial to have sampling efforts overlap.

1. ***Conduct comprehensive survey of stream habitat conditions across the Washington lower Columbia Region.***

   Objective: Verify working hypotheses for stream habitat conditions based on previous surveys, fill in missing data, establish baseline conditions, use to stratify area for routine monitoring in a representative subset of areas, validate priority areas for protection and restoration, identify site-specific problems for habitat projects.

   Indicator: Channel morphology, depth, width, stream flow, substrate, woody debris, pools, riparian cover and condition, bank stability, etc.

   Sampling: Standardized wadeable and nonwadeable stream measurement protocols. Stratified random sampling with replicates in strata based on existing habitat assessments as summarized in WDFW EDT analyses. Strata include combinations of watershed, streams, and land use categories. Surveys include all strata – not just priority protection and restoration areas. Incorporate and supplement existing datasets.

   Analysis: Spatial and categorical summaries, estimated vs. observed conditions.

2. ***Monitor trends in stream habitat conditions through periodic sampling of representative and indicator sites.***

   Objective: Detect changes in local stream conditions that affect the quantity and quantity of habitat provided for fish.

   Indicator: Channel morphology, depth, width, stream flow, substrate, woody debris, pools, riparian cover and condition, bank stability, etc.

   Sampling: Standardized wadeable and nonwadeable stream measurement protocols. Long term index sites to factor out among-site variability and maximize statistical power to identify temporal changes; replicate but periodic sampling (e.g., 3 years of 10) to distinguish changes in conditions on a decadal scale from inherent sampling variability and background noise; stratified selection of sample sites based on statistical surveys described above to identify sites representative of watershed types, stream types, and uses (forest, agriculture, urban); inclusion of non-randomly selected indicator sites expected to be most sensitive to trends.

   Analysis: Within and among site differences, changes over time.

7.5.4 Intensively Monitored Subbasins

In an effort to monitor long-term changes to habitat conditions, a more aggressive schedule is proposed for the Mill, Abernathy, Germany cluster, EF Lewis and the Wind basins. These annually monitored basins can also be used to validate the broader scale comprehensive surveys. Water quantity should be continuously available for gauged systems and seasonally available for summer low flow "spot checks".

1. ***Validate comprehensive survey of watershed conditions and processes with site-specific assessments.***

   Objective: Test and calibrate remote sensing and GIS information used in comprehensive regional assessment.
   Indicators: Geomorphology, land use, vegetation cover, road density, landslides, wetlands.
   Sampling: Ground surveys at representative sites in strata identified through comprehensive survey.
   Analysis: Estimated vs. observed conditions.

Table 11. In-depth habitat monitoring strategies for stream habitat and water quantity by basin.

BASIN		Level 1	Level 2	Level 3
COAST	Grays	Complete Watershed[1]		
	Skamokawa			
	Elochoman	Low flow spot surveys	Low flow spot surveys	
	Mill/Abernathy/ Germany	Complete Watershed* (annual) Install stream gauges CIFA	Complete Watershed* Install stream gauges CIFA	Complete Watershed * CIFA
CASCADE	L. Cowlitz	Complete Watershed		
	Coweeman	Low flow spot surveys	Low flow spot surveys	
	Toutle			
	U. Cowlitz	Complete Watershed *		
	Cispus			
	Tilton			
	Kalama	Complete Watershed * Install stream gauge CIFA	Upper Watershed * Install stream gauge CIFA	Low flow spot surveys
	NF Lewis	Complete Watershed *		
	U. Lewis	Complete Watershed * Install stream gauge		
	EF Lewis	Complete Watershed (annual) CIFA	Complete Watershed CIFA	Complete Watershed CIFA
	Salmon	Install stream gauge		
	Washougal	Complete Watershed CIFA	Complete Watershed CIFA	Low flow spot surveys
GORGE	L. Gorge			
	U. Gorge			
	Wind	Complete Watershed[2] (annual) Update data access[3] CIFA	Upper Watershed * Update data access[3] CIFA	Upper Watershed * Update data access[3] CIFA
	Little White Salmon			

* routine adult abundance monitoring ongoing
1 routine adult abundance monitoring ongoing in the lower basin
2 routine adult abundance monitoring ongoing in the upper basin
3 data is not currently available on-line
4 CIFA = Comprehensive Instream Flow Assessment

7.6 Action Effectiveness Monitoring

Action effectiveness monitoring determines if specific habitat, hydropower, hatchery, harvest, and ecological interaction measures produce the specific intended effect. This is a key elements of the monitoring plan and aspects of this are currently being implemented by other regional entities (i.e. the SRFB's Project Effectiveness Program contained within the Comprehensive Monitoring Program). This type of monitoring helps determine whether some types of actions work better than others and what level of contribution toward recovery is contributed by an action or suite of actions.

Effects of actions may be estimated directly based on estimates of desired population attributes (e.g., abundance, productivity, spatial structure, diversity) or indirectly based on effects on limiting factors. Formal experiments and rigorous statistical analysis may be required, for instance involving test and control populations. Action effectiveness monitoring complements and sometimes depends on status monitoring for baseline conditions. It can be used to evaluate the effects of individual projects and/or suites of actions. However, fish response need not be monitored routinely unless we do not know what to expect from project scale restoration actions. If such situations arise, sufficient analysis will be conducted in order to establish a predictable pattern of response. Furthermore, attention will be paid to other ongoing effectiveness studies so as not to unnecessarily duplicate costly monitoring efforts.

7.6.1 Stream Habitat

1. ***Monitor effects of watershed and stream habitat protection and restoration actions on stream habitat conditions.***

   Objective: Determine whether actions produce desired improvements in habitat conditions.
   Indicator: Patterns of land use, vegetation, etc. at the landscape/watershed scale, site-specific riparian and stream habitat parameters.
   Sampling: Periodic sampling of a representative series of test and control watersheds and streams in close conjunction with routine habitat monitoring and intensively monitored watersheds.
   Analysis: Trend and multivariate analysis.

2. ***Monitor relative distribution, abundance, and condition of fish in relation to specific habitat improvements.***

   Objective: Determine degree to which habitat improvements translate into a fish response.
   Indicator: Adult and juvenile numbers and distribution.
   Sampling: Periodic sampling of a representative series of test and control sites in close conjunction with routine biological monitoring.
   Analysis: Trend and multivariate analysis.

3. ***Concentrate a portion of habitat status and action effectiveness monitoring in one or more intensively monitored watersheds to optimize opportunities for evaluating linkages between habitat and fish (e.g., Mill/Abernathy/Germany, Kalama, East Fork Lewis, Wind). Consider subbasins containing multiple high priority populations and other ongoing studies such as the SRFB-sponsored Intensively Monitored Watershed project in the Mill, Abernathy, Germany basins..***

   Objective: Identify and quantify relationships. Integrate efforts with any ongoing longterm studies.

Indicator: As described in biological and habitat monitoring.
Sampling: Combination of routine and statistical designs to build a long term dataset.
Analysis: Trend and multivariate analysis.

7.6.2 Mainstem/Estuary

1. ***Monitor effects of small scale and large scale activities (e.g., channel deepening) that affect habitat.***

Objective: Determine whether projects produce desired effects.
Indicator: Habitat quantity and quality.
Sampling: Periodic sampling of a representative series of test and control sites in close conjunction with routine biological monitoring.
Analysis: Trend and multivariate analysis.

7.6.3 Hydropower

1. ***Monitor adult and juvenile collection, passage, and survival rates at Bonneville Dam.***

Objective: Determine most effective means of passage to guide operations and construction.
Indicator: Fish numbers and rates.
Sampling: Statistical samples at passage upstream and downstream facilities, marking of representative groups.
Analysis: Numbers relative to prescribed performance standards.

2. ***Monitor the relative abundance, distribution and dewatering of chum and fall Chinook redds in the Bonneville Dam tailrace.***

Objective: Estimate impacts of hydropower operations.
Indicator: Redd and stranded fish numbers by site and elevation.
Sampling: Annual representative index areas.
Analysis: Numbers relative to operational patterns.

3. ***Monitor adult and juvenile collection, passage, and survival rates at Cowlitz, Lewis and Toutle Dams.***

Objective: Determine most effective means of passage to guide operations and construction.
Indicator: Fish numbers and rates.
Sampling: Statistical samples at passage upstream and downstream facilities, marking of representative groups.
Analysis: Numbers relative to prescribed performance standards.

4. ***Monitor the downstream channels of Mayfield, SRS and Merwin Dams for changes in substrate and flow***

Objective: Assess loss of substrate, spawning gravels and flow fluctuations.
Indicator: Changes in sediment and flow conditions over time or in relation to dam operations
Sampling: Sediment surveys and monitoring of existing flow gauges
Analysis: Substrate, spawning gravel and flow as a function of operational patterns

7.6.4 Harvest

1. ***Monitor annual harvest and harvest rates of representative index stocks in in-basin, Columbia River mainstem, and ocean fisheries.***

Objective: Determine whether direct and incidental fishing impacts fall within intended limits for each fishery.
Indicator: Numbers harvested and released, catch per effort.
Sampling: Statistical angler surveys, catch sampling, coded-wire tag marking of representative stocks, natural production identification.
Analysis: In-season and post-season estimates from run reconstructions, impact rates relative to benchmarks, observed vs. expected impact rates.

2. ***Monitor catch and release mortality of wild salmon and steelhead in selective fisheries.***

Objective: determine wild fish mortality and develop methods to reduce mortality.
Indicator: Interception rates, short-term mortality, long-term mortality.
Sampling: Sport and commercial catch sampling and monitoring, marking released wild fish, recovery sampling at dams, weirs, natural spawning areas, and hatcheries.
Analysis: Mortality rates and interception rates by gear type and fishery. Total impact to index stocks.

7.6.5 Hatchery

1. ***Monitor effects of fish culture practices within the hatchery.***

Objective: Evaluate hatchery performance and identify best management practices.
Indicator: Growth and survival rates
Sampling: Pond inventories, treatment and control
Analysis: Multivariate.

2. ***Monitor numbers and performance of hatchery fish returning to hatcheries.***

Objective: Evaluate hatchery performance, hatchery rack operations, passage success above these racks and identify best management practices.
Indicator: Release numbers, return numbers, survival rates
Sampling: Pond inventories, adult traps, CWT tagging of representative hatchery release groups
Analysis: Trend and multivariate.

3. ***Monitor in-basin and out-of-basin stray rates of hatchery fish in wild spawning areas relative to hatchery practices.***

Objective: Determine the potential for negative and/or positive interactions between hatchery and wild fish.
Indicator: Hatchery-wild proportions on spawning grounds, hatcheries of origin.
Sampling: Routine biological monitoring of representative wild populations. Annual hatchery releases and returns, marking of hatchery fish, CWT tagging of representative hatchery release groups.
Analysis: Run reconstructions.

7.6.6 Ecological Interactions

1. ***Monitor occurrences of new exotic aquatic fishes, invertebrates or plants based on incidental observations during other biological status monitoring, anecdotal reports, and follow-up sampling where appropriate.***

   Objective: Identify emerging threats.
   Indicator: Species types and numbers.
   Sampling: Opportunistic.
   Analysis: Reference to historical baselines.

2. ***Continue to monitor abundance of American shad based on Bonneville Dam counts.***

   Objective: Identify significant changes in numbers or population dynamics.
   Indicator: Annual fish counts and run timing.
   Sampling: Dam counts.
   Analysis: Annual trends.

3. ***Monitor annual angler participation, harvest, and exploitation rate in northern pikeminnow management program in Columbia River mainstem.***

   Objective: Determine whether program is achieving desired 10-20% annual exploitation rates intended to reduce pikeminnow predation on juvenile salmonids by 50%.
   Indicator: Anglers registered, numbers and sizes of fish caught, annual percentage of tagged fish caught.
   Sampling: Preseason tagging of pikeminnow, angler registration, catch sampling.
   Analysis: Annual differences relative to objectives.

4. ***Conduct periodic censuses of the abundance and distribution of nesting Caspian terns.***

   Objective: Determine if management measures continue to achieve desired redistribution of terns to areas of reduced salmonid predation.
   Indicator: Tern numbers by area.
   Sampling: Ground and/or aerial surveys.
   Analysis: Trends in population size and use of East Sand, Rice, and other islands.

5. ***Conduct periodic censuses of the abundance, distribution, and diet of marine mammals throughout the lower Columbia River mainstem and particularly near Bonneville Dam.***

   Objective: Identify emerging threats.
   Indicator: Numbers by area.
   Sampling: Boat or aerial surveys, behavioral monitoring near Bonneville Dam.
   Analysis: Trends in population size and increased numbers and predation near Bonneville Dam.

6. ***Monitor and evaluate the establishment of escapement rates through harvest management actions in relation to the nutrient and other ecological value of returning salmon***

   Objective: Evaluate the relation of returning adult salmon at or above planned escapement rates to the productivity of the habitat
   Indicator: Numbers of spawning adults
   Sampling: Ground and/or aerial surveys.
   Analysis Trends in spawner/recruit ratios in relation to planned escapement levels

7.7 Implementation/Compliance Monitoring

Implementation/compliance monitoring evaluates whether actions were implemented as planned or meet established laws, rules or benchmarks. Detailed elements of compliance monitoring are presented in Chapter 8 of this report (Plan Implementation) with the primary task as follows:

1. ***Maintain a coordinated database of federal, tribal, state, local, and non-governmental programs and projects implemented throughout the recovery region.***

   Objective: Track execution of management actions relative to this recovery plan.
   Indicator: Numbers and types of programs and projects by area.
   Sampling: Periodic polls and surveys.
   Analysis: Categorical summaries (implemented, partially implemented, not implemented).

7.8 Critical Uncertainty Research

Critical uncertainty research targets specific issues that constrain effective recovery plan implementation. Critical uncertainty research includes evaluations of cause and effect relationships between fish, limiting factors, and actions that address specific threats related to limiting factors.

7.8.1 Salmonid Status and Population Viability

1. ***Validate recovery goals and preliminary estimates of persistence probabilities based on life cycle analyses and long term data sets.***

7.8.2 Stream Habitat

1. ***Apply monitoring feedback loops to inform EDT analysis and improve estimates of fish productivity and capacity based on habitat and fish productivity data.***
2. ***Determine relative short term and long term tradeoffs in the benefits of site-specific and process based actions.***

7.8.3 Mainstem/Estuary

A research, monitoring, and evaluation (RME) plan for the Columbia River estuary and plume was recently developed (Johnson et al. 2003) for the purpose of fulfilling certain requirements of Reasonable and Prudent Alternatives of the 2000 Biological Opinion on the Operation of the Federal Columbia River Power System (NMFS 2000). Research needs were identified in that process at a 2003 workshop. The following research needs were identified at that workshop:

1. ***Move from a collection of available conceptual frameworks to an integrative implementation framework, where we combine what we have learned in the various conceptual frameworks to identify the most important areas for restoration actions, and what are the most likely avenues for success.***
2. ***Implement selected restoration projects as experiments, so that we can learn as we go.***
3. ***Implement pre- and post-restoration project monitoring programs, to increase the learning.***

4. *"Mining" of existing, underutilized data to minimize the risk of collecting redundant or unnecessary data, and to compare with current and projected conditions.*
5. *Make more use of ongoing PIT tagging and other tagging and marking studies and data to determine origin and estuarine habitat use patterns of different stocks.*
6. *Collect additional shallow water bathymetry data for refining the hydrodynamic modeling, and identifying/evaluating potential opportunities for specific restoration projects.*
7. *Determine operational and hydrologic constraints for the FCRPS, so that we have a better understanding of feasibility and effectiveness of modifying operations.*
8. *Identify and implement off-site mitigation projects in CRE tributaries.*
9. *Establish a data and information sharing network so that all researchers have ready and up-to-date access.*
10. *Increased genetic research to identify genotypic variations in habitat use.*
11. *Understanding salmonid estuarine ecology, including food web dynamics.*
12. *Understanding sediment transport and deposition processes in the estuary.*
13. *Understanding juvenile and adult migration patterns.*
14. *Identifying restoration approaches for wetlands and developing means for predicting their future state after project implementation.*
15. *Improve our understanding of the linkages between physical and biological processes to the point that we can predict changes in survival and production in response to selected restoration measures.*
16. *Improve our understanding of the effect of toxic contaminants on salmonid fitness and survival in the CRE and ocean.*
17. *Improve our understanding of the effect of invasive species on restoration projects and salmon and of the feasibility to eradicate or control them.*
18. *Improve our understanding of the role between micro- and macro-detritus al inputs, transport, and end-points.*
19. *Improve our understanding of the biological meaning and significance of the Estuarine Turbidity Maximum relative to restoration actions.*
20. *Identify end-points where FCRPS BO RPA action items are individually and collectively considered to be satisfied, so that the regulatory impetus is withdrawn.*
21. *Increase our understanding of how historical changes in the estuary morphology and hydrology have affected habitat availability and processes.*

7.8.4 Hydropower

1. *Determine feasibility of re-establishing self-sustaining anadromous populations upstream of hydropower facilities in the Lewis, Cowlitz and Tilton systems.*
2. *Determine effects of flow on habitat in the estuary & lower mainstem.*
3. *Identify delayed effects of passage on fish condition and survival.*

7.8.5 Harvest

1. ***Evaluate innovative techniques (e.g., terminal fisheries and tangle nets) to improve access to harvestable stocks and reduce undesirable direct and indirect impacts to wild populations.***
2. ***Evaluate appropriateness of stocks used in weak stock management.***

7.8.6 Hatchery

1. ***Develop a strategy for assessing the interactions between hatchery and wild fish***
2. ***Determine relative performance of hatchery and wild fish in wild in relation to broodstock divergence and hatchery practices.***
3. ***Experimentally determine net effects of positive and negative hatchery effects on wild populations.***
4. ***Experimentally evaluate the efficacy of hatchery program integration, segregation, and supplementation.***
5. ***Determine hatchery effects on disease and predation on wild fish.***

7.8.7 Ecological Interactions

1. ***Experimentally evaluate nutrient enrichment benefits and risks using fish from hatcheries or suitable analogs (same as measure I.M6).***
2. ***Determine the interactions and effects of shad on salmonids.***
3. ***Determine the significance of marine mammal predation on adult and juvenile salmonids and alternatives for management in the Columbia River mainstem and estuary.***

7.8.8 Bull Trout

The following research needs were identified in the draft bull trout recovery plan (USFWS 2002) for the Washington lower Columbia River Recovery Unit:

1. ***Distribution and abundance of bull trout consistent with recovery. The draft plan identifies interim criteria until uncertainty regarding appropriate numbers of populations, spatial distribution, and population sizes are identified.***
2. ***Guidelines for evaluating habitat elements necessary for bull trout and inventory of habitat inventory of streams that provide basic cold water habitat conditions necessary for bull trout.***
3. ***Productive capacity of each potential local bull trout population.***
4. ***Presence of bull trout and potential importance for recovery of Cowlitz and Kalama rivers.***
5. ***More thorough understanding of the current and future role that the mainstem Columbia should play in the recovery of bull trout.***
6. ***Effectiveness and feasibility of using artificial propagation in bull trout recovery.***
7. ***Describe the genetic makeup of bull trout in the mainstem Columbia and Klickitat rivers.***

7.8.9 Other Species of Interest

1. ***Identify status, limiting factors, and management alternatives for lamprey.***
2. ***Determine relative significance of mainstem and tributary spawning, environmental and habitat conditions related to population dynamics of smelt.***
3. ***Determine impacts of shad on salmonids and other ecosystem effects.***

7.9 Reporting, Data, and Coordination

Regional coordination and data management will ensure efficient implementation of a comprehensive and complementary program as well as accessibility and effective application of the associated data.

1. ***Conduct a data management needs assessment and use to develop a data management plan.***

   Explanation: Additional assessments are needed to coordinate with complementary data management activities throughout the region.

2. ***Maintain consistent regionally-standardized datasets and archive in regional data storage and management facilities (e.g., Pacific State Marine Fisheries Commission StreamNet, Washington Department of Fish and Wildlife SSHIAP, NOAA Fisheries biological datasets).***

   Explanation: Existing infrastructures will be used to archive relevant data and metadata generated through monitoring and research activities. Data will be compiled and subject to rigorous quality assurance/quality control protocols by the collecting agency. Collecting agencies will be responsible for maintaining databases and providing access upon request. Information will be also distributed to multiple archives to maximize accessibility.

3. ***Produce and distribute regular progress and completion reports for monitoring and research activities.***

   Explanation: Regular reporting is critical for making new information available to technical/scientific staff, decision-makers, stakeholders, and the public.

4. ***Closely coordinate Washington lower Columbia River monitoring, research, and evaluation efforts with similar efforts throughout the basin, including prioritization of activities and standardization of data methods.***

   Explanation: A variety of MR&E efforts are underway at local and regional scales across the Pacific Northwest. Coordination of Washington lower Columbia River efforts will provide synergistic benefits. For instance, many critical uncertainties are common among different areas and need not be addressed in each area. Standardization of data methods will greatly enhance comparative and interpretative power of monitoring and research activities.