PNNL-14632

Plan for Research, Monitoring, and Evaluation of Salmon in the Columbia River Estuary

FINAL DRAFT
August 10, 2004

Prepared by the Pacific Northwest National Laboratory
with funding from the Bonneville Power Administration

Pacific Northwest National Laboratory
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Bonneville Power Administration

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Cover Photo: View of the Columbia River estuary looking downstream with Tenasillahe Island on the right.

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Overview

The Columbia River estuary is a key element of the basin-wide research, monitoring, and evaluation effort developed in response to the 2000 Biological Opinion on operation of the Federal Columbia River Power System (FCRPS). This Opinion considered whether FCRPS operations would jeopardize the continued existence of 12 salmonid species in the Columbia River basin listed under the Endangered Species Act. During up and downstream migrations, all these anadromous fish use the estuary, defined here to be the Columbia River from Bonneville Dam into the plume in the Pacific Ocean.

The purpose of this *plan* for research, monitoring, and evaluation (RME) in the Columbia River estuary is to provide a strategic framework to conduct an estuary RME *program*. A formal, integrated RME program does not currently exist; however, it was called for in Action 161 of the Reasonable and Prudent Alternative in the Opinion. Specifically, the estuary RME plan contained herein 1) establishes RME goals and objectives for salmon-related activities in the estuary; 2) develops performance indicators and monitored attributes that are responsive to the objectives; 3) identifies methods to obtain and analyze data on the monitored attributes; and 4) uses project and program level assessments to make recommendations as part of a phased action plan for estuary RME.

Goals and Objectives

The NOAA Fisheries/Action Agencies' overall goal for the Columbia River estuary is to **conserve and restore estuary habitats to improve the viability[1] of endangered and threatened salmonid populations**. The goal of estuary RME is threefold: 1) Status Monitoring –quantify the status and trends in listed salmon habitat usage and survival in the estuary; 2) Action Effectiveness – quantify the effects of the habitat restoration[2] actions on listed salmon in the estuary; and 3) Uncertainties –resolve uncertainties related to salmon recovery/habitat restoration actions in the estuary. To achieve the overall goal, this plan describes the research, monitoring and evaluation needed to address the following estuary RME objectives.

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[1] Population viability is a measure of the status of anadromous salmonids used by NOAA Fisheries and defined by four performance criteria: abundance, productivity, spatial structure, and diversity. In the estuary, viability will be assessed by measuring attributes associated with performance indicators for juvenile salmon life history diversity, spatial distribution, growth, and survival.

[2] In this document, the term "restoration" generally refers to any or all of the five fundamental restoration approaches commonly reported in the literature: creation, enhancement, *restoration*, conservation, and protection (defined in the glossary).

Status Monitoring

- SM 1. Describe the present status of the estuary ecosystem in terms of habitat conditions, habitat connectivity, and fauna relative to pre-European settlement conditions.
- SM 2. Monitor the spatial distribution, life history diversity, and growth of juvenile salmon in the estuary.
- SM 3. Estimate the survival rates of juvenile salmon of listed Evolutionarily Significant Units (ESUs) in the tidal-freshwater reach (RM 46-146), the estuarine reach (RM 0-46), and the plume.
- SM 4. Determine the water quality in estuary salmon spawning and rearing habitat relative to state and federal water quality standards and salmon survival needs.
- SM 5. Describe trends in the physical condition of estuary salmon spawning and rearing habitat in terms of substrate type, accretion rates, reduction/oxygenation potential, groundwater level, large woody debris, water velocity and water surface elevation compared to present conditions.
- SM 6. Determine the status and trends of abundance, species composition, and distribution of invasive species in the estuary such as purple loosestrife, shad, and New Zealand mud snails.
- SM 7. Provide biennial summaries of the status and trends of hydrographic and oceanic conditions affecting salmon survival within the estuary and salmon population size.

Action Effectiveness Research

- AER 1. Implementation Monitoring. Determine if restoration projects in the estuary, as implemented, meet the project-specific performance goals.
- AER 2. Effectiveness Monitoring. Determine whether individual restoration projects in the estuary are effectively changing relevant structural or functional parameters relative to reference and/or control sites.
- AER 3. Validation Monitoring. a) Determine the extent to which habitat restoration projects in the estuary, collectively, are affecting targeted ecosystem processes that support listed salmon. b) Determine the cumulative effect of estuary habitat restoration on salmon population viability.

Uncertainties Research

- UR 1. Determine the significance of the estuary, which includes the plume, to listed salmonid Evolutionarily Significant Units.
- UR 2. Identify changes that could be made to FCRPS operations that would improve habitat conditions in the estuary.
- UR 3. Determine the highest priority habitat types for restoration in the estuary.
- UR 4. Develop a method to assess whether the offsite mitigation program involving habitat restoration in the estuary is working.

Performance Indicators and Monitored Attributes

To address these objectives, we identified 12 performance indicators and 47 associated monitored attributes (see table below). Performance indicators are characteristics of the ecosystem that are both relevant to a project objective and sensitive to predicted changes. Performance indicators are typically comprised of a suite of monitored attributes, the specific variables that are measured to assess the response of the system. Monitored attributes are called "metrics" or "parameters" in other monitoring plans. As an example, the status monitoring objective for ecosystem status includes a performance indicator for habitat conditions, which has the monitored attributes of vegetative cover, geology/soils, floodplain topography, bathymetry, and area affected. Many of the performance indicators developed for status monitoring in the estuary are applicable to action effectiveness and uncertainties research, although spatial and temporal scales for sampling will differ. The performance indicators and associated monitored attributes for status monitoring follow:

Performance Indicator	**Monitored Attribute**
Habitat conditions	Vegetation cover
	Geology/soils
	Floodplain topography
	Bathymetry
	Area protected, conserved, restored, enhanced, or created
Habitat connectivity	Passage barriers
	Total edge floodplain and tidal channels
Fauna	Nearshore fauna
	Avifauna
Life history diversity	Species composition
	Age-structure
	Evolutionarily Significant Unit
	Temporal distribution
Spatial distribution	Spatial distribution
	Migration pathways
Growth	Growth rate
	Residence time
	Prey availability
	Foraging success
Survival	Survival rate
	Predation index
Water quality	Temperature
	Salinity
	Dissolved oxygen
	pH
	Turbidity
	Nutrients
	Toxics

Performance Indicator	Monitored Attribute
Physical condition	Substrate type
	Accretion rates
	Reduction/oxygenation potential
	Ground water level
	Large woody debris
	Sediment contamination
	Water velocity
	Inundation regime
Invasive species	Species list
	Spatial distribution
	Abundance
River discharge	Hydrograph
Plume conditions	Juvenile salmon usage
	Anchovy/herring index
	Zooplankton prey base
	Sea surface temperature (El Nino state)
	Pacific decadal oscillation
	Upwelling

Methods

For each monitored attribute, data collection protocols and methods, including sampling design considerations for status monitoring and action effectiveness, are recommended. Adaptation of the Environmental Protection Agency's Environmental Mapping and Assessment Program (EMAP) approach could prove to be useful for design of the status monitoring effort. The ecological concepts of salmonid habitat capacity, habitat opportunity, and realized function are used to design action effectiveness research. The method descriptions for each monitored attribute include the following elements:

- *Geographic Scale* – The spatial extent over which sampling or analysis will occur: the estuary not including the plume; the estuary including the plume; or restoration site-specific.
- *Temporal Scale-Frequency* – How often the sampling or analysis will be performed.
- *Data Collection Method* – The primary technique to be used to collect the data.
- *Example Protocol/Data Source* – Reference where the data collection method is described.
- *Use in Status Monitoring* – How the data applies to status monitoring.
- *Use in Action Effectiveness Research* – How the data applies to action effectiveness research.

Action Plan

Project-Level Recommendations

A project-level assessment was used to identify ongoing or planned projects for research or monitoring in the estuary that are related to estuary RME. This process produced an inventory of estuary RME projects. Then, we assessed coverage of the attributes to be monitored to meet the objectives for status monitoring, action effectiveness research, and uncertainties research by examining whether the attributes were included in the scopes of work (objectives) for these projects. To summarize, we made the following conclusions about project coverage of the estuary RME performance indicators.

- *Habitat Conditions and Connectivity* – The projects need to be developed further, in greater detail, and integrated with the overall estuary RME effort. Projects in preparation to map subtidal habitats and survey the study area using LIDAR should be useful. The geology/soils attribute of the habitat condition indicator could be further addressed by continuing the vibracores study. Although habitat mapping is well underway, further hyper-spectral or digital photogramatic imagery for habitat mapping is warranted. Landscape analysis of habitat changes is ongoing, but habitat connectivity analysis is still in the planning stage. A habitat connectivity measurement tool to address the tidal channel and allometry attributes would be useful to assess trends in restoration efforts design to reconnect shallow water habitats to the estuary, e.g., dike breach and tidegate restoration actions.

- *Fauna* – A few projects currently involve this indicator. Fauna were addressed in previous work as part of the Bi-State Water Quality Study and the Columbia River and Estuary Data Development Project.

- *Salmon Life History Diversity, Spatial Distribution, and Juvenile Salmon Growth* – Existing projects are addressing these indicators and, although reports are not yet available, these projects should ultimately produce the required data. The residence time attribute of the growth indicator is under covered. A new project will monitor habitat (including fish) and toxic chemicals in the estuary. However, systematic, standardized monitoring of habitats in the tidal freshwater reach (RM 46-146) is negligible. Also, none of these projects integrate and coordinate estuary monitoring into a pilot monitoring study as is being done upriver in selected tributary habitats in the Columbia Basin.

- *Survival* – The suite of projects is sufficient, but methodologies and protocols are still being developed. Survival data for juvenile salmonids in the estuary do not exist; however, the existing projects are progressing to develop the required data. Techniques to estimate survival for juvenile salmon in the 70-90 mm size range need to be developed. A predation index, as a monitored attribute of the survival indicator, does not currently exist for the estuary.

- *Water Quality* – The existing projects, coupled with the new water quality monitoring effort seem to provide sufficient coverage. There is a need for integration and coordination into the overall estuary RME effort and a commitment to a long term effort if adequate trend data are to be developed.

- *Physical Condition* – Monitored attributes of estuary water, such as circulation patterns, hydraulic characteristics, and temperature, are covered well by existing projects, especially the Columbia River estuary monitoring and modeling project (CORIE). On the other hand, geologic and substrate physical conditions are not as well covered.

- *Invasive Species* – To our knowledge, research and monitoring of invasive species is negligible at this time. There is a distinct need to revive this work.

- *River Discharge and Plume Conditions* – These indicators are well covered by existing projects.

Detailed project-level recommendations are provided by performance indicator. All ongoing projects and new starts identified in the project inventory should be continued. These projects help meet estuary RME goals and objectives by providing data for status monitoring, action effectiveness research, and uncertainties research. In addition, the Action Agencies should consider developing a pilot status monitoring study in the estuary as part of basin-wide RME. It may be possible to achieve this by supporting or expanding an existing status monitoring project. This would extend to the estuary the basin-wide RME concept of a regionally coordinated, programmatic approach.

The individual projects, however, need to be implemented in the context of an overall estuary RME Program. Toward this end, we performed a program-level assessment that examined four key elements of any successful RME program that is based on an adaptive management process like the one intended for estuary RME: 1) coordination and implementation, 2) data management and analysis, 3) information reporting, and 4) program evaluation. We determined that most of the essential program level elements for estuary RME do not exist. As part of the action plan for estuary RME, the project- and program-level assessments we performed led to specific recommendations to improve the current situation for RME in the estuary.

Program-Level Recommendations

This estuary RME plan provides a strategic framework for the Action Agencies to directly implement RPA Action 161 (Estuary Monitoring Program). The fundamental program-level recommendation is to establish and support an estuary RME Program, because currently no recognized program exists. We have the following general recommendations for the estuary RME Program and its phased development and implementation.

Coordination and Implementation

- Establish an estuary RME coordination committee that includes the Action Agencies, the Estuary Partnership, and other entities charged with monitoring oversight.
- Develop a statement of roles and responsibilities of each agency and entity working on RME in the estuary. In addition, consider establishing a memorandum of understanding between the key parties regarding the roles and responsibilities, governance structure, and organization of the estuary RME program.
- Use contractual mechanisms to require that 1) performance criteria be developed in the planning phase of each habitat restoration project; 2) post-restoration monitoring of performance indicators be conducted, and 3) resulting data be compiled and reported to standards appropriate for estuary-wide analyses.
- Coordinate with other basin-wide RME groups, other federal monitoring programs, interested parties, and state and local monitoring efforts. Integrate estuary RME with the Pacific Northwest Aquatic Monitoring Partnership by attending PNAMP meetings to describe and report estuary RME activities and develop an estuary module for PNAMP.
- Establish a stable funding base to support a comprehensive estuary RME program.

Data Management and Analysis

- Develop estuary RME data specifications to support a coordinated data management system.
- Adopt standardized methods for status monitoring to allow comparisons through time for given monitored attributes.
- Adopt standardized methods for action effectiveness research to allow comparisons across projects and to address the cumulative effects of projects.
- Build a database of results from status monitoring and action effectiveness research.
- Establish a central, web-accessible repository for estuary data, and a homepage with links to a networked system of databases. Specifically, this system should be linked to basin-wide RME data to facilitate basin-wide evaluations.

Information Reporting

- Convene annual estuary RME workshops to present new data, evaluate the conduct of the estuary RME program, exchange information, and provide input to the estuary RME coordinating committee.
- Write biennial estuary RME summary reports and adaptive management recommendations at the program level for submittal to the Action Agencies, estuary restoration project leaders, and other related entities (e.g., subbasin planners, PNAMP).
- Establish procedures that link decision makers and data managers to the estuary RME coordinating committee in a manner consistent with basin-wide adaptive management.

Program Evaluation

- Review protocols for status monitoring and action effectiveness research every 5 years as new science becomes available.
- Apply results from ongoing research to update and consolidate the conceptual ecosystem model for the estuary.
- Include peer-review elements in the estuary RME Program.
- Revisit program goals, objectives, and design/plan.

Phased Development and Implementation of NOAA Fisheries/Action Agencies' Columbia River Estuary Salmon RME Program

A phased approach (se table below) is recommended for development and implementation of the NOAA Fisheries/Action Agencies' estuary RME program. The phases include program initiation and infrastructure, science basis, implementation, and information transfer. The implementation of projects and development of the science basis for project prioritization and monitoring are already underway, and the initiation of the program and establishment of the infrastructure to ensure that these efforts are coordinated, focused and efficient is therefore a top priority. The following recommendations for actions in each phase are based on the project- and program level recommendations.

Phase 1 – Program Initiation and Infrastructure – FY05 and FY06

- Formalize the estuary RME program.
- Develop data management/analysis, information reporting, and program evaluation systems for estuary RME.

Phase 2 – Program Science Basis – FY04 and beyond

- Consolidate the conceptual models of the "estuary" ecosystems (tidal freshwater and estuary/plume) and apply the new model to revise the estuary RME plan.
- Fulfill the project level recommendations for uncertainties research and coverage of the performance indicators.

Phase 3 – Program Implementation – FY04 and beyond

- Execute the project and program recommendations.
- Periodically review the ongoing RME activities in the estuary to ensure that gaps in coverage are addressed by projects, coordinate with other RME efforts such as PNAMP and with entities implementing the estuary subbasin plan, and revise this RME plan if necessary due to programmatic changes or new scientific data.

Phase 4 – Program Information Transfer – FY05 and beyond

- Implement the information reporting recommendations.

Timeline for Development and Implementation of the Estuary Program.

Activity	**FY04**	**FY05**	**FY06**	**FY07**	**FY08**	**FY09**
Finalize estuary RME plan	*					
Phase 1 Program Initiation & Infrastructure		*	*			
Phase 2 Science Basis	*	*	*	*	*	*
Phase 3 Implementation	*	*	*	*	*	*
Phase 4 Information Transfer		*	*	*	*	*

Preface

The Bonneville Power Administration funds this project (Project No. 2002-077-000; Contract No. 652) as part of implementation of the 2000 *Biological Opinion on Operation of the Federal Columbia River Power System*. The project is conducted in coordination with the U.S. Army Corps of Engineers Portland District and the National Oceanic and Atmospheric Administration. The purpose of the project is to coordinate and facilitate activities of the estuary/ocean subgroup for research, monitoring, and evaluation (RME) arising from the Biological Opinion. The estuary/ocean subgroup is tasked by NOAA Fisheries and the Action Agencies with developing a RME plan for the Columbia River estuary, including the plume. The estuary/ocean subgroup functions under the auspices of the basin-wide RME planning process to implement the Biological Opinion. The estuary RME plan contained herein is the result of the estuary/ocean subgroup's efforts to date. The estuary RME plan will be released as a stand-alone document and it will also be incorporated into the federal basin-wide RME plan.

The Biological Opinion provided specific actions pertaining to the estuary, but it did not specify a performance standard or goal for protecting and restoring estuarine functions relative to Columbia River salmon populations. The Opinion, however, did call for habitat restoration to be the cornerstone of actions in the estuary for salmon. For the purposes of this plan, the estuary/ocean subgroup examined a variety of goals for the estuary identified in federal, state, and local programs, and developed a goal statement and objectives for Columbia River estuary habitat restoration to support endangered and threatened salmonid populations. The resulting NOAA Fisheries/Action Agencies' goal statement for their estuary program is congruent with existing goals for the estuary as well as the intent of the Opinion: **Conserve and restore estuary habitats to improve the viability of endangered and threatened salmonid populations.**

During development of the estuary RME plan, it became clear that its basis is different from the basis of other basin-wide RME efforts such as Tributary Habitat RME because the state of the science relative to ecosystem processes and salmon in the Columbia River estuary is not as advanced as it is in the tributaries. Fundamental information about important attributes of salmon biology such as life history diversity and spatial distribution is not well-known, and a comprehensive conceptual model of the estuary ecosystem has not been developed. Likewise, to date significantly less effort has been made to improve habitat conditions and monitor in the estuary than has been made upstream at the mainstem dams and in the tributaries. Accordingly, this plan recommends research to address uncertainties; as the results of such research in combination with restoration project monitoring data are evaluated within an adaptive management framework, the plan will be revised.

During the estuary/ocean subgroup process, scientists from the Pacific Northwest National Laboratory drafted sections of the plan that were then reviewed by staff from the BPA Fish and Wildlife Division, COE Portland District Environmental Planning Division, and NOAA Fisheries Habitat Conservation Division. The Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP) of the Northwest Power and Conservation Council (NPCC) and NOAA Fisheries reviewed the September 2003 version of the estuary RME plan as part of the basin-wide RME plan (ISAB/ISRP 2004-01). The Lower Columbia River Estuary Partnership's Science Work Group, NPCC staff, state and tribal fisheries management agencies, and others will have an opportunity to review the August 2004 draft.

This draft estuary RME plan is a work in progress. The current version of the plan contains substantial new material regarding goals, objectives, performance indicators, monitoring variables, uncertainties, methods, existing and planned projects, project coverage, and action planning. It is anticipated that some aspects of this plan will be further developed by other projects in 2004. Finally, it is important to recognize the following points:

- Funding of actions recommended in this plan will be determined in processes elsewhere, such as the COE Anadromous Fish Evaluation Program and the Council's Fish and Wildlife Program. One purpose of this plan is to provide a framework that the funding agencies and project entities can use to coordinate activities and make decisions about scopes of work.

- This document focuses on listed salmon species, although its ecosystem-based approach necessarily affects other species as well. RME for salmon is best undertaken within the context of other biota and physical processes using an ecosystem perspective.

- Major habitat areas that are not addressed in this plan, or in other RME plans for the Columbia Basin, are the nearshore ocean along the continental shelf to Alaska, and the open ocean salmonid habitats in the Gulf of Alaska. These areas may also contribute substantially to stock-specific survival of salmon and steelhead.

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Abbreviations and Acronyms

AER – action effectiveness research

BiOp – Biological Opinion

BON – Bonneville Dam

BPA – Bonneville Power Administration

COE – U.S. Army Corps of Engineers

CRE –Columbia River Estuary (RM 0-146)

CRE&P – Columbia River from BON into the plume

CREDDP – Columbia River Estuary Data Development Program

CREST – Columbia River Estuary Study Taskforce

CRFMP – Columbia River Fish Mitigation Project

EMAP – EPA Environmental Monitoring and Assessment Program

ENSO – El Nino Southern Oscillation

EOS – Estuary/Ocean Subgroup (for RME)

EP-RME – Estuary/plume research, monitoring, and evaluation

ERMECC – Estuary RME Coordinating Committee (proposed)

EPA – Environmental Protection Agency

ESA – Endangered Species Act

ESU – evolutionarily significant unit

ETM – estuarine turbidity maxima

FCRPS – Federal Columbia River Power System

GI – general investigation

GIS – geographic information system

ISAB – Independent Scientific Advisory Board

ISRP -- Independent Scientific Review Panel

LCREP – Lower Columbia River Estuary Partnership

NMFS – National Marine Fisheries Service (now called NOAA Fisheries)

NOAA – National Oceanic and Atmospheric Administration

NPCC – Northwest Power and Conservation Council (formerly Northwest Power Planning Council)

NRC – National Research Council

ODEQ – Oregon Department of Environmental Quality

ODFW – Oregon Dept. Fish and Wildlife

ORD – EPA Office of Research and Development

OWEB – Oregon Watershed Enhancement Board

PDO – Pacific Decadal Oscillation

PNAMP – Pacific Northwest Aquatic Monitoring Partnership

PNNL – Pacific Northwest National Laboratory

RM – river mile

RME – research, monitoring, and evaluation

RPA – Reasonable and Prudent Alternative

SARE – *Salmon at River's End*

SM – status monitoring

SWG –Science Work Group of the Estuary Partnership

TBD – to be determined

TRT – Technical Recovery Team

UR –uncertainties research

USFWS – U.S. Fish and Wildlife Service

USGS – U.S. Geological Survey

WDFW – Wash. Dept. Fish and Wildlife

WRDA – Water Resources Development Act

WSRFB – Washington Salmon Recovery Funding Board

Glossary

Adaptive management – A structured learning process for testing hypotheses through management experiments in natural systems, collecting and interpreting new information, and making changes based on monitoring information to improve the management of ecosystems; i.e., "learning by doing."

Action effectiveness research – Evaluation of how effectively actions specifically designed to aid listed salmon produce the desired biological and physical response.

Attribute – Frequently called "metric" or "parameter," this is the specific variable that is measured to assess the response of the system, e.g. "percent cover" or "survival."

Columbia River Estuary – The tidally influenced lower portion of the river from the mouth to Bonneville Dam, not including the tributaries.

Conceptual model – A graphical representation or a simple set of diagrams that illustrate a set of relationships among factors important to the function of an ecosystem or its subsystems.

Connectivity – see "Habitat Connectivity."

Conservation -- Maintenance of biodiversity (Meffe et al. 1994).

Creation -- Bringing into being a new ecosystem that previously did not exist on the site (NRC 1992).

Disturbance – Any relatively discrete event in time that disrupts or alters some portion or portions of an ecosystem.

Ecosystem – A community of organisms in a given area together with their physical environment and its characteristic climate.

Ecosystem function – Ecosystem function is defined as the role the plant and animal species play in the ecosystem. It includes primary production, prey production, refuge, water storage, nutrient cycling, etc.

Ecosystem process – Ecosystem processes are any interaction among physicochemical and biological elements of an ecosystem that involve changes in character or state.

Ecosystem structure – Ecosystem structure is defined as the types, distribution, abundances, and physical attributes of the plant and animal species comprising the ecosystem.

Effectiveness monitoring – Activities designed and undertaken to assess how well a particular restoration project performs.

Enhancement -- Any improvement of a structural or functional ecosystem attribute (NRC 1992).

Estuarine turbidity maxima – Circulation phenomena in an estuary that traps particles and promotes biogeochemical, microbial and ecological processes that sustain a dominant pathway in the estuary's food web (from http://depts.washington.edu/cretmweb/).

Estuary – For the purpose of the estuary RME plan, the estuary for the Columbia River is the tidally influenced part of the river, i.e., the reach from the mouth (RM 0) to Bonneville Dam (RM 146). Lower river tributaries are not considered.

Habitat – The physical, biological, and chemical characteristics of a specific unit of the environment occupied by a specific plant or animal.

Habitat capacity – A category of habitat assessment metrics including "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics (cf. Simenstad and Cordell 2000).

Habitat connectivity – A measure of how connected or spatially continuous a corridor between habitats or among habitats in a matrix is.

Habitat opportunity – A category of habitat assessment metrics that "appraise the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features (cf. Simenstad and Cordell 2000).

Indicator – Characteristic of the system that is both relevant to a project objective and sensitive to predicted changes in the system. Indicators are often comprised of a suite of monitored attributes.

Lower Columbia River – The tidally-influenced freshwater part of the estuary from RM 46 to RM 146.

Monitored attribute – See "attribute."

Ocean-type life history – General life history pattern for salmon in which juveniles migrate to sea during their first year after emergence.

Oligohaline – Water having low salinity.

Performance indicator – see "Indicator."

Performance standard – Also called "performance criteria," a specified numerical objective deemed necessary to improve ecosystem function, improve salmon survival, and ultimately result in recovery for listed fish. A performance standard can be expressed as an absolute quantitative target, a range, or a change in condition from some baseline.

Plume – The layer of Columbia River water in the nearshore Pacific Ocean.

Population viability – Measure of the status of anadromous salmonids used by NOAA Fisheries and defined using four performance criteria: abundance, productivity, spatial structure, and diversity. The latter two criteria are an "especially critical portion of the role of the estuary" (Fresh et al. 2004).

Protection --

Protocol – Standardized procedures of an assessment methodology to measure attributes of an ecological system.

Realized function – A category of habitat assessment metrics that "includes any direct measures of physiological or behavioral responses that can be attributable to fish occupation of the habitat and that promote fitness and survival," for example, survival, habitat-specific residence time, foraging success, and growth (cf. Simenstad and Cordell 2000).

Restoration -- Return of an ecosystem to a close approximation of its previously existing condition (NRC 1992).

Standard – see "Performance standard."

Status monitoring – Activities to monitor trends in the status of the ecosystem and fish populations and conditions in the habitats they use.

Stream-type life history – General life history pattern for salmon in which juveniles migrate to sea after one year of rearing in their natal stream system.

Stressor – A component of a conceptual model. A physical, chemical, or biological entity or process that induces effects on individuals, populations, communities, or ecosystems.

Subarea – A portion of a larger area that has unique characteristics.

Uncertainties research – Research to address uncertainties in the analytical assessments used in the Biological Opinion (NMFS 2000) and subsequent planned check-in evaluations.

1.0 Introduction

The purpose of this *plan* for research, monitoring, and evaluation (RME) in the Columbia River estuary is to provide a strategic framework to conduct an estuary RME *program*. A formal, integrated RME program does not currently exist. Specifically, the estuary RME plan 1) establishes RME goals and objectives for salmon-related activities in the estuary; 2) develops performance indicators and monitored attributes that are responsive to the objectives; 3) identifies methods to obtain data on the monitored attributes; and 4) uses project and program level assessments to make recommendations as part of a phased action plan for the estuary RME program. This programmatic framework is anchored by monitoring coordination, data management and dissemination, and adaptive management and program evaluation. The anticipated audience for the estuary RME plan includes entities responsible for, interested in, or affected by research, monitoring, and evaluation in the Columbia River estuary, such as the Bonneville Power Administration, the Corps of Engineers (COE), the Columbia River Estuary Study Task Force, the Lower Columbia River Estuary Partnership, National Oceanic and Atmospheric Administration (NOAA) Fisheries, the Northwest Power and Conservation Council (NPCC), the Oregon Watershed Enhancement Board, and the Washington Salmon Recovery Funding Board. The estuary RME plan will be carried out jointly through the COE's Anadromous Fish Evaluation Program, the NPCC's Fish and Wildlife Program and its subbasin planning effort, and various regional monitoring programs.

The intended outcome of implementation of the estuary RME plan is two-fold. First, it will provide data on the results of the NOAA Fisheries/Action Agencies' estuary program to allow decision-makers to assess whether program goals are being met. (The Action Agencies for the FCRPS Biological Opinion are the Bonneville Power Administration, the Bureau of Reclamation, and the Corps of Engineers.) A second, related result of estuary RME is that the data generated will be applied in management decisions designed to improve estuary habitats used by listed salmonids.

1.1 Background

The function of the Columbia River estuary[1] (Figure 1) in the life history of threatened and endangered salmonids is more than simply serving as a corridor for passage between the tributaries and the Pacific Ocean. The estuary provides critical habitat for various life history stages of salmon and steelhead, ranging from the rearing and feeding of fry, fingerlings, and smolts to the passage upstream of adults (Bottom et al. 2001). Usage of estuary habitat by juvenile salmonids varies by species and life history stage (Rich 1920). Generally, the closer the natal stream is to the estuary and the smaller the

[1] The Columbia River estuary is defined as the tidally-influenced portion of the river from the mouth to Bonneville Dam (river miles 0-146). This is consistent with Bottom et al. (2001) and Lower Columbia River Estuary Program (1999). Although lower Columbia River tributaries, such as the Cowlitz and Willamette rivers, are not part of the estuary RME study area; the principles for tributaries in the basin-wide RME Plan could be applied to these rivers where monitoring and research are also addressed under state and local programs.

juvenile migrant, the more likely it is that juveniles will use estuary habitats as more than just a migration corridor. (Information on salmon biology and ecology in the Columbia River estuary can be found in Bottom et al. 1984, 2001; Dawley et al. 1985a,b, 1986; Durkin et al. 1981; Kirn et al. 1986; Ledgerwood et al. 1991; McCabe et al. 1983, 1986; McConnell et al. 1983; and Reimers and Loeffel 1967.) However, estuarine wetland habitat area presumably used by juvenile salmonids has declined by 43% for tidal marshes and 77% for tidal swamps since 1870 (Thomas 1983). Almost 58 square miles or one-quarter of the estuary below Puget Island has been converted to diked floodplain, uplands, and non-estuarine wetlands (Thomas 1983). In recognition of the estuary's importance to salmon population viability, the 2000 Biological Opinion on operation of the Federal Columbia River Power System (FCRPS) called for the restoration[1] of estuarine habitat as a pivotal action to avoid jeopardizing the continued existence of listed salmonid populations (NMFS 2000).

Figure 1. Estuary RME Study Area in the Columbia River from Bonneville Dam into the Plume. The inset shows the study area relative to the Columbia Basin.

While the Biological Opinion provided actions in its Reasonable and Prudent Alternative (RPA) that pertain to the estuary (Table 1), it did not specify a goal for estuarine functions relative to Columbia River salmon populations. To fill this need, the estuary/ocean RME subgroup of the basin-wide RME process examined a variety of goals for the estuary identified in federal, state and local programs, and developed a

[1] In this document, the term "restoration" generally refers to any or all of the five fundamental restoration approaches commonly reported in the literature: creation, enhancement, *restoration*, conservation, and protection (defined in the glossary).

goal statement and objectives for the Columbia River estuary relative to endangered and the threatened salmon and steelhead populations listed in Table 2. The following goal statement for the NOAA Fisheries/Action Agencies' estuary program is congruent with existing, broader goals for the estuary as well as the intent of the Biological Opinion: **Conserve and restore estuary habitats to improve the viability of endangered and threatened salmonid populations.**

Table 1. Summary of Reasonable and Prudent Alternative Actions in the FCRPS Biological Opinion Related to the Columbia River Estuary (NMFS 2000).

Action No.	Description
158	Action plan to rapidly inventory estuarine habitat, model physical and biological features of the historical lower river and estuary, identify limiting biological and physical factors in the estuary, identify impacts of the FCRPS system on habitat and listed salmon in the estuary relative to other factors, and develop criteria for estuarine habitat restoration.
159	A plan addressing the habitat needs of salmon and steelhead in the estuary.
160	An estuary restoration program with a goal of protecting and enhancing 10,000 acres of tidal wetlands and other key habitats over 10 years, beginning in 2001, to rebuild productivity for listed populations in the lower 46 river miles of the Columbia River.
161	A monitoring and research program...to address the estuary objectives of this biological opinion.
162	A conceptual model of the relationship between estuarine conditions and salmon population structure and resilience.
163	A compliance monitoring program for inclusion in the first 1- and 5-year plans.
185	Fish marking and recapturing programs aimed at defining juvenile migrant survival for both transported and non-transported migrants and adult returns for both groups.
186	Comparative evaluations of the behavior and survival of transported and downstream migrants to determine whether causes of D can be identified for the reach between Bonneville Dam and the mouth of the Columbia River.
187	Studies and analyses to evaluate relationships between ocean entry timing and SARs for transported and downstream migrants.
193	State-of-the-art, novel fish detection and tagging techniques for use, if warranted, in long-term research, monitoring, and evaluation efforts.
194	Studies to develop a physical model of the Lower Columbia River and plume. This model will characterize potential changes to estuarine habitat associated with modified hydrosystem flows and the effects of altered flows where they meet the California Current to form the plume.
195	Causes of mortality below Bonneville Dam after juvenile salmonid passage through the FCRPS.
196	Studies to develop an understanding of juvenile and adult salmon use of the Columbia River estuary. These studies support the actions to develop criteria for estuarine restoration (Action 158), restoration planning (Action 159), and implementation (Action 160) in Section 9.6.2.2.
197	Studies to develop an understanding of juvenile and adult salmon use of the plume.

Table 2. Technical Recovery Team, Evolutionarily Significant Unit, and ESA Status of listed salmonids addressed in the 2000 FCRPS Biological Opinion.

Technical Recovery Team	Evolutionarily Significant Unit	ESA Status
Willamette and Lower Columbia River	Lower Columbia R. Chinook (*Oncorhynchus tshawytscha*)	threatened
	Lower Columbia R. Steelhead (*O. mykiss*)	threatened
	Upper Willamette R. Chinook (*O. tshawytscha*)	threatened
	Upper Willamette R. Steelhead (*O. mykiss*)	threatened
	Columbia R. Chum (*O. keta*)	threatened
Interior Columbia River Basin	Upper Columbia R. Spring Chinook (*O. tshawytscha*)	endangered
	Upper Columbia R. Steelhead (*O. mykiss*)	endangered
	Mid Columbia R. Steelhead (*O. mykiss*)	threatened
	Snake R. Spring/Summer Chinook (*O. tshawytscha*)	threatened
	Snake R. Fall Chinook (*O. tshawytscha*)	threatened
	Snake R. Steelhead (*O. mykiss*)	threatened
	Snake R. Sockeye (*O. nerka*)	endangered

To fulfill the FCRPS Biological Opinion and assess progress toward the estuary program goal, the Action Agencies are funding research, monitoring, and evaluation activities. The Action Agencies' have worked with NOAA Fisheries and federal, state, and tribal fisheries agencies since 2001 to develop a comprehensive RME plan for the Columbia River Basin (called the basin-wide plan). In the draft basin-wide RME plan (RME Plan 2003), RME activities are focused on the 12 salmon evolutionarily significant units listed under the Endangered Species Act and addressed in the Biological Opinion (Table 2). Using a hierarchical context of the ecosystems, subbasins, and habitats supporting these species, the basin-wide plan encompasses RME activities in habitats used by juvenile and adult life stages of salmon: natal streams and tributaries, the mainstem hydrosystem, and the estuary including the Columbia River plume. As a subset of the basin-wide RME effort, the plan contained herein covers RME in the Columbia River estuary. The habitat restoration in the estuary that is the subject of this plan is expected to benefit lower river chum and fall Chinook in particular, because the life histories of these stocks use the estuary more than other threatened and endangered stocks (Roegner et al. In Preparation). While the Biological Opinion contained specific recommendations for RME on tributary habitats and the hydrosystem, it did not provide such direction for the estuary. Therefore, this document offers a plan for estuary RME including goals and objectives, performance indicators and monitored attributes, methods, and an action plan.

While this estuary RME plan provides a strategic framework for the Action Agencies to directly implement RPA Action 161 (Estuary Monitoring Program), estuary RME also is related to other estuary RPA actions that are part of the Action Agencies' overall estuary program (Figure 2). Estuary RME, however, does not cover Actions 185, 186, and 187, which concern phenomena pertaining to the juvenile fish transportation (barging) program that have been hypothesized to manifest themselves in the estuary. These actions are addressed in the Hydrosystem component of the basin-wide RME plan (see RME Plan 2003).

The Action Agencies have the responsibility to coordinate and integrate estuary RME with implementation of other estuary RPA actions, so that the estuary program is adaptively managed. In the Endangered Species Act 2003 Check-In Report for the FCRPS (Bureau of Reclamation et al. 2003), the Action Agencies concluded that the estuary RPA actions were being addressed. In January 2003, the estuary/ocean subgroup for RME assessed how well the estuary/ocean RME actions in the Biological Opinion were covered by ongoing or planned projects (Estuary/Ocean RME Subgroup 2003). This "gap analysis," which found that existing or proposed research was generally adequate to meet estuary/ocean RME needs as defined by the Biological Opinion, has been updated for this RME Plan and the gaps identified are described in Section 5.0: Action Plan. The relevant actions specified in the FCRPS Biological Opinion and their outcomes or import for estuary RME are as follows:

- <u>Action 158</u> provided an overall programmatic action plan for RPA implementation in the estuary (Berquam et al. 2003). The 158 action plan is the guiding document for all estuary-related RPA actions. It was coordinated between the Action Agencies and NOAA Fisheries to minimize duplication of effort for the various estuary RPA actions during implementation.

- <u>Action 159</u> produced an ecologically based approach for habitat restoration to benefit listed-salmon in the estuary (Johnson et al. 2003). The 159 document includes guidelines for monitoring and evaluation at the habitat restoration project level.

- <u>Action 160</u> called for implementation of on-the-ground habitat protection and enhancement work. Monitoring and evaluation to assess performance of these projects will fall under the action effectiveness research described in this estuary RME plan.

- <u>Action 161</u> called for the implementation of an RME program to address the estuary objectives of the Biological Opinion (see Section 5.0 of this estuary RME Plan).

- <u>Actions 162 and 194</u> entailed modeling efforts, the results of which will be used in estuary RME as appropriate.

- <u>Action 195</u> addressed sources of mortality to listed-salmonid smolts below Bonneville Dam, an important topic for research in estuary RME along with juvenile survival rates.

- <u>Actions 196 and 197</u> involved study of salmonid usage in the estuary and plume, respectively, important research topics for estuary RME.

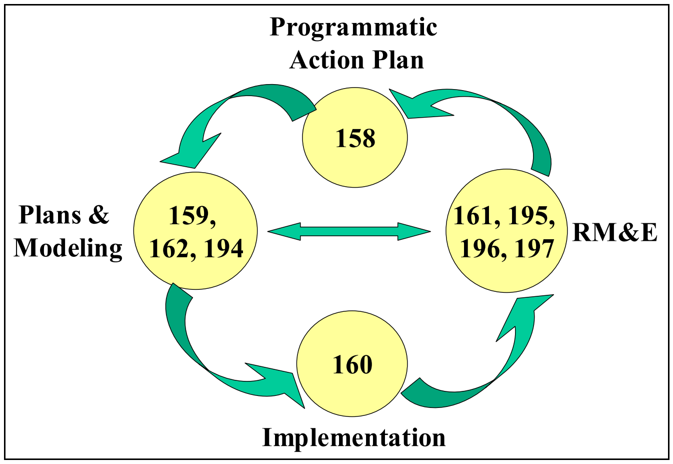

Figure 2. Relationship between estuary RME and Other Relevant Estuary RPA Actions (from Berquam et al. 2003). Action 161 is the RME program for the estuary.

This estuary RME plan is designed to 1) prescribe monitoring for status and trends in the estuary ecosystem and its populations of salmon and their habitats, including measurements of progress toward meeting offsite mitigation requirements in the estuary as mandated in the Biological Opinion; 2) offer a technical approach to assess the effectiveness of habitat restoration[1] actions; and 3) identify key uncertainties in salmon habitat restoration efforts in the estuary. These three design elements are consistent with the following key concepts from the Biological Opinion and basin-wide RME effort:

- <u>Status Monitoring</u> – Monitor status and trends of the ecosystem[2] and fish populations and conditions in the habitats they use. Status monitoring[3] also includes an accounting of the cumulative amount of habitat improved through specific actions in the estuary and plume for listed salmon (the ESA Habitat Team called this “habitat tracking”).

- <u>Action Effectiveness Research</u> -- Evaluate how effectively actions specifically designed to aid listed salmon produce the desired biological and physical responses.

- <u>Uncertainties Research[4]</u> – Seek to resolve key uncertainties in the estuary knowledge base.

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[1] As used here, habitat restoration includes the suite of strategies that can be applied to improve habitat conditions – restoration, conservation, creation, enhancement, and protection (Johnson et al. 2003).

[2] “Status of the ecosystem” refers to a holistic characterization of selected physical and ecological features of the estuary, such as a habitat inventory, geology/soils characterization, land classification, and passage barriers. As data are produced, current status will be assessed relative to previous data.

[3] For brevity, the term “status” monitoring inherently means “status and trends” monitoring.

[4] “Critical Uncertainties Research,” as used in the Biological Opinion, is defined as research to address uncertainties in the analytical assessments used in the Opinion and subsequent planned check-in evaluations. The only critical uncertainties in the Opinion for the estuary are related to the hydrosystem and are covered in the Hydrosystem RME plan (RME Plan 2003, Ch. 4). “Uncertainties Research,” as used herein, pertains to key uncertainties that require resolution to implement estuary RME.

1.2 Study Area

For the purpose of the estuary RME plan, the estuary of the Columbia River includes the plume the estuary proper, and the tidally influenced part of the river upstream to Bonneville Dam (Figure 3). While some definitions of estuaries utilize the maximum extent of seawater intrusion, under the Clean Water Act, all tidally influenced areas are included. Lower river tributaries are not considered because salmon-related monitoring and research in these areas are covered under state and local programs; however, the principles for tributaries developed in the basin-wide RME Plan may also be applied to these rivers.

A number of publications provide descriptive information about the estuary study area: the *Salmon at River's End* report by Bottom et al. (2001); Fresh et al.'s *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead*; the Biological Assessment for the Columbia River Channel Improvements Project by the COE (2001); the RPA Action 158 action plan by Berquam et al. (2003); the RPA Action 159 habitat restoration report by Johnson et al. (2003); and the Northwest Power and Conservation Council (NPCC) subbasin plan for the estuary (Lower Columbia Fish Recovery Board 2004).

Important earlier compendiums include: *The Columbia River Estuary and Adjacent Ocean Waters* by Pruter and Alverson (1972); "Columbia River Estuary" in *Changes in Fluxes in Estuaries: Implications from Science to Management* by Dyer and Orth (1994); and *Columbia River: Estuarine System* by Small (1990), which contains reviews of earlier work supported by the Columbia River Estuary Data Development Program (CREDDP) on physical and biological processes (CREDDP 1984a, 1984b). Another comprehensive environmental study of the lower Columbia River was the Bi-State Water Quality Study (TetraTech 1996; Fuhrer et al. 1996), completed as part of the process to include the Columbia River estuary in the Environmental Protection Agency's National Estuary Program. The brief study site description that follows draws from these major works and other literature. It is intended to provide context for the estuary RME plan.

The Columbia River watershed is the second largest in the United States with a drainage basin area of 660,480 km^2 (Simenstad et al. 1990). The width of the river is less than a mile some 52 miles from the Pacific Ocean, nearly 9 miles at RM 20, and approximately 2 miles at the jetties at the river mouth (Neal 1972). The river bottom is below sea level at Bonneville Dam and the estuary contains scattered deep areas, for example near 100 ft at Grays Point (Neal 1972). Historically, unregulated flows were estimated to range from a minimum of 2,237 m^3/s (79,000 cfs) in the fall to maximum flood flows of over 28,317 m^3/s (1 million cfs) during spring freshets (Sherwood et al. 1990). Since the 1930s, however, the timing of the Columbia River's discharge has been progressively regulated due to construction and operation of 28 major dams and approximately 100 minor dams that reduce spring freshet flows and increase fall/winter flows. For example, hydrographic modeling estimated that the spring freshet (May-July) flow reduction attributable to flow regulation is 33.1%, and the total reduction in freshet mean flow when climate and water withdrawal are included is 43% of pre-1900 flows (Jay 2001 as cited in Fresh et al. 2004). Alterations in the physical processes of the estuary that are attributable to human intervention include decreased freshwater discharge rates, tidal prism, and mixing and increased flushing time and fine sediment deposition, resulting in a net accumulation of sediment (Sherwood et al. 1990).

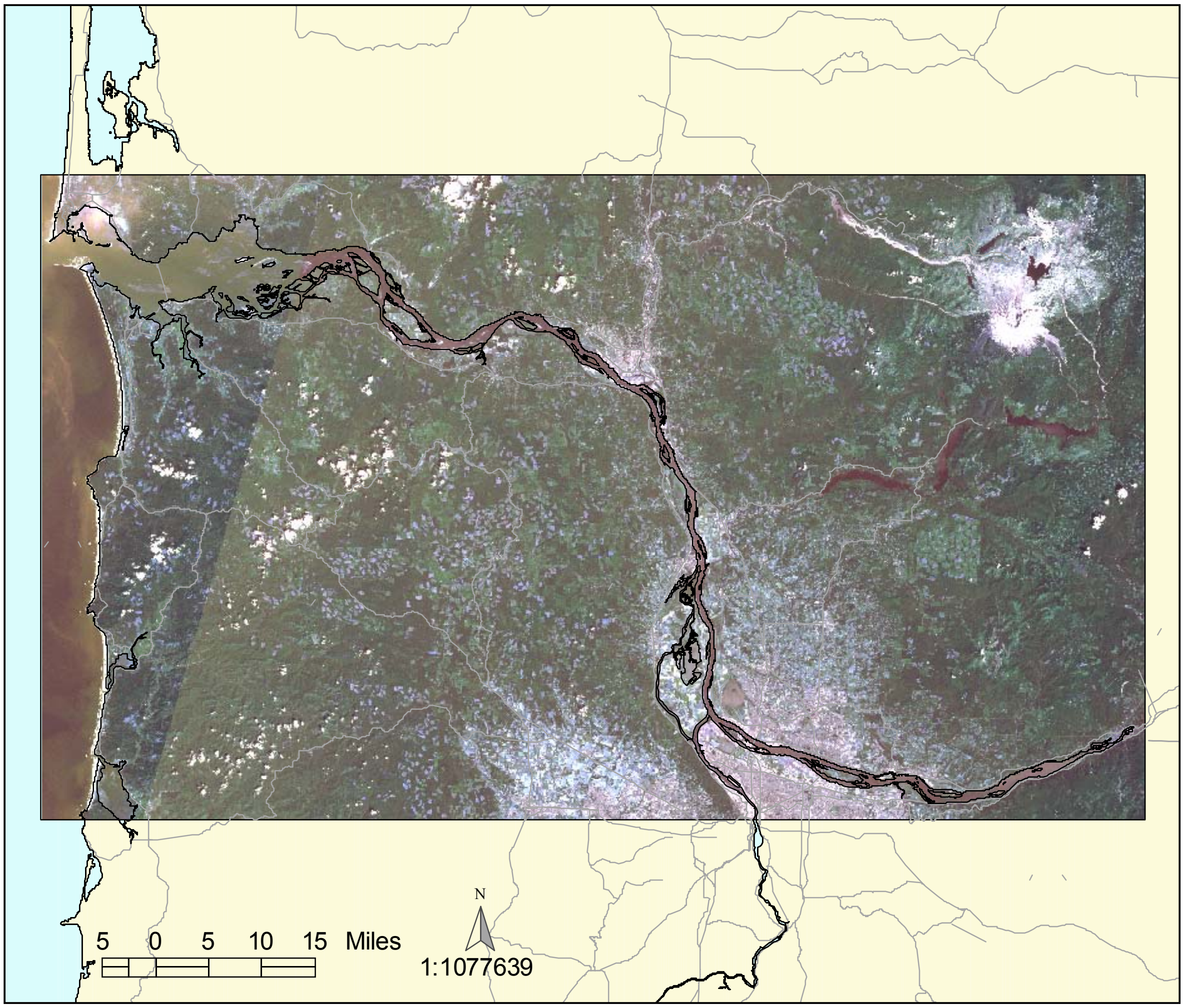

Figure 3. Satellite Photograph of the Estuary Study Area. (The map was made from LandSat data provided by R. Garano through the Estuary Partnership's habitat mapping project funded by BPA and COE.)

Despite alterations to river discharge patterns by the FCRPS and other factors, the estuary is still river-dominated because of relatively high flow volumes. However, the semidiurnal tidal range in the estuary is relatively large at 3.6 m and oceanic tides affect water levels throughout the entire lower reach to Bonneville Dam (RM 146) (Sherwood and Creager 1990; Neal 1972). Maximum seawater intrusion during low river flow is variable but less than 23 miles (Neal 1972). Flushing time has been calculated using several methods; calculations using a river flow of 549 x 10^7 cu ft/tidal cycle and maximum salinity intrusion of 19 nautical miles, for example, predict total flushing time ranging from 4.97 tidal cycles using the fraction-of-freshwater method to 9.0 tidal cycles using the modified tidal-prism method (Neal 1972). As an extension of the estuary, the Columbia River plume is a dominant factor affecting the hydrography of Pacific Northwest coastal waters (Garcia-Berdeal et al. 2002; Hickey and Banas 2003).

The Columbia River estuary, which occupies a drowned river valley, has been classified as a meso-tidal estuary according to Sherwood and Creager (1990). According to Neal (1972), the Columbia River estuary resists classification by Pritchard's (1955) approach based on mixing characteristics because of temporal and regional variability between three of the classes: vertically stratified, partially mixed, and well mixed. However, the study area defined for this estuary RME plan is too broad to allow for a discreet classification.

The ecoregions containing the Columbia River estuary according to the Environmental Protection Agency (EPA) classification (Omernik and Gallant 1986) are Coast Range, Puget Lowland, Willamette Valley and Cascades. The classification on the Oregon side has been refined for the purpose of water quality management to include Coastal Mountains, Coastal Lowlands, Willamette Valley Plains and Western Cascades (Clarke et al. 1991). The study area contains five physiographic provinces: Southern Washington Cascades, Western Cascades, Puget Trough, Willamette Valley, and Coast Ranges (Franklin and Dyrness 1988).

Estuarine landcover is shown by maps using LandSat (Figure 4) and compact airborne spectrographic imaging. Several categories of herbaceous wetlands, shrub-scrub wetlands, and coniferous and deciduous forest wetlands have been identified (Garono and Robinson 2003). For the purpose of a change analysis from 1870 to present, Thomas (1983) found that only five habitat types could be delineated. In order by elevation from highest to lowest, these are tidal swamps, tidal marshes, shallows and flats, medium depth water, and deep water. He assessed the change in these habitat types in seven subareas: the river mouth, mixing zone, Youngs Bay, Baker Bay, Grays Bay, Cathlamet Bay and the upper estuary. Not only habitat loss but habitat conversion is documented in Thomas' maps (1983). Perhaps the most critical findings for salmon are that below Puget Island the area of tidal swamps has been reduced by 77%, and that 65% of the 1870 tidal marshes has been lost while new marshes totaling about 22% of the original area have been formed (a net loss of 43%) (Thomas 1983). The study also showed net losses of medium and deep water habitats (35% and 7%, respectively), and a gain of shallows and flats caused mostly by shoaling in formerly deeper water areas (10%).

1.3 Relationship to Other Regional Salmon-Related Programs and Monitoring Efforts

The estuary RME planning effort is closely related to other initiatives in the estuary being undertaken by the COE, the Lower Columbia River Estuary Partnership (Estuary Partnership), Northwest Power and Conservation Council's (NPCC), and others. A subbasin plan (Lower Columbia Fish Recovery Board 2004) is currently being developed for the Columbia River estuary and its tributaries as mandated in the NPCC's Fish and Wildlife Program (NPPC 2000). The draft subbasin plan summarizes the objectives of this RME plan and recommends that future research, monitoring and evaluation in the estuary be consistent with this plan. On another front, the COE is undertaking a General Investigations Study for Lower Columbia River Ecosystem Restoration, due in 2007. The purpose of this study is to provide a comprehensive, long-range approach to investigate and recommend appropriate solutions to accomplish ecosystem restoration in the estuary, encompassing wetland/riparian habitat restoration, stream and fisheries improvement, water quality, and water-related infrastructure improvements. The intended outcome of the General Investigations Study is a strategic master plan for long-range, large COE projects in the estuary.

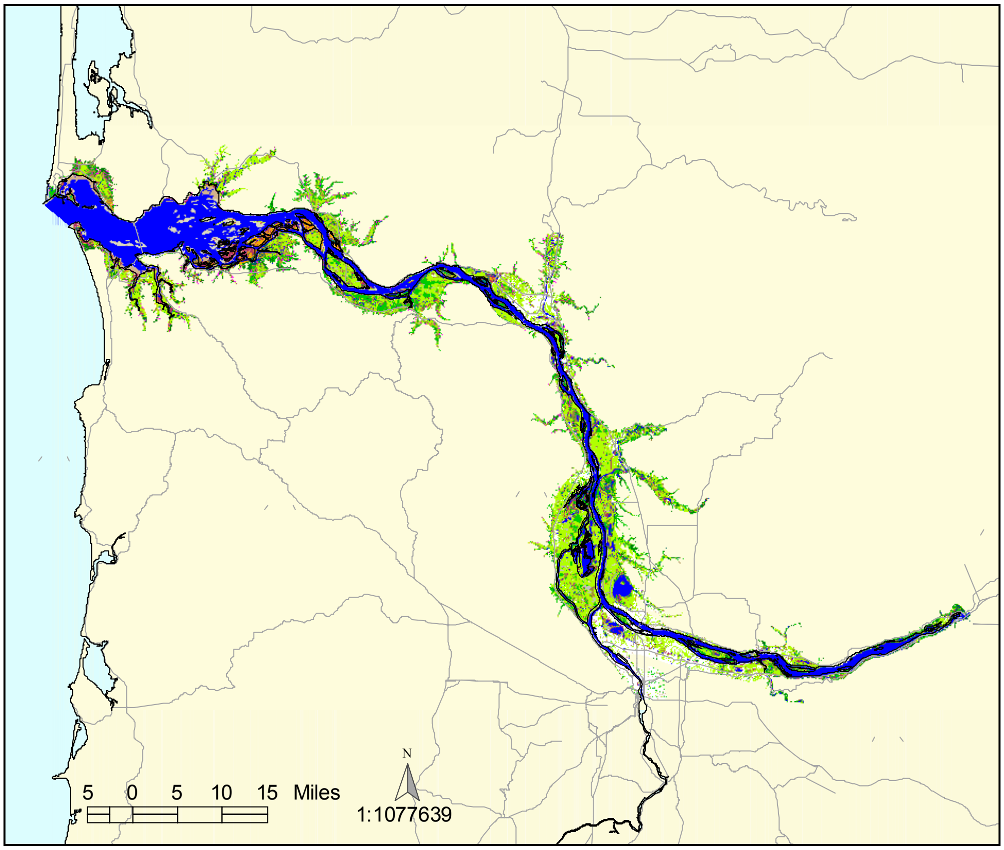

Figure 4. LandSat Cover Map of Columbia River Estuary. (Produced from LandSat data provided by R. Garano, Earth Design Consulting, Inc., through the Estuary Partnership's habitat mapping project funded by BPA and COE.)

Knowing the relationship between estuary RME and other regional and national monitoring programs is important to avoid duplication of effort and to learn from other experiences. We reviewed 36 documents relevant to the estuary RME plan. (See Appendix A for an annotated bibliography of these documents that describes their particular purpose, status, and how the work relates to estuary RME.) This RME plan draws directly on three of the monitoring programs summarized in Appendix A for indicators and other elements of the plan (Figure 5):

1. Lower Columbia River Estuary Program (1998) – The Estuary Partnership's (previously called Program) *Aquatic Ecosystem Monitoring Strategy* provides a broad underpinning for the estuary RME plan. The *Monitoring Strategy* makes specific recommendations for monitoring oversight, data management, and monitoring and research on pollutants, toxics, habitat, exotic species, and primary production (Appendix B). Many of these recommendations are embedded in the estuary RME plan. RPA Action 161 states that the monitoring and research program to implement this RME plan and address estuary objectives of the Biological Opinion should be "closely coordinated" with the monitoring and research efforts of the Estuary Partnership following from its *Monitoring Strategy*.

2. Oregon Watershed Enhancement Board (2004, http://www.oweb.state.or.us/monitoring/) – As described in the program statement, "Recent legislation, Senate Bill 945, directs the Oregon

Watershed Enhancement Board (OWEB) to develop and implement a statewide Monitoring Program in coordination with state natural resource agencies for activities conducted under the Oregon Plan for Salmon and Watersheds….OWEB programs support efforts that improve water quality, restore salmon runs, and strengthen ecosystems that are critical to healthy watersheds and sustainable communities. OWEB is responsible for three interrelated monitoring functions: strategic guidance and support for cooperative monitoring activities; accountability for restoration investments; and reporting on the progress of the Oregon Plan." The estuary RME plan incorporates some of the monitoring protocols from the OWEB Monitoring Program and the estuary RME program will be coordinated with OWEB.

3. Washington Salmon Recovery Funding Board (Monitoring Oversight Committee 2003a,b,c,d and WSRFB 2003a,b,c,d) – MOC (2003) developed a comprehensive monitoring strategy (Volume 2), including the necessary technical information, and provided an action plan (Volume 3), including costs, priorities, and timelines, in order to fulfill State Senate Bill 5637, on monitoring of watershed health and salmon recovery. Many of the elements of the broad Washington Monitoring Strategy are consistent with the estuary RME Plan. For example, the distinction between status/trend and effectiveness monitoring is the same. WSRFB (2003a-d) serve as planning documents to implement the monitoring strategy. The estuary RME program will be coordinated with the Washington Monitoring Strategy.

The basis of the estuary RME plan is different from the basis of other basin-wide RME elements such as Tributary Habitat RME and other plans that are primarily focused on monitoring freshwater environments. Fundamental information about important attributes of salmon biology related to the estuary such as life history diversity and spatial distribution is not well-known, and less monitoring has occurred in the estuary to date. Monitoring in the estuary also is different from tributary monitoring on many counts, from the appropriate objectives of restoration projects, to the appropriate indicators and protocols for data collection and analysis.

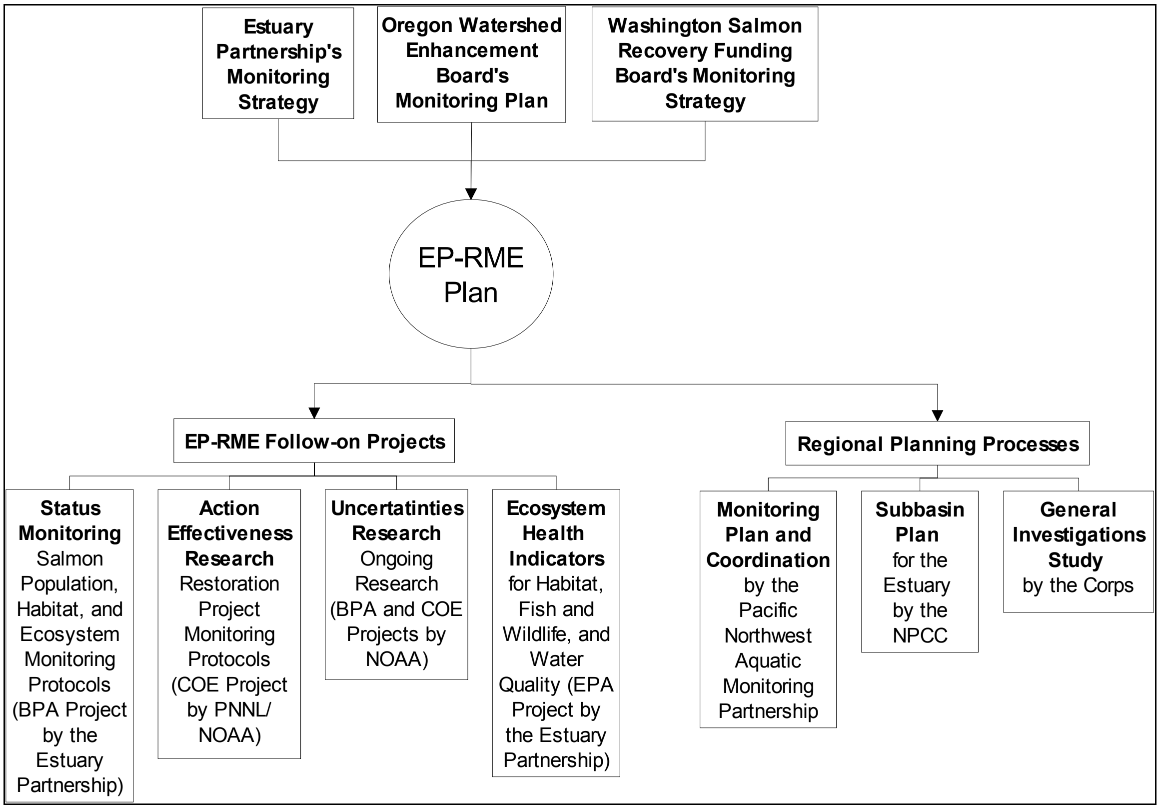

Figure 5. Relationship of the Estuary RME Plan to Other Monitoring Efforts, Follow-on Projects, and Regional Planning Processes.

Thus, while this estuary RME plan has drawn from existing programs to the extent possible for the purpose of ultimately providing efficiencies in basin-wide analyses and coordination, this estuary RME plan will in turn be able to provide valuable information to existing programs about the appropriate RME for the complicated and highly-managed estuarine environment of the second-largest river in the nation. Major programs and processes that may benefit from the synthesis in this plan and from the results of research projects conducted in the course of the estuary RME program include the NPCC subbasin plan, the Pacific Northwest Aquatic Monitoring Partnership, and the Corps General Investigation study. This RME Plan will also guide projects for status monitoring, action effectiveness, ecosystem health indicators and uncertainties research throughout the implementation of the estuary RME program (Figure 5).

1.4 Approach

The estuary RME plan is bounded by the geographic scope of the Columbia River estuary and by the FCRPS Biological Opinion requirements for research, monitoring and evaluation in this study area. The framework provided in this estuary RME plan incorporates existing and planned monitoring programs in the estuary (Figure 5) that can be utilized for analyses related to listed salmon and are thus responsive to the Biological Opinion. The Estuary Partnership's Monitoring Strategy, the OWEB Monitoring Plan, and the Washington Salmon Recovery Funding Board's Monitoring Strategy mentioned above are sound pieces to build on for an estuary RM plan. As with these pieces and basin-wide RME, estuary RME for listed salmonids is best undertaken from an ecosystem perspective, in the context of biological and physical processes, a concept recognized in other RPA actions. Status and trends in available estuarine habitat and the effectiveness of restoration activities are the focal points in the estuary RME plan, because a primary "action" within the estuary is the restoration of salmonid habitat.

The development of the estuary RME plan (Figure 6) applied accepted strategies for estuarine monitoring, which are referenced to the specific goals and conditions of the estuary throughout this document. The design is rooted in goals derived from the Biological Opinion. First, objectives required to meet these goals were developed. The next step would ideally include a fully developed conceptual ecosystem model because of the importance of the conceptual model in determining linkages between objectives and performance indicators (e.g., Batiuk et al. 1992). However, such a model is not currently available, so we could only provide an example of how one might be used in estuary RME planning. The next step was to develop performance indicators[1] and their associated monitored attributes[2] for estuary RME based on a review of existing literature and conditions in the estuary, in the context of applicable recommendations for status monitoring, action effectiveness research, and uncertainties research in the basin-wide RME plan. With the monitored attributes identified, we then identified methods and sampling protocols. Finally, project-level and program level coverage assessments of the performance indicators and monitored attributes were used to specify an action plan to implement estuary RME. In the sense that this estuary RME plan functions as an "umbrella" document for monitoring in the estuary, it should be periodically revised to cover new monitoring efforts and respond to changing program goals in an adaptive management framework (Thom 2000).

In developing this monitoring plan, we also reviewed monitoring plans and reports from major coastal restoration efforts across the country: Chesapeake Bay (Batiuk *et al*. 2000, 1992), Florida Everglades (USACE & SFWMD 1999), Louisiana coastal wetlands (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2001), Tijuana Estuary (Zedler 2001a), San Francisco Bay Delta (CALFED 2000; Josselyn and Buchholz 1984; Williams and Orr 2002), and the more recent Puget Sound nearshore ecosystem (Fresh et al. 2003), which is still in the planning stages. Our intent was to learn from these efforts and apply relevant elements from them to the Columbia River estuary RME plan.

[1] A performance Indicator is a characteristic of the system that is both relevant to a project objective and sensitive to predicted changes in the system. It is usually comprised of a suite of attributes.

[2] Monitored Attribute, frequently called "metric" or "parameter," is the specific variable that is measured to assess the response of the system, e.g. "salinity" or "growth rate."

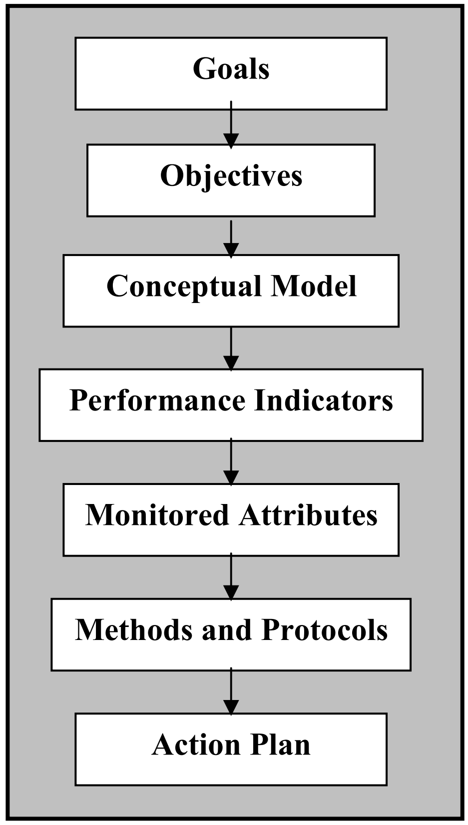

Figure 6. Schematic of the Development of the EP-RME Plan.

Partnerships are often critical to the success of restoration programs (Harrington and Feather 1996). As these partnerships develop, coordination is critical to make use of all existing information, maximize efficiencies in budgets and effort, and learn from related projects. Currently, collaborations between local, state and federal agencies, non-governmental organizations, and others working in the Columbia estuary are rapidly developing. This estuary RME plan assesses the coverage provided by various efforts within the defined geographic area relative to program objectives and identifies gaps in the knowledge base.

In conclusion, development of this estuary RME plan progresses in dependent order as follows: Goals >> Objectives >> Performance Indicators >> Monitored Variables >> Methods >> Action Plan. The performance indicators are based on the objectives, which are based on the goals. This approach means that program goals and objectives are directly linked in a logical progression to action plan recommendations. That is, the requirements for status monitoring, action effectiveness research, and uncertainties research drive the estuary RME action plan recommendations.

1.5 Contents

The estuary RME plan is organized as follows: Goals and Objectives (Section 2), Performance Indicators and Monitored Attributes (Section 3), Methods (Section 4), and Action Plan (Section 5). This *plan* will provide guidance for an estuary RME *program* that will monitor performance and provide information to evaluate the NOAA Fisheries/Action Agencies estuary program, helping to attain the goals of the basin-wide RME program and the FCRPS Biological Opinion relative to the estuary. Although RME mandates in the Biological Opinion were the impetus for this estuary RME plan, this plan has broader applications. It builds on the goals of existing regional and national programs in the estuary and uses an ecosystem approach to further the ongoing effort by various agencies and organizations to develop the science basis for long-term management of the Columbia River estuary and its resources.

2.0 Goals and Objectives

For the purpose of this estuary RME plan, we developed goals and objectives as part of a logical, stepwise planning process (see COE and NOAA restoration planning publications by Thom and Wellman 1996; Diefenderfer et al. 2003; Thom et al. 2004). The estuary RME goals (Section 2.1) drove the objectives developed for status monitoring (Section 2.2), action effectiveness research (Section 2.3), and uncertainties research (Section 2.4).

2.1 Goals

The FCRPS Biological Opinion provided RPA actions that pertain to the estuary, but did not specify a performance standard[1] or goal for estuarine functions relative to the support of Columbia River salmon (NMFS 2000). The Biological Opinion, however, did call for habitat restoration to be the cornerstone of improvements to the estuary to avoid jeopardizing the continued existence of listed salmon and steelhead populations (NMFS 2000). Therefore, to develop goals and objectives for Columbia River estuary relative to listed salmonids for the purpose of this plan, the estuary/ocean RME subgroup examined a variety of salmon-related goals for the estuary from existing federal, state, and local programs. The resulting NOAA Fisheries/Action Agencies' goal for their estuary program is congruent with existing regional and national goals for estuarine protection and restoration, as well as the intent of the Biological Opinion: **Conserve and restore estuary habitats to improve the viability[2] of endangered and threatened salmonid populations.** This goal relies, in part, on the latest science basis for estuary actions, science that emphasizes population viability and the importance of life history diversity and spatial distribution (Fresh et al. 2004). The goal also implicitly incorporates survival as a fundamental indicator of population viability, which is consistent with the RME plans for the tributaries and hydrosystem (RME Plan 2003).

Informed by this goal, status monitoring studies and action effectiveness and uncertainties research can be designed to evaluate whether estuary actions funded by the Action Agencies are resulting in positive trends in population viability, as measured through life history diversity, spatial distribution, growth, and survival. The estuary/ocean RME subgroup developed three specific sub-goals

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[1] It is beyond the scope of the estuary RME plan to develop standards due to several reasons: 1) for many monitored variables, e.g., water temperature, the Action Agencies do not have the authority to set a standard; 2) often there is little or no data to support a standard, e.g., habitat connectivity; 3) performance standards for monitored variables in action effectiveness research will necessarily have to be project-specific, and should not be prescribed estuary-wide; and 4) considerable variability within the estuary would necessitate that estuary-wide standards have a very broad range, thus limiting their usefulness.

[2] Population viability is a measure of the status of anadromous salmonids used by NOAA Fisheries and defined by four performance criteria: abundance, productivity, spatial structure, and diversity. The latter two criteria are an "especially critical portion of the role of the estuary" (Fresh et al. 2004).. In the estuary, viability will be assessed by measuring attributes associated with performance indicators for juvenile salmon life history diversity, spatial distribution, growth, and survival.

corresponding to the areas of emphasis in the Biological Opinion: status monitoring, action effectiveness research, and uncertainties research. The NOAA Fisheries/Action Agencies' estuary program and RME goals are provided in Figure 7 together with summaries of existing goals for the estuary from other key national and regional programs. The presentation shows a hierarchical relationship among the goals from the national to the regional to the Columbia River estuary.

National Estuary Habitat Restoration Program Goal and EPA National Estuary Program Goal: The restoration of 1,000,000 acres of estuary habitat by the year 2010 (Estuary Restoration Act of 2000). Established by Congress in 1987 to improve the quality of estuaries of national importance (EPA 2004).

↓

Columbia River Estuary Comprehensive Conservation and Management Plan Goal: Avoid further loss of existing habitat, restore degraded habitats, focus on elimination of pollutants, and solve existing pollution problems (LCREP 1999).

↓

NOAA Fisheries/Action Agencies' Columbia River Estuary Program Goal: Conserve and restore estuary habitats to improve the viability of endangered and threatened salmonid populations.

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NOAA Fisheries/Action Agencies Research, Monitoring and Evaluation (RME) Goals for the Columbia River Estuary:

Status Monitoring: Quantify the status and trends in the abiotic and biotic environments of listed salmon in the estuary.

Action Effectiveness: Quantify the effects of habitat restoration actions on listed salmon in the estuary.

Uncertainties Research: Resolve key uncertainties related to salmon habitat restoration actions in the estuary.

Figure 7. Hierarchy of Goals Pertinent to Columbia River Estuary RME.

2.2 Objectives

RME objectives for the estuary were developed to support the NOAA Fisheries/Action Agencies estuary program and its RME goals. These objectives use information drawn from the Biological Opinion, the Tributary Habitat component of the basin-wide RME plan, other regional restoration and monitoring planning documents, and literature from estuarine restoration and fisheries science. For example, objective statements are the second step in planning for restoration monitoring, bridging goals and the development of performance indicators corresponding to the objectives (Diefenderfer et al. 2003). A synopsis of the objectives for status monitoring, action effectiveness research, and uncertainties research appears in Table 3, followed by more detailed explanations of each objective and its rationale.

The purposes of the three elements of the estuary RME prescribed by the Biological Opinion – status monitoring, action effectiveness research, and uncertainties research – relative to the estuary are also discussed. More specific information about the indicators, monitored attributes, monitoring methods, and sampling protocols that correspond to each of these objectives is developed herein (Section 4).

Table 3. Estuary RME Objectives for Status Monitoring, Action Effectiveness Research, and Uncertainties Research.

Status Monitoring
SM 1. Describe the present status of the estuary ecosystem in terms of habitat conditions, habitat connectivity, and fauna relative to pre-European settlement conditions.
SM 2. Monitor the spatial distribution, life history diversity, and growth of juvenile salmon in the estuary.
SM 3. Estimate the survival rates of juvenile salmon of listed ESUs through the tidal-freshwater reach (RM 46-146), the estuarine reach (RM 0-46), and the plume.
SM 4. Determine the water quality in estuary salmon spawning and rearing habitat relative to state and federal water quality standards and salmon survival needs.
SM 5. Describe trends in the physical condition of estuary salmon spawning and rearing habitat in terms of substrate type, accretion rates, reduction/oxygenation potential, groundwater level, large woody debris, water velocity and water surface elevation compared to present conditions.
SM 6. Determine the status and trends of abundance, species composition, and distribution of invasive species in the estuary such as purple loosestrife, shad, and New Zealand mud snails.
SM 7. Provide biennial summaries of the status and trends of hydrographic and oceanic conditions affecting salmon survival within the estuary and salmon population size.
Action Effectiveness Research
AER 1. Implementation Monitoring. Determine if restoration projects in the estuary, as implemented, meet the project-specific performance goals.
AER 2. Effectiveness Monitoring. Determine whether individual restoration projects in the estuary are effectively changing relevant structural or functional parameters relative to reference and/or control sites.
AER 3. Validation Monitoring. a) Determine the extent to which habitat restoration projects in the estuary, collectively, are affecting targeted ecosystem processes that support listed salmon. b) Determine the cumulative effect of estuary habitat restoration on salmon population viability.
Uncertainties Research
UR 1. Determine the significance of the estuary, which includes the plume, to listed salmonid Evolutionarily Significant Units.
UR 2. Identify changes that could be made to FCRPS operations that would improve habitat conditions in the estuary.
UR 3. Determine the highest priority habitat types for restoration in the estuary.
UR 4. Develop a method to assess whether the offsite mitigation program involving habitat restoration in the estuary is working.

2.2.1 Status Monitoring

Status monitoring is the "measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality" (from Suter 1993, cited in Noon 2003). Status monitoring can describe differences in the value of monitored attributes of certain performance indicators among locations at a given moment in time (snap-shot) or changes in their values across time at a given location (trend).

The objectives for status monitoring in the estuary, although specific to estuarine and plume environments, are congruent with the status monitoring objectives for mainstem and tributary habitats. The first objective (ecosystem status) is broad-scale, responsive to the first level prescribed in the Biological Opinion for RME. The remaining objectives address the second RME level (fish population and habitat status monitoring). Performance indicators and associated monitored attributes were developed to address each of these objectives. This terminology (performance indicators and attributes) is consistent with the material on status monitoring in the basin-wide RME Plan.

SM 1. Describe the present status of the estuary ecosystem in terms of habitat conditions, habitat connectivity, and fauna relative to pre-European settlement conditions.

Ecosystem status entails a holistic characterization of selected physical and ecological features of the estuary, important habitat conditions and habitat availability. In general, the ecosystem status indicators for the estuary are congruent with those for Tributary Habitat in the basin-wide RME Plan. An important element of this objective is the status and trends in the quantity, location, and connectivity of the habitats preferentially used by salmonid fishes.

SM 2. Monitor the spatial distribution, life history diversity, and growth of juvenile salmon in the estuary.

Fresh et al. (2004, p. 4) stated "…the concepts of spatial structure and life history diversity are [an] especially critical portion of the role of the estuary…" in salmon life cycles. The estuary RME plan incorporates these concepts as shown in the indicators selected for monitoring, e.g., salmon life history diversity and spatial distribution. This objective addresses when juvenile salmonid fishes of each ESU are present, where they are located, and how much benefit (in terms of growth) they are deriving in the estuary.

SM 3. Estimate the survival rates of juvenile salmon of listed ESUs through the tidal-freshwater reach (RM 46-146), the estuarine reach (RM 0-46), and the plume.

This objective pertains to juvenile survival over the reach from Bonneville Dam to the river mouth (the estuary) and, possibly, in the Columbia River plume. Survival rates are commonly estimated for the hydrosystem from Lower Granite to Bonneville dams (Bickford and Skalski 2000). Survival in the mainstem is a key element of status monitoring for Hydrosystem RME. This objective extends these data to the lower 146 miles of the Columbia River where improved survival could help reverse salmon population declines in the Columbia River Basin (Kareiva et al. 2000). Survival rate by ESU from Bonneville Dam to the mouth of the Columbia River will be an important indicator, but a difficult one to accomplish because of the need to recapture (detect) tagged fish at strategic cross-sections of the large expanse of the estuary. To increase the detail of the survival information, survival rates may be estimated for sub-reaches within this area. This objective also implicitly involves avian and fish predation on juvenile salmonids in the study area.

SM 4. Determine the water quality in estuary salmon spawning and rearing habitat relative to state and federal water quality standards and salmon survival needs.

Water quality characteristics include temperature, salinity, dissolved oxygen, pH, pollutants, toxics, and nutrients. In extreme cases, water quality may directly affect salmonid fish survival, but water quality monitoring is important as a broader indicator of ecosystem health.

SM 5. Describe trends in the physical condition of estuary salmon spawning and rearing habitat in terms of substrate type, accretion rates, reduction/oxygenation potential, groundwater level, large woody debris, water velocity and water surface elevation compared to present conditions.

Aspects of the physical condition include accretion rate, groundwater level, surface water level and velocity, reduction/oxygenation potential, and large woody debris. These features are elements of habitats required by salmonid fishes, and their measurement is fundamental to the determination of the quantity and quality of available habitat. This objective is consistent with similar work in hydrosystem and tributary habitats.

SM 6. Determine the status and trends of abundance, species composition, and distribution of invasive species in the estuary such as purple loosestrife, shad, and New Zealand mud snails.

Invasive plants and animals are a growing concern in the estuary (Lower Columbia River Estuary Partnership 1999), because they can negatively impact the ecosystem as a whole and interfere with salmonid survival. Data on abundance (or density), species composition, and spatial distribution has been and should continue to be used to generate invasive species maps and provide a basis to assess the impacts of these species on salmonids.

SM 7. Provide biennial summaries of the status and trends of hydrographic and oceanic conditions affecting salmon survival within the estuary and salmon population size.

This objective addresses the issue of the effect of oceanic and hydrographic conditions on salmon populations. Bisbal and McConnaha (1998) argued for consideration of ocean conditions in salmon management. The monitoring information developed in response to this objective is intended to provide this context.

2.2.2 Action Effectiveness Research

Action effectiveness research determines the biological and ecological effects of particular management actions relative to project or program objectives. As applied to the estuary[1], the primary management action is habitat restoration; flow management by FCRPS operators for the purpose of affecting estuary habitat is not currently being undertaken as a management action. Fundamental elements of monitoring habitat restoration projects can be found in Thom and Wellman (1996), Zedler

[1] Currently, there are no "actions" being undertaken in the plume. Therefore, action effectiveness research in the estuary pertains to only the reach RM 0-146.

(2001) and Rice et al. (2003). Restoration projects ongoing in the estuary are currently being monitored to varying degrees. The intensity of monitoring in the estuary is expected to increase corresponding to the number of projects implemented. Evaluation of the cumulative effects of multiple restoration projects in the estuary relative to the objectives of various programs sponsoring restoration projects will also be necessary. The conclusions generated from this research and monitoring will inform decision making in the adaptive management process for the NOAA Fisheries/Action Agencies' estuary program as a whole. The three objectives for action effectiveness research in the estuary are designed to assess the effects of the habitat restoration actions called for in the FCRPS Biological Opinion.

AER 1. Implementation Monitoring. Determine if restoration projects in the estuary, as implemented, meet the project-specific performance goals.

This objective involves the assessment of projects relative to project goals, e.g., the degree of function attained in a restored area or the size of habitat restored. Assessment of the implementation of the adaptive management plan in case of failure to meet the goals is also included. This objective is referred to as "implementation monitoring."

AER 2. Effectiveness Monitoring. Determine whether individual restoration projects in the estuary are effectively changing relevant structural or functional parameters relative to reference and/or control sites.

Trends in those performance indicators assessed under status and trends monitoring are analyzed to meet this objective: e.g., juvenile salmon usage, water quality, and vegetation cover. This analysis utilizes a network of reference and status monitoring sites. This objective is referred to as "effectiveness monitoring."

AER 3. Validation Monitoring. a) Determine the extent to which habitat restoration projects in the estuary, collectively, are affecting targeted ecosystem processes that support listed salmon. b) Determine the cumulative effect of estuary habitat restoration on salmon population viability.

This objective answers the question, "what was the cumulative effect of all habitat restoration efforts in the estuary?" There is not a model for this in the literature and it will require substantial research and development to accomplish this. Variables may include detritus flux, prey resources, survival in the estuary, and others. The answer to this question is critical to objectively determining whether habitat restoration actions in the estuary are positively affecting salmon. This objective is referred to as "validation monitoring."

2.2.3 Uncertainties Research

The resolution of uncertainties in the existing estuary knowledge base is fundamental to the implementation of appropriate restoration actions, status monitoring, and action effectiveness research. Uncertainties are those pieces of information currently unavailable that managers require for informed decision making. Many of the uncertainties presented in this section were identified in the *Columbia River Estuary and the Columbia River Basin Fish and Wildlife Program (*Bisson et al. 2000), the *Coordinated Research Plan for Estuarine and Ocean Research on Pacific Salmon* (Brodeur et al. 2000).

the *Salmon at River's End* report (Bottom et al. 2001), the *Research Needs Identification Workshop for the Columbia River Estuary* (COE and Estuary Partnership 2003), the *Ecosystem-Based Approach for Restoration Projects in the Columbia River Estuary* (Johnson et al. 2003), or the *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead: an Evaluation of Selected Factors on Population Viability* (Fresh et al. 2004). The estuary/ocean RME subgroup reviewed the uncertainties in these documents in the context of particular management questions.

The key management questions in the estuary, with associated uncertainties and research needs, are outlined below. Detailed methods to resolve the uncertainties are being developed through the respective research projects. As mentioned above, the "critical uncertainties" identified in the Biological Opinion that pertain to the estuary are rooted in the hydrosystem; for example, delayed mortality. Since this subject matter is addressed under Hydrosystem RME in the basin-wide RME plan (RME Plan 2003), it is not included here. The resolution of the uncertainties identified below is fundamental to successful implementation of estuary RME. In the view of the estuary/ocean subgroup, all these uncertainties are important; therefore, they are not prioritized.

UR 1. Determine the significance of the estuary, which includes the plume, to listed salmonid Evolutionarily Significant Units.

Background – There is a lack of fundamental data on habitat usage, growth, and survival of juvenile salmon in the estuary. Status monitoring objective 2 calls for monitoring of status and trends of these important parameters, but basic research on salmon ecology in the estuary is also needed.

Uncertainty 1a – The linkage between habitat conditions and growth and survival of juvenile salmonid fishes in the estuary.

Research Need – Obtain empirical data on the mechanistic relationship between the effects of various habitat types and conditions in the estuary and juvenile salmon use/growth/survival. This information is important to the prioritization of actions to improve growth and survival.

Uncertainty 1b – Ecological functions of the estuary and plume that are limiting for the salmon ESUs.

Research Need – Determine the extent of any estuary ecological functions that are limiting for juvenile salmon. Knowledge of limiting factors may lead to more effective resource allocation. Improve the understanding of plume dynamics and their role in salmon life histories.

UR 2. Identify changes that could be made to FCRPS operations that would improve habitat conditions in the estuary.

Background – Operation of the hydrosystem generally reduces the magnitude of the spring freshet and increases flows in winter compared to the natural river, and returning to a more "natural" state might improve habitat conditions for salmon in the estuary. For the purpose of estuary RME, the working definition of "natural state" is pre-European historic condition. Given current development and uses, historic condition is relevant because it serves as a baseline for analysis of the changes in the estuary and identification of habitat types that may be suitable goals for restoration activities. Historic conditions are not necessarily achievable today, nor can we control environmental conditions. Yet, historic conditions are important because they provide context for management decisions about estuary habitats for listed salmon.

Uncertainty 2a – The effects of hydrograph changes due to the FCRPS on juvenile salmon habitat structure and function. Understanding the effects of the hydrosystem on habitat and function may provide the basis for management actions to aid recovery.

Research Needs – Use sediment core samples and depositional modeling to compare late-prehistoric (natural), early-historic (1900-1950) and contemporary (1950-2000) accretion and deposition processes, channel migration, and floodplain development. Characterize existing conditions. Use hydrodynamic modeling to examine water velocity regimes and water surface elevations.

Uncertainty 2b – The primary driver of the historic (pre-European) estuarine food web.

Research Need – Use sediment core samples and hydrodynamic modeling to determine the relative contribution of micro- and macro-detritus to the historic estuarine food web. This fundamental data on the estuary ecosystem will be important in the identification of restoration project performance criteria.

UR 3. Determine the highest priority habitat types for restoration in the estuary.

Background – Interest in salmon habitat restoration in the estuary is increasing. It is generally agreed that habitat restoration is the most practical approach to improving conditions for salmon in the estuary (LCREP 1999). It is, therefore, important to base the prioritization of projects on the best available scientific information. Usage of estuary habitats by listed salmon with diverse life histories is a data gap that must be resolved if trends in this important indicator are to be established as restoration efforts progress. This uncertainty is related to Uncertainty No. 1 and 2. Uncertainty No. 3 concerns one of the primary restoration methods being employed in the estuary: dike breaches. The purpose of dike breaching or removal is to increase the accessibility of habitat to listed salmon.

Uncertainty 3a – Habitat usage by juvenile salmon in the tidal freshwater reach of the estuary (RM 46-146).

Research Need – Monitor juvenile abundance, distribution, residence time, and growth in the tidal freshwater reach. This information is still largely unknown and is important for analyzing trends in the use of restored habitats.

Uncertainty 3b – Spatial and temporal usage of estuary habitats by listed salmon and steelhead with various life histories.

Research Need – Investigate life history strategy diversity and associated genetic diversity corresponding to habitats in the estuary. An understanding of trends in life history diversity is important to assessing the performance of restoration projects.

Uncertainty 3c – Accessibility of habitat to juvenile salmon.

Research Need – Identify an acceptable index of connectivity and apply it to the estuary. To assess the increase in habitat accessibility, a suitable index of connectivity must be identified to enable baseline data and trends in the expected improvements to be measured.

UR 4. Develop a method to assess whether the offsite mitigation program involving habitat restoration in the estuary is working.

Background – The Biological Opinion RPA includes habitat improvement actions in the tributaries and estuary to help mitigate for the effects of FCRPS operations. To make an informed decision about the effectiveness of this strategy, managers need data on the biological effects of the estuary habitat restoration program, i.e., knowledge of whether or not it improves salmon survival.

Uncertainty 4 – Cumulative effects of multiple habitat restoration projects on estuary ecosystem functionality and salmon population fitness.

Research Need – Develop method and data to measure cumulative effects of multiple restoration projects on variables representing ecosystem functionality and salmon population fitness, and demonstrate the overall impact(s) of the restoration program on habitat conditions in the estuary ecosystem and salmon recovery.

3.0 Performance Indicators and Monitored Attributes

This section contains descriptions of the performance indicators and their associated monitored attributes. The performance indicators evolve directly from the RME objectives identified in Section 2.2 and from what is known about estuarine ecosystem structure and processes. Monitored attributes, in turn, are selected for measurability and clear linkage with the indicators. Any performance indicators and monitored attributes associated with uncertainties research will be determined under specific research projects. It is, however, likely that many of the elements identified here for status monitoring and action effectiveness research will also be components of uncertainties research, a critical element of estuary RME.

Development of a monitoring program can benefit significantly from a conceptual model of the ecosystem. According to the National Research Council's (1992) conclusions and recommendations on monitoring ecosystems, "Indicators should be chosen based on a conceptual model that clearly links stressors (e.g., pollutants, management practices) and indicators with pathways that lead to effects on the structure and function of ecological systems." The "indicators" referred to by the National Research Council are comparable to the "performance indicators" identified in this estuary RME plan. Indicators must be representative of the project or program objectives and be tightly linked, as demonstrated in a conceptual model, to structures, functions or processes expected to change as a result of management actions. Noon (2003) states, "In most cases it will be sufficient to model a restricted, but relevant, component of the system. Thus, a complete model of an ecological system is seldom necessary to proceed with a reliable monitoring program."

Johnson et al. (2003) recommended that the various estuary ecosystem models be critically examined and integrated for use in estuary/ocean RME and habitat restoration planning. Existing models have been examined in this plan as described in Section 3.1. However, a model of appropriate scope and detail does not exist at this time, and therefore this estuary RME plan has not been systematically developed from a conceptual model as best practices would recommend. The Action Agencies intend to develop such a model. When it is available, the model will be applied in future iterations of the estuary RME plan in an adaptive management framework, with revisions to the status monitoring and action effectiveness indicators as necessary. The following material provides an example of conceptual ecosystem modeling for the Columbia River estuary.

3.1 Conceptual Ecosystem Model

Several ecosystem models for the estuary, each developed for a different purpose, are available. For example, the COE (2001) included a conceptual model for the estuary in the Biological Assessment for the Channel Improvements Project (Appendix E of COE 2001). To be useful to RME planning, this model would need to be more detailed and comprehensive. For instance, the food web submodel emphasizes only the pathways involving juvenile salmon, and does not provide critical details within subcomponents of the model, such as prey resource species. In another effort, Bottom et al. (2001) present the framework for a conceptual model that is guiding research on juvenile salmon usage in the estuary (see NOAA projects in Section 5.1). This model focuses entirely on juvenile salmon, but currently lacks the linkage to processes that result in the formation, maintenance or destruction of habitats supporting juvenile salmon. Neither of these models addresses the Columbia River plume.

In order to clearly link the degradation and planned restoration of the ecosystem to effects on functions (e.g., for salmon), it is important that the conceptual model for the estuary address factors controlling habitat development and maintenance. For restored salmon habitats to be self-maintaining in the long run, explicit understanding of the factors controlling habitat-forming processes is critical. Also, whenever possible, the model should emphasize mechanistic cause and effect relationships and avoid simple correlations. This is especially important in a large and complex ecosystem such as the estuary.

In addition to models, conceptual frameworks important to salmon habitat use, such as the habitat's "capacity," "opportunity," and "realized function" (Simenstad and Cordell 2000), have also been published. These categories of habitat assessment metrics can help to frame the monitoring and analysis of habitat restoration relative to listed stocks of Columbia Basin salmon. From Simenstad and Cordell (2000),

- *Habitat capacity* -- "Habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics.

- *Habitat opportunity* -- "…the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features.

- *Realized function* -- "…include any direct measures of physiological or behavioral responses that can be attributable to fish occupation of the habitat and that promote fitness and survival," for example, survival, habitat-specific residence time, foraging success and growth.

To demonstrate the applicability of a conceptual model to RME planning, a short example application of an existing submodel of juvenile salmon survival is provided (Figure 8). Although its is known that juvenile salmon occur in shallow habitats along the lower Columbia river and estuary, the understanding of why they occur there, and what benefit they might derive from inhabiting these areas has not been quantified. We know that most prey for juvenile salmonids feeding in the estuary is found in shallow water habitats, but we lack the data to quantify the relative advantages of various habitat types to salmonid rearing (Bottom et al. 2001). Substantial areas of marshes, tidal channels and swamps have been lost and degraded in the estuary. Efforts to restore some of these habitats are underway. However, justification of the expense for restoration projects is weakened by a lack of definitive understanding on how these habitats may contribute to the overall survival of juvenile salmon.

As an example application, the model shown in Figure 8 outlines the present conceptual understanding of the "survival pathway" for the juvenile salmon in the estuary. The model indicates that survival, in part, is dependent on feeding minus energy costs. Refuge and resting areas contribute to feeding, as does the opportunity to find productive feeding areas. They may also reduce energy loss. The present hypothesis is that current velocities, bathymetry and turbidity all affect the quality of refuge and feeding opportunity (Bottom et al. 2001). NOAA Fisheries and others are currently evaluating this hypothesis. This work is attempting, among other objectives, to develop numerical relationships between current velocities and juvenile salmonid use of shallow water habitats. These numerical relationships, coupled with numerical modeling of predicted bathymetry and currents, can then be used to optimize restoration of current velocities for salmon feeding.

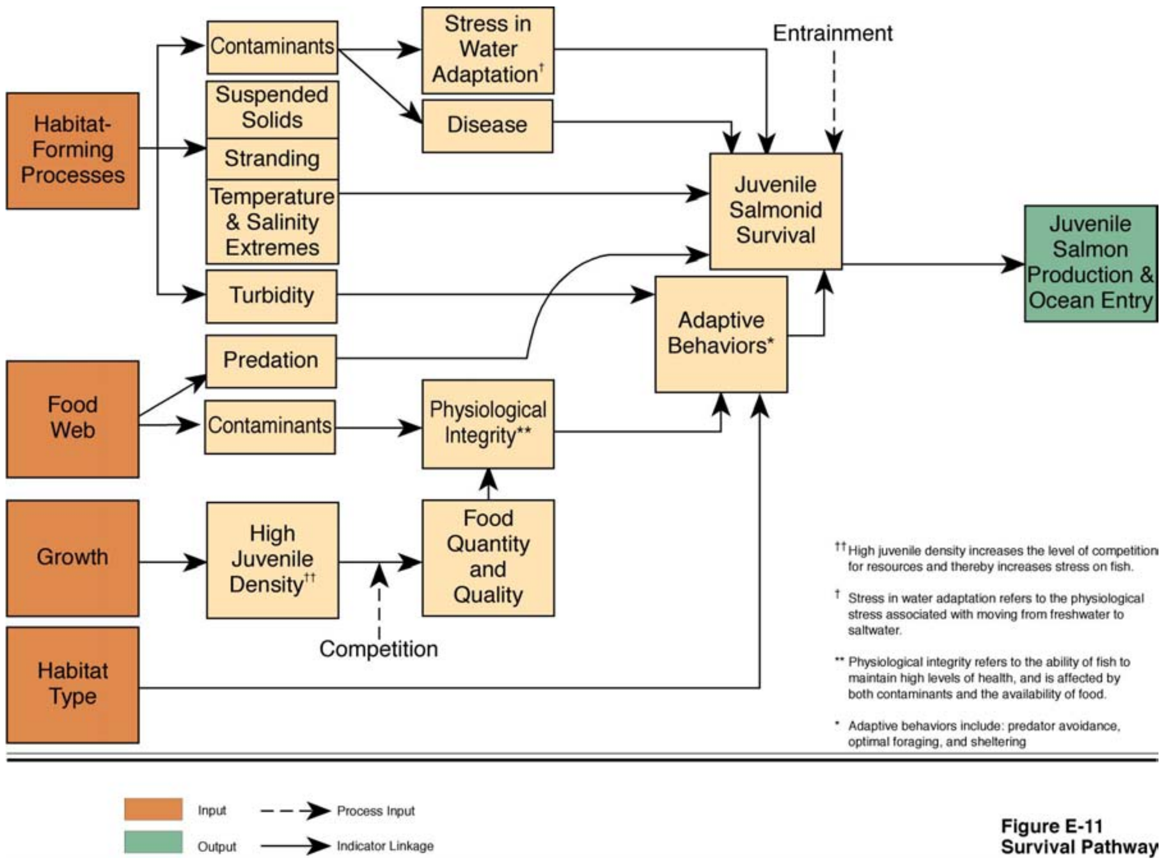

Figure 8. Survival Submodel from Lower Columbia River and Estuary Juvenile Salmonid Model (from Appendix E in COE 2001).

This conceptual model provides guidance on monitoring restored areas. For example, it is likely that the research examining current velocities will result in a range of current velocities optimal for juvenile salmon for selected habitat geomorphologies. In order for this information to be more generally applied, a wider array of habitat conditions needs to be evaluated. In addition, there is considerable uncertainty in our ability to create optimal current velocity conditions through restoration actions. This is because natural forces that form habitats are not predictable on the scale at which juvenile salmon operate. Hence, monitoring of restored sites presents several opportunities: 1) to generalize the understanding of current velocities among a wider array of hydrogeomorphic conditions; 2) to verify the numerical model; and 3) to directly assess whether the restoration project met its goal of providing habitat conditions conducive to salmon feeding and refuge. This information can then be used through the adaptive management process to improve the design of future restoration projects, and the data also permit a more quantitative assessment of losses associated with past actions.

In summary, the basic research underway in the estuary should be applied to enhance existing conceptual models. One example is to incorporate into the model improved understanding of the linkages between juvenile salmon habitat usage, residence times, food sources, production rates and energy transfer within the ecosystem. A second example is to address the ecological effects on salmonids of invasive species such as shad in the estuary. Finally, the next-generation model should be peer-reviewed. With comprehensive treatment of components relevant to salmonid habitats, this model would be a critical underpinning of a reliable monitoring program.

3.2 Status Monitoring

The performance indicators for status monitoring (Table 4) are system characteristics that are relevant to the status monitoring objectives and sensitive to changes in the system. The significance of these indicators to the estuary is described in the "Rationale" column of Table 4. Monitored attributes associated with each indicator are also listed. The attributes are measurable parameters, and are also called "metrics." The indicators serve as categories of attributes; the attributes are the parameters that are actually measured. The same indicator/attribute structure was employed in the *Washington Comprehensive Strategy for Watershed Health and Salmon Recovery* (Monitoring Oversight Committee 2002b).

The estuary/ocean RME subgroup developed the performance indicators and their monitored attributes in Table 4. For the purpose of estuary RME planning for status monitoring, the estuary/ocean subgroup consulted with researchers (e.g., E. Casillas, NOAA Fisheries, and C. Peterson, Portland State University), reviewed existing regional monitoring plans and strategies (e.g., LCREP 1998; MOC 2002a-c; Hillman 2004; and the Tributary Habitat section of the basin-wide RME Plan), and examined monitoring plans for other estuaries (e.g., San Francisco Bay-Delta by CALFED 2000; Gulf of Maine by Neckles and Dionne 2000; and coastal ecosystems by Thayer et al. 2004). Performance indicators and monitored attributes for the estuary are consistent with efforts in Columbia Basin tributaries, as well as estuaries nationally. Many of the monitored attributes identified in Table 4 have utility for the evaluation of more than one performance indicator but, for parsimony, each is listed only once.

The "river discharge" and "plume conditions" indicators are included in Table 4 because the results of monitoring these indicators will be important to assess ecosystem conditions affecting salmonid survival in the estuary. Bisbal and McConnaha (1998) argued the case for salmon management to include consideration of ocean conditions. The estuary RME plan recommends that reports of results from Columbia River discharge and plume monitoring efforts be reviewed biennially by estuary managers and summarized in a biennial report of estuary monitoring data. The estuary RME indicators for plume conditions are intended to provide relevant summary synthesis information to Columbia Basin salmon managers and the Action Agencies.

Table 4. Performance Indicators and Monitored Attributes for the Status Monitoring Component of Estuary RME.

ID.	SM Objective	Performance Indicator	Rationale	Monitored Attribute	Comment
SM 1	Status of the estuary ecosystem	Habitat conditions	This indicator provides a detailed characterization of ecosystem structure in the estuary that will be used to prioritize restoration actions and monitor trends in habitat quantity and quality.	Vegetation cover	Provides classification of native and non-native vegetation and can show location of plant communities that support juvenile salmonid rearing habitat and prey base development.
				Geology/soils	Influences ecosystem functionality and sustainability.
				Floodplain topography/channel hydraulic geometry	Includes upper intertidal and supratidal topographic survey of floodplain, measurement or calculation of the tidal prism, depth/width/cross-sectional area of channels, and impoundment features (dikes, ditches, tidegates, etc.).
				Bathymetry	Shows location and depths of main and side channels.
				Area protected, conserved, restored, enhanced, or created	Provides a way to track habitat actions. Requested by Federal ESA Habitat Team
		Habitat connectivity	This landscape-level indicator shows the linkages between different habitat types in the ecosystem and provides a way to assess the status of ecosystem structure.	Passage barriers	Restrict access by salmon to wetland habitats. Barriers include dikes, levees, tidegates, culverts. Requested by Federal ESA Habitat Team.
				Total edge, density, and sinuousity of floodplain and tidal channels.	Provides an interface for transfer of energy between wetlands and the main channel; salmon forage.

ID.	SM Objective	Performance Indicator	Rationale	Monitored Attribute	Comment
		Fauna	Fauna indicate status of ecosystem restoration and habitat use	Nearshore fauna	Fauna monitored depend on habitat type (e.g., epibenthic plankton, sedentary infauna, surface epifauna, macroinvert's)
				Avifauna	Species presence or absence documents habitat use.
SM 2	Role of estuary ecosystem	Life history diversity	Life history diversity of salmon has decreased in the Columbia Basin (National Research Council 1996). An increase in life history diversity will result in an increase in the spatial structure (distribution and abundance) of ESA-listed salmon. Fresh et al. (2004) explain the importance of this indicator.	Species composition	Provides data on which salmon are using the estuary.
				Age/size-structure	Reveals the life history strategy by species.
				Stock identity	Provides genetic analyses to determine ESU.
				Temporal distribution	Provides data on when the fish are present in the estuary. The combination of species composition, age-structure, and temporal distribution characterizes life history diversity.
		Spatial distribution	This indicator reveals the role of the estuary to salmon by showing where they are located through time. Fresh et al. (2004) also explain the importance of this indicator.	Spatial distribution	Describes where the juvenile salmon are, i.e., which habitats they are using.
				Migration pathways	Characterize the corridors where juvenile salmon predominately are found migrating downstream.
		Growth	This indicator is called for in the NOAA 2000 Biological Opinion as a general standard.	Growth rate	Calculated as the change in length or weight of the sampled juvenile salmon population per unit time.
				Residence time	Shows the amount of time juvenile salmon spend in the estuary
				Prey availability	Use an invertebrate productivity index
				Foraging success	Based on stomach contents

ID.	SM Objective	Performance Indicator	Rationale	Monitored Attribute	Comment
SM 3	Survival of juvenile salmon in estuary	Survival	Survival is an important indicator because even small survival increases in estuary may aid recovery (Kareiva et al. 2000). In addition, terns, northern pikeminnows, seals, sea lions, etc. eat salmon at all life stages, decreasing salmon population sizes.	Survival rate	Estimated for juveniles of selected species and life history types for the reach from Bonneville Dam to the CR mouth, and also for selected areas of the estuary.
				Predation index	Requested by Federal Habitat Team.
SM 4	Water quality in estuarine salmonid spawning and rearing habitat	Water quality	Satisfactory water quality is a key component of aquatic habitat quality. Toxics may play a critical role in salmonid viability. The dynamics of turbidity in the estuary and plume and effect on salmon viability are not well understood.	Temperature	Self-explanatory.
				Salinity	Self-explanatory.
				Dissolved oxygen	Self-explanatory.
				pH	Self-explanatory.
				Turbidity	Self-explanatory.
				Nutrients	Nitrogen and phosphorous
				Toxics	Need to select indicator toxins, and assess fish tissue and body burden. Possibilities include mercury and PCBs.
SM 5	Physical condition of estuary fish spawning and rearing habitat	Physical condition	The physical condition indicator characterizes the quality of habitats used by salmonid fishes and is useful for examining changes caused by habitat restoration.	Substrate type	Related to the soils variable for ecosystem monitoring.
				Accretion rates	Reveals sedimentation rates from measurements of prehistoric, early historic, pre-diking, post-diking, and post restoration.
				Reduction/oxygenation potential	Measured from pore water at selected sites and used to evaluate organic accumulation.
				Surface and ground water level	Mapping groundwater surface elev. and trends.
				Large woody debris	Map
				Sediment contamination	Need to select indicator contaminants.

ID.	SM Objective	Performance Indicator	Rationale	Monitored Attribute	Comment
				Water velocity	Self-explanatory
				Inundation regime.	Self-explanatory
SM 6	Invasive species in the estuary	Invasive species	Invasive species can inhibit or prevent the restoration of habitat quality and quantity for native species by competing for prey, decreasing diversity, and limiting habitat availability.	Species list	Tracks which invasive species are present.
				Spatial distribution	Describes where the invasives are located.
				Abundance	Provides data on population sizes.
SM 7	Hydrographic and ocean conditions affecting salmon survival within the estuary	River discharge	The river discharge indicator characterizes the amount of freshwater input to the river-dominated estuary.	Hydrograph	Shows daily river discharge at a USGS monitoring station at Beaver.
		Plume conditions	This indicator characterizes conditions in the plume in the nearshore ocean, a key environment in the life history of juvenile salmon emigrating from the CR Basin affecting survival and ultimately adult returns and population levels. The plume is important because of ecological interconnections between estuary and ocean due to ocean currents, tides, and river discharge. Conditions in the Columbia River plume may affect survival of juveniles during their early ocean residence (Bisbal and McConnaha 1998).	Juvenile salmon usage	Indicates temporal and spatial distributions and abundance by species of juvenile salmon.
				Anchovy/herring index	Reflects conditions in the lower estuary for juvenile salmon; the higher the anchovy/herring index, the better conditions are for salmon because predation rates decrease (Emmett et al. 2001)
				Zooplankton prey base	Provides data on the quantity and quality of food available to juvenile salmon during their migration upon exiting the estuary.
				Sea surface temperature (El Nino state)	El Nino is a disruption of the ocean-atmosphere system in the tropical Pacific (Philander 1990) revealed by sea surface temperature and affecting productivity and predator distribution in the nearshore ocean off the CR.

ID.	SM Objective	Performance Indicator	Rationale	Monitored Attribute	Comment
				Pacific decadal oscillation	Is a recurring shift of ocean-atmosphere a climatic regime in the North Pacific Ocean that affects salmon productivity (Mantua et al. 1997).
				Upwelling	Influences the productivity of the nearshore ocean off the CR by bringing deep, nutrient-rich waters up to the surface layer over the continental shelf.

3.3 Action Effectiveness Research

To assess the effectiveness of habitat restoration actions on the Columbia River estuary and meet the three objectives identified in Section 2.2.2, pertinent elements of the datasets developed through status monitoring (Section 3.2) and restoration project-specific monitoring will be subjected to analysis, synthesis, and evaluation. That is, status monitoring data can also serve to address action effectiveness research questions, or vice versa. For example, spatial distribution data may be analyzed in conjunction with habitat physical conditions data in a principle components analysis to develop hypotheses about the primary conditions affecting spatial distribution. Or, data from a restoration project site may be compared with data from a status monitoring reference site to evaluate the trajectory of restoration progress. (Sampling design is discussed in Section 4.0.) This melding of status monitoring and action effectiveness research is analogous to that prescribed for Tributary Habitat RME.

The framework organizing action effectiveness research will be the estuary habitat “capacity,” “opportunity,” and “realized function” (Table 5; Simenstad and Cordell 2000) with respect to listed stocks of Columbia Basin salmon. Realized function corresponds well to the viability concept as defined by Fresh et al. (2004) for the estuary, which includes four performance criteria: abundance, productivity, spatial structure, and life history diversity. The question to be answered to assess the effectiveness of habitat restoration actions is as follows: Is the habitat opportunity and capacity adequate to support necessary realized functions throughout associated salmonid life histories?

Table 5. Definitions of Selected Action Effectiveness Research Terms (from Simenstad and Cordell 2000).

- **Habitat Capacity** – A category of habitat assessment metrics including "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics.
- **Habitat Opportunity** – A category of habitat assessment metrics that "appraise the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features.
- **Realized Function** – A category of assessment metrics that "include any direct measures of physiological or behavioral responses that can be attributable to fish occupation of the habitat and that promote fitness and survival," for example, survival, habitat-specific residence time, foraging success and growth.

As described in 2.2.2, three levels of monitoring data will be required to meet the objectives for action effectiveness: project-specific “implementation monitoring,” project-related ecosystem structure and function “effectiveness monitoring,” and regional cumulative effects “validation monitoring.” This is consistent with classifications by MacDonald et al. (1991) used in Columbia tributary monitoring protocols by Hillman and Giorgi (2002), and with a major concurrent restoration planning effort in the Pacific Northwest, the Puget Sound nearshore ecosystem (Fresh et al. 2003). Taylor et al. (2003) surveyed 143 of 260 projects funded under the Washington State Salmon Recovery Funding Board, finding that most performed “implementation” and “effectiveness” monitoring, while little “validation” monitoring occurred.

Action effectiveness research in the estuary and the Columbia Basin tributaries (see basin-wide RME plan) has some differences and similarities. The diversity of habitats and spatial scales are greater in the estuary than in tributary areas, thereby affecting experimental designs. In addition, the aquatic environment in the estuary is more dynamic than it is in the tributaries, with changing water surface elevations, water currents, and salinities, among other variables. The Tributary Habitat RME subgroup, however, confronted some of the same issues that are inherent for action effectiveness research in the estuary. For example, control or reference sites will be difficult to identify and maintain through time, and adequate replication and isolation of individual action effects will be difficult to accomplish. The estuary/ocean subgroup will continue to coordinate with Tributary Habitat and Hydrosystem RME planners in order to make the estuary RME plan for the estuary as consistent as possible with RME efforts upstream.

The first two objectives of action effectiveness research (implementation and effectiveness monitoring) will be addressed through 1) the efforts associated with specific projects and associated reference sites and overseen by the coordinators of those projects, and 2) the status monitoring at selected long-term monitoring sites on the estuary and reference sites associated with key projects, as described in Section 4.0. The third level of action effectiveness research (validation monitoring) is being developed concurrently in a COE project addressing the cumulative effects of multiple restoration projects. Coverage for the action effectiveness objectives is discussed in detail in Section 5.0, Action Plan.

To assess action effectiveness, data for monitoring variables associated with habitat capacity, opportunity and realized function must be analyzed. Habitat capacity, opportunity and realized function may be viewed as three categories of “metrics” (Simenstad and Cordell 2000), or, in the terminology of this estuary RME plan, three categories of performance indicators and monitored attributes. To facilitate judgments about action effectiveness, the relevant indicators are categorized in Table 6 with respect to the most applicable of the three areas of analysis. However, many attributes will contribute to more than one area of analysis.

The analyses of habitat capacity and opportunity use data from implementation and effectiveness monitoring indicators, while the analysis of realized function uses data from effectiveness and validation indicators. If monitoring shows that, through habitat restoration actions, habitat opportunity and capacity improve relative to historical levels, and that salmon exhibit improved realized functions associated with their use of restored habitats, then this information may serve as a surrogate for direct cause and effect measurement of the benefits of estuary habitat restoration actions to salmonids.

Table 6. Performance Indicators and the Action Effectiveness Research Component of Estuary RME by Category. Starred attributes were identified as suggested minimum monitoring attributes for hydrological reconnection projects in unpublished work by PNNL/NOAA in 2004.

ID.	Objective	Performance Indicator	Monitored Attribute	Opport.	Capacity	Function
AER 1	Implemen-tation	Habitat condition	Vegetation cover*	●	●	
			Geology/soils	●	●	
			Bathymetry*	●	●	
			Floodplain topo./hydraulic geometry*	●	●	
			Area (size) restored*	●	●	
		Habitat connectivity	Passage barriers*	●		
			Tidal channel edge/density/sinuosity*	●	●	
AER 2	Effective-ness (project-specific)	Life history diversity	Species composition*			●
			Age/size-structure*			●
			Stock identity*			●
			Temporal presence*			●
		Spatial distribution	Spatial distribution			●
			Migration pathways			●
		Growth	Growth rate at restored site			●
			Residence time-restored site			●
			Prey availability-restored site			●
			Foraging success-restored site			●
		Survival	Survival rate at restored site			●
			Predation index at restored site		●	
		Water quality	Temperature*		●	
			Salinity*		●	
			Dissolved oxygen*		●	
			pH		●	
			Nutrients		●	
		Physical condition	Accretion rates	●	●	
			Redox potential		●	
			Surface and ground water level*	●	●	
			Large woody debris	●	●	
			Water velocity	●	●	
			Water elevation	●	●	
		Invasive species	Species	●	●	
			Distribution	●	●	
			Abundance	●	●	
AER 3	Validation	Growth	Growth rate in estuary			●
			Prey availability in estuary		●	●
			Foraging success in estuary			●
		Survival	Survival rate in estuary			●
		Cumulative Effects	TBD - ecosystem & salmonid pop. attributes	●	●	●

Sampling design considerations for action effectiveness are developed in Section 4.2 of this plan. Data collection methods, the spatial and temporal scale of monitoring, and example protocols are provided in Section 4.3. The sampling design, indicators, monitored attributes and protocols are expected to be further refined in a concurrent research project of the COE Anadromous Fish Evaluation Program investigating the cumulative effects of multiple restoration projects. For example, the cumulative effects project team used Table 4 of this RME plan to produce a subset table of suggested minimum project-specific monitoring indicators for those projects with hydrologic reconnection as a goal (starred in Table 6).

3.4 Uncertainties Research

Uncertainties research necessarily involves many of the performance indicators and associated monitored attributes identified for status monitoring and action effectiveness research, because these indicators and attributes are fundamental measures of the structures, functions and processes occurring in the estuary. Uncertainties research may directly utilize data produced on the attributes, and, in turn, it may contribute to the fundamental understanding of the nature and role of the attribute in the system. For example, the habitat conditions indicator pertains to all four uncertainties, while river discharge is closely related to UR 1 and UR 2, the significance of the estuary to salmon and the effect of FCRPS operations on estuary habitat conditions. All four uncertainties involve multiple performance indicators.

Table 7. Performance Indicators and the Uncertainties Research Component of Estuary RME. Table 3 lists the four uncertainties. Shading/bullet means the indicator is pertinent.

Performance Indicator	UR 1	UR 2	UR 3	UR 4
Habitat conditions	●	●	●	●
Habitat connectivity	●	●	●	●
Fauna	●	●	●	●
Life history diversity	●	●	●	●
Spatial distribution	●	●	●	●
Growth	●	●	●	●
Survival	●	●	●	●
Predation	●	●		
Water quality		●		●
Physical condition	●	●	●	●
Invasive species		●	●	
River discharge	●	●		
Plume conditions	●	●		

4.0 Methods

This section provides guidance on methods to acquire and analyze data for each monitored attribute, and includes sampling design considerations for status monitoring and action effectiveness research. A stratified random sampling design is recommended for status monitoring, and paired reference[1]/restoration sites are recommended for project-specific, post-restoration research. Detailed sampling designs for status monitoring and action effectiveness research are critical to the EP-RME plan, but are beyond the scope of the current planning effort. However, new COE and Estuary Partnership projects are being implemented to pick up where the EP-RME plan leaves off and fill the needs for detailed sampling designs (Figure 5). In this section, we advocate the use of standard methods for status monitoring and action effectiveness research throughout the estuary to the extent possible to facilitate estuary-wide and basin-wide evaluations. This will support NOAA/Action Agency estuary goals, as well as goals for other habitat restoration programs in the estuary. Such standardization is recommended by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP 2004) and the Tributary Habitat RME plan (RME Plan 2003).

4.1 Sampling Design Considerations for Status Monitoring

4.1.1 EMAP

Status monitoring in the estuary should leverage the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). EMAP is developing tools to assess the status and trends of ecological resources nationwide. Its goal is to assess current conditions and forecast future risks to environmental conditions. According to metadata on the EMAP-Estuaries Program database (http://www.epa.gov/emap/nca/html/data/westcstl/), "EMAP provides a strategy to identify and bound the extent, magnitude and location of environmental degradation and improvement on a regional scale."

EPA's Office of Research and Development (ORD) is leading a five-year National Coastal Assessment using EMAP. The results of the first year of monitoring work on estuaries, including sites in the Columbia River, have been disseminated via the web under the auspices of the Coastal 2000 study. The Coastal 2000 sampling design is the first EMAP study to incorporate existing non-federal monitoring programs; EPA-EMAP developed partnerships with coastal states to leverage existing state and regional programs to develop EMAP datasets and analyses. The Coastal 2000 study design team and state agencies identified sites currently being monitored that met location-specific criteria with respect to bias and random location. The advantages of federal-state partnerships are that historical data provided by

[1] A useful definition of a wetland reference site is given by Brinson (1993): "Wetland or one of a group of wetlands within a relatively homogeneous biogeographical region that represents typical, representative, or common examples of a particular hydrogeomorphic wetland type, or examples of altered states."

state monitoring programs can inform trends analyses, and EPA can aggregate and compare state-collected estuarine data at regional and national levels.

Coastal 2000 is based on an EMAP-Estuaries sampling design that "combines the strengths of systematic and random sampling with our understanding of estuarine systems…[to] provide a design that will allow probability-based estimates of the status of the Nation's estuarine systems, the variability associated with that status, its spatial and temporal components, and the temporal trends associated with changes in these systems" (http://www.epa.gov/emap/nca/html/data/westcstl/). The study uses statistically valid subsampling to assess estuarine condition. Leading the EMAP sampling effort are the Oregon Department of Environmental Quality and the Washington Department of Ecology, though other entities and agencies such as the National Marine Fisheries Service were involved in field sampling and analysis efforts.

The five year (1999-2004) EPA-ORD EMAP study on the Columbia River involved sampling at 12 small-system stations on the Washington side and 17 small-system stations on the Oregon side in 1999, and 50 mainstem stations in 2000 (L. Edmond, pers.comm.; Figure 9). The 1999 Oregon date currently are available on the web[1]. The study area is the tidally-influenced reach from Bonneville Dam to the mouth, which is congruent with the NOAA Fisheries/Action Agencies' estuary program study area (Figure 1). The 2000 data are expected to provide a good picture of current water quality, fish tissue, and sediment conditions in the lower river. However, certain monitoring attributes that are crucial to the evaluation of restored sites, such as hydraulic geometry and marsh vegetation, are not components of the existing EMAP study. The national study protocols (EPA 2001) were modified to some extent based on conditions in the Columbia River estuary (L. Edmond, pers.comm.).

Fifteen datasets (listed below) were obtained during the 1999 and 2000 EMAP sampling efforts in the estuary. Datasets such as water quality and sediment analyte concentration contain values for multiple parameters, such as those cited in the "monitored attribute" column of Table 4.

1. Station locations information
2. Station visit information
3. Water quality data by station
4. Benthic grab data by replicate
5. Benthic abundance data by station/taxon
6. Sediment analyte concentration data
7. Sediment grain composition data
8. Sediment toxicity test data
9. Netted organism abundance data by replicate
10. Trawl abundance/length data by station/taxon

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[1] Available URL: http://oaspub.epa.gov/coastal/

11. Tissue chemistry concentration data
12. Fish/invertebrate pathology data
13. Objects observed in trawl/from boat
14. Sediment analyte concentration merged with grain composition data
15. Sediment toxicity merged with grain composition data.

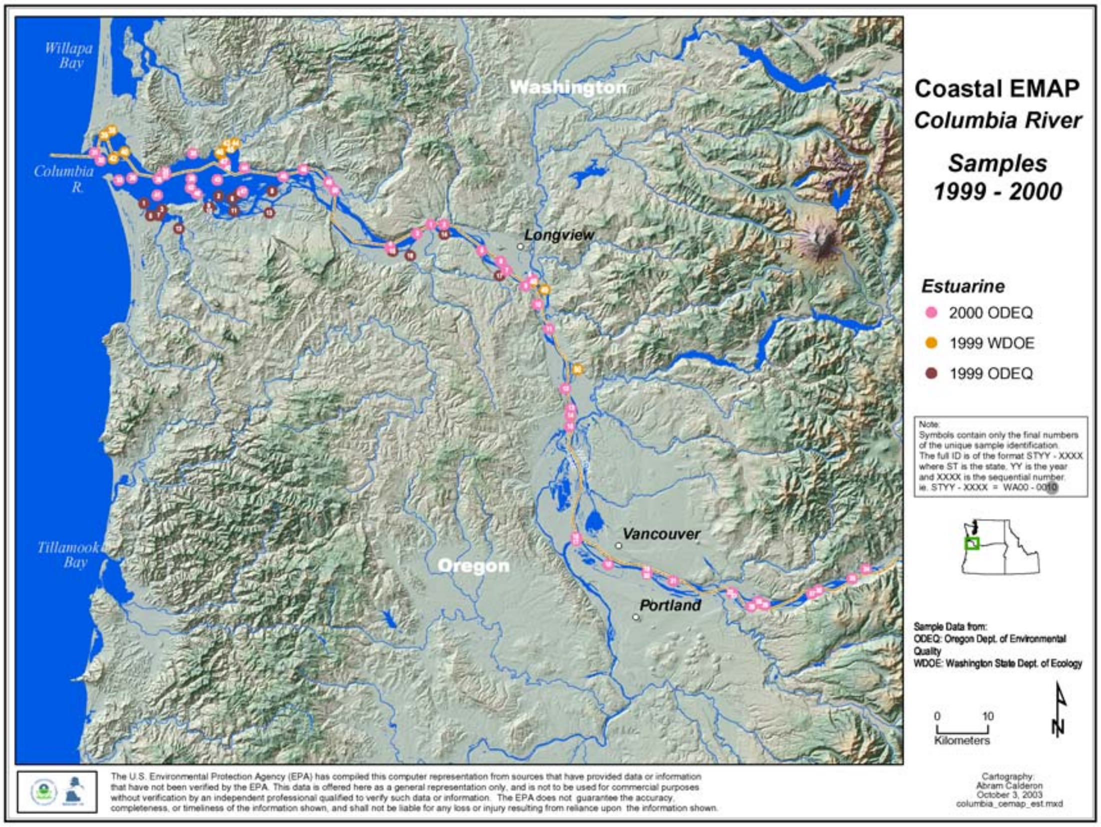

Figure 9. Map of Coastal EMAP Sampling Sites in the Columbia River Estuary (Source: U.S. Environmental Protection Agency, Region 10).

For the purpose of statistical analysis, EMAP researchers are post-stratifying some of its data to address habitat heterogeneity in the estuary (L. Edmond, pers.comm., EPA). As noted above, the estuary comprises diverse environments that have been classified according to different schemes (e.g., Thomas 1983; Garono and Robinson 2003). For the purpose of estuary RME status monitoring, we propose that the estuary be pre-stratified according to an accepted classification of habitat types that is congruent with project-specific implementation monitoring. As an example, the habitat types mapped by Thomas (1983) are tidal swamps, tidal marshes, shallows and flats, medium depth water, and deep water. Tidal swamps and marshes were also stratified according to brackish or freshwater status by the Columbia River Estuary Data Development Program (1984a).

In summary, applying an EMAP sampling design for status monitoring in the estuary has the advantages of having baseline data generated in 1999 and 2000 and the protocols and modifications already developed by EPA (EPA 2001; L. Edmond pers.comm.). The sampling design would require further development in order to select strata and the appropriate number of sampling locations. (This is an element of a new project by the Estuary Partnership; Figure 5.) In addition, it is recommended that the design incorporate the reference sites recommended for restoration project monitoring (see Section 4.2.1) in order to minimize the overall sampling effort and program cost. While the EMAP sampling design calls for new sites to be randomly selected for every sampling interval (e.g., every year), programs such as the Puget Sound Ambient Monitoring Program have incorporated fixed sites into modified EMAP designs (L. Edmond, pers.comm.).

4.1.2 Pilot Study

A pilot study is recommended to implement a modified EMAP sampling design for status monitoring and integrate it with action effectiveness research in the estuary (see Section 4.1.1). Pilot studies for status monitoring, which are part of the basin-wide RME effort, are underway or planned for Idaho (Salmon River subbasin), Oregon (John Day River subbasin) and Washington (Wenatchee River subbasin). The purpose of the pilot studies is to assess the feasibility of implementing a regionally coordinated, programmatic approach to RME (RPA Action 161). Such an approach is driven by the myriad of federal, state, and tribal monitoring efforts in these subbasins (PNAMP 2004). The same is true for the Columbia River estuary. A pilot status monitoring study in the estuary would complement those in the tributary subbasins by providing field evaluations of monitoring protocols, methodologies, and sampling designs intended to generate data of known precision and accuracy at habitat and ecosystem scales. In addition, status monitoring work in the estuary would be integrated with action effectiveness research on habitat restoration projects (Biological Opinion Action 160) by monitoring reference sites and providing baseline and trends data that could be analyzed with 1999 and 2000 EMAP data (see Section 4.1.1).

Data from status monitoring and action effectiveness studies collectively will enable managers to evaluate changes in the status of the estuary biologically and physically with respect to listed salmon and program goals. Existing monitoring programs in the estuary are limited in scope relative to the requirements identified in this RME Plan. Not every parameter measured in EMAP's coastal study would need to be measured for the purpose of long-term monitoring relative to Biological Opinion goals, but some additional parameters relevant to habitat restoration identified in Table 4 would be added to EMAP's list. The pilot study would be able to utilize the monitoring protocols being developed by the new COE cumulative effects study (Figure 5), which would also be used in restoration-project specific monitoring, providing efficiencies to the program as a whole (reduced total number of sampling stations) and standardization for the purpose of estuary-wide analyses. The pilot study would provide scientifically defensible status monitoring of fish populations and associated biotic and abiotic attributes in the estuary to inform salmon recovery actions, and a sound basis for long-term monitoring in association with action effectiveness research.

4.2 Sampling Design Considerations for Action Effectiveness Research

4.2.1 Site Specific Assessment

A network of reference sites in tidal marshes, tidal swamps, and estuary habitats having relatively undisturbed ecosystem structure and processes should be identified for the purpose of action effectiveness research on restoration projects. For statistical power, the number of reference sites in each habitat category should be equal to or greater than the number of restoration project sites in that category. However, it may not be possible to identify enough relatively pristine areas to fulfill this need. Following the recommendations in *An Approach to Improving Decision Making in Wetland Restoration and Creation* (Kentula et al. 1992), the network of reference sites in each category may be considered a population for the purpose of statistical analysis and compared against the population of project sites. The trajectories of development of restoration and reference sites may also be analyzed as pairs, where suitable paired sites exist. An example of this method is provided by the Elk River estuarine marsh restoration in Grays Harbor, Washington (Thom et al. 2002).

The natural or reference sites also serve as a source of information from which to develop performance criteria for restoration project sites (Kentula et al. 1992). Trajectories of post-restoration ecosystem development may then be predicted, and monitoring data used as the basis of annual analyses to determine whether projects are meeting expectations or require adjustments within an adaptive management framework (Kentula et al. 1992, Thom 2000, Thom 1997). Although the stratified random sampling method proposed for status monitoring requires sampling sites to be randomly selected, it is hoped that some of these status sampling sites will overlap with the identified reference sites to provide for long-term sampling efficiency. Likewise, some status monitoring sampling sites may overlap with restoration project sites. Thus, status monitoring sites could, in some cases, even serve for both reference and restoration sites in a paired analysis. To facilitate such multiple uses of the monitoring data, the monitoring protocols selected for status monitoring and action effectiveness sampling should be congruent, as described in Table 8. The new COE study on cumulative effects of restoration (Figure 5) will produce a manual of restoration monitoring protocols for the estuary. Once developed, it is recommended that this be reviewed and considered for adoption estuary-wide.

4.2.2 Habitat Opportunity Methods

While habitat capacity and realized function monitoring comprise commonly-measured indicators such as water quality, vegetation, and fish populations (Table 6), the methods for indicators used in habitat opportunity assessment are less well known and deserve further discussion. The most dominant historical change to habitat in the estuary that is not hydrosystem-related is the installation of dikes, tide gates and other barriers to fish passage. In some cases, such barriers significantly altered habitats behind them, in addition to preventing passage (Simenstad and Feist 1996). It is expected, however, that habitat restoration actions in the estuary will improve habitat opportunity for listed salmonids. More specifically, the area of estuarine habitat currently accessible within a given geographic area is expected to increase toward the area of estuarine habitat that was historically accessible. Furthermore, the length of tidal channel edge that is available to listed salmonids is expected to increase toward pre-settlement levels. However, these length and area values vary temporally with water level in an estuary, which in turn varies with flow the regulated Columbia River.

Although only passage barriers and tidal channel edge, density and sinuosity are shown for the "connectivity" indicator in Table 8, habitat opportunity in fact integrates several variables. The restored "habitat area" variable integrates the habitat conditions indicator: temporal scale, or the period of year in which habitat is available. Habitat availability is associated with the attributes "floodplain topography" and "inundation regime," which in turn are associated with habitat conditions and hydrodynamics indicators: geomorphic features, the total edge and penetration of tidal channels. Furthermore, they are also associated with habitat conditions; water velocity, and hydrodynamics (Simenstad and Cordell 2000). The calculation of connectivity has similar importance in tributary restoration (Hillman and Giorgi 2002).

Several variables that correspond to habitat opportunity for listed salmonids can be calculated using geographic information systems (GIS) and data sources including diking district records and remote sensing imagery. For example, "diked area," "tidal area," and "nontidal area" classes can be calculated and subjected to a change analysis. Although resolution previously limited the width of tidal channels that could be visualized with remote sensing (e.g., NOAA Coastal Services Center 1997), recent research in the estuary has visualized tidal channels down to a width of 1-m (R. Garono, pers.comm.); full color and near infrared (4 spectral bands) digital aerial photography at 0.25-m^2 spatial resolution is also being used in coastal applications (Finkbeiner et al. 2003; D. Woodruff, pers.comm.). For these channels, variables such as density/area, sinuosity, and total edge length can be calculated using GIS (e.g., Desmond et al. 2000). Coats et al. (1995) and Williams et al. (2002) identified bifurcation ratios, channel order, and other variables to monitor regarding tidal channel. These physical parameters have been correlated with ecological processes in studies of allometry (Hood 2002). These tools are recommended in Table 8 for monitoring habitat conditions and opportunity indicators. In conclusion, the monitoring plan for action effectiveness research in the estuary RME is consistent with the monitoring recommendations under the Estuary Restoration Act (NOAA 2004).

4.3 Monitoring Methods and Terminology

Four guiding principles were applied in the selection of methods for the monitored attributes in the estuary. First, methods that have been developed for or applied in the Columbia River estuary were sought because of the importance of regional specificity and the significance of existing baseline data collected in accordance with these methods. Second, consistency with Hillman and Giorgi (2002) and Hillman (2004) was valued because of the importance of basin-wide evaluations synthesizing indicators in both tributary habitat and the estuary. Third, to establish the credibility of the planned monitoring program, published peer-reviewed methods were favored, as were those currently in use and accepted in the scientific community. Fourth, in the absence of a comprehensive set of protocols developed specifically for the estuary[1]; however, existing protocols developed and tested through long-term monitoring programs on the West Coast were relied on heavily.

Projects to standardize monitoring protocols for the estuary are beginning concurrent with the development of this RME plan. These projects include 1) water quality, habitat monitoring, and ecosystem health work by the Estuary Partnership, and 2) salmon monitoring, a methods manual, and cumulative effects monitoring by the COE. These efforts pertain mostly to status monitoring and action effectiveness, respectively (for further information, see Section 5.1.1 and Appendix C). These projects will review and refine the protocols identified in Table 8 and the considerations for sampling design in this RME plan and identify other protocols used on the estuary. The Columbia River estuary protocols and sampling designs developed through these projects will thus be tailored to monitoring the unique characteristics of the estuary and are intended to become standard in the estuary. Therefore, once developed, it is recommended that they be reviewed and considered for adoption.

Certain key sources were especially useful for the monitoring methods referenced in Table 8. They include the Estuarine Habitat Assessment Protocol developed for the Puget Sound Estuary Program (Simenstad et al. 1991), which is used extensively in the Pacific Northwest. Rice et al. (In Press) provided details on methods for sampling estuarine habitats in the Pacific Northwest. For water quality parameters, the EPA and other standard methods utilized by the U.S. Geological Survey are recommended for consistency with historical data and other regional monitoring. Action effectiveness research protocols developed through a well-known long-term restoration monitoring research program in California and recently published in the *Handbook for Restoring Tidal Wetlands* (Zedler 2001) were also utilized (Callaway et al. 2001). In addition, the Monitoring Oversight Committee (2002b. p. 76) of the Washington State Salmon Recovery Funding Board recommended standardized protocols for action effectiveness research. Thayer et al. (2004) provided 12 steps to develop a project-specific monitoring plan.

A major multi-agency effort to synthesize existing protocols for the inventory and monitoring of salmon habitat in the Pacific Northwest was also consulted for the recommendation of protocols in Table 7 (Johnson et al. 2001). Johnson et al. (2001) relies heavily on Simenstad et al. (1991) for estuary and nearshore marine monitoring protocols, and the majority of methods recommended by Johnson et al. (2001) are for tributaries. However, Johnson et al (2001) do recommend several protocols applicable to estuarine monitoring in the estuary, and the use of these protocols for estuary research would help to contribute to consistency in data throughout the region: *Automated Water Quality Monitoring* (British Columbia Ministry of Environmental Lands and Parks 1999) as well as the *Oregon Plan for Salmon and Watersheds: Water Quality Monitoring Technical Guidebook* (OPSW 1999); protocols for subtidal benthic macroinvertebrate assemblages in Puget Sound, which may require modification for the Columbia River estuary (Puget Sound Estuary Program 1987); the timber-fish-wildlife method for stream temperature surveys, which may be applicable in temperature studies of tidal channels (Schuett-Hames

[1] Monitoring and evaluation protocols for the estuary are currently being developed via projects funded by BPA (2003-013-00) and COE (EST-P-04-001).

1999); a guide to photographic documentation for aquatic inventory (Osprey Environmental Services 1996); and a fish habitat description and assessment manual (Williams 1989). The EPA's EMAP study has also developed a Quality Assurance Project Plan, although modifications for application on the West Coast have not been published. And, the Washington State Salmon Recovery Funding Board is planning to develop estuary monitoring protocols.

Methods for measuring the monitored attributes at the ecosystem and habitat/population levels (Table 4) are recommended in Table 8. As a rule of thumb, to the extent possible, data on the monitored attributes involving salmonid populations should be differentiated with respect to life history and ESU. Both the monitored attributes and the methods developed for the estuary will require additional research establishing their suitability before final selection for estuary RME. The appropriate scale for applying each method is also suggested in Table 8. For example, "site specific" refers to project implementation and effectiveness sampling at restoration and reference sites, while "CRE" refers to general estuarine sampling not linked to a specific project. While project performance criteria will of necessity be developed on a project-by-project basis to appropriately reflect each unique site, the methods and attributes labeled "site specific" in Table 8 are recommended for post-restoration monitoring. The terminology in the methods table (Table 8) has the following working definitions:

- *Geographic (Spatial) Scale* – The spatial extent over which sampling or analysis will occur. CRE is only the Columbia River estuary, including the plume.
- *Temporal Scale-Frequency* – How often the sampling or analysis will be performed.
- *Data Collection Method* – The primary technique used to collect the data.
- *Example Protocol/Data Source* – Reference where the data collection method was described.
- *Use in Status Monitoring* – How the data applies to status monitoring.
- *Use in Action Effectiveness Research* – How the data applies to action effectiveness research.
- *Site Specific* – Means "restoration" sites and includes both restoration and reference sites.

Table 8. Methods to Measure the Attributes of Each Performance Indicator. The terminology is defined in the text above.

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
Habitat conditions	Vegetation cover	Presence/ absence of rooted vascular plant species; percent cover; species composition	CRE and site specific	Every 5 years for CRE; annually for restoration sites	Hyperspectral imagery and/or digital aerial photography; field survey	Garano et al. 2003; Thom et al. 2002; Finkbeiner et al. 2003; Dr. Dana Woodruff, personal communication; Osprey Environmental Services 1996; Williams 1989	Trends in percent cover by plant type over time	Compare plant cover before and after action at a specific site
	Geology/ soils	Geologic regime; size composition; percent organic matter	CRE and site specific	Once, baseline/ historical	Vibracores; sediment analysis; radio carbon dating	Peterson et al. 2000	One time characteri-zation	Characterize site to understand historical processes to evaluate restoration potential
	Floodplain topography	Surface elevations; accretion; channel hydraulic geometry; tidal prism	CRE and site specific	5 year cycle	LIDAR survey	Haugarud and Harding 2002; Bowen and Waltermire 2002; Williams et al. 2002; Callaway et al. 2001	Trends in topography over time	Characterize changes in topography before and after action at a specific site
	Bathymetry	Bottom elevations	CRE	5 year cycle	Multibeam sonar bottom mapping; LIDAR (shallow waters if feasible)	Multibeam – Bates and Byham 2001; LIDAR – Brock et al. 2002; Sallenger et al. 2003	Trends in bathymetry over time	Characterize changes in bathymetry before and after action at a specific site

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Area affected	Tally of acres protected, conserved, restored, enhanced, or created	CRE	Annual	Summary of project records and GIS analysis	N/A	N/A	Show cumulative area affected by restoration actions
Fauna	Nearshore fauna	Density, species composition, energetic biomass content, residence time and flux of organisms	Site-specific	To be determined	Various	Simenstad et al. 1991; Taylor 2003; Callaway et al. 2001; Rice et al. (In Press); (cumulative effects TBD); Puget Sound Estuary Program 1987; Williams 1989	Trends in prey pop's	Demonstrate changes in ecological functioning at a site
	Avifauna	Presence/ absence of birds, especially piscivorous	CRE	Annual	Field survey (count)	Simenstad et al. 1991; Audubon Society bird count	Show trends in piscivorous bird populations	N/A
Habitat Connectivity	Passage barriers	Number and location of tide gates, culverts, plugs, and other barriers or constrictions	CRE and site-specific	Annual	Use GIS to record number removed/ length of new area available	Osprey Environmental Services 1996	Show trends in the number of barriers	Barrier removal or modification is a common action

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Total edge, density and sinuousity of floodplain and tidal channels.	Total edge, density, and sinuousity of floodplain and tidal channels/ organized by subarea and habitat type	CRE and site-specific	3 year cycle	Digital aerial photo/spectral data/GIS	Coats 1995; Williams and Orr 2002; Williams et al. 2002; Finkbeiner 2003; Hood 2002; Desmond et al. 2000	Trends in the amount of wetland channel edge	Characterize changes before and after restoration action; allometry: relationships between scale of tidal channels and ecological patterns/processes, e.g. Salmonid prey production/foraging associated with size of restored tidal channel
Life history diversity	Species composition	Which salmon species are present	CRE and site-specific	Monthly	Examination of fish captured in beach and purse seines, trap nets	Murphy and Willis 1996; Roegner et al. In Preparation; Rice et al. In Preparation	Trends in species composition over time	Identify species present at a restored site
	Age/size-structure	Age of juvenile salmon present. Expressed as life stage (fry, fingerling, subyearling, yearling)	CRE and site-specific	Monthly	Scale and otolith analysis of fish captured in beach and purse seines, trap nets	Murphy and Willis 1996; Roegner et al. In Preparation; Rice et al. In Preparation	Trends in age structure over time	Identify age structure of juvenile salmon using a restored site
	Stock identity	Composition of juvenile salmon pop. classified by ESU	CRE and site-specific	Monthly	Genetic analysis of fish captured for sp. comp.	Murphy and Willis 1996; Teel et al. 2000	Trends over time in the ESUs inhabiting the study area	Identify the ESUs for juvenile salmon using a restored site

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Temporal distribution	When juvenile fish are present and abundance peaks	CRE and site-specific	Monthly	Periodic sampling w/ beach and purse seines, trap nets; tagging and tracking	Murphy and Willis 1996; Skalski et al. 2001; Rice et al. In Press	Trends in temporal distribution over time	Identify when juvenile salmon are using a restored site
Spatial distribution	Spatial distribution	Where juvenile salmon are located in the estuary	CRE and site-specific	Monthly	Telemetry, nets, seines	Murphy and Willis 1996; Roegner et al. In Preparation; Thorpe et al. 1981; Skalski et al. 2001	Trends in spatial distribution over time	Determine where salmon are located at a restored site
	Migration pathways	Primary routes of passage during outmigration through the estuary	CRE and site-specific	Seasonally	Telemetry	Murphy and Willis 1996; Thorpe et al. 1981; Skalski et al. 2001	Trends in migration pathways over time	Determine if a restored site is part of a migration pathway
Growth	Growth rate	Amount of weight gained (lost) on average by juvenile salmon per unit time	CRE and site-specific	Monthly	Weighing fish captured in periodic sampling w/ beach and purse seines, trap nets	Murphy and Willis 1996; Roegner et al. In Preparation	Trends in growth rates over time by habitat type	Determine biological benefit from a restored site
	Residence time	Amount of time juvenile salmon inhabit particular areas	CRE and site-specific	Seasonally	Telemetry	Murphy and Willis 1996; Thorpe et al. 1981; Skalski et al. 2001	Trends residence time over time by habitat type	Determine biological benefit from a restored site

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Prey availability	Type and energy content of prey items	CRE and site-specific	Seasonally	Prey samplers such as zooplankton nets, bottom corers, neuston nets.	Simenstad et al. 1991; Taylor et al. 2003; Tranter and Fraser 1974	Trends in prey availability over time	Identify prey production/presence at a restored site
	Foraging success	Index of food habits of juvenile salmon	CRE and site-specific	Seasonally	Stomach contents analysis	Murphy and Willis 1996; Roegner et al. In Preparation; Bottom et al. 1984	Trends in foraging success over time	Identify fish prey and success at a restored site
Survival	Survival rate	Proportion of total population entering an area that are alive when they leave	CRE	Seasonally	Acoustic tag fish and survival estimation using a single release-recapture model	Acoustic tagging in Thorpe et al. 1981; survival estimation in Burnham et al. 1987	Trends in survival rates over time	Monitor to assess effects of actions, depending on project objectives
	Predation index	Relative approximation of the amount of predation on juvenile salmon	CRE	Seasonally	Sampling of distribution and abundance and analysis of gut contents of predators	Zimmerman and Ward 1999	Trends in predation indices over time	Monitor to assess effects of actions, depending on project objectives
Water quality	Tempera-ture	Maximum daily maximum and maximum weekly maximum	CRE and site specific	Seasonally 1st 5 years; annual, rotating seasons, thereafter; site specific see protocols (e.g., storm event)	Data logging equipment	Callaway et al 2001; YSI (http://www.ysi.com/index.html); OPSW 1999; British Columbia Ministry of Environmental Lands and Parks 1999; Schuett-Hames 1999; National Estuarine Research Reserve System 2004	Routine monitoring for trends; benchmark indicators for estuaries TBD under MOC 2002b	Monitor to assess effects of actions, depending on project objectives
	Salinity	Parts per thousand						
	Dissolved oxygen	mg/L						
	pH	acidity						

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Turbidity	Water clarity is related to suspended materials in the water column; plume dynamics	CRE and site specific	Seasonal, 1st 5 years; annual, rotating seasons, thereafter; site specific see protocols (e.g., storm event)	Secchi Disk or LiCor sensor	Callaway et al. 2001; Simenstad et al. 1991; LiCor (http://env.licor.com/); OPSW 1999	Routine monitoring for trends	Monitor to assess effects of actions, depending on project objectives
	Nutrients	Total nitrogen, total suspended nitrogen, ammonia, nitrite, nitrite + nitrate, total phosphorus, orthophosphate, dissolved organic carbon, suspended organic carbon, and inorganic suspended carbon.	CRE	Annual	Spectropho-tometer or autoanalyzer	Callaway et al. 2001; OPSW 1999; Standard EPA Methods (EPA 1991, Fuhrer 1996)	Routine monitoring for trends	N/A
	Toxics	Contaminants, trace elements, pesticides	CRE	Annual	Various	Standard EPA Methods (EPA 1991, Fuhrer 1996)	Routine monitoring for trends	N/A

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
Physical condition	Substrate type	Dominant soil type and composition (grain size, percent organic matter)	Site-specific	Annual	Core samples	Standard EPA Methods (EPA 1991); Rice et al. In Preparation	N/A	Monitor to assess effects of actions, depending on project objectives
	Accretion/ erosion rates	mm/yr	Site-specific	Annual	Sediment elevation table or Marker horizon	Callaway et al. 2001	N/A	Monitor to assess effects of actions, depending on project objectives
	Reduction/ oxygenation potential	Ability to support vegetation	Site-specific	Annual	Redox Electrode	Callaway et al. 2001	N/A	Monitor to assess effects of actions, depending on project objectives
	Surface and ground water level	Plant community potential; fish habitat potential	Site-specific	Seasonal (4X/year)	Piezometer or water level recorder; pressure transducer	Callaway et al. 2001	N/A	Monitor to assess effects of actions, depending on project objectives
	Large woody debris	Pieces/km	CRE	6 year cycle	Digital aerial photo/hyperspectral imagery	Finkbeiner 2003; BURPTAC 1999	Map and trends in LWD	Site characterization; impacts on salmonids and other fauna
	Sediment contamination	Presence and concentration of contaminants	Site-specific areas of concern	As warranted	State of Washington Sediment Management Standards; Laboratory analysis of sediments	Simenstad et al. 1991	N/A	Site characterization; impacts on salmonids and other fauna

Performance Indicator	Monitored Attribute	Description	Spatial Scale	Temporal Scale	Data Collection Method	Example Protocol	Use in Status Monitoring	Use in Action Effectiveness Research
	Water velocity	cm/sec	Site-specific	Seasonal (4x/year)	Flow Meter; Timed float	Callaway et al. 2001	N/A	Monitor to assess effects of actions, depending on project objectives
	Inundation Regime	Percentage of time and frequency a site is covered with water	Site-specific	2 weeks/ season (4 seasons)	Data logger or water collector	Callaway et al. 2001	N/A	Monitor to assess effects of actions, depending on project objectives
Invasive species assessment	Species list	Presence/absence	CRE	5 yrs	Site surveys	Waldeck et al. (2003); Cohen et al. 2001	Trends	N/A
	Spatial distribution	Location	CRE	5 yrs	Site surveys	Waldeck et al. (2003); Cohen et al. 2001	Trends	N/A
	Abundance	Population size	CRE	5 yrs	Site surveys	Waldeck et al. (2003); Cohen et al. 2001	Trends	N/A
River discharge	Hydro-graph	Daily mean streamflow at Beaver for the CRE	CRE	Annual	Stream gauge	DART (www.cqs.washington.edu/dart/)	Provide context regarding environ-mental conditions	Provide context regarding environmental conditions
Plume conditions	Juvenile salmon usage	Temporal and spatial distributions and abundance	Plume	Annual	Trawl net	Schabetsberger, et al. In Press	Provide context regarding environ-mental conditions	Provide context regarding environmental conditions
	Anchovy/ herring index	Species composition and density	CRE	Annual	Purse seine	Dawley et al. 1985ab; Emmett et al. In Press	ditto	ditto

Performance Indicator	**Monitored Attribute**	**Description**	**Spatial Scale**	**Temporal Scale**	**Data Collection Method**	**Example Protocol**	**Use in Status Monitoring**	**Use in Action Effectiveness Research**
	Zooplankton prey base	Species composition and density	Plume	Annual	Bongo nets, hydroacoustics	Peterson et al. 2002	ditto	ditto
	Sea surface temperature	Water temperature in surface layer	Plume	Weekly	NOAA buoy array	www.pmel.noass.gov/ tao/elnino	ditto	ditto
	Northern oscillation index	Stage of the Pacific decadal oscillation	estuary	Weekly	Index of climate variability based on sea level pressures	Mantua et al. 1997; Schwing et al. In Press http://www.pfeg.noaa.gov/ products/PFEL/modeled/indices/ NOIx/noix.html	ditto	ditto
	Upwelling	Index of upwelling	estuary	Weekly	Index based on Ekman mass transport calculation	http://www.pfeg.noaa.gov/ products/PFEL/modeled/indices/ upwelling/upwelling.html	ditto	ditto

5.0 Action Plan

This section provides an action plan to implement RME in the estuary. The action plan starts with a *project-level* assessment of how well ongoing and planned projects meet estuary RME objectives (recall Section 2.2). Then, coverage of *program-level* elements is examined. This section builds on the "Gap Analysis for Biological Opinion-Related Estuary/Ocean RME" submitted by the Estuary/Ocean RME Subgroup to the NOAA Fisheries/Action Agency RME Policy Group on January 28, 2003. For both the project and program levels, specific actions are recommended within a phased development approach.

5.1 Project-Level Assessment

The project-level assessment was carried out by the estuary/ocean RME subgroup. First, they identified ongoing or planned projects for research or monitoring in the estuary related to estuary RME. This process produced an inventory of estuary RME projects (Section 5.1.1). Second, the estuary/ocean subgroup assessed coverage of the attributes to be monitored to meet the objectives for status monitoring, action effectiveness research, and uncertainties research by examining if the attributes were included in the project descriptions (see Appendix C). This examination resulted in a subjective assessment of coverage by the projects (Section 5.1.2), from which the action plan (recommendations) for projects was developed (Section 5.3.1).

5.1.1 Project Inventory

Twenty-five projects related to estuary RME are ongoing or have received funding commitments and are scheduled to start before the end of FY2004 (Table 9). Four projects are in the preparation or proposal stage (Table 9). (See Appendix C for descriptions of all 27 projects and their specific application to estuary RME). The projects were categorized and sorted by type, with the number of projects of a given type in parentheses, as follows: Status Monitoring only (15); Status Monitoring and Action Effectiveness and/or Uncertainty Research (8); and Action Effectiveness Research (6). The funding agencies include the BPA, COE, Coast Guard, NOAA, ODEQ, and USGS. Project leads include federal, state, and local agencies, a private firm, and non-governmental organizations. It is evident from Table 8 that the estuary RME effort is well underway. The Action Agencies and other participating parties are working to coordinate these projects (see coordination Section 5.2.4). A main purpose of the estuary RME *plan* is to provide the framework for the Action Agencies and others to amalgamate the existing and new projects into a cohesive estuary RME *program*.

Table 9. Projects Addressing Estuary RME. The projects are organized as follows: ongoing, have data; ongoing, no data yet; new start, no data yet; and proposed. Identification numbers for SM objectives, AER objectives, and UR are presented in Table 3.

ID.	Title	SM	AER	UR	Proj. No.	Sponsor	Lead Entity	Performance Indicators
	Ongoing, have data						5.1.1.1	
P1	Aquatic Non-indigenous Species Survey	**6**			unk.	Coast G.	5.1.1.2 PSU	Invasive species assessment
P2	Total Dissolved Gas Monitoring	**4**			unk.	COE	5.1.1.3 COE	Water quality
P3	Acoustic Telemetry on Continental Shelf	**1**			200007600	BPA	Kintama	Plume conditions
P4	Estuary Habitat Mapping	**1**	**1**	**3**	200201200	BPA/ COE	5.1.1.4 Estuary Part.	Habitat conditions
P5	Bathymetric Survey RM 3-40	**1**			unk.	COE	COE	Bathymetry
P6	Baitfish/Salmonid Marine Survival Relationships in the estuary	**1, 3, 4**			unk.	NOAA	5.1.1.5 NOAA/ NWFSC	Plume conditions, survival, water quality
P7	Ambient Water Quality Monitoring	**4**			unk.	ODEQ/BPA	5.1.1.6 ODEQ/OHSU	Water quality
P8	Long-Term Water Quality Monitoring	**4**			unk.	USGS	5.1.1.7 USGS	Water quality
P9	Hydrograph	**1**			unk.	USGS	5.1.1.8 USGS	Hydrograph
P10	Sampling PIT Tagged Juvenile Salmonids Migrating in the estuary	**2**			BPS-00-11	COE	NOAA/ NWFSC	Life history diversity, growth

P11	Survival and Growth of Juvenile Salmonids in the Columbia River Plume	**1, 2, 3**		**3**	199801400	BPA	NOAA/ NWFSC	Plume conditions, life history diversity, usage, growth
P12	Estuarine Habitat and Juvenile Salmon – Current and Historical Linkages	**1, 2, 4, 5**		**1**	EST-02-02	COE	NOAA/ NWFSC	Habitat conditions, life history diversity, spatial distribution, growth, water quality, phy. cond.
P13	Vibracore studies in the Columbia Estuary			**2b**	unk.	XXX	PSU	Habitat conditions
P14	Evaluation of Juvenile Steelhead and Fall Chinook Following Transportation	**2, 3**			TPE-W-00-01	COE	OSU	Life history diversity, spatial distribution, survival
	Ongoing, no data yet							
P15	Evaluation of the Relationship Among Time of Ocean Entry, Physical, and Biological Characteristics of the Estuary and Plume	**2**		**3**	EST-02-03	COE	NOAA	Life history diversity
ID.	**Title**	**SM**	**AER**	**UR**	**Proj. No.**	**Sponsor**	**Lead Entity**	**Performance Indicators**
P16	Estimation of Salmon Survival Using Miniature Acoustic Tags	**2, 3**		**3**	EST-02-01	COE	NOAA/ PNNL	Life history diversity, spatial distribution, survival
	New start, no data yet							
P17	Blind Slough Restoration Project - Brownsmead, Oregon		**2**		2003-015-00	BPA	CREST	Life history diversity, spatial distribution, growth, physical cond..
P18	Effectiveness Monitoring of the Chinook River Estuary Restoration Project.		**2**		2003-006-00	BPA	Sea Resources	Life history diversity, growth, physical cond., invasive spp.
P19	Evaluation of Cumulative Ecosystem Response to Restoration		**3**	**3, 4**	EST-04-NEW	COE	TBD	Life history diversity, usage, growth, physical cond., invasives
P20	Preserve and Restore Col. R. Estuary Islands to Enhance Salmonid and Columbia Deer Habitat		**2**		2003-0008-00	COE	USGS	Life history diversity, growth, physical cond., invasive spp.
P21	Crims Is. Baseline Fisheries Survey		**2**		unk.	COE	USGS	Life history diversity, spatial dist.

P22	Implement the Habitat Restoration Program for the estuary	**1**	**1**		200301100	BPA	5.1.1.9 Estuary Partnership	Habitat conditions
P23	Lower Columbia River and Columbia River Estuary Ecosystem Monitoring	**1, 2, 4**			200300700	BPA	5.1.1.10 Estuary Partnership	Life history diversity, spatial distribution, growth, water quality
P24	Additional Monitoring of Habitat Usage By Juvenile Salmon	**2**			unk.	COE	NOAA/ NWFCS	Life history diversity, spatial distribution, growth
P25	Historic Habitat Opportunities and Food-Web Linkages of Juvenile Salmon in the Estuary	**1, 2, 4, 5**		**1, 3**	200001000	BPA	NOAA/ NWFSC	Habitat conditions, life history diversity, spatial distribution, growth, water quality physical cond.
	Proposed or In Preparation							
P26	Optimization of FCRPS for Juvenile Salmonids	**1**	**3**		200304500	BPA	OHSU	Habitat cond. conn'y, phy cond.
P27	Evaluation of Habitat Restoration Opportunities in the Lower Grays River		**2**		unk.	COE	TBD	Habitat conditions, connectivity, physical condition
P28	Subtidal habitat classification method assessment	**1**				NOAA	UI	Habitat conditions
P29	LIDAR survey	**1**				USGS	USGS	Habitat conditions

The projects in Table 9 were also categorized by their status: ongoing and have data (14); ongoing but no data yet (2), new start, no data yet (9), and proposed/preparation (4). The ongoing projects with data include a mix of water quality, fish, and habitat monitoring. For example, the initial phase of the non-indigenous species survey (P1) was completed and provided useful information on the seriousness of the invasive species issue. Further funding for this work is still being sought. Various hydrographic water quality monitoring efforts (P2, P7, P8, P9) are ongoing and more are planned. Habitat mapping efforts (P4) and bathymetry surveys (P5) are providing useful data on the current physical state of the estuary. Ongoing studies of migration characteristics of juvenile salmon using tagged fish (P3, P10, P14, P15, P16) are producing or are about to produce data. Of particular note, the plume study (P11) is distinguished for its cutting edge research on the interaction and mechanistic linkages between juvenile salmon and the plume and nearshore oceanic environment. With the exception of habitat mapping and water quality monitoring, the current estuary RME monitoring effort is concentrated in the lower 46 river miles, as shown by sampling locations for some of the estuary RME projects (Figure 10) and the CORIE sampling stations (Figure 11).

Of the nine new project starts without data yet (Table 9), five deal with action effectiveness research for restoration actions (P17-21). Their status reflects the recent (FY04) prioritization of resources to fund habitat restoration work in the estuary, in part through the Estuary Partnership's Habitat Restoration Program (P22). P22 will build on the status monitoring aspects of this plan to develop a detailed status monitoring sampling design and plan for the estuary. Three new starts (P23-25) will enhance the status monitoring efforts and perform uncertainties research.

5.1.2 Project Coverage

The action plan for estuary RME is based on an assessment of project coverage (Table 10) of the needs for status monitoring, action effectiveness research, and uncertainties research as defined in the table of performance indicators and monitored attributes (Tables 4, 5 and 7) and the associated methods and protocols (Table 8) relative to the completed, ongoing, and proposed projects (Table 9). The estuary/ocean subgroup performed the coverage assessment by examining project content (goals, objectives, methods, expected results) relative to each monitored attribute for each performance indicator. Coverage for the indicators was based on the collective coverage of the respective monitoring variables. Also, note the project scales range from system-wide to site-specific. The coverage assessments for the monitored attributes and the indicators were necessarily subjective and qualitative. However, they do reveal gaps in coverage, implying incomplete implementation of estuary RME. [An earlier version of this coverage assessment relative to the Biological Opinion RPA actions for the estuary/plume was previously submitted to the NOAA Fisheries/Action Agencies' RME Policy Group (Estuary/Ocean RME Subgroup 2003)].

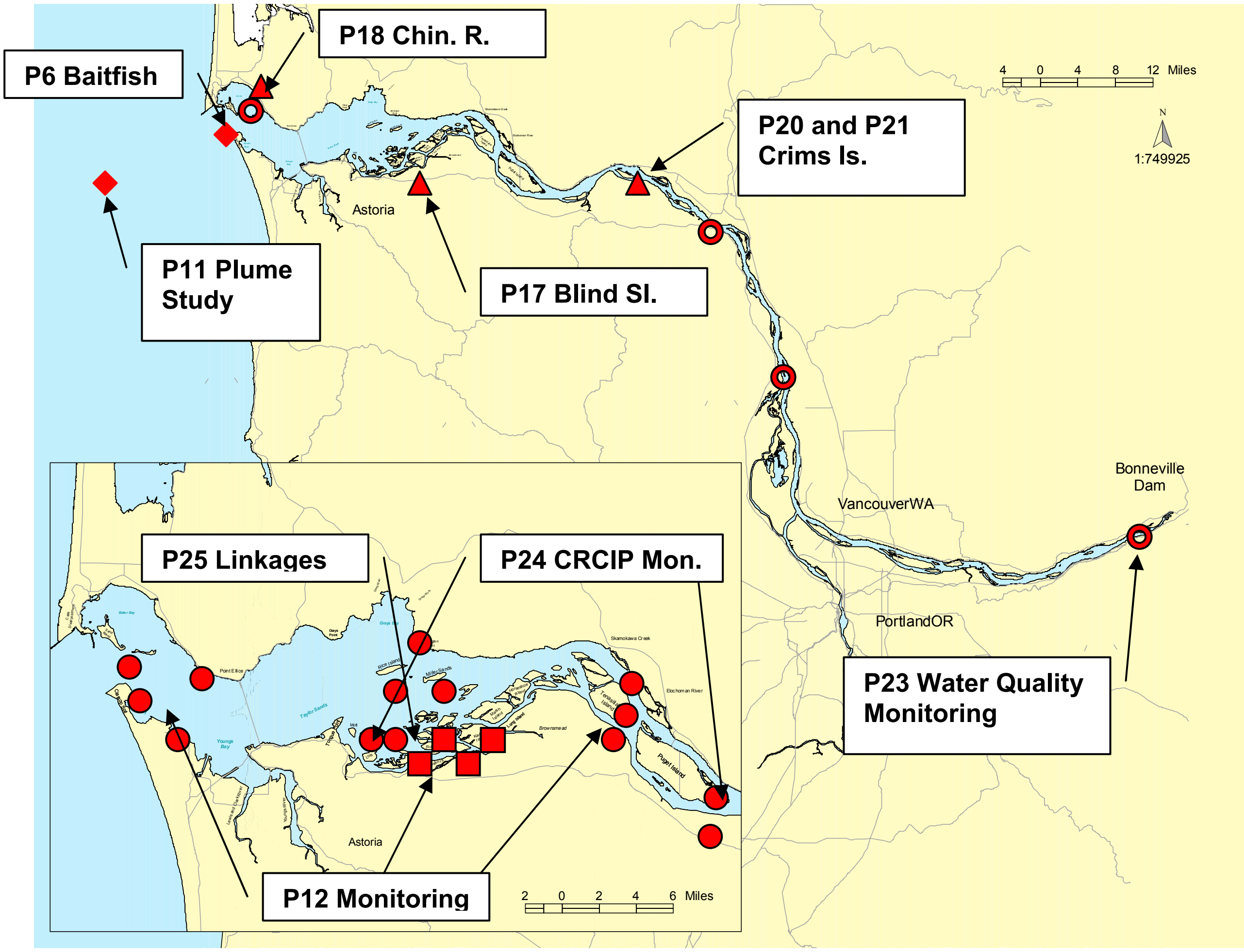

Figure 10. Map of Estuary Study Area Showing Some Monitoring Projects.

▲ = habitat restoration sites with AER
● = beach seine sites for SM
■ = marsh sites for UR
◆ = purse seine or trawl sites
◎ = LCREP/USGS water quality monitoring sites

Coverage of the performance indicators for status monitoring and action effectiveness research ranges from negligible to complete (Table 10). In some cases, coverage is unknown at this time. Based on the number of projects covering a particular performance indicator, the indicators for salmon life history diversity, survival, and growth and water quality have the most coverage. The least coverage is for habitat conditions, habitat connectivity, fauna, physical condition, and invasive species. A pilot monitoring study is not explicitly covered at this time. Action effectiveness evaluation by individual restoration projects will require pre-construction funding and long-term support to provide meaningful results.

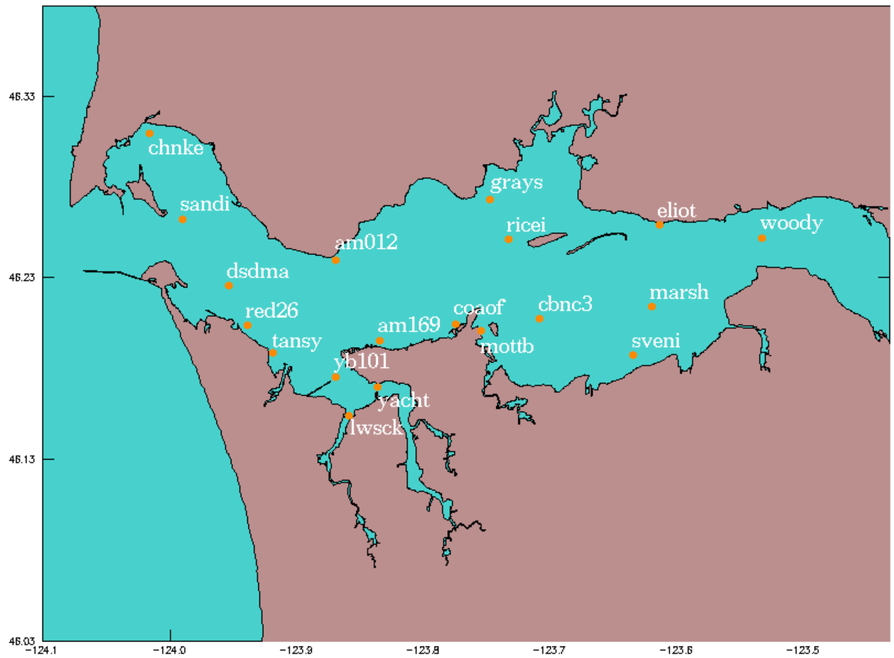

Figure 11. Map of CORIE Sampling Stations from http://www.ccalmr.ogi.edu/CORIE/network/.

Coverage of the uncertainties research is incomplete (Table 11). In some instances, for example the physical characterization of the estuary and the dynamics of the plume, no projects exist. In most instances, a project has been started to address the uncertainty, but data are not available yet to resolve it (Table 11). However, NOAA researchers (P12 and P25) along with others are actively addressing the uncertainties. In both Tables 10 and 11, there are newly started projects that should contribute substantially to estuary RME when they are fully functioning. Thus, the coverage assessment needs to be revisited on a regular basis as the estuary RME program matures. In summary, we make the following conclusions about project coverage of the estuary RME performance indicators.

- *Habitat Conditions and Connectivity* – The projects need to be developed further, in greater detail, and integrated with the overall estuary RME effort. Projects in preparation to map subtidal habitats (P28) and survey the study area using LIDAR (P29) should be useful. The geology/soils attribute of the habitat condition indicator could be further addressed by continuing the vibracores study (P13), as the sample cores have been collected and are ready for further analysis (Dr. C. Peterson, pers. comm..). Although habitat mapping is well underway (P4), further hyper-spectral or digital photogramatic imagery for habitat mapping is warranted. Landscape analysis of habitat changes is well underway, but habitat connectivity analysis is still in the planning stage. A habitat connectivity measurement tool to address the tidal channel and allometry attributes would be useful to assess trends in restoration efforts design to reconnect shallow water habitats to the estuary, e.g., dike breach and tidegate restoration actions.

- *Fauna* – A few projects currently involve this indicator. Fauna were addressed in previous work as part of the Bi-State Water Quality Study and the Columbia River and Estuary Data Development Project.

- *Salmon Life History Diversity, Spatial Distribution, and Juvenile Salmon Growth* – Existing projects (P12 and P25) are addressing these indicators and, although reports are not yet available, these projects should ultimately produce the required data. The residence time attribute of the growth indicator is under covered. A new project (P23) was recently started to monitor habitat (including fish) and toxic chemicals in the estuary. However, systematic, standardized monitoring of habitats in the tidal freshwater reach (RM 46-146) is negligible. Also, none of these projects integrate and coordinate estuary monitoring into a pilot monitoring study as is being done upriver in selected tributary habitats in the Columbia Basin.

- *Survival* – The suite of projects is sufficient (P11, P14, and P16), but methodologies and protocols are still being developed. Survival data for juvenile salmonids in the estuary do not exist; however, the existing projects are progressing to develop the required data. Techniques to estimate survival for juvenile salmon in the 70-90 mm size range need to be developed Currently, the minimum size of fish that can be tagged is about 90 mm (Dr. T. Carlson, pers. comm.),; thus, smaller tags are required. A predation index, as a monitored attribute of the survival indicator, does not currently exist for the estuary.

- *Water Quality* – The existing projects (P2, P7, and P8), coupled with the new water quality monitoring effort by the Estuary Partnership (P23), seem to provide sufficient coverage. There is a need for integration and coordination into the overall estuary RME effort and a commitment to a long term effort if adequate trend data are to be developed.

- *Physical Condition* – Monitored attributes of estuary water, such as circulation patterns, hydraulic characteristics, and temperature, are covered well by existing projects, especially the Columbia River estuary monitoring and modeling project (CORIE) by the Oregon Health Sciences University in collaboration with NOAA Fisheries (P12 and P25). On the other hand, geologic and substrate physical conditions are not as well covered.

- *Invasive Species* – To our knowledge, research and monitoring of invasive species is negligible at this time. There is a distinct need to revive the Portland State Univ. work (P1).

- *River Discharge and Plume Conditions* – These indicators are well covered by existing projects (P9 and P11).

Table 10. Coverage [C] by Projects (see Table 8) of the estuary RME Performance Indicators and Monitored Variables (see Table 4). The symbols represent coverage as follows: ● complete, ongoing; ○ complete coverage, but data still being analyzed; ⊙ incomplete, project(s) exists but not started or few or no data yet; ◯ negligible or no activities; ?? unknown. Shading means the project pertains to the attribute.

Indicator	Attribute	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Habitat Condition	Veg. cover	⊙																													
	Geology/soils	◯																													
	Floodplain top.	⊙																													
	Bathymetry	○																													
	Area affected	⊙																													
Habitat Connecti-vity	Passage barriers	⊙																													
	Total edge tidal channels	◯																													
Fauna	Nearshore fauna	⊙																													
	Avifauna	??																													
Salmon life history diversity	Species composition	○																													
	Age-structure	○																													
	ESU	○																													
	Temporal distribution	○																													
Spatial distribution	Spatial distribution	○																													
	Migration pathways	⊙																													
Juvenile salmon	Growth rate	○																													
	Residence time	⊙																													

Indicator	Attribute	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
growth	Prey availability	⊙																													
	Foraging success	⊙																													
Survival	Survival rate	⊙																													
	Predation index	○																													
Water quality	Temperature	◯																													
	Salinity	◯																													
	Dissolved oxygen	◯																													
	pH	◯																													
	Turbidity	⊙																													
	Nutrients	⊙																													
	Toxics	⊙																													
Physical condition	Substrate type	⊙																													
	Accretion/erosion rates	⊙																													
	Reduction/oxygenation potential	⊙																													
	Ground water level	⊙																													
	Large woody debris	○																													
	Sediment contamination	⊙																													
	Water velocity	◯																													
	Inundation Regime	◯																													

Indicator	Attribute	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Invasive species	Species list	◯																													
	Spatial distribution	◯																													
	Abundance	◯																													
River discharge	Hydrograph	●																													
Plume conditions	Juvenile salmon usage	○																													
	Anchovy/herring index	○																													
	Zooplankton prey base	○																													
	Sea surface temperature	●																													
	Northern oscillation index	●																													
	Upwelling	●																													

● complete, ongoing; ○ complete, but data still being analyzed; ⊙ incomplete; ◯ negligible, ?? unknown

Table 11. Coverage [C] by Projects (see Table 9) of the estuary RME Uncertainties (see Section 2.2.3). The symbols represent coverage as follows: ● complete, ongoing; ○ complete coverage, but data still in pipeline; ⊙ incomplete, project exists but not started or no data yet; ◯ negligible or no activities; ?? unknown. Shading means the project pertains to the uncertainty.

No.	Uncertainty	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
UR. 1a	Effects on habitat/survival	⊙																													
UR 1b	Limiting attributes	⊙																													
UR 2a	Hydrograph effects	⊙																													
UR 2b	Food web drivers	⊙																													
UR 3a	Tidal freshwater habitat usage	◯																													
UR 3b	Habitat usage by life history type	⊙																													
UR 3c	Habitat accessibility	⊙																													
UR 4	Cumulative restoration effects	⊙																													

5.2 Program-Level Assessment

The individual projects described in the preceding subsection need to be integrated into a formal estuary RME program. Although various entities involved in estuary RME agree with this need, the program does not yet exist. This document is meant to provide a plan and design for a successful program that is based on an adaptive management process (Figure 12).

Adaptive management is a structured learning process for testing hypotheses through management experiments in natural systems, collecting and interpreting new information, and making changes based on monitoring information to improve the management of ecosystems. Adaptive management is being implemented on large programs ranging from the Mississippi River Delta to the Colorado River to the Northwest Forest Plan (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2001; Ringold et al. 2003; Stevens and Gold 2003). In this case, the overarching hypothesis for the program is derived from the NOAA Fisheries/Action Agencies goal for the Columbia River estuary: Conserving and restoring estuary habitats improves the viability of endangered and threatened salmonid populations.

In the estuary RME adaptive management process (Figure 12), the estuary/ocean subgroup in the EP-RME plan herein has carried out the first two steps, program goals/objectives and design/plan. For the remaining four steps (coordination and implementation, data management and analysis, information reporting, and program evaluation), we describe and assess their current status in this section of the EP-RME plan. These elements are consistent with recommendations in the Estuary Partnership's Monitoring Strategy (LCREP 1998) and RPA actions for the estuary in the FCRPS Biological Opinion (NMFS 2000).

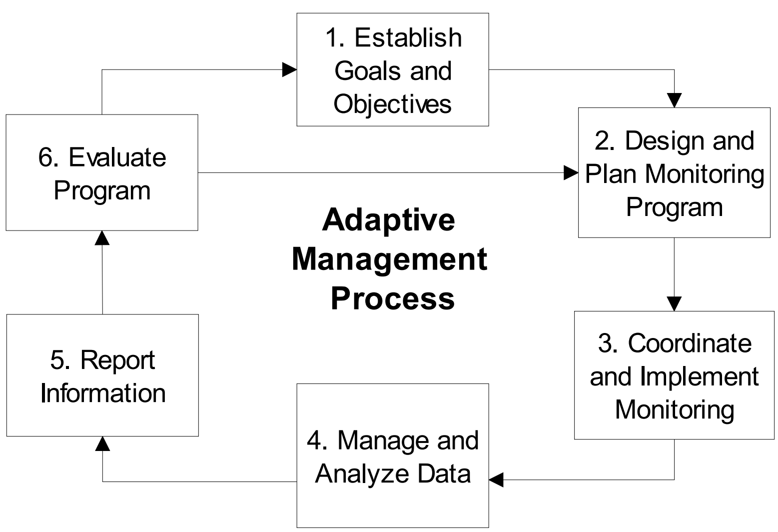

Figure 12. Schematic of an Adaptive Management Process for the Estuary RME Program.

5.2.1 Coordination and Implementation

Coordination is critical to develop an efficient and useful monitoring effort (LCREP 1998). This activity is an essential component of the adaptive management process (Thom and Wellman 1996). Coordination involves implementing this estuary RME plan and evaluating whether the estuary RME objectives are being met. At this time, coordination is provided de facto by the funding and implementing organizations through their respective project review and coordination processes. The estuary RME Program, however, will require a dedicated and funded monitoring oversight entity, yet to be determined. At a minimum, the Policy Group for basin-wide RME and the ISRP/ISAB will scrutinize the estuary RME plan and its implementation. We recommend that the Action Agencies and affected parties form a joint Estuary RME Coordinating Committee (ERMECC) to continue to develop and coordinate the estuary RME effort. It would be the ERMECC's responsibility to integrate the results of individual project monitoring and see that the data is analyzed from an estuary-wide perspective. Establishment of a coordinating body is necessary to reduce the risk that adaptive management could occur only in response to perceived problems. Instead, it is important that adaptive management be built into routine, cyclic program management. Strong, central coordination is essential to the successful implementation and evaluation of this program.

Coordination of the estuary RME program with other regional monitoring efforts is also essential to a successful program. For example, it will be appropriate to coordinate with the six regional monitoring programs and processes identified in Figure 5: 1) the Estuary Partnership's *Aquatic Ecosystem Monitoring Strategy*, 2) the Oregon Watershed Enhancement Board's *Monitoring Strategy for the Oregon Plan for Salmon and Watersheds*, 3) The Washington Salmon Recovery Funding Board (SRFB) *Monitoring and Evaluation Strategy and Sampling Protocols*, 4) the Pacific Northwest Aquatic Monitoring Partnership (PNAMP2004) effort to coordinate monitoring in the region, 5) the Northwest Power and Conservation Council Subbasin Plan, and 6) the Corps of Engineers General Investigations Study. Of special note, PNAMP is working to achieve substantive coordination among state, federal, and tribal watershed and salmon monitoring programs in the Pacific Northwest (PNAMP 2004). Its guiding principles involve resource policy and management, efficiency and effectiveness, science basis, and information sharing. It will be focused on areas where regional programs overlap, which is primarily in tributary habitats, however, its scope does include Puget Sound and Pacific Northwest coastal estuaries. The estuary/ocean RME subgroup is tracking this basin-wide effort and recommends that the estuary RME program be coordinated with PNAMP and any regional coordination advances.

Coordination of RME efforts also involves using identical or comparable sampling protocols to measure the same indicators and attributes, wherever possible, and sharing data for basin-wide and estuary-wide analyses for the purposes of evaluating the effects of restoration and making adaptive management recommendations. With respect to the first topic, this estuary RME plan is the first to recommend a sampling design and specific sampling protocols focused on monitoring the Columbia River estuary for salmonid recovery resulting from habitat restoration actions. With the exception of the Estuary Partnership's *Monitoring Strategy*, the above-mentioned efforts have largely focused on tributary habitats. In an effort to support regional coordination and efficiency, the Columbia River Tributary RME plan utilizes protocol recommendations from Johnson et al. (2001). In recommendations for estuarine monitoring, Johnson et al. (2001) rely heavily on the *Estuarine Habitat Assessment Protocol* (Simenstad et al. 1991) developed for the Puget Sound. This estuary RME plan also relies on the Simenstad et al. (1991) protocol, because it is the most highly developed estuarine monitoring protocol available for the Pacific Northwest; however, some methods have advanced since the publication of this protocol in 1991, and the Columbia River estuary and Puget Sound nearshore ecological systems are distinctly different.

A COE research project (P19) was initiated in 2004 to produce a methods manual tailored to monitoring habitat restoration projects in the estuary. It should be consistent with the *Estuarine Habitat Assessment Protocol* to the extent appropriate for monitoring in this region. It should be reviewed and considered for adoption for all estuary restoration monitoring. Developments in EMAP protocols for estuarine monitoring on the West Coast should also be tracked and adopted as appropriate for status monitoring. The Washington SRFB's *Field Sampling Protocols for Effectiveness Monitoring of Habitat Restoration and Acquisition Projects* rely to a large extent on the EPA's EMAP program, and companion estuarine monitoring protocols may soon be developed.

With respect to the second coordination topic, the SRFB's *Monitoring and Evaluation Strategy* provides a "data pyramid" that shows how data progress from project databases to program databases to indicators reportable to policy makers, and finally to decision-making for program funding. This estuary RME plan recommends that a process such as this be entered into by all agencies and organizations collecting relevant data on the estuary, to produce data and reports available to all stakeholders. Furthermore, according to the *Monitoring Strategy for the Oregon Plan for Salmon and Watersheds* ("OWEB Monitoring Strategy"), a structure for monitoring programs throughout the Pacific Northwest is being produced through collaborative efforts of the NMFS Northwest Fisheries Science Center, the Washington State Salmon Recovery Office, and the Oregon Plan Monitoring Team (OWEB 2004). The structure has three tiers, representing spatial scales ranging from "statewide, regional, basin" (tier 1), to "sub-basin, ESU, Oregon Plan report area" (tier 2), to "HUC 5-6 watersheds, stream reaches, and reach and site activity" (tier 3).

The objective of the OWEB Monitoring Strategy is to "scientifically evaluate the effectiveness of the Oregon Plan in restoring salmon populations and improving watershed conditions to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits." OWEB proposes that their monitoring strategy be refined through activities including the assessment and gap analysis of other monitoring programs. In terms of spatial scale, our review suggests that the estuary RME plan is congruent with OWEB Monitoring Strategy tier 2 monitoring at the sub-basin and ESU scales, and tier 3 monitoring at the stream reach and site activity scales. While the action effectiveness objectives of the estuary RME plan concern evaluating Biological Opinion-related habitat restoration actions, not Oregon Plan actions, the intent is likewise to "scientifically evaluate the effectiveness…in restoring salmon populations and improving watershed [habitat] conditions." The OWEB Monitoring Strategy does call for incorporating the assessment of estuary and near ocean environments in the monitoring design; therefore, if the estuary is included in Oregon Plan assessment, there will be direct overlap with estuary RME with respect to study area. Provided that indicators and protocols selected are comparable, this could provide for efficiencies in one or both programs.

5.2.2 Data Management and Analysis

Besides monitoring coordination, a successful estuary RME program must include data management and analysis to produce information useful to decision makers and the public. This function is currently performed to varying degrees at the project level, but not at the program level. Although project level analysis is critical, the program will require its own comprehensive synthesis of data. No single entity is presently responsible for data management and dissemination. The estuary RME projects should feed data to a central, program-level data location and provide biennial reports as a key mechanism for data dissemination. Several entities have proposed comprehensive database systems for the estuary, but to date none have been funded. The data management approach proposed in the basin-wide RME plan (RME Plan 2003) would be appropriate for the estuary. The estuary RME program supports the basin-wide data management plan for RME (RME Plan 2003) and the PNAMP data management module (PNAMP 2004) which include efforts to 1) develop a RME information system architecture, 2) use existing data centers where appropriate, 3) develop a cost-sharing approach, 4) promote free exchange of information, and 5) emphasize that metadata (e.g., purpose, method, proper uses, record of raw data) are essential.

The specific requirements for estuary RME data and their management remain to be developed. Such requirements should directly address the performance indicators and monitored attributes (Table 4) and include specifications for data attributes, collection protocols, methods, standards, users, reporting requirements, etc. Some of these requirements are incorporated in the methods table (Table 8), but others need to be developed. For example, to form a data management system, we need to 1) decide what data will be collected, by whom, how often, where, and when; 2) define data standards; 3) define metadata needs; 4) establish access methods and policies; and 5) establish how the data will be used. A long-term funding commitment would be necessary for this effort. Much of this is beyond the scope of the estuary RME plan; however, we recommend attention be given to this critical issue.

Data produced by existing monitoring programs, primarily operated by state and federal agencies, should be integrated into estuary RME analyses to avoid duplication of efforts. This is consistent with recommendations for coordination in the Estuary Partnership's Strategy. The Estuary Partnership (LCREP 1998) recommends that a coordinated framework be built on existing monitoring programs including ambient water quality monitoring by the Oregon Department of Environmental Quality and Washington Department of Ecology, the USGS National Stream Quality Accounting Network, COE temperature and total dissolved gas sampling, and other state, federal, tribal, municipal and university programs. Also consistent with the Estuary Partnership's recommendations for data management (1998), this estuary RME plan also recommends the establishment of a central, web-accessible repository for estuary data, and a homepage with links to a networked system of databases. Specifically, this system should be linked to basin-wide RME data to facilitate basin-wide evaluations. The data management and analysis effort will feed directly into information reporting.

5.2.3 Information Reporting

The information from status monitoring, both estuary-wide and restoration and reference site monitoring, and action effectiveness research should be summarized in a biennial *State of the Estuary* report. The objective of this report would be to provide the public, action agencies, and stakeholders with information on trends in the estuary ecosystem. Not every indicator will be monitored annually or biennially, therefore, it is also recommended that in every sixth year the *State of the Estuary* report summarize major one-time or non-annual monitoring efforts, such as bathymetry, floodplain topography, vegetation mapping, or geological coring. Whether sponsored by the action agencies or by other entities, all major monitoring efforts within the estuary should be summarized to the extent that data is available. Annual reporting at the project level will be a key mechanism for data dissemination. In general, the entities responsible for estuary RME data and information reporting will have to understand the needs of the decision-makers responsible for program evaluation.

5.2.4 Program Evaluation

In an adaptive management process, program evaluation includes adjusting program objectives and methodologies based on new information. As such, this will bring the estuary RME program full-circle from the initial establishment of goals and objectives, to coordination and implementation, data management and analysis, information reporting, and program evaluation (Figure 12). As Noon (2003) stated, monitoring programs "*…must be constantly revisited and revised as scientific knowledge is acquired….*" Procedures should be established that link decision-makers to estuary RME monitoring overseers and data managers in a manner consistent with basin-wide adaptive management described in the RME plan.

Building on the biennial reporting cycle described in Section 5.2.2, the Action Agencies and ERMECC should review the reports relative to the central hypothesis of the program stated above. The collective monitoring data should also be reviewed against more specific hypotheses developed based on the objectives of the status monitoring, action effectiveness research, and uncertainties research components of the program (Table 3). The ERMECC would be tasked to "determine if the projects collectively meet program goals," as described in AER Objective 1b (Table 3). The ERMECC would make adjustments to the program based on successes and failures. The ERMECC would have several areas of oversight with the potential for adjustment through management actions: 1) the management of existing restoration project trajectories, 2) the characteristics and funding of new restoration projects, 3) the characteristics and funding of new uncertainties research, 4) the goals and objectives of the Action Agencies' estuary program and any other aspect of this estuary RME plan, which could be modified under the direction of the ERMECC.

The program evaluation for restoration monitoring at sites throughout the estuary also presents the opportunity to use information gained to improve the conceptual model of estuary structure and function, and in some cases to verify numerical models of components of the system. The improved models can then be used through the adaptive management process to help better design future restoration projects. An important responsibility of the ERMECC should be to ensure that the conceptual model of the estuary is continually improved through evaluation of data collected through the status monitoring, action effectiveness research, and uncertainties research components of the program.

Contract stipulations by the funding agencies can be effective to ensure project specific information is available during program evaluation. Such information could be the basis of annual analyses during program evaluation to determine whether program is meeting expectations. Contracts for restoration and monitoring projects should require that monitoring data be reported relative to project-specific performance standards. Furthermore, contracts for restoration projects should state that funding is contingent on review of annual reports and implementation of on-the-ground adjustments at project sites as necessary. This will strengthen the program evaluation step in the adaptive management process for estuary RME.

5.3 Recommendations

The action plan for estuary RME is comprised of project- and program-level recommendations based on the coverage assessments above. The action plan also includes a detailed recommendation for phased development and implementation.

5.3.1 Project-Level Recommendations

Project-level recommendations are provided in Table 12. In general, all ongoing projects and new starts identified in Table 8 should be continued. These projects help meet estuary RME goals and objectives by providing data for status monitoring, action effectiveness research, and uncertainties research, as indicated in Tables 10 and 11. For the performance indicators not currently being addressed by a project (see the project column in Table 12), the estuary/ocean subgroup recommends modifications to existing projects or formation of new projects as follows:

- *Habitat Connectivity Measurement Tool* – Develop a habitat connectivity measurement tool to address the tidal channel attribute to assess trends in restoration efforts design to reconnect shallow water habitats to the estuary, e.g., dike breach and tidegate restoration actions.

- *Fauna Study* – Determine the importance of the fauna performance indicator for estuary RME. After this determination, a new project may need to be developed or an existing project modified to cover this indicator.

- *Pilot Monitoring Study* – Modify and, if necessary, expand existing status monitoring projects (e.g., P12 and P23) to complement the pilot monitoring efforts in the John Day (Oregon), Salmon (Idaho), and Wenatchee (Washington) river basins. This would extend the basin-wide RME concept of a regionally coordinated, programmatic approach to the estuary. This study should specifically address the lack of monitoring in the tidal freshwater reach of the estuary study area.

- *Invasive Species* – Revive research and monitoring of invasive species in the estuary.

Table 12. Recommendations by Indicator (Table 4) Addressing Needs for Status Monitoring, Action Effectiveness Research, and Uncertainties Research.

Indicator	Category	Recommendation	Projects	Expected Outcome
Habitat conditions	SM	Expand habitat mapping with hyperspectral and/or digital aerial imagery, inventory dikes, tidegates, culverts; analyze vibracores	P22, P4	Additional detailed vegetation cover and feature maps
Habitat connectivity	SM, AER	Develop connectivity measurement tool to perform connectivity analysis, produce connectivity "map", inventory passage barriers	**None**	Documentation of improvement in habitat connectivity from restoration actions
Fauna	SM, AER	Develop monitoring effort for fauna	P12, P21	Improved ecosystem-based monitoring
Life history diversity	SM, AER, UR	Establish causal mechanism relating habitat structure and function to habitat restoration strategies.	P12, P23, P24, P25	Help resolve U3
		Develop habitat monitoring protocols and implement specially designed pilot studies, in coordination with ongoing monitoring.	P23 P26 P7	Improved habitat monitoring Help resolve U3
		Monitor juvenile salmonids in the tidal freshwater reach.	P12	Improved extent of monitoring in all estuary habitat types
Spatial distribution	SM, AER, UR	Coordinate monitoring efforts, assess the comprehensiveness of the sampling, and revise as nec. Determine habitats, pathways, residence times for juvenile salmon, especially fry, fingerlings, and subyearlings.	P12, P4, P23, P24, P25, P16, P14	Comprehensive monitoring program of fish distribution
Growth	SM, AER, UR	Establish causal mechanism relating habitat structure and function to juvenile growth and rest. strategies.	P12, P23, P24, P25	Help resolve U3
Survival	SM, AER, UR	Continue development of new tagging and detection methods.	P3, P16	Fundamental data on survival through estuary
	SM	For predation, assess relative success of tern relocation, pikeminnow removal; assess marine mammal impacts	Projects in other programs	Evaluation of predator impacts
Water quality	SM	Coordinate the many projects	P2, P7, P23	Trends in water quality
Physical condition	SM, AER	Collect more subsurface data to aid restoration	P23, P26	Better information

Indicator	Category	Recommendation	Projects	Expected Outcome
Invasive species	SM, AER	Revive this effort	**None** (P1 is inactive)	Evaluation and treatment recomm. and effects on salmonids
River discharge	SM	Continue routine measurements	P9	River discharge data
Plume conditions	SM, UR	Develop and prioritize parameters to characterize plume conditions	P11	Routine, annual characterization of plume conditions

5.3.2 Program-Level Recommendations

This estuary RME plan provides a strategic framework for the Action Agencies to directly implement RPA Action 161 (Estuary Monitoring Program). The fundamental program-level recommendation is to establish and support an estuary RME Program, because currently no recognized program exists. We have the following recommendations for the estuary RME Program and its phased development and implementation.

Coordination and Implementation

- Establish an estuary RME coordination committee that includes the Action Agencies, the Estuary Partnership, and other entities charged with monitoring oversight.
- Develop a statement of roles and responsibilities of each agency and entity working on RME in the estuary (Table 13). In addition, consider establishing a memorandum of understanding between the key parties regarding the roles and responsibilities, governance structure, and organization of the estuary RME program.
- Use contractual mechanisms when possible to require that 1) performance criteria be developed in the planning phase of each habitat restoration project; 2) post-restoration monitoring of performance indicators be conducted, and 3) resulting data be compiled and reported to standards appropriate for estuary-wide analyses.
- Coordinate with other basin-wide RME groups, other federal monitoring programs, interested parties, and state and local monitoring efforts. Integrate estuary RME with the Pacific Northwest Aquatic Monitoring Partnership by attending PNAMP meetings to describe and report estuary RME activities and develop an estuary module for PNAMP.
- Attempt to establish a stable funding base to support a comprehensive estuary RME program.

Table 13. Roles and Responsibilities Matrix for the Estuary RME Program. (To be completed by the affected parties.)

Sector	Agency	Coordination and Implementation	Data Mngt and Analysis	Information Reporting	Program Evaluation
Action Agencies	BPA				
	COE				
Federal Agencies	NOAA Fisheries				
	PNNL				
	USEPA				
	USFWS				
	USGS				
State and Tribal Agencies	CRITFC				
	ODEQ				
	ODFW				
	WDOE				
	WDFW				
Non-Governmental Organizations	Columbia Land Trust				
	CREST				
	Estuary Partnership				
	LCFRB				
	Nature Conservancy				
	NPCC				
	OWEB				
	Sea Resources				
	Watershed Councils				

TO BE DETERMINED

Data Management and Analysis

- Develop estuary RME data specifications to support a coordinated data management system.
- Adopt standardized methods for status monitoring to allow comparisons through time for given monitored attributes.
- Adopt standardized methods for action effectiveness research to allow comparisons across projects and to address the cumulative effects of projects.
- Build a database of results from status monitoring and action effectiveness research.
- Establish a central, web-accessible repository for estuary data, and a homepage with links to a networked system of databases. Specifically, this system should be linked to basin-wide RME data to facilitate basin-wide evaluations.

Information Reporting

- Convene annual estuary RME workshops to present new data, evaluate the conduct of the estuary RME program, exchange information, and provide input to the estuary RME coordinating committee.
- Write biennial estuary RME summary reports and adaptive management recommendations at the program level for submittal to the Action Agencies, estuary restoration project leaders, and other related entities (e.g., subbasin planners, PNAMP).
- Establish procedures that link decision makers and data managers to the estuary RME coordinating committee in a manner consistent with basin-wide adaptive management.

Program Evaluation

- Review protocols for status monitoring and action effectiveness research every 5 years as new science becomes available.
- Apply results from ongoing research to update and consolidate the conceptual ecosystem model for the estuary.
- Include peer-review elements in the estuary RME Program.
- Revisit program goals, objectives, and design/plan.

5.3.3 Phased Development and Implementation of NOAA Fisheries/Action Agencies' Columbia River Estuary Salmon RME Program

A phased approach (Table 14) is recommended for development and implementation of the NOAA Fisheries/Action Agencies' estuary RME program. The phases include program initiation and infrastructure, science basis, implementation, and information transfer. The implementation of projects and development of the science basis for project prioritization and monitoring are already underway, and the initiation of the program and establishment of the infrastructure to ensure that these efforts are coordinated, focused and efficient is therefore a top priority. Currently, for example, restoration projects in the estuary are funded by BPA, the COE, the NOAA Restoration Center, EPA, Ducks Unlimited and others, with differing project-specific requirements for implementation and monitoring. The following recommendations for actions in each phase are based on the project- and program level recommendations above (see subsections 5.3.1 and 5.3.2 for details).

Phase 1 – Program Initiation and Infrastructure – FY05 and FY06

- Formalize the estuary RME program.
- Develop data management/analysis, information reporting, and program evaluation systems for estuary RME (Section 5.3.2).

Phase 2 – Program Science Basis – FY04 and beyond

- Consolidate the conceptual models of the "estuary" ecosystems (tidal freshwater and estuary/plume) and apply the new model to revise the estuary RME plan.

- Fulfill the project level recommendations for uncertainties research and coverage of the performance indicators (Section 5.3.1).

Phase 3 – Program Implementation – FY04 and beyond

- Execute the project and program recommendations (Sections 5.3.1 and 5.3.2, respectively).
- Periodically review the ongoing RME activities in the estuary to ensure that gaps in coverage are addressed by projects, coordinate with other RME efforts such as PNAMP and with entities implementing the estuary subbasin plan, and revise this RME plan if necessary due to programmatic changes or new scientific data.

Phase 4 – Program Information Transfer – FY05 and beyond

- Implement the information reporting recommendations (Section 5.3.2).

Table 14. Timeline for Development and Implementation of the Estuary Program.

Activity	FY04	FY05	FY06	FY07	FY08	FY09
Finalize estuary RME plan	*					
Phase 1 Program Initiation & Infrastructure		*	*			
Phase 2 Science Basis	*	*	*	*	*	*
Phase 3 Implementation	*	*	*	*	*	*
Phase 4 Information Transfer		*	*	*	*	*

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Washington Salmon Recovery Funding Board (WSRFB). 2003b. Sampling procedures, designs, and expected costs -- Fish passage projects effectiveness monitoring (culverts, bridges, fishways, logjams, dam removal). Draft report, Olympia, Washington, May 23, 2993. MP-1.

Washington Salmon Recovery Funding Board (WSRFB). 2003c. Sampling procedures, designs, and projected costs -- In-stream habitat projects effectiveness monitoring (channel connectivity, off channel habitat, wetland restoration). Draft report, Olympia, Washington, May 23, 2003. MP-6.

Washington Salmon Recovery Funding Board (WSRFB). 2003d. Sampling Protocols -- Effectiveness monitoring habitat restoration projects requirements. Draft report, Olympia, Washington, 2003 May 23. MP-X.

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Appendix A

Annotated Bibliography of Monitoring Plans, Strategies, Protocols, and Guidance Documents Relevant to the Estuary/Plume Research, Monitoring, and Evaluation Plan

Bilby, R. E. and nine co-authors. 2003. A review of strategies for recovering tributary habitat. Northwest Power and Conservation Council, Pub. No. ISAB 2003-2, Portland, OR, 2003 Mar 31.

Purpose: Answer the question, "What concepts and strategies should be incorporated in habitat recovery actions to improve their chances for success?"

Synopsis: Whether tributary habitat improvements have achieved or are likely to achieve the goal of recovering conditions favorable to production of wild populations of salmon in the Columbia basin is addressed in this document. The work emphasizes the importance of clearly stated and well-conceived biological objectives. It discusses implementation strategies, as well as implementation incentives, and provides a scientific foundation for habitat recovery. Monitoring and evaluation is a key element of the guidance.

Application to estuary RME: Many of the principles outlined here for tributary habitats will be applicable to lower river and estuary habitats. This paper will help inform the estuary RME plan.

Bisbal, G. A. 2001. Conceptual design of monitoring and evaluation plans for fish and wildlife in the Columbia River ecosystem. Environmental Management 28: 433-453.

Purpose: Provide a generic template to design monitoring and evaluation plans for fish and wildlife in the Columbia River ecosystem.

Synopsis: This paper addresses the issue of monitoring and evaluation for management programs intended to help rebuild fish and wildlife populations in the Columbia basin. Bisbal proposes a sequence of seven steps: 1) management framework, 2) monitoring objectives, 3) monitoring needs, 4) data and information archive, 5) procurement, 6) data and information management, and 7) evaluation. The process appears to be analogous to adaptive management.

Application to estuary RME: The estuary RME plan will be consistent with the useful guidance provided in this paper.

Bisson, P. and nine co-authors. 2000. The Columbia River Estuary and the Columbia River Basin Fish and Wildlife Program. Independent Scientific Advisory Board of the Northwest Power and Conservation Council. Portland, Oregon. ISAB 2000-5.

Purpose: Provide an assessment of the relevance of the Columbia River estuary to the NPCC's Fish and Wildlife Program

Synopsis: This report by the ISAB was conducted at the NPCC"s request to assess the impact of estuarine conditions on the Council's mission in its Fish and Wildlife Program. The ISAB concluded that the NPCC "…should recognize the potential value of the estuary to the Fish and Wildlife Program and the immediate need to improve our understanding of its ecological processes."

Application to estuary RME: The estuary RME plan will draw on the uncertainties identified in this report.

Brodeur, R.D., G.W. Boehlert, E. Casillas, M.B. Eldridge, J.H. Helle, W.T. Peterson, W.R. Heard, S. Lindley, and M.H. Schiewe. 2000. A coordinated research plan for estuarine and ocean research on Pacific salmon. Fisheries 25(6):7-16.

Purpose: Propose a plan for research on Pacific salmon in estuarine and oceanic environments.

Synopsis: This paper provides a justification for estuarine and oceanic research on salmon. The approach is multidisciplinary including research on physical conditions as wells as various trophic levels supporting salmon growth. Predator prey interactions are especially important.

Application to Estuary RME: The estuary RME plan will also draw on the uncertainties identified in this paper.

Busch, D. E. and J. C. Trexler. 2003. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Washington, DC: Island Press.

Purpose: Provide information presented at a symposium entitled "Interdisciplinary Approaches to Ecological Monitoring of Major Ecosystem Restoration Initiatives" held at the 1999 annual meeting of the Ecological Society of America in Spokane, Washington.

Synopsis: The book has 15 chapters organized in 5 sections: 1) Introduction, 2) Principles of Ecosystem Monitoring Design, 3) Information Management and Modeling for Monitoring programs, 4) Monitoring Habitats, Populations, and Communities, and 5) Summary and Synthesis. The second section has especially pertinent guidance on monitoring program design.

Application to estuary RME: This book will provide technical knowledge and a scientific basis to aid development of new monitoring programs at the ecosystem level. As such, it has much useful information and guidance for estuary RME.

CALFED. 1999. Comprehensive Monitoring, Assessment, and Research Program. http://calwater.ca.gov/programs/science/cmarp/old%20files/executive_summary.html/.

Purpose: Describe CALFED's Comprehensive Monitoring, Assessment, and Research Program.

Synopsis: The proposed program addresses eight CALFED program elements and actions to be implemented over 30 years. These include long-term levee protection, water quality, ecosystem restoration, water use efficiency, water transfers, watershed, delta conveyance, and storage.

Application to estuary RME: This is an example of a large, multi-disciplinary program. Its scope is well beyond that of estuary RME.

CALFED. 2000. Comprehensive monitoring, assessment, and research program for chinook salmon and steelhead in the Central Valley rivers. Draft report obtained from a website http://calfed.ca.gov/programs/cmarp/ (no longer in service).

Purpose: Describe the monitoring and research needs to determine whether the habitat for chinook salmon and steelhead in Central Valley rivers will be restored by CALFED's and other programs.

Synopsis: The CALFED Ecosystem Restoration Program's goal is to "improve and increase aquatic and terrestrial habitat and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species." The objectives are to: (1) document whether CALFED programs results in an increase in abundance of juvenile and adult salmon in the San Joaquin and eastside rivers; and (2) monitor indicators for salmon health, habitat quality, and ecosystem processes to provide a basis for adaptive management. The report includes a conceptual model that shows hypotheses and assumptions about how the ecosystem (tributaries to Bay-Delta) operates relative to salmon life history. Recommendations for status monitoring of adult and juvenile salmon and steelhead and habitat condition are made. This status monitoring work integrates existing monitoring and new monitoring efforts. One chapter is devoted to describing the coverage provided by existing monitoring programs. Focused research is recommended for the most uncertain hypotheses presented in the conceptual model. The indicators are for adult and juvenile salmon and steelhead characteristics. Habitat-based indicators are not included, because so many environmental factors can confound them. The five indicators are: (1) trends in adult escapement and harvest; (2) trends in population crashes; (3) trends in egg to fry survival of wild salmon and steelhead; (4) trends in abundance of wild juvenile salmon and steelhead; and (5) trends in survival of wild juvenile salmon and steelhead.

Application to estuary RME: This monitoring plan is one piece of a large effort to recover salmon and steelhead stocks in California. Application of this work to estuary RME, however, is unclear other than they advocate status monitoring for trends and use a conceptual ecosystem model as a framework.

Crawford, B. L. Singleton, and P. Dickason. 2003. Survey of environmental monitoring programs and associated databases within Washington State. Washington Salmon Recovery Funding Board, Monitoring Oversight Committee. Olympia, WA, 2003 Oct.

Purpose: Inventory existing local, state, and federal monitoring programs and associated databases relevant to salmon recovery efforts in Washington State.

Synopsis: The report provides an analysis of survey results. A total of 145 different monitoring programs or databases were identified. Survey respondents noted whether their databases were web-accessible and/or GIS-based. The appendices are extensive as they briefly describe each database. This report shows the large magnitude of the database issue.

Application to estuary RME: Some of the monitoring programs/databases identified in this report will be applicable to the estuary, including smolt monitoring by PSMFC at Bonneville Dam; EMAP by WDE; salmon habitat inventory and assessment program and salmonid stock inventory by WDFW; dredged material management program by WDNR; monitoring of aquatic and wetland mitigation efforts by the USCOE; Columbia River information system by USFWS; stream gauging program by USGS; culvert inventories, watershed characterization, and stream habitat surveys by Cowlitz and Wahkiakum Conservation Districts; and habitat project monitoring by the LCFRB.

Hillman, T.W. 2003. Monitoring strategy for the upper Columbia Basin. Draft report prepared for the Upper Columbia Regional Technical Team of the Upper Columbia Salmon Recovery Board, Boise, ID, 2003 Nov 1.

Purpose: Develop a custom monitoring plan for the upper Columbia Basin for the State of Washington's Upper Columbia Salmon Recovery Board.

Synopsis: This document draws from existing monitoring strategies (ISAB, Action Agency RME, and Washington SFRB) to address three major questions: 1) What are the current habitat conditions and abundance, distribution, life-stage survival, and age-composition of fish in the UCB (status monitoring)? 2) How do these factors change over time (trend monitoring)? 3) What effects do tributary habitat actions have on fish populations and habitat conditions (effectiveness monitoring)? The document identifies valid statistical designs for status/trends and effectiveness monitoring, discusses issues associated with sampling design, examines how sampling should occur at different spatial scales, addresses habitat classification, and identifies biological and physical/environmental indicators (attributes) and associated measurement methods (protocols). The implementation chapter provides a useful checklist of elements essential to have a valid monitoring plan.

Application to estuary RME: estuary RME will use a similar framework of status/trend and action effectiveness monitoring. Hillman (2003), however, did not breakout uncertainties research. His treatment of statistical and sampling considerations provides an excellent primer that the estuary RME Plan will include at a minimum by reference. Hillman's (2003) implementation checklist will help direct the estuary RME Plan.

Hillman, T.W. and A.E. Giorgi. 2002. Monitoring protocols: effectiveness monitoring of physical/environmental indicators in tributary habitats. Draft report to the BPA, Portland, OR, 2002 July 25.

Purpose: As part of the FCRPS RME effort, identify protocols for physical/environmental variables that will be used to assess the effectiveness of offsite mitigation actions in Columbia Basin tributaries for the FCRPS Biological Opinion.

Synopsis: Material in this document was incorporated into the FCRPS RME Plan. This material addresses action effectiveness research in the tributaries. Although it briefly describes status, trend, validation, or compliance monitoring, the document does not address these types of monitoring. It also does not address biological monitoring. The report does provide recommendations for pathways-general indicators-specific indicators, e.g., water quality-temperature-maximum daily mean temperature. Methods and performance standards are also presented. An overview of sampling and statistical design is provided with references to pertinent scientific literature. The report closes with application checklists for problem statement and overarching issues, statistical design, sampling design, measurements, and results.

Application to estuary RME: The physical/environmental indicators and methods will be cross-checked with the estuary RME plan. The classification scheme proposed in the report will be applied to the estuary. Many of the performance standards presented by Hillman and Giorgi (2002) will be applicable to estuary RME.

Independent Scientific Review Panel. 2002. Review of March 27, 2002 draft guidelines for action effectiveness research proposals for FCRPS offsite mitigation habitat measures. Memo to Doug Marker, Fish and Wildlife Director, Northwest Power and Conservation Council, Portland, OR; 2002 Apr 19; ISRP 2002-5.

Purpose: Provide a critical review of the Action Agencies' draft guidelines for action effectiveness research proposals for FCRPS offsite mitigation habitat measures.

Synopsis: The draft proposal guidelines lack an overarching design, which is necessary to provide a framework for the individual action effectiveness research projects. The ISRP advocated the need for "top-down" design and coordination. The preferred design is before/after measurements at treatment and control sites. The success of habitat restoration will depend on the coordination and combined results from multiple sites.

Application to estuary RME: The estuary RME plan will include an overarching, top-down design for the estuary.

Johnson, D.H., N. Pittman, E. Wilder, J.A. Silver, R.W. Plotnikoff, B.C. Mason, K.K. Jones, P. Roger, T.A. O'Neil, and C. Barrett. 2001. Inventory and monitoring of salmon habitat in the Pacific Northwest -- Directory and synthesis of protocols for management/research and volunteers in Washington, Oregon, Idaho, Montana, and British Columbia. Washington Department of Fish and Wildlife, Olympia, WA, 2001 Oct 15.

Purpose: Provide a catalog of protocols for habitat and water quality commonly applied in Pacific Northwest fresh- and marine waters.

Synopsis: This report is an effort to standardize format and methods for salmonid habitat data. The objectives were to: (1) provide a synthesis of protocols applicable to the PNW; (2) recommend a subset for use by volunteers and another subset for researchers/managers; link the protocols with specific types of projects; (4) establish a QA/QC framework for the data; and (5) as possible, identify format and locations where data are sent. Organized protocols into categories: freshwater habitats, water quality, riparian/upland habitat, and estuarine/nearshore/marine habitat. The estuary/nearshore/marine protocols are listed on pp. 35-36. They reference Simenstad et al. (1991) for many of the estuary protocols. The protocols seem to be applicable to both status monitoring and action effectiveness research, although the authors definitely had the latter at their forefront.

Application to estuary RME: Along with Simenstad et al. (1991), we will examine protocols from Johnson et al. (2001) and include them in the EPO-RME plan when appropriate. Others working in the Columbia Basin have already utilized the work of Johnson et al. (2001), e.g., Hillman and Giorgi (2003) for the Upper Columbia River Fish Recovery Board.

Laustrup, M. and M. LeValley (eds.). 1998. Missouri River Environmental Assessment Program. Report by the Missouri River Natural Resources Committee. USGS-BRD Environmental and Contaminants Research Center, Columbia, Missouri.

Purpose: Describe the Missouri River Environmental Assessment Program, which is intended to provide the scientific understanding required for informed decision-making.

Synopsis: The goal of the program is to provide the scientific basis for balanced management of the Missouri River's main stem and floodplain fish and wildlife resources while avoiding or minimizing conflicts with other river uses. This document lays out a "portrait of the river" followed by a 14-page description of the environmental assessment program. The program includes (1) long-term monitoring to identify baseline conditions of river resources and trends in these conditions over time, and (2) focused investigations to predict cause-effect relationships between human actions and biological responses. Cost estimates are $12.5M per year. The program period is envisioned to be 15 years.

Application to estuary RME: The long-term monitoring and focused investigations in this plan are analogous to status monitoring and action effectiveness research, respectively, that will be in the estuary RME plan.

McConnaha, C. 2003. The ecosystem diagnostic and treatment model: application to the estuary. Personal communication, Mobrand Biometrics, Inc. Vashon Island, WA.

Purpose: Phone conversation with Chip McConnaha to discuss potential for applying EDT to the estuary.

Synopsis: EDT is a life cycle tool. As such, estuary survival is a parameter in the model. Some work as been done with EDT in Puget Sound, but nothing in the estuary in detail. EDT, however, is not "fully fleshed out" as a habitat model, although Mobrand Biometrics is moving in that direction. Regardless, the model is useful because the user creates hypotheses about how the system works, and then tests them through the relationships between environmental conditions and the response variables, salmon production and survival. EDT is intended to be a tool within a M&E plan in an ecosystem adaptive management context. That is, one would monitor the attributes (indicator variables) along with production and survival at various life stages. The model is continually evaluated and refined as new data become available. It is a type of conceptual ecosystem model.

Application to estuary RME: At this time, an EDT model of the estuary does not exist. Therefore there a direct application of EDT is not possible. The estuary RME plan, however, could mention that such an application is worth considering.

Lower Columbia River Estuary Program. 1998. Aquatic Ecosystem Monitoring Strategy for the Lower Columbia River and Information Management Strategy. Volume II of the Lower Columbia River Estuary Plan, Portland, Oregon.

Purpose: Provide a detailed strategy and process for comprehensive, cooperative, coordinated monitoring of the estuary.

Synopsis: This is the companion volume to Volume I, the Comprehensive Conservation and Management Plan. The goal of monitoring is to "…further our understanding of the river, track trends in the health of the river and its resources, pinpoint problem areas, assure compliance with water quality standards, and assess the effectiveness of management actions over time." The strategy builds on existing monitoring efforts and identifies necessary, new monitoring. The study area includes the tidally-influenced river reaches from the mouth of the Columbia River to Bonneville Dam and from the mouth of the Willamette River to Willamette Falls. The monitoring strategy has the following components: coordination and oversight; data management; pollutant and toxics monitoring; habitat monitoring; food web understanding; primary productivity measuring; and exotic species monitoring. The monitoring plan identifies six habitat attributes for monitoring: channel configuration, vegetative state, bottom composition, floodplain and estuarine function, disturbed areas, and bathymetry. The strategy calls for four phases of implementation and explains the phases for each monitoring component. Table 6 contains a summary of on-going data collection efforts in the estuary.

Application to estuary RME: The estuary RME plan will build on the LCREP Monitoring Strategy. It is especially important that the indicators be consistent. The estuary RME plan represents a next step to implement the Monitoring Strategy.

Monitoring Oversight Committee. 2002a. The Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery. Executive Report, Volume 1 of 3, 2002 Dec.

Purpose: Develop a comprehensive monitoring strategy (Volume 2), including the necessary technical information, and provide an action plan (Volume 3), including costs, priorities, and timelines, in order to fulfill SSB 5637, monitoring of watershed health and salmon recovery.

Synopsis: This document provides an overview of the Washington monitoring strategy and action plan. It lists the specific tasks for the entire monitoring effort. The topic matter includes: goals and objectives, key questions, guiding principles, monitoring activities, statistical designs, performance measures, standardized monitoring protocols, quality assurance and control, data management, adaptive management, organizational and oversight structures, funding sources, and implementation actions by state agencies. Other monitoring efforts include those by the State of Oregon, USFS/BLM, USEPA, Federal Columbia River Power System, Lower and Upper Columbia River Fish Recovery Boards, and the Northwest Power and Conservation Council. A survey of local needs was described. The strategy called for three types of monitoring: status and trends (what is the condition of the environment?), effectiveness (was the project implemented and was the desired outcome achieved?), and validation (was the outcome linked, cause-effect, with increased salmon survival or abundance?). Four main guiding principles emerged: use an adaptive management approach; make monitoring information accessible to all interested parties; evaluate and account for the state's investments; and determine trends in fish, water, and habitat conditions. Associated with these guiding principles, the authors offered recommendations for specific actions, such as establish a monitoring oversight committee, adopt standard monitoring protocols, establish a data portal, produce annual reports of spawner and smolt abundance, harvest data, and productivity estimates, create one or more intensively monitored watersheds, and track status and trends in habitat, fish populations, and water quality. The WA Monitoring Strategy is a comprehensive, state-wide effort encompassing many different salmon habitats.

Application to estuary RME: Many of the elements of the broad WA Monitoring Strategy will be applicable to the estuary RME Plan, although the latter will be focused on the estuary. For example, the distinction between status/trend and effectiveness monitoring will be the same. The estuary RME Plan will include a description of the WA Monitoring Strategy, one of the main monitoring efforts in the Pacific Northwest.

Monitoring Oversight Committee. 2002b. The Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery. Comprehensive Strategy, Volume 2 of 3, 2002 Dec.

Purpose: Provide the detailed comprehensive strategy for the State of Washington's watershed health and salmon recovery effort.

Synopsis: See action plan elements in the executive report (MOC 2002a).

Application to estuary RME: Beyond what was said under MOC (2002a), application to estuary RME appears unclear. The level of detail provided by the Monitoring Oversight Committee will be beyond the scope of estuary RME.

Monitoring Oversight Committee. 2002c. The Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery. Action Plan, Volume 3 of 3, 2002 Dec.

Purpose: Provide the detailed action plan for the State of Washington's watershed health and salmon recovery effort.

Synopsis: See action plan elements in the executive report (MOC 2002a).

Application to estuary RME: Beyond what was said under MOC (2002a), application to estuary RME appears unclear. The level of detail provided by the Monitoring Oversight Committee will be beyond the scope of estuary RME.

Neckles, H. and M. Dionne (eds.). 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. A report by the Global Programme of Action Coalition (GPAC) for the Gulf of Maine, workshop June 2-3, 1999, at the Wells National Estuarine Research Reserve, Wells, ME.

Purpose: Summarize the tidal marsh inventory model and monitoring protocols resulting from the two-day workshop of resource managers, scientists, and community members.

Synopsis: The GPAC vision is "A healthy marine and coastal environment in the Gulf of Maine where human use and biological diversity thrive in harmony." They recognized the need for a Gulf-wide inventory of potential tidal marsh restoration opportunities and regionally applicable standards to evaluate restoration projects. The Inventory Database should include a minimum of 14 descriptors and identifiers addressing name, location, ownership, disturbances/impacts, project type, etc. Core variable to include during restoration monitoring include hydroperiod, pore water salinity, baseline habitat maps, vegetation % cover, nekton and bird species and densities, among other core variables.

Application to estuary RME: The inventory database for restoration projects is a useful idea and will be included as a recommendation in the estuary RME Plan. We will compare the core monitoring variables identified by Neckles and Dionne (2000) with those in the estuary RME Plan.

NOAA Fisheries. 2003. Monitoring requirements under the Estuary Restoration Act. DRAFT edition. 2003 July 1.

Purpose: Provide draft protocols for monitoring habitat restoration projects in estuaries.

Synopsis: The following text of this important work is reprinted from the ***DRAFT*** document.

"The Estuary Restoration Act directs NOAA to develop standard monitoring protocols for estuary habitat restoration projects. These protocols outline basic guidelines for accurately measuring the success of restoration activities in meeting project goals, including minimum required parameters for each habitat type. Because restoration project monitoring is often the responsibility of local project partners, the costs of monitoring and likely access of these parties to specialized equipment and technical expertise were considered in developing a set of standards that are both fiscally responsible and biologically pertinent.

Below is a draft list of minimum standards for restoration monitoring plans. The Council plans to finalize these minimum standards in September 2003. We especially want to call your attention to criterion number four, which requires parallel monitoring of at least one reference site. If you have any questions or comments on the draft standards, please contact Mary Baker at 206 526 6315 or Mary.Baker@noaa.gov by August 29, 2003. DRAFT July 1, 2003. *Monitoring Requirements Under the Estuary Restoration Act*.

A restoration monitoring plan must include information to allow for successful implementation and evaluation of the project over the long term. Among the critical elements to include in a monitoring plan are:

1. Monitoring parameters must be directly linked to the goals established for the project and/or the restoration of the watershed as a whole. Success criteria should drive selection of monitoring parameters.

2. Methods for evaluating results must be established (for example, statistical tests of hypotheses, trend analysis, or other quantitative or qualitative approaches) that directly relate to the goals for the project and watershed.

3. Pre-project (baseline) monitoring must occur to establish initial conditions for each measure included in the monitoring plan. Determining variability in each parameter before the project begins allows for a more accurate assessment of progress toward project goals. Historical databases and other existing information about the study site and surrounding area can also contribute to assessing baseline conditions.

4. Project sites must be compared to reference sites to evaluate progress toward reaching goals. Reference sites can be of two types: sites in a similar state of decline or impact as the project area before construction, and sites that represent the condition to which the project area should be restored. Ideally, reference sites would be monitored according to the same plan as the project site, so that natural variability and other regional fluctuations can be detected. However, reference site selection will depend both on the project goals and on the availability of potential reference sites.

5. Monitoring must be conducted with a frequency appropriate to each parameter in the context of project goals and the status of the project. Immediately following construction it is imperative to intensively monitor those parameters that will drive the success of the project (e.g., hydrology, plant survival), in order to allow for corrective measures. As the restored habitat matures, these measurements may become less frequent, while functional parameters (e.g., wildlife use, nutrient cycling) may be more closely monitored. The monitoring schedule should be designed to measure each parameter at the most appropriate time of day, month and/or year; for example, according to wildlife activity levels, tidal cycles, migratory patterns, vegetation growing seasons, and other relatively predictable variations.

6. Monitoring must include provisions for adaptive management. Data must be provided in a timely fashion to project managers to allow for potential mid-course corrections…"

Application to estuary RME: The monitoring plan for action effectiveness research in the estuary RME will be consistent with the monitoring requirements under the Estuary Restoration Act.

Pacific Northwest Aquatic Monitoring Partnership (PNAMP). 2004. Recommendations for coordinating state, federal, and tribal watershed and salmon monitoring programs in the Pacific Northwest. Draft report, January 6, 2004.

Purpose: Describe the purpose, scope, goals, and guiding principles of the PNW Aquatic Monitoring Partnership.

Synopsis: PNAMP is a newly formed partnership for aquatic monitoring in the Pacific Northwest. Their overall goal is effective, real coordination among state, federal, and tribal monitoring programs. The guiding principles involve resource policy and management, efficiency and effectiveness, science basis, and information sharing.

Application to estuary RME: The estuary/ocean subgroup for RME will track this basin-wide effort. The estuary RME Plan will reference this work in the coordination section of the action plan chapter. A similar coordination effort among state, federal, local, and tribal entities is appropriate for the estuary and will be spelled out in the estuary RME Plan.

Puget Sound Water Quality Action Team. 2002. Puget Sound Update 2002. Eighth report of the Puget Sound Ambient Monitoring Program, Olympia, WA; 2002 Sep.

Purpose: Provide information from the Puget Sound Ambient Monitoring Program and related research to evaluate efforts to protect and restore Puget Sound's water quality and biological resources and to identify issues requiring attention.

Synopsis: The report is organized around five major monitoring components: physical environment, pathogens and nutrients, toxics, human health, and biological resources. Accomplishements and highlights for each of the areas are described.

Application to estuary RME: This report is a good example of what an annual estuary monitoring report might entail.

Rice, C.A., W.G. Hood, L.M. Tear, C.A. Simenstad, L.L. Johnson, G.D. Williams, and B.E. Feist. In Press. Monitoring rehabilitation in temperate North American estuaries, with emphasis on anadromous salmon in the Pacific Northwest.

Purpose: Describe estuary monitoring techniques and sampling designs.

Synopsis: The premise in this book chapter is that monitoring rehabilitation (creation, enhancement, restoration) of estuarine ecosystems "by necessity" requires understanding and quantifying the relationships between dynamic estuarine processes and sensitive indicators of ecosystem function. Focus is placed on anadromous salmon habitats in PNW estuaries. The authors point out that freshwater tributary habitats for free flowing systems are largely unidirectional in nature (upstream-downstream; channel-floodplain), whereas estuaries are decidedly multidirectional, with forcings from both ocean and watershed environments. The document contains a useful list of principles for rehabilitating estuary habitat (p. 15). Monitoring programs should be considered at all project phases, be based on a conceptual model of the system, include indicators of ecosystem processes and not just attributes, incorporate ecosystem and landscape perspectives, use metrics that are biologically or physically meaningful and linked to the goals, have as much statistical rigor as possible, occur over a sufficient time period, and be adaptive. There is a good discussion of sampling fishes as part of monitoring rehabilitation projects on pp. 53-56.

Application to estuary RME: In the estuary RME plan, AER will also be based on the premise that monitoring must address the relationships between ecological processes and functions. Rice et al. (In Press) provide details on sampling methods that the estuary RME will refer to.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L.L. Conquest. 1991. Estuarine habitat assessment protocol. Prepared for the USEPA, Region 10, Office of Puget Sound, Seattle, WA; 1991 Sep. EPA 910/9-91-037.

Purpose: Establish procedures to quantitatively assess the function of estuarine wetlands and associated nearshore habitats for fish and wildlife as part of the Puget Sound Estuary Program.

Synopsis: Applied a functional approach and focused the protocols on one particular estuarine function, use as habitat by fish and wildlife species. The idea is to link habitat characteristics with functions that support fish and wildlife. Measure characteristics, termed attributes, of estuarine habitats that are functionally important to fish and wildlife, i.e., promote fish and wildlife usage, growth, and survival.

The protocol is designed to accrue information to improve habitat restoration efforts. It is organized so that the user can address a question from the perspective of the habitat type, fish and wildlife assemblage, or attribute. Attributes are categorized as minimum, recommended, and preferred. Sampling design in estuarine habitats is explained.

Application to estuary RME: The functional approach to estuarine habitat assessment espoused by Simenstad et al. (1991) will be fundamental to estuary RME. Many of the protocols to measure specific attributes will also be used in the estuary RME Plan.

Steyer, G.D., C.E. Sasser, J.M. Visser, E.M. Swenson, J.A. Nyman, and R.C. Raynie. 2003. A proposed coast-wide reference monitoring system for evaluating wetland restoration trajectories in Louisiana. Environmental Monitoring and Assessment 81:107-117.

Purpose: Propose a coast-wide monitoring strategy that includes monitoring at both the project and landscape levels.

Synopsis: This peer-reviewed paper advocates use of a multiple reference site approach that uses "aspects of hydrogeomorphic functional assessments and probabilistic sampling." Trajectories in reference sites are compared with those at project sites. This paper provides an approach to evaluate wetland ecosystems.

Application to estuary RME: This approach will be examined for the action effectiveness element of the estuary RME plan.

Tanner, C. D. 2000. Intertidal habitat projects monitoring program. Prepared for the Elliot Bay/Duwamish Restoration Program Panel by USFWS, Western Washington Office, Seattle, WA, 2000 Mar. Panel Publication 23.

Purpose: Describe the monitoring approach for intertidal habitat restoration projects undertaken by the Elliot Bay/Duwamish River Restoration Program in Seattle, WA.

Synopsis: Monitoring is needed for restoration work, which is to take place at four specific sites. The monitoring program identifies objectives against which the project can be assessed for success. Specific categories (performance indicators) are established and will be compared against certain criteria (performance standards). The categories are intertidal area, tidal regime, slope erosion, sediment structure, sediment quality, marsh vegetation establishment, riparian vegetation establishment, bird use, fish access/presence, and invertebrate prey resource production. The success criteria are listed in Table 1 on p. 17. The monitoring program also identifies potential problems and suggests contingency measures. The document is intended to also be an outreach tool to explain the monitoring program to interested parties.

Application to estuary RME: We will cross-check the indicators and consider adapting the criteria as performance standards where appropriate in the estuary RME plan.

Taylor Associates, Inc., Cascadia Consulting Group, and R2 Resource Consultants Inc. 2003. Assessment of monitoring methods and benefits for Salmon Recovery Funding (SRF) Board projects and activities. Final report prepared for Interagency Committee for Outdoor Recreation Salmon Recovery Funding Board, Olympia, WA, 2003 June.

Purpose: Perform a pilot survey of 143 of 260 completed projects recipient of SRF Board funding to document project success and summarize monitoring activities.

Synopsis: Projects mostly performed "implementation" and "effectiveness" monitoring and little "validation" monitoring (see Monitoring Oversight Committee 2002 for definitions). Fish/redd sampling (species, density, age structure), riparian vegetation surveys, and habitat characterization (channel morphology) were the three top methods (metrics in parentheses) used to evaluate projects. The authors recommended monitoring programs at the *project-type level*, e.g., barrier removal.

Application to estuary RME: This report will pertain to estuary action effectiveness research. Although estuary projects were not specifically analyzed, the report identified the need for more validation monitoring.

Thayer, G. and nine co-authors. 2003. Science-based restoration monitoring of coastal habitats. Volume One: A framework for monitoring plans under the Estuaries and Clean Water Act of 2000 (Public Law 160-457). NOAA Coastal Ocean Program. Decision Analysis Series No. 23.

Purpose: Meet provisions of the law by developing a guidance manual for monitoring plans for restoration of coastal habitats.

Synopsis: This first of two volumes "…provides technical assistance, outlines necessary steps, and provides useful tools for the development and implementation of sound scientific monitoring of coastal restoration efforts." It is not intended to be a "cookbook" because of site-, regional-, and ecosystem-specific variability. The following habitat types are discussed: water column, rock bottom, coral reefs, oyster reefs, soft bottom, kelp and other macroalgae, rocky shoreline, soft shoreline, submerged aquatic vegetation, marshes, mangrove swamps, deepwater swamps, and riverine forests. This report contains a framework for developing a monitoring plan, including descriptions of the stages of restoration and monitoring, project design, and data management. Twelve steps to develop a monitoring plan are explained. Volume Two will provide detailed description of various approaches to monitoring by habitat type.

Application to estuary RME: This work will pertain to action effectiveness research in the estuary RME plan. The twelve steps to develop a monitoring plan for a restoration project will be referenced.

Thom, R.M. and K.F. Wellman. 1996. Planning aquatic ecosystems restoration monitoring programs. Report prepared for the U.S. Army Corps of Engineers, Institute for Water Resources, Alexandria, VA, 1996 Dec. IWR Report 96-R-23.

Purpose: Provide a unified approach to plan, implement, and interpret monitoring programs for aquatic ecosystem restoration projects.

Synopsis: A carefully designed monitoring program lies at the heart of an adaptive management process for aquatic habitat restoration efforts. Specifically, Thom and Wellman (1996) explain how project monitoring will (1) allow project managers to make informed, mid-course corrections, (2) demonstrate if the project is meeting its goals and objectives, and (3) advance the state-of-knowledge in restoration science. The report shows the logical progression of a restoration project from setting goals and objectives to identifying monitoring methods (indicators, metrics, protocols, etc.) to interpretation and dissemination of results. The report is not a "how to" manual, but rather a guide to the fundamental elements of cost-effective restoration project monitoring. A monitoring plan should be developed during the project design/preparation phase because it will be tightly linked to the goals and objectives for the project. The authors list seven steps to develop a monitoring program for a given restoration project: (1) define the restoration vision, goals, and objectives, (2) develop the conceptual model, (3) choose performance criteria, (4) choose monitoring parameters and methods, (5) estimate cost, (6) categorize the types of data, and (7) determine the level of effort and duration.

Application to estuary RME: This report will be included by reference in the estuary RME Plan. This report will provide details for action effectiveness monitoring that will be beyond the scope of the estuary RME Plan.

U.S. Army Corps of Engineers, Rock Island District. 1997. An evaluation of the upper Mississippi River system environmental management program. Final report to Congress, 2001 Jun 19.

Purpose: Describe the accomplishments of this extensive monitoring program for the upper Mississippi River.

Synopsis: Long-term monitoring program in place (status monitoring). Also, the document includes an explanation of habitat rehabilitation and enhancement projects (action effectiveness research). Describes some program alternatives, i.e., improvements from an adaptive management perspective.

Application to estuary RME: The thorough peer-review elements of the program will be included as a recommendation in estuary RME.

USFWS and NMFS. 2000. Notice of availability of a final addendum to the habitat planning and incidental take permitting process. Federal Register 65 (106): 35242-35257.

Purpose: Provide an explanation of adaptive management and a related monitoring program in the HCP process.

Synopsis: The report includes the following statement (p. 35253): "….a monitoring program needs to be designed that will adequately detect the results of the adaptive management strategy. Integration of the HCP's monitoring program into the adaptive management strategy is essential. The monitoring program plays an essential role of determining whether the chosen strategy (ies) is providing the desired outcome…."

Application to estuary RME: The estuary RME plan will include adaptive management.

Washington Salmon Recovery Funding Board. 2003a. Monitoring and evaluation strategy for habitat restoration and acquisition projects. Draft report, Olympia, WA, 2003 May 23. SRFB MP-0.

Purpose: Address elements of the Comprehensive Monitoring Strategy (MOC 2002b) including: overall SRFB effectiveness and validation monitoring strategy; prioritized monitoring by type and category; estimates costs; and reporting metrics.

Synopsis: This report explains further the relationship between the hierarchical levels of monitoring in the SRFB strategy from implementation to effectiveness to validation (examples provided for a tree planting project): Level 0 is project implementation or compliance monitoring (were the trees planted, yes/no?); Level 1 is effectiveness monitoring in meeting design criteria (were the trees planted in the correct locations and did they survive transplanting?); Level 2 is effectiveness monitoring for effects on habitat conditions (did the trees increase shade levels and reduce stream temperatures?); Level 3 is effectiveness monitoring on local salmon abundance (did the project results in more fish?); and Level 4 is intensive (validation) monitoring (is there cause-effect between tree plantings and increased salmon abundance at the watershed scale?). Level 4 gets at cumulative effects of multiple actions in a watershed. It is intended to answer the question "To what extent did our recovery action lead to more fish?" Level 4 monitoring is dependent on monitoring at Levels 0-3. Priorities for effectiveness monitoring are provided based on response times and success probability. For example, in estuaries, habitat restoration is rated high with medium-high success probability over a long time frame. WSRFB (2003a) advocates a BACI (before and after, control and impact) design for action effectiveness research on habitat restoration/protection projects. Table 2 (p. 13) provides monitoring categories, levels, indicators, metrics, statistical test, and decision criteria. Cost estimates are provided for out-years by project category and level of monitoring. An interesting "Data Pyramid" is presented (p. 21) that shows how data progress from project databases to program databases to indicators reportable to policy-makers to funding decision-makers in government and elsewhere. The SRFB, OWEB, BPA, NOAA, USFS, etc. have agreed upon metrics for implementation monitoring. For estuaries, these include # acres restored, # acres created, and # acres invasive species controlled. The strategy included QA/QC and reporting requirements as part of an adaptive management process.

Application to estuary RME: This report has useful material that we will consider for estuary RME. For example, we might apply Table 2 on WSRFB (2003a) to AER. The monitoring categories would be our AER objectives, the indicators would be our indicators, and the metrics would be our monitored variables. The estuary/ocean subgroup will decide if the estuary RME plan will include costs like this strategy does.

Washington Salmon Recovery Funding Board. 2003b. Sampling procedures, designs, and expected costs -- Fish passage projects effectiveness monitoring (culverts, bridges, fishways, logjams, dam removal). Draft report, Olympia, WA, 2003 May 23, MP-1.

Purpose: Provide the procedures and protocols for monitoring the implementation and effectiveness of fish passage projects, such as, bridges, culverts, dam removals, debris removals, fishways, weirs, and water management.

Synopsis: The goal of fish passage improvement projects is to restore passage to habitat areas fully or partially blocked, thereby increasing habitat area and overall watershed productivity. The goal of monitoring is to determine if the projects are effective at doing this. The authors call for a BACI design for multiple projects.

Application to estuary RME: Some of this material might be useful for AER on projects where barriers are removed or improved, like a dike or tidegate.

Washington Salmon Recovery Funding Board. 2003c. Sampling procedures, designs, and projected costs -- In-stream habitat projects effectiveness monitoring (channel connectivity, off channel habitat, wetland restoration). Draft report, Olympia, WA, 2003 May 23. MP-6.

Purpose: Provide the procedures and protocols for monitoring the implementation and effectiveness of instream habitat improvement projects, such as channel connectivity, off-channel connectivity, and wetlands.

Synopsis: The goal of instream habitat improvement projects is to restore access to lost channels and side channels for juvenile rearing, thereby increasing habitat area and overall watershed productivity. The goal of monitoring is to determine if the projects are effective at doing this. Again, the authors call for a Before-After-Control-Impact design for multiple projects.

Application to estuary RME: Some of this material might be useful for AER on projects where channel connectivity is restored or created.

Washington Salmon Recovery Funding Board. 2003d. Sampling Protocols -- Effectiveness monitoring habitat restoration projects requirements. Draft report, Olympia, WA, 2003 May 23.

Purpose: Establish sampling protocols for effectiveness monitoring of habitat restoration projects funded by the WSRFB.

Synopsis: This report is in response to recommendations in the Comprehensive Monitoring Strategy (MOC 2003b) for standardized monitoring protocols and use of the USEPA's EMAP approach where appropriate. The following protocols are provided: delineating reaches for wadeable streams; presence/absence of listed salmon using electrofishing, adult observations, or carcass counts; juvenile presence/absence using snorkeling or beach seine; instream juvenile salmon abundance using electrofishing or snorkeling; adult spawner abundance; and various physical features in tributaries.

Application to estuary RME: Most of these protocols will not likely be relevant to the estuary

Appendix B: Estuary Partnership's Monitoring Strategy

The Estuary Partnership's monitoring and evaluation strategies are shown in the table below. Specific Biological Opinion-related RME efforts in the estuary/ocean arena will be coordinated with this broad, ongoing effort. This material is from LCREP (1998), *Lower Columbia River Estuary Plan, Aquatic Ecosystem Monitoring Strategy for the Lower Columbia River and Information Management Strategy. Volume II.*

	Monitoring Oversight	Data Management	Conventional Pollutants	Toxic Contaminants	Habitat Monitoring	Exotic Species	Primary Productivity, Food Web
Phase One	♦set up coordination structure and monitoring committee, ♦develop interagency agreements and contracts, process to identify and allocate resources, ♦begin discussions on expansion of existing programs	♦locate all existing data, ♦improve access to data, ♦heighten public awareness	♦continue existing ambient programs for temp., TDG, bacteria, DO, pH, SS, TOC, C, nutrients, ♦track TMDLs for temp and TDS, ♦explore increasing scope and number of ambient sites, ♦begin discussions on consistent bacteria standards,	♦work w/USGS to redesign NASQAN to include toxics, ♦explore expanding existing ambient programs to include toxics, ♦establish baseline sampling network for toxics in sediments, ♦ develop random network for monitoring toxics in fish tissue, ♦begin discussions on discharge monitoring stations,	♦conduct workshop on measuring biological integrity, ♦develop agreements to share habitat data with all parties, ♦ develop habitat monitoring procedures, ♦contract for special study to survey existing habitat metadata,	♦develop agreements with all involved entities to share data and develop comparable procedures for monitoring exotic species, ♦evaluate existing information on exotic species to begin developing strategy for monitoring	♦explore expanding existing ambient monitoring programs to include productivity parameters DO, pH, TOC, nutrients, chlorophyll a, and BOD, ♦work with monitoring partners to begin development of index of biotic integrity for macroinvertebrates
Phase Two	♦continue oversight, ♦expand ambient programs, ♦expand special projects, ♦implement phase two components, implement phase two components, ♦ensure information reaching public, ♦add extra staff as needed	♦agreements on consistent monitoring protocol and procedures and data management standards, ♦ develop strategies for linking databases, ♦all data on STORET X, ♦ track development of other relevant data	♦expand existing ambient monitoring for other parameters and more sites, ♦ conduct synoptic study of temp in mouths of tributaries, ♦further define temp TMDL, ♦facilitate adoption of consistent bacteria standard, ♦work with USACE for QA/QC for TDG	♦expand existing sites to include toxics, ♦implement sampling for toxics in sediment and fish tissue, ♦contract for special study to analyze existing data, ♦develop sampling design and conduct reconnaissance sampling for toxics in water and suspended sediments, ♦contract for special study on hot spots, ♦establish discharge	♦complete analysis of metadata, ♦begin development of habitat monitoring scheme, ♦conduct second habitat monitoring workshop, ♦contract to conduct remote sensing, ♦contract to begin habitat monitoring ♦contract for aerial photography or high-resolution video	♦complete review of existing data and finalize monitoring strategy, ♦implement sampling program aimed at species not currently being sampled, ♦contract to evaluate impacts of introduced species, ♦ develop strategy for monitoring introduction, ♦create educational	♦expand existing sites to include productivity parameters, ♦ develop agreements with monitoring partners to incorporate IBI into sediment sampling for toxics, ♦contract for special study of suspended particulate mater, nutrients, and primary production including interactions with macrioinvertebrates,

	Monitoring Oversight	Data Management	Conventional Pollutants	Toxic Contaminants	Habitat Monitoring	Exotic Species	Primary Productivity, Food Web
				monitoring stations, ♦coordinate on radionuclide monitoring	multiple spectral scanning to characterize habitat,	program	
Phase Three	♦continue oversight, implement phase three monitoring components ♦begin developing five year monitoring assessment report	♦implement short term approach to managing data using Estuary Program homepage to link a networked system of databases, ♦work with DEQ, Ecology and EPA to analyze data and develop reports	♦continue expanded ambient monitoring, implement TMDL management actions for temp and TDG, ♦ contract to conduct bacterial survey at selected beaches, ♦ conduct survey of water contract recreationists, ♦conduct evaluation of data and status report	♦evaluate results and adjust sediment toxic monitoring, ♦evaluate fish tissue study and conduct statistical analysis to determine future direction, ♦ evaluate results of reconnaissance sampling and implement long term program to track trends, ♦establish continuous turbidity sampling at selected sites, ♦contract for health study of human health risks ♦develop guidance on management of contaminated non-dredge sediments.	♦contract for system wide bathymetry, ♦contract for analysis of habitat metadata to reconstruct historical landscape patterns, ♦begin assessment of overall habitat monitoring scheme	♦implement program to monitor mechanisms of introduction, ♦develop agreements to implement ongoing program to assess impacts of introduced species, ♦ continue and expand educational efforts,	♦assess results of special study on primary production and food webs to determine if useful way to measure biological integrity, ♦develop agreements to implement long term monitoring of productivity depending on assessment, ♦complete survey of metadata to assess historic and current sampling plans, ♦conduct an assessment of food webs from benthic invertebrates through fish, ♦develop a model of primary production
Phase Four	♦continue oversight, ♦implement any remaining monitoring components, ♦seek resources for and implement recommendations from 5 year monitoring assessment report	♦seek resources to implement the data recommendations from the 5 year report to possibly include totally interactive data management system	♦continue existing ambient programs ♦ implement permanent program for monitoring conventional pollutants based on recommendations of 5 year report	♦contract for study to identify trends in sediments through core sampling and analysis, ♦use cores to determine the effect of extreme hydrologic events, ♦contract to evaluate the impact of native versus hatchery fish on tissue contaminant data, ♦evaluate recomm. from 5 year report and adjust	♦continue coordination of interagency habitat monitoring and assessment of data, ♦evaluate results of 5 year report and adjust existing habitat monitoring program, ♦develop and implement new strategies	♦evaluate results of 5 year report and adjust existing nonindigenous species monitoring efforts based on finding of the report	♦contract for reconstruction of history of water quality in estuary and behind selected reservoirs using diatoms in sediments, ♦contract for a reconstruction of organic matter sources for food webs using multiple stable isotopes, ♦evaluate recommendations of 5 year report and adjust monitoring efforts

Appendix C:

Annotated Bibliography of Projects Relevant to the Estuary/Plume Research, Monitoring, and Evaluation Plan

P1 Lower Col. R. Aquatic Nonindigenous Species Survey

Header: Category = Status Monitoring; Funding agency = Coast Guard; Implementors = PSU/OSU/UW

Status: Ongoing, have data

Years of Actual Data: 2002

Lead Scientists: Robyn Draheim Waldeck and Mark Systema (PSU), John Chapman (OSU), and Jeff Cordell (UW)

Description: (Abstract from http://sgnis.org/publicat/drahcord.htm.) The lower Columbia River Estuary is extensively altered by upstream damming and hydroelectric projects, loss of wetlands, reduced freshwater flow oscillations, altered shipping, fishing, and land use practices, by regional climate changes ranging from el Niño events to global warming and by introductions of aquatic nonindigenous species (ANS). Our literature review, and 2002 field sampling indicate that the increasing rate of new introductions, their increasing likely impacts, and the mechanisms bringing these introductions are in common with other eastern Pacific estuaries. However, the relatively high summer freshwater flows of the Columbia River estuary create unique assemblages of introduced species. We did not find some widespread ANS we expected, such as the smooth cordgrass, *Spartina alterniflora*, and the European green crab, *Carcinus maenas*, and we were unable to confirm numerous sightings of the mitten crab *Eriocheir sinensis* in the Columbia River. Large alterations of the estuary discovered in the survey include: the replacement of the previously dominant *Pseudodiaptomus inopinus* by the introduced *Pseudodiaptomus forbesi*, *P. forbesi* is now being dominant, and its range extended north from San Francisco Bay, California; a new and unidentified gammaridean amphipod, *Monoporeia* that appeared in the estuary in the last few years and extensive populations of the New Zealand mud snail, *Potamopyrgus antipodarum*.

Publications: Waldeck et al. (2003)

Application to estuary RME: This project pertains directly to the performance indicator on invasive species.

P2 Total Dissolved Gas Monitoring

Header: Status Monitoring, USGS, COE

Status: Ongoing, have data

Years of Actual Data: Approx. ten

Lead Scientists: Dwight Tanner (USGS)

Description: Total Dissolved Gas data can be found at http://www.nwd-wc.usace.army.mil/report/tdg.htm. (The following description is from http://oregon.usgs.gov/projs_dir/pn307.tdg/) The U.S. Geological Survey collects real-time data for total dissolved gas, temperature, and barometric pressure. Quality assurance consists of daily intersite comparisons of the data and calibration every two weeks. Monitoring stations were installed from the forebay of the John Day dam near Rufus, Oregon (river mile 215.6) to Camas, Washington (river mile 121.7). Each station measures dissolved gas pressure, barometric pressure, and water temperature. These data are logged hourly and transmitted by satellite every 4 hours to the U.S. Geological Survey and U.S. Army Corps of Engineers.

Publications: Tanner et al. (1997); Tanner and Johnston (2001); Tanner and Bragg (2001); Tanner et al. (2002)

Application to estuary RME: This project is one of the sources for water quality data.

P3 Acoustic Telemetry on the Continental Shelf

Header: Status Monitoring, 2000-076-00, BPA, Kintama

Status: Ongoing, started in 2000, have feasibility data

Years of Actual Data: Feasibility work to date.

Lead Scientists: David Welch (Kintama)

Description: (Abstract from FY03 proposal, see Proposal 200300900 under the Columbia Estuary Province at http://www.cbfwa.org/) This proposal reviews the results from our previous research on the ocean biology of Pacific salmon and outlines the reasons for developing an expanded, multi-year research survey. The intent of this survey is to map ocean conditions determining the growth and survival of Pacific salmon along the West Coast of North America from the British Columbia-Washington border into SE Alaska, and to identify which stocks of Columbia River salmon forage in the continental shelf of these areas. The expanded geographic study area is needed because our initial results clearly demonstrate that a proportion of the Columbia River salmon are undertaking rapid, directed migrations that quickly take them well out of the area around the mouth of the Columbia River, and into regions with quite different growth and survival potential. Our research is finding that different populations of Columbia River salmon move to different locations along the coastal zone where they establish their ocean feeding grounds and (presumably) over-winter. Apparently the food chain determining feeding success, growth, and ultimately potential for survival of chinook and coho salmon changes in different parts of the coastal zones of British Columbia and Alaska, so the ocean environment cannot be considered either homogeneous or constant. The relative survival of different stocks of salmon in the ocean therefore may depend strongly on where in the ocean specific stocks migrate to feed. For example, our calculations indicate that the ocean survival of Snake River chinook should be much lower than that of other Columbia River stocks that they have been compared to (such as the Hanford Reach stock) because they migrate to different parts of the ocean. Our results show that ocean conditions in 1998 substantially reduced the growth and survival of salmon foraging off southern British Columbia relative to salmon foraging farther north. However, ocean conditions in 1999, 2000, & 2001 were dramatically different and apparently similar to those holding in the early 1970s, at the time that the Snake River hydrosystem was just being completed– and should have led to significantly better survival conditions. The near-record returns of salmon to the Columbia River in 2001 are consistent with a massive increase in ocean survival of the juvenile salmon when they went to sea in 1999. It appears that in 1999 the North Pacific Ocean underwent a sudden and dramatic shift in ocean conditions to one more favorable to Columbia River salmon. It is important to measure these improved conditions now, while they persist, because they are likely to be short-lived; greenhouse gas forcing is likely to drive ocean climate back towards a more extreme version of the warmer climate holding through the 1980s and 1990s. As the 1980s and 1990s appeared to be a time of progressively poorer marine survival for salmon– with many populations becoming unsustainable even in the absence of all fishing– direct measurement of the degree to which the ocean affects various salmon populations needs to be made.

Publications: Not available.

Application to estuary RME: This project could provide data on juvenile salmon migration pathways and residence times in the Pacific Ocean after they exit the Columbia River estuary.

P4 Columbia River Estuary Habitat Mapping

Header: Status Monitoring, 2002-012-00, BPA and COE, Estuary Partnership with Earth Designs and UW

Status: Ongoing, started in 2000, have data

Years of Actual Data: One Landstat data set (2000) and one set of CASI data (2000 and 2001)

Lead Scientist: Ralph Garano (Earth Designs)

Description: In 2000, the Estuary Partnership initiated this project to produce a spatial data set describing the current location and distribution of habitat cover types along the lower Columbia River. Previous studies (Thomas, 1980; Thomas, 1983; Graves et al., 1995; NOAA, 1997; Allen, 1999) have produced useful habitat data sets. Most of these studies, however, have used multiple and varied data sources and have differed somewhat in methodology: no single dataset has been produced using consistent a methodology and uniform scale data, which describes current estuarine and riparian habitat cover types from the Columbia's mouth to Bonneville Dam, a distance of ~230 km (Figure 1).

(The following material is from www.earthdesigns.com/lower columbia/.) "We classified estuarine and riparian floodplain habitats along ~230 km of the lower Columbia River, encompassing an area of 193,000 ha. While we did classify some of the upland areas in the Chinook watershed, most of the upland areas along the lower Columbia River were excluded by a DEM (elevation) mask. As we expected, the largest habitat class was the deep-water habitat, which covered 30.9% of the classified area. We found that much of the study area was vegetated: herbaceous and woody (shrub-scrub and forested) vegetation accounted for 29.9% and 23.2% of the classified area, respectively. Urban areas accounted for ~11.0% of the area classified. Vegetated wetland areas (herbaceous, shrub-scrub and forested) accounted for a relatively small proportion (8.4%) of the study area and unvegetated areas (mud and sand flats) subject to tidal inundation accounted for an additional 4.4% of the study area. Vegetated uplands accounted for 44.7% of the area classified."

Results from this study will be used by the Estuary Partnership and its cooperators to: (1) develop indicators of "habitat health" and biological integrity; (2) develop definitions of "critical salmonid habitat"; (3) identify and evaluate potential wetland conservation and restoration sites; (4) track exotic and invasive species; and (5) develop an understanding of how estuarine and riverine habitats have changed over the past 200 years. This study focuses on estuarine and riparian habitat cover types important to native species, particularly juvenile salmonids. This study is meant to provide support to the multiple efforts currently underway to recover 12 species of Columbia River salmonids identified as endangered or threatened under the Endangered Species Act.

Publications: Garono and Robinson (2003) and Garano et al. (2003).

Application to estuary RME: This project is the primary source for data on vegetative cover, which is one of the monitored attributes under the habitat inventory performance indicator.

P5 Bathymetric Survey RM 3-40

Header: Status Monitoring, COE, COE

Status: Ongoing, have data

Lead Scientists: Gail Sakach (CENWP)

Description: (The following description is from https://www.nwp.usace.army.mil/op/n/Hydro.htm.) Portland District's Hydrographic Survey covers an area from Cape Disappointment on the southern Washington Coast to the Chetco River on the southern Oregon coast and from the Pacific Ocean on the west to McNary Dam on the east. The navigational channels, more than 400 miles worth, consist of coastal entrances, deep and shallow draft harbors and river channels. Utilizing state-of-the-art data acquisition and differential global positioning systems, four full-time, in-house survey crews and one crew is able to monitor monthly dynamically active reaches of the navigation channels for shoaling or scouring. An extensive database of hydrographic surveys which include pre-dredge, progress, post-dredge, condition and material placement surveys are maintained within the District. The Office of Hydrographic Surveys has presently made available, over the internet, surveys of the Columbia River, from its mouth at the Pacific Ocean, to Bonneville Dam. These surveys represent the latest data available and can be viewed in Channel-Line (Survey-lines that run parallel to the channel; 7 lines across, spaced 150 feet apart) or Cross-Line (Survey-lines that run perpendicular to the channel; bank-to-bank and are generally spaced 500 feet apart) format. Channel-Line surveys of this area are taken on a monthly basis and are updated on our web site within 3 days of being received at the District Office. The Cross-Line surveys are taken annually and are updated on the web site as they are received (typically in January or February). The latest hydrographic surveys of the Columbia River, from Vancouver, Washington, to Bonneville Dam are now posted on the site.

Publications: Data are available from the website cited above.

Application to estuary RME: This project provides bathymetry data for the habitat inventory indicator.

P6 Baitfish/Salmonid Marine Survival Relationships in the CRE

Header: Status Monitoring, NOAA, NOAA/ NWFSC

Status: Ongoing, have data

Years of Actual Data: Unknown

Lead Scientist: Robert Emmett (NOAA)

Description: (The following description is from Emmett's 2001 proposal.) The goals for this project are to 1) relate salmon marine/estuarine survival with variations in baitfish population ecology, and 2) identify the importance of Northwest estuaries to salmon survival. The objectives are to identify the temporal abundance (timing), relative abundance, and age/size-class distribution of baitfish resources in the Columbia River estuary, relate the abundance and size-class distributions of Columbia River estuary baitfish resources with salmonid survival.

Publications: Emmett (2001)

Application to estuary RME: This research will improve understanding of the factors affecting marine survival of juvenile salmon. It provides data for the monitored variable called anchovy/herring index of the performance indicator for plume conditions.

P7 Ambient Water Quality Monitoring

Header: Status Monitoring, ODEQ, ODEQ

Status: Ongoing, have data

Years of Actual Data: The DEQ currently has four monitoring sites on the mainstem of the lower Columbia River and additional sites on the lower Willamette River. The primary site on the mainstem, located just upstream of the mouth of the Willamette on the Columbia has been sampled quarterly for approximately 10 years. The other sites below Bonneville, near Columbia City and in Cathlamet Channel have sampled quarterly for the past 3 years. The sites are monitored for basic water quality parameters including nutrients and metals. Toxics are not monitored at present.

Lead Scientists: Chris Watson (ODEQ)

Description: (The following description is from the website http://www.deq.state.or.us/wq/.) The Department of Environmental Quality (DEQ) is the state agency responsible for protecting Oregon's surface waters and groundwater to keep these waters safe for a wide range of uses, such as drinking water, recreation, fish habitat, aquatic life, and irrigation. DEQ's Water Quality Program accomplishes this in many ways by:

- Developing water quality standards for Oregon's waters.
- Monitoring water quality with regular sampling of more than 50 rivers and streams in the 18 designated river basins found in Oregon.
- Regulating over 1000 sewage treatment systems and approximately 200 industrial dischargers through individual permits that set limits on pollutants discharged. In addition, approximately 1000 facilities have general permits that limit discharges and over 1900 facilities are covered by storm water general permits.
- Regulating injection systems through a registration process and, when necessary, by issuing permits to protect groundwater.
- Inspecting septic system installations and working with local agencies to streamline this process.
- Helping public drinking water systems implement plans to protect drinking water.
- Offering low cost loans to public agencies and grants to different entities to help fund improvements to water quality.
- Controlling non-point sources of pollution (diffuse or unconfined sources of wastes or contaminants that are conveyed to surface water or groundwater) by maintaining a plan that describes how the state intends to manage non-point sources

Publications: Numerous publications on water quality can be found at the website cited above.

Application to estuary RME: This project provides data for the water quality performance indicator.

P8 Long-Term Water Quality Monitoring

Header: Status Monitoring, USGS, USGS

Status: Ongoing, have data

Years of Actual Data: USGS has one site at the Beaver Army Terminal (approx. river mile 50) that has been sampled regularly for more than 20 years. In addition they have data from two other sites that have recently been discontinued. Their data includes basic water quality parameters and pesticides.

Lead Scientists: Dwight Tanner and Greg Fuhrer (USGS)

Description: (The following description is from http://oregon.usgs.gov/projs_dir/or163/) As a result of increasing concern that urban, industrial, and agricultural activities are having an adverse effect on water quality in the lower Columbia River Basin, the Lower Columbia River Bi-State Water Quality (Bi-State) Program was initiated in 1990 by the Oregon and Washington State Legislatures. As part of the Bi-State Program, reconnaissance surveys of the lower river in 1991 and 1993 showed elevated levels of water-quality constituents including stream temperature, dissolved oxygen, fecal-indicator bacteria, chlorophyll, and trace elements in water-column samples throughout the 140-mile main-stem reach. The spatial-temporal variability of these elevated levels currently are unknown, because the surveys in 1991 and 1993 were conducted only during the summer and early fall.

Objectives of this study are to determine, to the extent possible:

1. The spatial and temporal distributions (annual, seasonal, and monthly) of water-quality constituent concentrations
2. Exceedances of water-quality standards or criteria for beneficial uses
3. Instream constituent loads and contaminant sources; and
4. Long-term trends in constituent concentrations.

From January through December 1994, the USGS collected data from 10 fixed stations. These samplings were coordinated with data-collection efforts in selected tributaries by the Oregon Department of Environmental Quality (ODEQ) and the Washington Department of Ecology. As a result, data-collection activities required quality-control data for interagency comparisons.

The fixed-station data were used in concert with historical data and other Bi-State data to address the study objectives. The approach is divided into the following three tasks:

- Task 1--Collection of fixed-station data from four main-stem and six tributary stations. These sites were:
    - Columbia River at Warrendale, OR.
    - Columbia River, rmi 102, downstream of Hayden Is., OR.
    - Willamette River at Portland, OR.
    - Multnomah Channel near mouth, at St. Helens, OR.

  - Columbia River near Columbia City, OR.
  - Kalama River above Spencer Creek, near Kalama, WA.
  - Cowlitz River at Kelso, WA.
  - Columbia River at Beaver Army Terminal near Quincy, OR.
  - Sandy River near Troutdale, OR.
  - Lewis River at Woodland, WA.
- Task 2--Collection of quality-control data for interagency comparisons with data collected by personnel from the USGS, ODEQ, and Washington Dept. of Ecology.
- Task 3--Interpretive USGS report including an analysis of current and historical water-quality data collected in the Lower Columbia River Basin.

Publications: Fuhrer et al. (1995). Also, 1994 water-chemistry data for the Bi-State project is available at http://oregon.usgs.gov/data_dir/mans_dir/qwmans_dir/columbiachem.html.

Application to estuary RME: This is another project collecting water quality data.

P9 Hydrograph

Header: Status Monitoring, USGS, USGS National Streamflow Information Program

Status: Ongoing, have data

Years of Actual Data: Many

Lead Scientists: XXX

Description: (The following description is from http://waterdata.usgs.gov/nwis/uv/?site_no=14246900&PARAmeter_cd=00065,00060,00010,00055#top_of_page.) Station -- 14246900 Columbia River at Beaver Army Terminal, near Quincy, OR. Lat 46° 10'55", long 123° 10'50", in NE 1/4 sec.16, T.8 N., R.4 W., Columbia County, Hydrologic Unit 17080003, on left bank, 0.7 mi downstream from Crims Island, 3.0 mi northwest of Quincy, and at mile 53.8. Drainage Area -- 256,900 mi^2, approximately. Period Of Record -- May 1968 to June 1970, June 1991 to current year. Gage -- Acoustic velocity meter with water-stage and velocity index recorder. Datum of gage is 0.52 ft above NGVD of 1929. May 1968 to June 1970 water-stage recorder with auxiliary water-stage recorder 5.6 miles downstream at datum 10.00 ft lower. Remarks -- Flow regulated by many reservoirs on Columbia River and in tributary basins. Flows affected by tide which can cause reverse direction during tidal cycle when mean daily flows are less than 250,000 ft3/s. Mean discharge values are based on a 24 hour day, not a tidal cycle. Extremes for Period of Record -- Maximum daily discharge, 581,000 ft3/s Jan. 28, 1970; minimum daily discharge, 63,600 ft3/s Sept. 9, 2001.

Publications: Data may be obtained from the website referenced above.

Application to estuary RME: This project provides the basic data on the hydrograph in the estuary for the river flow performance indicator.

P10 Estuarine Detection of Pit-Tagged Juvenile Salmonids Using A Pair-Trawl, 2003

Header: Status Monitoring and Uncertainties Research, BPS-00-11, COE, NOAA/ NWFSC

Status: Ongoing, started in 2000

Years of Actual Data: Four, 2000-2003

Lead Scientist: Dick Ledgerwood (NOAA)

Description: (Abstract from the AFEP Annual Review, November 2003, http://www.nww.usace.army.mil/planning/ep/fishres/AFEPREVIEW/.) We used a large surface trawl to detect migrating juvenile salmonids tagged with passive integrated transponder (PIT) tags in the Columbia River estuary at Jones Beach (RKm 75) for 794 hours in 2003. Equipment used with the large trawl consisted of a 2-coil antenna formed around an 86-cm diameter fish passage tunnel measuring 2 m in length and weighing about 200 kg in air. The trawl measure 105.5 m along each wing and, under tow, had a 91.5 m spread between the wings. Fish that entered between the wings were guided into a trawl body, which terminated at the entrance to the antenna. As in previous years, sampling, which targeted yearling salmonids, began in mid-April and continued through June. A total of 20,507 juvenile PIT-tagged salmonids were detected: 14,989 yearling chinook salmon, 1,106 subyearling chinook salmon, 231 coho salmon, 4,000 steelhead, 46 sockeye salmon, 8 searun cutthroat trout, plus 127 tags as yet unidentified in the PTAGIS regional database. Sampling effort increased commensurate with fish abundance in the estuary. Two daily sampling crews were used between 28 April and 15 June, and, during this intensive sampling period, we detected 2.4 % of yearling chinook salmon and 1.6 % of steelhead that had been previously detected at Bonneville Dam. We detected 3,972 yearling chinook salmon and 783 steelhead that had been transported and released downstream from Bonneville Dam. When specific barge loading and release information is made available, these data will provide a comparison of estuarine detection rates among transported fish and in-river migrant fish previously detected at Bonneville Dam. A comparison of travel speed from Bonneville Dam to Jones Beach between PIT-tagged fish we detected and radio-tagged fish (steelhead and subyearling chinook salmon) released and tracked by other researchers is pending. To maintain a more consistent daily sampling effort in 2003, we did not conduct weekly 36 to 48 hour continuous diel sampling efforts as in past years. Rather, we conducted nearly continuous day and night time sampling throughout much of the yearling salmonid migration period. Daily shut down periods were generally between 2 PM and 6 PM–when strong winds often contribute to difficult sampling conditions. Seasonal average detection rates during daylight and darkness hours for yearling chinook salmon were 9 and 33/hour and for steelhead 5 and 5/hour, respectively. In past years the highest detection rates for steelhead were during mid-day and our reduced sampling during late afternoon may explain the similar day time and night time detection rate for steelhead in 2003. The subsequent detection at Jones Beach of PIT-tagged fish previously detected at Bonneville Dam enables calculation of survival estimates for in-river migrants to Bonneville Dam. There were 39 groups of yearling chinook salmon, 15 groups of steelhead, and 6 groups of coho salmon having more than 7,000 PIT-tagged fish released in the Columbia River Basin in 2003. Estuarine detections from these major release groups were generally sufficient to provide in-river survival indices for the individual groups. The mean survival rates (S.E.) for in-river migrant yearling chinook salmon and steelhead from Lower Granite Dam to Bonneville Dam were 53.2% (2.3) and 30.9% (1.1), respectively.

Publications: Unknown.

Application to estuary RME: This project provides data on the survival and temporal distribution of PIT tagged juvenile salmon in the estuary.

P11 Survival and Growth of Juvenile Salmonids in the Columbia River Plume

Header: Status Monitoring and Uncertainties Research, 1998-014-00, BPA, NOAA/NWFSC

Status: Ongoing, have data

Years of Actual Data: Six, 1998-2003

Lead Scientists: Rick Brodeur, Edmundo Casillas, and Bill Peterson (NOAA) and Antonio Baptista and David Jay (OHSU)

Description: (Abstract from FY03 proposal, see Proposal 199801400 under the Columbia Estuary Province at http://www.cbfwa.org/) The nearshore ocean environment, particularly that associated with the Columbia River plume, is a critical habitat to outmigrating juvenile salmon. Recent evidence suggests that improvement in survival of the estuarine and early ocean life history phase of Columbia River salmon may be critical to recovery of endangered stocks. In the case of salmonids originating in the Columbia River Basin, survival success hinges on the complex interaction of smolt quality and the abiotic and biotic ocean conditions at the time of entry and during their first year of ocean existence. We hypothesize that variation in the physical and biological conditions of the nearshore environment, particularly that associated with the plume, affects overall survival of Columbia River stocks. We further hypothesize (a) that primary factors driving the variation in the nearshore and plume environment include oceanographic and land-based (river flow) processes modulated by climatic and anthropogenic factors, (b) that trophic relationships modulated by these physical variations affect growth and survival of juvenile salmon and (c) that management of the hydropower system can be used to regulate the Columbia River plume habitat to benefit salmon growth and survival. We propose to characterize, over an extended period, the physical and biological features of the nearshore ocean environment using meso-scale and fine-scale oceanographic surveys, develop coupled physical-biological models, and perform retrospective assessment of the Columbia River plume as it interacts with coastal circulation. With our new understanding of salmon-plume-coastal circulation interactions, we will develop a set of hydropower management scenarios that could benefit survival, growth, and health of juvenile salmon by changing the dynamics of the Columbia River plume.

Publications: Baptista et al. (1999); Emmett et al. (In Prep); Jay and Hickey (2001); Peterson and Mackas (2001), Schabetsberger et al. (In Press).

Application to estuary RME: This is the primary project to address the performance indicator on plume conditions.

P12 Estuarine Habitat and Juvenile Salmon: Current and Historic Linkages in the Lower Columbia River and Estuary

Header: Status Monitoring and Uncertainties Research, EST-02-02, COE, NOAA/NWFSC with OHSU, OSU, and UW

Status: Ongoing, have data

Years of Actual Data: Two, 2002 and 2003

Lead Scientists: Antonio Baptista and David Jay (OHSU), Dan Bottom, Edmundo Casillas, and Curtis Roegner (NOAA), Lance Campbell (OSU), and Charles Simenstad (UW)

Description: (Abstract from the AFEP Annual Review, November 2003, http://www.nww.usace.army.mil/planning/ep/fishres/AFEPREVIEW/.) In 2003, we continued the second year of a long-term monitoring program to determine salmon life histories and habitat associations in the lower Columbia River estuary and to evaluate salmonid responses to past and future habitat change. We conducted monthly beach-seine sampling at a series of seven lower estuary stations. As in the previous year, juvenile chinook salmon were present during all sampling periods but were most abundant May through July. Coho and chum salmon appeared in the estuary during a much shorter period in the early spring. We also conducted monthly trapnet surveys from April through August to compare salmonid use of selected emergent and forested wetlands in the Cathlamet Bay region. Salmonid densities in all of the marshes peaked sooner (April and May) than in 2002 and declined rapidly thereafter. These results may reflect high water temperatures in the marshes earlier in the spring compared with the previous year. Total abundances of salmon in Cathlamet Bay marshes were generally higher in the emergent than in the forested or shrub wetlands. Preliminary stomach analysis from 2002 indicate that insects (Chironomidae) and amphipods (Corophium spp) are common prey items for juvenile salmon in emergent and forested/shrub wetlands. As hypothesized from other estuaries, sizes of juvenile chinook salmon averaged slightly smaller in wetland habitats compared with near-channel sites sampled with the beach seine. Chinook with yearling life histories were captured primarily at beach-seine sites and rarely if ever entered shallow wetland habitats. These results are consistent with preliminary genetic analyses of a small subset of the 2002 samples, indicating that 83% of the fish captured in wetland habitats are most likely ocean-type migrants from the Lower Columbia ESU. However, representatives from other ESUs, including Upper Columbia, Upper Willamette, and Snake River were also present in the wetland samples. We established a scale digitizing protocol to determine whether scale patterns can be used to discern estuarine life-histories of juvenile salmon. Approximately 150 scales from 2002 samples were digitized and scale circuli were measured from a subset of these. Evidence of a prominent "check" on many of the scales will be investigated as a potential marker of estuary entry by juvenile salmon. We plan to evaluate whether microchemical signatures on scales can be used to independently validate life-history interpretations made from scale patterns. We continued physical monitoring of conductivity/salinity, temperature, and pressure/water level at six recording stations to support habitat characterizations within the Cathlamet Bay region. Atmospheric data were also recorded at one of these sites (Marsh Island). Real-time summaries and archival salinity, temperature, and water-level data are disseminated on the CORIE web site (http://www.ccalmr.ogi.edu/CORIE/network/). From independently-funded modeling forecasts, these data are being used to experimentally compute regional (Cathlamet Bay) and station-specific predictions of habitat opportunity for juvenile salmon based on criteria for water depth, velocity, and salinity. All results are preliminary and undergoing quality control. We continued analyses to reconstruct historic changes in potential rearing habitat for juvenile salmon in the Columbia River estuary. We published results of historical modeling to determine potential changes in water level for a demonstration reach (rkm 50 – rkm 90) in the tidal freshwater portion of the estuary. The results indicate that floodplain diking and flow reduction together have reduced by approximately 62% the total amount of shallow water habitat potentially available to downstream migrant salmon during the crucial spring-freshet period. We also acquired data needed to estimate historic changes in habitat types and features of the Columbia River estuary. We are using results of historic topographic surveys (Tsheets) geo-referenced in 2002 to georeference hydrographic survey results (H-sheets). When completed, the T-sheets and H-sheets will be merged to develop a seemless historic habitat coverage for the entire region from the river mouth to Bonneville Dam. A classification system for habitat change analysis was finalized with the aid of other cooperators and applied to two of four pilot regions. In these regions, we will compare historical habitat types with a classification of contemporary imagery to estimate changes in habitat distribution, connectivity, and landscape pattern.

Publications: Not available at this time.

Application to estuary RME: This project provides much of the status monitoring data for the performance indicators on life history diversity, spatial distribution, and growth.

P13 Vibracore studies in the Columbia Estuary

Header: Action Effectiveness Research, USGS and PSU

Status: Ongoing, have data

Years of Actual Data: One

Lead Scientists: Jim Peterson (USGS) and Curt Peterson (PSU)

Description: (The following description is from http://wfrc.usgs.gov/research/aquatic%20ecology/STPetersen3.htm.) At this time, three cores from the Columbia River estuary have been aged and analyzed. Aging suggests that the deepest sediments in the cores were laid down during the early 1900's, with fairly steady sedimentation through the last century. We have detected significant patterns of change through time in the algal pigments, diatom community, and in heavy metal concentrations.

Publications: Peterson et al. (2003)

Application to estuary RME: This project provides data on geology/soils for the habitat inventory indicator and data on many monitored attributes of the indicator on physical condition.

P14 Evaluation of Migration and Survival of Juvenile Steelhead and Fall Chinook Following Transportation

Header: Uncertainties Research, TPE-W-00-01, COE, OSU

Status: Ongoing, have data

Years of Actual Data: Four, 2000-2003

Lead Scientists: Carl Schreck, Shaun Clements, David Jepsen, and Mark Karnowski (OSU)

Description: (modified from abstracts for the AFEP Annual Review, November 2003, http://www.nww.usace.army.mil/planning/ep/fishres/AFEPREVIEW/) The goal of this study was to obtain information concerning how the fish transportation program can be managed to minimize juvenile steelhead mortality in the Lower Columbia River and estuary. We used both radio and acoustic telemetry to compare fish that were transported around several Snake and Columbia River hydroelectric facilities (barged fish) and fish that were migrating through the hydrosystem (run-of-river fish, ROR). Specific objectives for radio-telemetry were: 1) to document the spatial/temporal migration patterns of transported and ROR migrating steelhead and subyearling chinook salmon into and through the estuarine environment, 2) to determine whether transportation influences in-river migration success, relative to ROR fish, and 3) to determine whether barged fish had greater predation by piscivorous birds in the lower estuary. Specific objectives for acoustic telemetry were to 1) estimate in-river migration success and compare it to estimates based on radio-telemetry, 2) estimate mortality within different zones of the estuary, and 3) document movement patterns in the lower estuary and near-shore ocean. *Steelhead* -- On twelve dates during the steelhead out-migration, we surgically implanted either radio or acoustic transmitters into fish that were collected and barged from Lower Granite Dam (LGR hatchery and wild steelhead), and into fish that were collected from the Bonneville Dam juvenile migrant facility (ROR hatchery steelhead). Fish were liberated as 12 release-cohorts, with one group of barged and one group of ROR fish released simultaneously below Bonneville Dam. Fifteen fixed radio receiver sites were used to estimate in-river migration speed, proportion of fish migrating to the estuary, and mortality due to piscivorous birds. To document fine-scale movement patterns relative to tides within the estuary, radiotelemetered fish were tracked by boats. The acoustically tagged fish were monitored with up to 104 buoyreceiver systems, most of which were deployed in four main arrays (sets of multiple buoy-receiver systems): Jim Crow Point array (RKm 46); Astoria Bridge array (RKm 22); Sand Island array (RKm 7); and the ocean array (mouth of the Columbia River; RKm 0 to –5). Additional systems were deployed in specific areas to provide insight on migration patterns. The acoustic data provided an estimate of total mortality (not just that arising from the birds), mortality in different areas of the estuary, and proportion of fish reaching the ocean. The acoustically tagged juvenile steelhead migrated 180-187 kilometers downstream to the Jim Crow Point array (defined as the upper estuary limit) in 37 - 403 hours. Median swimming speed for pooled releases of barged fish was 3.5 km/h (0.4 – 4.8 km/h) and 3.4 km/h (1.3 – 4.6 km/h) for ROR fish. Median swimming speeds to this same location for fish implanted with radio transmitters were similar (barged fish: 3.8 km/h (0.4 – 4.5 km/h), ROR fish: 3.3 km/h (0.2 – 4.5 km/h). The proportion of fish that reached the upper estuary (near Jim Crow Point) was evaluated. Of the total number of acoustic tagged fish that were released, at least 82% (pooled releases, range 48-92%) of the barged steelhead successfully migrated to the estuary, while 69% (pooled releases, range 44-92%) of the ROR fish were successful. Of the total number of radio tagged fish released, at least 90% (pooled releases, range 80-100%) of the barged steelhead successfully migrated to the estuary, while 67% (pooled releases, range 47-87%) of the ROR fish were successful. Migration times through the estuary (~47 km) for acoustically tagged fish ranged from 12–78 h. Median travel time was 19 h for both barged and ROR fish. The additional receivers in the upper estuary showed a higher percentage of fish using smaller backwater channels than expected. Individual radio tagged fish were tracked with boats in the estuary. Analysis of this data showed that the fastest speeds in the estuary were obtained during an outgoing tide and the slowest during an incoming or the slack period after an incoming tide. The average movement during an incoming tide was still directed downstream unlike fall Chinook, which had an average upstream movement. In general, fish used one of three main routes when passing under the Astoria-Megler Bridge: they either crossed over to the Washington channel at some point in the upper estuary and remained in this channel; used a small channel that crossed approximately in the middle of the bridge; or stayed in the shipping channel on the Oregon side of the estuary. If the acoustic releases are pooled, 31% of barged fish and 38% of ROR fish used the Washington channel, 19% of barged fish and 28% of ROR fish used the middle channel, and 50% of barged fish and 34% of ROR fish used the Oregon channel. As in 2002, the later detection of these fish on the ocean array suggests that fish using the Washington channel had lowest survival in the lower estuary. Of all steelhead reaching the estuary, 20% were detected on piscivorous bird colonies, with 21% and 20% of ROR and barged fish, respectively, detected on the colonies. The numbers of fish detected on the upper estuary acoustic array (near Rkm 46) but not on the ocean array may represent a maximum estimate of mortality in the estuary or near-shore ocean environment. The maximum estimate of mortality in the area from the upper estuary array to the ocean was 43% (pooled releases, range 26-74%) of barged fish and 54% (pooled releases, range 40-67%) of ROR fish. Further analysis shows that the majority of this mortality occurs in the lower estuary (defined as the area from the Astoria Bridge, Rkm 22, to the ocean array) for both groups of fish. The acoustic data was examined to determine the proportion of fish reaching the ocean. Of the total numbers released, at least 47% (pooled releases, range 12-68%) of the barged steelhead successfully migrated to the ocean, while 32% (pooled releases, range 18-57%) of the ROR fish were successful.

Subyearling Chinook -- On six dates during the sub-yearling chinook out-migration, we surgically implanted radio transmitters into fish that were collected and barged from Lower Granite Dam (LGR fish), and into fish that were collected from the Bonneville Dam juvenile migrant facility (ROR fish). Fish were liberated as 6 releasecohorts, with one group of barged and one group of ROR fish released simultaneously below Bonneville Dam. Fifteen fixed radio receiver sites were used to estimate in-river migration speed, the proportion of fish migrating to the estuary, and mortality due to piscivorous birds. To document fine-scale movement patterns relative to tides within the estuary, fish were also tracked by boats. Following release, fish migrated to a river/estuary (transition) site at river kilometer 89.4 in 29.7-540.2 h, at a median rate of 2.7 km/h (range 0.3–4.8km/h). Median swimming speed for pooled releases of barged fish was 3.1 km/h (range 0.5-4.0 km/h) and 2.7 km/h (range 0.3-4.8 km/h) for ROR fish. The proportion of fish that migrated to the estuary was evaluated. Of the total number of fish released, at least 37.9% (pooled releases, range 4.4-73.3%) of barged fish migrated to the estuary, while 66.7% (pooled releases, range 29.4-86.7%) of ROR fish migrated to the estuary. Analysis of fish tracked by boats in the estuary indicated that fish migrated seaward faster on outgoing tides, and moved slower or, in contrast to the steelhead, reversed directions on incoming tides. Of all sub-yearling chinook reaching the estuary 5% were detected on piscivorous bird colonies, with 4% and 7% of barged and ROR fish respectively detected on the colonies.

Publications: Schreck and Stahl (2000).

Application to estuary RME: This project provides data on yearling fish from the Snake basin tagged with radio or acoustic transmitters. These data are applicable to the performance indicator on spatial distribution.

P15 Evaluation of the Relationship Among Time of Ocean Entry, Physical, and Biological Characteristics of the Estuary and Plume Environment and Adult Return Rates

Header: Uncertainties Research, EST-02-03, COE, NOAA/NWFSC

Status: Ongoing, no data yet

Years of Actual Data: None, waiting for adult returns.

Lead Scientists: Bill Muir and Bob Emmett (NOAA)

Description: (Abstract from the AFEP Annual Review, November 2003, http://www.nww.usace.army.mil/planning/ep/fishres/AFEPREVIEW/) This study examines the relationship among time of juvenile salmon ocean entry, physical and biological characteristics of the estuary and nearshore ocean plume environment, and smolt-to-adult return rates (SARs) for spring chinook salmon reared by the Clatsop Economic Development Committee Fisheries Project (CEDC) in the lower Columbia River. We will use regression analysis to compare smolt-to-adult return rates for serially released groups of coded-wire tagged spring chinook salmon with information collected from ongoing studies funded by the Bonneville Power Administration and others characterizing the physical and biological conditions of the estuary and plume environment. By enhancing our understanding of the linkages between ocean entry and the physical and biological estuarine and ocean conditions smolts encounter, transportation and hatchery release dates could be manipulated, possibly leading to higher SARs. During 2003, the second year of releases, 6 groups of spring chinook salmon were transferred from Willamette Hatchery to net pens in Blind Slough in the Columbia River estuary, reared for 14 days and released at 10 day intervals from 9 April through 27 May. Size and smolt development (gill Na+-K+ATPase activity) were similar among groups. Coded-wire tags will be recovered beginning in 2004 from 2002 releases and 2005 from 2003 releases.

Publications: Unknown.

Application to estuary RME: This project addresses the performance indicator on survival.

P16 A Study to Estimate Salmonid Survival through the Columbia River Estuary Using Acoustic Tags

Header: Uncertainties Research, EST-02-01, COE, NOAA/NWFSC and PNNL

Status: Ongoing, no data yet

Years of Actual Data: None, started project in 2002 with first survival estimation scheduled for 2005

Lead Scientists: Lynn McComas and John Ferguson (NOAA) and Tom Carlson (PNNL)

Description: (Abstract from the AFEP Annual Review, November 2003, http://www.nww.usace.army.mil/planning/ep/fishres/AFEPREVIEW/) This multi-year project is directed toward assessing feasibility, development, and use of miniaturized acoustic tags and dedicated detection arrays to determine salmonid smolt survival through the Columbia River and estuary below Bonneville Dam, based on the single release statistical model. The work is being completed in three phases. Feasibility and initial design parameters were appraised during the first phase, prototype testing is being evaluated during the second phase, and full implementation during the final phase. Over this third year of the study, efforts focused on factors affecting reception range of the prototype acoustic tag, biological evaluation of the tag, and prototype detection array deployment and survival demonstrations. Two studies were completed to determine causes for the restricted-range limitation observed during early testing. Initial compatibility testing between the acoustic tag and detection array indicated a code discrimination range of less than 128 m (425 ft), and a consistent code discrimination (minimum) range of only 68 m (160 ft). Data collected over two 4-day periods of continuous operation refined maximum range to approximately 150 m (500 ft), and minimum range to 90 m (300 ft). Environmental effects were not generally correlated to discrimination potential. However, range appeared to increase in the presence of small, wind-induced wavelets on the water surface. A separate evaluation determined that the signal was multipath-susceptible at ranges over approximately 90 m. A probable cause for the multipath effect is surface reflected secondary signal impingement on direct-path reception. Small surface waves effectively redirect these reflected signals, resulting in increased discrimination range. Based on these estimates, 24 nodes will be needed to sample the proposed primary array transect from West Sand Island to Clatsop Spit, when the cabled-array is deployed in the Columbia River mouth. Prototype micro-acoustic tags were implanted in hatchery reared subyearling chinook salmon to assess the biological impacts of the tag. The study encompassed growth and survival over the 30-day design life of the tag and post-tagging swimming behavior and susceptibility to predation. Each evaluation was composed of three treatments comprised of tagged individuals (acoustic transmitters implanted), sham-tagged fish (surgery without tag), and control fish (handling only). Statistical analyses of these data are currently ongoing. Growth and survival were evaluated using 100 fish per group. At the beginning of the evaluation period, the three groups were similar in length (F = 1.53, df = 2, P = 0.22) and weight (F = 1.57, df = 2, P = 0.21). All three groups were reared together in a raceway for 30 days following the surgical procedure. Preliminary analysis indicated a significant difference in length (F = 6.33, df = 2, P = 0.00) and weight (F = 5.37, df = 2, P = 0.01) growth at the close of the evaluation. The affect of the miro-acoustic tag on swimming behavior was assessed over 25 replicates involving simultaneous observations of three fish (one fish from each treatment) in separate aquaria. Preliminary results suggest that there were no differences in time spent at specific depths within the water column among the treatments 24 hours after tagging and handling. Test individuals from the three treatments made similar numbers of trips to the surface, and exhibited similar active swimming behavior. Predation vulnerability was assessed during 24-hour replicates using 9 juvenile chinook salmon prey (3 from each treatment) and one bass predator per replicate. Prey were allowed 24 hours to recover from handling and surgery immediately prior to a replicate. Predators were acclimated to holding facilities for 2 to 3 weeks and trained to feed on juvenile salmon before being used in a replicate. Predators were used in only one replicate and were sacrificed immediately after the trial. Over 11 replicates, 4 control fish were ingested, compared to 6 sham tagged and 7 tagged fish. The final phase of field testing in 2003 is a survival demonstration for a three-node, bottom-mounted cabled array, due for deployment in December. The demonstration will use one functional and two 'dummy' nodes connected sequentially to assess system integrity, geodetic anchoring stability, and range evaluation in the estuary environment over a minimum 2-week period. Planning and anchor fabrication for the deployment are ongoing.

Publications: Unknown.

Application to estuary RME: This project will be the primary means to obtain survival rates for subyearling Chinook salmon in the reach from Bonneville Dam to the mouth of the Columbia River. Thus, this project addresses the survival indicator.

P17 Blind Slough Restoration Project - Brownsmead, Oregon

Header: Action Effectiveness Research, 2003-015-00, BPA, CREST

Status: New start, no data yet

Years of Actual Data: None yet

Lead Scientist: Alan Whiting (CREST)

Description: (Abstract from FY03 proposal, see Proposal 200301500 under the Columbia Estuary Province at http://www.cbfwa.org/) The project restores tidal exchange between the Columbia River Estuary and Blind Slough in the community of Brownsmead, Oregon. BPA funding will provide 25% cost share for Section 1135 of the Army Corps of Engineers environmental restoration program to partially underwrite the cost of project implementation, planning, engineering, and design. BPA funds will also be used to develop and implement an effectiveness monitoring program for the project. The Columbia River Estuary Study Taskforce (CREST), Clatsop Diking Improvement Company No. 7, and the Army Corps have prioritized the following array of activities to restore Blind Slough: installation of water control structures to breach the Blind Slough dike, replacement and/or installation of five (5) constricted culverts, and channel enhancement. The goal of these activities is to restore historic hydrologic and bio-physical connection to the Columbia River Estuary. Restoration of Blind Slough enhances water quality and reconnects seven (7) miles of habitat for aquatic species including migrating salmonids. Funds will provide 25% of construction costs during the project implementation phase, as well as engineering, planning and required environmental feasibility studies. In addition, funds are used to develop an effectiveness monitoring program that partners Clatsop Diking Improvement Company No. 7, CREST, the Nicolai-Wickiup Watershed Council, and volunteer landowners from the Brownsmead area. The monitoring activities assist in testing scientific assumptions developed about reconnecting diked tidelands to the estuarine tidal prism. These assumptions were identified in part by the success of previous restoration projects implemented in the Brownmead area which demonstrated water quality improvements and increased fish access to tidal wetland habitat. Through the development of a comprehensive effectiveness monitoring program, information on water quality improvements and increased fish use of the Blind Slough will be compiled and applied to future restoration projects.

Publications: n/a

Application to estuary RME: This project entails action effectiveness research for a restoration project. As such, it may collect data on life history diversity, spatial distribution, growth, survival, water quality, and physical condition.

P18 Effectiveness Monitoring of the Chinook River Estuary Restoration Project

Header: Action Effectiveness Research, 2003-006-00, BPA, Sea Resources

Status: New start, no data yet

Years of Actual Data: Started in 2003

Lead Scientists: Robert Warren (Sea Resources)

Description: (Abstract from FY03 proposal, see Proposal 200300600 under the Columbia Estuary Province at http://www.cbfwa.org/) Certain estuarine habitat types are recognized as important rearing and staging areas for some salmonid species – especially those that exhibit ocean-type life history patterns. Over the past 150 years, the Columbia River estuary has suffered considerable loss of these critical habitat types due to a variety of development activities. It is possible that restoration of these estuarine habitat types will aid in the recovery of some endangered Columbia River salmon stocks. However, since little is known about the ecological importance of the estuary for Columbia River salmon, current restoration plans in the estuary are based on inferences from studies in other watersheds. Therefore, it is important that any early restoration projects in the Columbia River estuary be carefully monitored in order to evaluate salmon responses to estuary restoration. The Chinook River estuary restoration project offers an excellent opportunity to answer some of the uncertainties regarding estuary restoration and salmon recovery. The project described in this proposal will design and implement a long-term monitoring and evaluation plan to investigate salmon responses to the Chinook River estuary restoration project. We will establish a pre-restoration baseline condition of existing estuary use by juvenile salmon as well as monitor certain habitat attributes. We will continue to monitor these parameters after the restoration project is completed in order complete pre and post project comparative analyses. We will use a variety of capture and marking techniques to determine abundance and length of residency of salmon in the Chinook River estuary. We will also implement a concurrent habitat monitoring component to measure specific habitat attributes by installing five data loggers for continuous monitoring of temperature, salinity, dissolved oxygen and tidal stage.

Publications: n/a

Application to estuary RME: This project entails action effectiveness research for a restoration project. As such, it may collect data on life history diversity, spatial distribution, growth, survival, water quality, and physical condition.

P19 Optimization of FCRPS impacts on Juvenile Salmonids: Restoration of Lower-Estuary and Plume Habitats

Header: Action Effectiveness Research, 2003-045-00, BPA, OHSU

Status: New start, no data yet

Years of Actual Data: None

Lead Scientists: David Jay and Antonio Baptista (OHSU)

Description: (Abstract from FY03 proposal, see Proposal 200304500 under the Columbia Estuary Province at **http://www.cbfwa.org/**) This project assembles a group of leading coastal scientists to tackle a complex, urgent problem, optimization of the interaction of the Federal Columbia River Power System (FCRPS) with the lower Columbia River estuary and plume in support of endangered salmonids. The timing and magnitude of flows released by the FCRPS strongly affect juvenile salmonids as they move through the estuary and plume. Restoration of the properties of the lower estuary and plume that constitute habitat for juvenile salmonids requires advances on several fronts. We seek to: Objective 1: Define how the lower-estuary and plume interacted historically with coastal currents, how operation of the FCRPS has altered the lower-estuary and plume, and how climate change and the FCRPS will impact the system in coming decades. Objective 2: With Action Agencies, define needs and opportunities for science-based input to operational FCRPS management practices, given uncertain climate and coastal circulation forecasts. Objective 3: With FCRPS managers, define management scenarios: a) that are based on physical understanding, b) that can be evaluated in terms of habitat opportunity and other constraints on the system, and c) whose implementation can lead to a qualitative *improvement in survival* of juvenile salmonids. Innovative oceanographic methods, remote sensing, management science and analyses of numerical model results will be used to achieve the goals of the project, as it moves from research toward provision of definite strategies over the next 6 to 10 years. A Project Advisory Board (PAB) that includes Action Agency personnel, FCRPS managers and external scientists will be formed to help ensure productive application of the insights achieved. Tight cooperation with work carried out in the estuary and plume by the National Marine Fisheries Service (NMFS) will be facilitated by participation of PIs in this project as well as in two projects proposed by NMFS.

Publications: n/a

Application to estuary RME: This project involves a hydrographic model that can be used to address some of the monitored attributes under the performance indicators on habitat inventory and physical condition.

P20 Preserve and Restore CRE Islands to Enhance Juvenile Salmonid and Columbia Deer Habitat

Header: Action Effectiveness Research, 2003-0008-00, COE, USFWS/CLT/USGS

Status: New start, no data yet

Years of Actual Data: Started in 2003

Lead Scientists: Alan Clark (USFWS)

Description: (Abstract from FY03 proposal, see Proposal 200300800 under the Columbia Estuary Province at http://www.cbfwa.org/) This project would acquire and restore 626 acres of tidal emergent marsh, swamp, slough, and riparian forest habitat on islands in the upper Columbia River Estuary to benefit fish and wildlife. This is a cooperative effort between BPA, USFWS, Columbia Land Trust, USGS, Corps of Engineers, WDFW, and ODFW. The Columbia Land Trust would acquire 426 acres on Crims Island and 109 acres on Walker Island. USFWS would acquire an additional 90 acres on Crims Island. At Crims Island, the Corps of Engineers would provide funding through Section 1135 of the Clean Water Act to enhance 75 acres of tidal emergent marsh by excavating canary grass wetland and connecting subtidal channels to the mainstem Columbia. In addition, tidal flow would be reestablished to 100 acres of wooded swamp by excavating a man-made plug in a channel and 100 acres of riparian forest would be reestablished on upland areas of the island. These actions would provide productive rearing and foraging habitat for juvenile salmon and increase the export of detrital nutrients to the estuary. A monitoring program would be initiated to measure the response of fish, especially juvenile salmon, and vegetation to these enhancements. Approximately 150 acres of existing tidal emergent marsh on Crims and Walker Islands would be restored by controlling invasive exotic plants, principally purple loosestrife and reed canarygrass. Columbian white-tailed deer would be reintroduced to these and nearby islands to restore this native species to the upper estuary. This action would establish a new subpopulation of the deer on secure habitat to meet the goals of the Columbian White-tailed Deer Recovery Plan. Funding for the reintroduction would be shared between BPA, USFWS, WDFW, and ODFW.

Publications: n/a

Application to estuary RME: This project entails action effectiveness research for a restoration project. As such, it may collect data on life history diversity, spatial distribution, growth, survival, water quality, and physical condition.

P21 Crims Is. Baseline Fisheries Survey [[Blaine]]

Header: Action Effectiveness Research, COE, USGS

Status: New start, no data yet

Years of Actual Data: Started in 2003

Lead Scientists:

Description:

Publications:

Application to estuary RME:

P22 Implement the Habitat Restoration Program for the Lower Columbia River and Eestuary

Header: Status Monitoring, 2003-011-00, BPA, Estuary Partnership

Status: New start, no data yet

Years of Actual Data: Started in 2003

Lead Scientists: Deborah Marriott and Scott McEwen (Estuary Partnership)

Description: (Abstract from FY03 proposal, see Proposal 200301100 under the Columbia Estuary Province at http://www.cbfwa.org/) Restoration of habitat for juvenile salmonids migrating through the Lower Columbia River (below Bonneville Dam) and the Columbia Estuary is an important component of regional recovery plans. The lower river and estuary are critical areas in the migration corridor for Columbia Basin anadromous fish, especially ocean-type listed as Threatened or Endangered, because they provide refugia from predators, feeding grounds, and areas to transition physiologically from freshwater to saltwater. However, over the last 100 years, the amount of available wetland habitat in this region has decreased by about 75% over historical levels because of dike and levee building, hydrosystem operations, and other activities. Efforts to protect existing habitat and restore altered habitat have been initiated and a long-term action plan developed. The work to be accomplished under this project will continue to institutionalize this effort as it implements the habitat restoration program for the long term and takes action on beneficial, already-scrutinized habitat restoration projects in the short term (three years). The outcome of this project will be increased survival of juvenile salmonids.

Publications: n/a

Application to estuary RME: This project carries out habitat restoration projects in the estuary below Bonneville Dam. An infrastructure is being established to identify projects, prioritize them, obtain funding (BPA in this case), perform site-specific design work, and implement restoration actions. This project is included in estuary RME because it is anticipated that the Estuary Partnership will keep a tally of the amount of land restored, which is one of the monitored variables in the ecosystem status indicator.

P23 Lower Columbia River and Columbia River Estuary Ecosystem Monitoring

Header: Status Monitoring, 2003-007-00, BPA, Estuary Partnership

Status: New start, no data yet

Years of Actual Data: Scheduled to start in 2004

Lead Scientists: Deborah Marriott and Scott McEwen (Estuary Partnership) with subcontractors Thom and Johnson (PNNL), Counihan, Fuhrer, and Waite (USGS), and Simenstad (UW)

Description: (Abstract from FY03 proposal, see Proposal 200300700 under the Columbia Estuary Province at http://www.cbfwa.org/) Our ability to understand the relationship of sensitive organisms such as salmonids to the Lower Columbia River and Columbia River Estuary ecosystem is greatly hindered by major data gaps and poor access to existing data. The Lower Columbia River Estuary Partnership proposes to implement elements of its Aquatic Ecosystem Monitoring and Data Management Strategy to address habitat and toxics monitoring needs, and data management. The proposal addresses RPAs 161, 163, and 198. A pilot habitat monitoring program will be implemented to develop protocols, procedures, and indicators for measuring habitat condition for both long term habitat monitoring and restoration project M and E requirements. It will focus specifically on habitats important for juvenile salmonids. A technical team will develop the methods, critique and test the methods, assess the results, and recommend future work. Based on the results, a long term habitat monitoring program will be implemented. Additionally, a toxic contaminant monitoring project will be implemented to address issues such as the accumulation of toxic contaminants in sensitive habitat areas, contaminant trends over time, and possible impacts on sensitive species. Toxic contaminant concentrations in fish and macroinvertebrate tissues, sediments and the water column will be determined. A technical team will assess the results and recommend future work. Based on the results, a long term toxics monitoring program will be implemented.

Publications: n/a

Application to estuary RME: This project should make a significant contribution to status monitoring in the estuary for the indicators on life history diversity, spatial distribution, and water quality.

P24 Additional Monitoring of Habitat Usage by Juvenile Salmon as Mandated by the Channel Improvements Biological Opinion

Header: Status Monitoring, COE, NOAA/NWFSC

Status: New start, no data yet

Years of Actual Data: Scheduled to start in 2004

Lead Scientists: Dan Bottom, Ed Casillas, and Curtis Roegner (NOAA)

Description: The Biological Opinion (BiOp) on Channel Improvements by NOAA Fisheries (May 2002) requires the COE to add two supplemental monitoring transects to the NOAA Fisheries effort. One transect spans the estuary from Cathlamet Bay to Grays Bay (Figure 1). The other is the freshwater, tidal portion of the lower river, about 5 miles upstream of Puget Island (Figure 2). The stated justification (BiOp p. 27) is to “Provide additional habitat and salmonid distribution information for the estuary …[u]seful in establishing inventory information for future monitoring or restoration.” The monitoring would start before channel improvement construction activities and extend for three years after completion of the project. Data analysis would focus on the value and use of different habitat types for juvenile salmonids.

Publications: n/a

Application to estuary RME: This project would supplement status monitoring being conducted under project no. P12.

P25 Historic Habitat Opportunities and Food-Web Linkages of Juvenile Salmon in the Columbia River Estuary: Implications for Managing Flows and Restoration

Header: Uncertainties Research, 2003-010-00, BPA, NOAA/NWFSC

Status: New start, no data yet

Years of Actual Data: Started in 2003 with first field season scheduled for 2004

Lead Scientists: Antonio Baptista and David Jay (OHSU), Dan Bottom, Edmundo Casillas, and Curtis Roegner (NOAA), and Charles Simenstad (UW)

Description: (Abstract from FY03 proposal, see Proposal 200301000 under the Columbia Estuary Province at http://www.cbfwa.org/) The Columbia River estuary serves as an important migration, rearing, and transition environment for juvenile anadromous salmon before they enter the sea. Historical modifications to the estuary, including diking of peripheral wetland and floodplain habitats and regulation of river flows by dams, have reduced salmonid access to shallow rearing habitats and may have eliminated sources of macrodetritus that fuel the estuary's food webs. Although there is emerging evidence that these estuarine changes are limiting juvenile salmon production and life history diversity, lack of information about historic and modern habitat conditions in the estuary, or the ecological consequences of habitat change, undermine existing salmon recovery efforts of the Columbia Basin Fish and Wildlife Program. This proposal addresses specific information needs identified in a recent interdisciplinary assessment of the hydroelectric system's impacts on estuarine habitat conditions for juvenile salmon. The primary elements of this proposal include: (1) retrospective analyses to reconstruct historic bathymetric features and assess effects of climate and river flow on the extent and distribution of shallow water, wetland and tidal-floodplain habitats; (2) computer simulations using a 3-dimensional numerical model to evaluate the sensitivity of salmon rearing opportunities to various historical modifications affecting the estuary (including channel changes, flow regulation, and diking of tidal wetlands and floodplains); and (3) life-history specific information based on present and historic food web sources as determined by stable isotope, microchemistry, and parasitology techniques. From these data and additional modeling simulations that will be selected during an estuarine habitat restoration workshop, we will (4) examine effects of alternative flow-management and habitat-recovery scenarios on habitat opportunity and the estuary's productive capacity for juvenile salmon.

Publications: n/a

Application to estuary RME: This project addresses many of the uncertainties (Section 2.4).

P26 Evaluation of Cumulative Ecosystem Response to Restoration

Header: Action Effectiveness Research, EST-04-NEW, COE, TBD

Status: New start, no data yet

Years of Actual Data: Started in 2004

Lead Scientists: Thom (PNNL) and Roegner (NOAA)

Description: (Summary from proposal dated December 2003, submitted to the COE Portland District) The goal of this study is to develop standardized techniques and protocols that will facilitate evaluation of the performance of salmon habitat restoration actions and support the decision-making process for said actions in the Columbia River Estuary (estuary) aimed at increasing population levels of listed Columbia Basin salmon. The management implications of this research are two-fold. It will provide techniques (1) to obtain data to compare project results in order to support decisions regarding what projects to pursue for restoration of the ecosystem, and (2) to evaluate the ecological performance of the collective habitat restoration effort in the estuary and its effects on listed salmon.

The objectives of this study are to: 1) Develop standard monitoring protocols and methods to prioritize monitoring activities that can be applied to estuary habitat restoration activities for listed salmon. 2) Develop the empirical basis for a cumulative assessment methodology, together with a set of metrics and a model depicting the cumulative effects of estuary restoration projects on key major ecosystem functions supporting listed salmon. 3) Design and implement field evaluations of the cumulative effects of restoration projects using standard methods, and sensors or remotely operated technologies, to measure the effects on listed salmon through ecosystem response. 4) Develop an adaptive management system including data management and dissemination to support decisions by the Corps of Engineers and others regarding estuary habitat restoration activities intended to increase population levels of listed salmon.

The recommended methods combine state-of-the-science synthesis, innovative indicator development and field-testing, and the creation and implementation of ecosystem-specific monitoring protocols and data management systems to produce annual estimates of ecosystem and listed-salmon responses to cumulative restoration actions. Future management actions will be supported by a robust adaptive management decision framework. Theory on cumulative impact assessment will be applied in reverse to assess what cumulative gains to the ecosystem and selected resources (e.g., listed salmon) are achieved by the multiple restoration projects planned in the estuary. The adaptive management system will be designed to incorporate project-specific, salmon-specific, and ecosystem measures and efficiently integrate existing and planned monitoring efforts. Self-maintenance and accessibility to stakeholders, Federal Columbia River Power System managers, restoration managers and the interested public will be key attributes of data and reporting systems, in order to facilitate communications and partnerships, negotiations, and management decision making.

Publications: n/a

Application to estuary RME: This project is designed to address uncertainties in the knowledge base for the estuary.

P27 Evaluation of Habitat Restoration Opportunities in the Lower Grays River

Header: Action Effectiveness Research, COE, PNNL and WDFW

Status: Proposed

Years of Actual Data: n/a

Lead Scientists: David Geist (PNNL) and Joe Hymer (WDFW)

Description: (Excerpt from a proposal dated November 2003 by PNNL to COE Portland District.) There may be opportunities to restore tidal wetlands and other key habitats within the lower Grays River. Restoration of these habitats would improve conditions for the four species of anadromous salmonids that utilize the Grays River, and go toward increasing the amount of tidal wetland habitat consistent with the requirements of the Biological Opinion. The Bonneville Power Administration (BPA) is funding a watershed assessment within the Grays River sub-basin (Project 2003-013-00). The watershed assessment will be conducted by the Pacific States Marine Fisheries Commission (PSFMC) and the Pacific Northwest National Laboratory (PNNL). The goals of the BPA study and the study proposed here are the same: enhance and restore the ecological integrity and ecosystem function of the Grays River watershed. The objectives of the BPA study are specific to chum salmon spawning and are geographically restricted to the drainage above approximately rivermile 12. The objectives of the study proposed here are to (1) perform a comprehensive watershed and biological analysis, including hydrologic, geomorphic and ecological assessment; and (2) develop a prioritized list of actions that might be taken to protect and restore ecosystem structure and function to the lower Grays River based on comprehensive geomorphic, hydrologic, and stream channel assessments. This statement of work identifies tasks to be completed during FY2004 that will be used to support decision making about ecosystem restoration projects in the lower Grays River. The work is broken into a set of initial tasks focused in the lower river (primarily) where hydrologic and hydraulic simulation models will be developed, the geomorphology will be characterized, and salmon habitat will be assessed (Phase I). After this initial phase, identification and prioritization of possible restoration projects will be accomplished (Phase II).

Publications: n/a

Application to estuary RME: This project involves the indicators on habitat inventory and connectivity.

P28 Subtidal Habitat Mapping Using Multibeam Sonar

Header: Status Monitoring, NOAA, UI

Status: In preparation

Years of Actual Data: n/a

Lead Scientists:

Description:

Publications: n/a

Application to estuary RME: This project involves the indicators on habitat conditions.

P29 LIDAR Survey of the Columbia River Estuary

Header: Status Monitoring, USGS, USGS

Status: In preparation

Years of Actual Data: n/a

Lead Scientists:)

Description:

Publications: n/a

Application to estuary RME: This project involves the indicators on habitat conditions.