Columbia Estuary Ecosystem Restoration Program

2013 STRATEGY REPORT

DRAFT

Prepared by the Bonneville Power Administration and U.S. Army Corps of Engineers, Portland District

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Preface

The 2013 Strategy Report was developed by the Bonneville Power Administration (BPA) and U.S. Army Corps of Engineers, Portland District (Corps) by updating the 2012 Strategy Report with new knowledge provided in the recently released the 2012 Synthesis Memorandum and other program development activities. The BPA/Corps take full responsibility for the report's content.

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Executive Summary

The 2013 Strategy Report for the Columbia Estuary Ecosystem Restoration Program (CEERP) was produced by the Bonneville Power Administration (BPA) and U.S. Army Corps of Engineers, Portland District (Corps) to establish the strategic, scientific basis for the ecosystem restoration and associated research, monitoring, and evaluation (RME) that they are funding in the lower Columbia River and estuary (LCRE) during 2013. The overall goal of the CEERP is to understand, conserve, and restore ecosystems in the LCRE. The program's objectives are to 1) increase the capacity and quality of estuarine and tidal-fluvial ecosystems,[1] 2) increase the opportunity for access by aquatic organisms to shallow-water habitats,[2] 3) improve ecosystem realized functions[3]. Primary approaches to restoration are to restore hydrologic connections between main stem and floodplain, create and/or enhance shallow-water habitat, and reestablish native vegetation.

The CEERP's three main drivers are the following:

- Northwest Power and Conservation Council (Council) Fish and Wildlife Program − the Council's program has strategies for estuary habitat reconnections, long-term effectiveness monitoring, estimation of juvenile salmon survival rates, impacts from estuary stressors, and partnerships.
- Water Resources Development Acts (Sections 206, 536, and 1135) and the Lower Columbia River Ecosystem Restoration General Investigations Study − the Corps has authorities to restore LCRE ecosystems under various federal laws.
- Biological Opinions for operation of the Federal Columbia River Power System − LCRE habitat restoration is an offsite mitigation action to help hydrosystem operations avoid jeopardizing Endangered Species Act (ESA)-listed salmonids.

The Strategy Report is one of three inter-related, annual CEERP deliverables; the others are the Action Plan and Synthesis Memorandum. The Strategy Report contains strategies for prioritizing andimplementing restoration and RME actions subsequently outlined in the companion Action Plan, the results of which are evaluated in the Synthesis Memorandum, which in turn is used adaptively in the next Strategy Report. The CEERP deliverables are intended to guide or inform, as appropriate, the Actions Agencies (BPA/Corps), the National Marine Fisheries Service, the Council, restoration project sponsors, researchers, and various interested parties.

The 12-month period for the CEERP deliverables is a calendar year (CY) and started with CY 2012. The 2012 Synthesis Memorandum, a comprehensive compilation of science to date concerning juvenile salmon ecology and ecosystem restoration in the LCRE, was released in August 2012. The 2012 Synthesis Memorandum feeds the 2013 Strategy Report and 2013 Action Plan, due in October 2012 to

[1] Habitat capacity/quality is a habitat assessment metric involving "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality" (cf. Simenstad and Cordell 2000).

[2] Habitat access/opportunity is a habitat assessment metric that appraises the capability of juvenile salmon to access and benefit from the habitat's capacity" (cf. Simenstad and Cordell 2000).

[3] Realized function is 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" (cf. Simenstad and Cordell 2000).

provide direction for CY 2013 activities. Within the CEERP's adaptive management process, the CEERP deliverables will be updated annually for applicability, transparency, and accountability.

The 2012 Synthesis Memorandum established that the CEERP knowledge base concerning juvenile salmon ecology and ecosystem restoration in the LCRE supports actions to restore shallow-water habitats, such as hydrologic reconnections and riparian and channel improvements. The prevailing finding is that juvenile salmon tend to use restored areas. Bioenergetics research has shown potential benefits to juvenile salmon growth in shallow tidal freshwater water areas. These types of habitats produce prey that are consumed onsite or are exported to the main stem of the Columbia River to be consumed there. Restored habitats can help increase habitat diversity, which is hypothesized to contribute to increased early life-history diversity in salmon and, thereby, salmon population resiliency. The existing knowledge base provides a science-based, strategic foundation for CEERP restoration and RME actions.

The BPA/Corps strategy for LCRE habitat restoration is to use an ecosystem-based landscape approach applying the best available ecological science for the CEERP. A formal adaptive management process is in place to implement the CEERP strategy through annual cycles of project development, prioritization, implementation, monitoring and research, and synthesis and evaluation, circling back to revisit the strategy. The strategy involves using existing processes, programs, technical groups, and plans to avoid redundancy and increase efficiency, such as those of the Corps' Anadromous Fish Evaluation Program and the Council's Fish and Wildlife Program. The Expert Regional Technical Group for estuary habitat restoration provides guidance for CEERP projects. For example, bigger area is better than smaller area; close to the main stem is better than farther away; restoring remnant channels is better than excavating new ones; natural processes are preferred over engineered processes; and a holistic perspective from a landscape scale is better than narrow, site-specific perspective. CEERP strategy is informed by supporting resources, including the Lower Columbia Estuary Partnership's characterization of disturbance regimes, habitat suitability modeling, landscape change analysis, and the LCRE ecosystem classification system.

The BPA/Corps strategy for RME is to determine restoration success through focused action effectiveness monitoring and research and to answer key questions regarding ecosystem functioning through ecosystem function monitoring and research. Both types of RME encompass work to monitor compliance and implementation of CEERP restoration actions; monitor status and trends of LCRE ecosystems supporting juvenile salmonids; research, monitor, and evaluate juvenile salmonid performance in the LCRE relative to environmental, physical, or biological performance objectives; research, monitor, and evaluate LCRE migration and habitat conditions that may be limiting achievement of biological performance objectives; determine the effectiveness of restoration actions; and investigate critical uncertainties related to the scientific relationships between habitat conditions, including restored sites, and the survival, growth, and condition of fish residing and migrating through the LCRE.

In addition to guiding CEERP restoration and RME efforts, the Strategy Report will be incorporated into the BPA/Corps 2013 Comprehensive Report and 2014−2018 Implementation Plan. This work will be responsive to the 2011 U.S. District Court ruling on BiOp implementation. By describing the fundamental strategy for implementing estuary habitat actions and RME, the 2013 Strategy Report is one component of the BPA/Corps response to the ruling. Also, the 2013 Strategy Report and the 2013 Action Plan address the Council's and Independent Scientific Review Panel's programmatic issues concerning the LCRE restoration effort, including provisions of the Council's 2009 Fish and Wildlife Program and

Recommendation 3 for monitoring and evaluating the effectiveness of habitat actions in the estuary from the Council's 2010 RME/Artificial Production Categorical Review.

In closing, the 2013 CEERP Strategy Report describes the BPA/Corps' fundamental strategy for estuary habitat actions and RME—apply an ecosystem-based approach to restore, enhance, or create ecosystem structures, processes, and functions in the estuary, and perform RME to assess the effectiveness of these actions, while building our understanding of ecosystem functions in the LCRE. The CEERP will use, as appropriate, information from projects funded outside of the CEERP for other purposes, such as predation, toxic materials, dredging, hydrosystem operations, and tributary habitat improvements, and other topics. The BPA/Corps intend for the CEERP to take advantage of lessons learned and knowledge gained from previous restoration and RME efforts in the LCRE and elsewhere to achieve a cost-effective and biologically effective ecosystem restoration program.

Acronyms and Abbreviations

AA	Action Agencies
AEMR	action effectiveness monitoring and research
AFEP	Anadromous Fish Evaluation Program
BiOp	Biological Opinion
BPA	Bonneville Power Administration
CEERP	Columbia Estuary Ecosystem Restoration Program
Corps	U.S. Army Corps of Engineers
Council	Northwest Power and Conservation Council
CREST	Columbia River Estuary Study Taskforce
CY	calendar year
EFMR	Ecosystem Function Monitoring and Research
EOS	Estuary/Ocean Subgroup
EP	Estuary Partnership (Lower Columbia Estuary Partnership)
ERTG	Expert Regional Technical Group
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
GIS	geographic information system
ISRP	Independent Scientific Review Panel
LCFRB	Lower Columbia Fish Recovery Board
LCRE	lower Columbia River and estuary
NMFS	National Marine Fisheries Service
RME	research, monitoring, and evaluation
SBU	survival benefit unit
SRWG	Studies Review Work Group
SWG	Science Work Group
TBD	to be developed
y	year(s)

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."

***conceptual ecosystem model* –** A graphical representation or a simple set of diagrams that illustrates a set of relationships among factors important to the function of an ecosystem or its subsystems (Busch and Trexler 2003).

***connectivity* –** See "habitat connectivity."

controlling factors – The basic physical and chemical conditions that construct and influence the structure of the ecosystem.

***control site* –** Locations with traits similar to the subject site prior to restoration. These sites are sampled over time to monitor any temporal shifts in baseline conditions and how the subject area might have responded over time had no restoration taken place.

***core indicators* –** A standard subset of the suite of possible indicators that is usually measured at sample locations (Roegner et al. 2009a). They must be relevant to the objective.

ecosystem – A community of organisms in a given area together with the 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 interactions among physicochemical and biological elements of an ecosystem that involve changes in character or state.

***ecosystem structure* –** Ecosystem structure is defined as the types, distributions, abundances, and physical attributes of the plant and animal species composing the ecosystem.

extensive monitoring – Monitoring of a few selected core indicators over a large spatial scale.

***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* or access –** 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).

***habitat usage* –** Measures of juvenile salmonid/habitat relationships in the estuary such as residence time, growth, and diet.

***indicator* –** A measurable parameter that characterizes an important aspect of the ecosystem and is sensitive to changes in the system.

intensive monitoring – Monitoring of many core and higher order indicators locally, i.e., over a small spatial scale.

Life-history diversity – Different spatial and temporal patterns of migration, habitat use, spawning, and rearing displayed within a population of Pacific salmon.

limiting factor – Physical, chemical, or biological features that impede species and their independent populations from reaching viability status.

monitoring – The systematic process of sampling design, collection, storage, and analysis of data related to a particular system at specific locations and times (Busch and Trexler 2003).

monitored indicator – See "indicator."

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

protocol – The standardized methodology to collect data for a monitoring indicator (Busch and Trexler 2003).

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).

reference site – Locations considered to be representative of the desired outcome of the restoration action. Reference sites are used to characterize the spatial heterogeneity of the target condition and any temporal shift in the target condition over time due to climate change, maturation, etc. This differs from a "control" site, which should be similar to the restored site before restoration.

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

sample − To collect data under a prescribed sampling design.

stream-type life history – General life-history pattern for salmon in which juveniles migrate to sea after 1 year of rearing in their natal stream system.

stressor – An entity or process that is external to the estuary or anthropogenic and that affects controlling factors on estuarine ecosystem structures or processes. A component of a conceptual model.

track − To access, assess, and summarize information made available by others.

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1.0 Introduction

This Strategy Report describes the Columbia Estuary Ecosystem Restoration Program's (CEERP's) science-based approach to restoring, enhancing, or creating ecosystem structures, processes, and functions in the lower Columbia River and estuary (LCRE)[1] (Figure 1)—especially those that support juvenile salmonid growth, fitness, and survival. The restoration strategy incorporates an ecosystem-based landscape approach using supporting resources to develop on-the-ground projects both opportunistically and strategically. The concurrent research, monitoring, and evaluation (RME) strategy is to determine action effectiveness and reduce uncertainty in ecosystem functioning. The 2013 Strategy Report is based on the 2012 Strategy Report (BPA/Corps 2012a), which fed the 2012 Action Plan (BPA/Corps 2012b). The purpose of report herein is to describe the strategies for CEERP ecosystem restoration actions and associated RME in tidally-influenced areas of the LCRE floodplain during CY 2013.

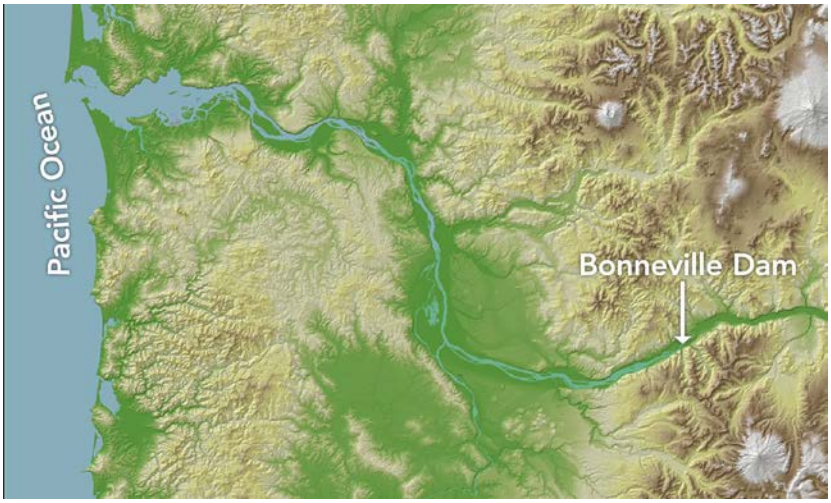


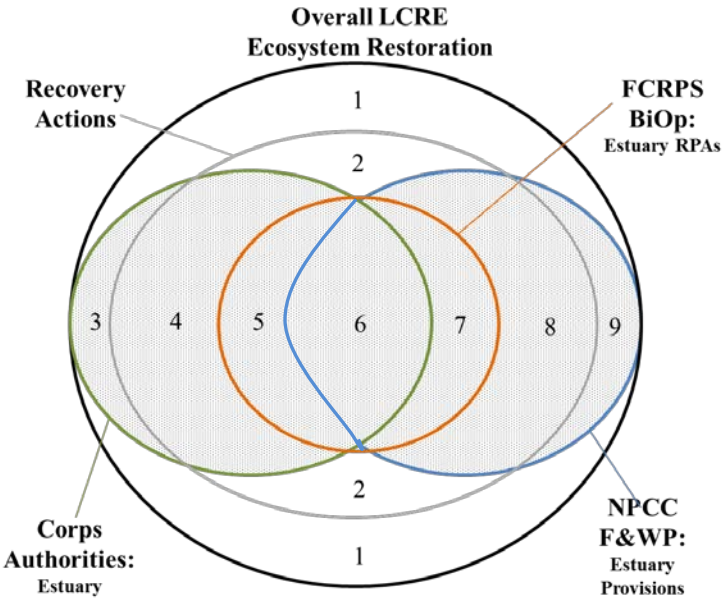
Figure 1. Map of Lower Columbia River and Estuary Study Area

The Bonneville Power Administration (BPA) and U.S. Army Corps of Engineers (Corps) jointly established the CEERP to implement ecosystem restoration actions and RME in the LCRE in response to various requirements, mandates, and authorities.[2] CEERP's overall goal is to understand, conserve, and restore ecosystems in the LCRE. The CEERP is an important ecosystem restoration program, but is not the only one in the LCRE (Figure 2). Other restoration efforts include those of the Oregon Department of Fish and Wildlife, the Oregon Watershed Enhancement Board, the Lower Columbia Fish Recovery Board, the National Oceanic and Atmospheric Administration Restoration Center, the Washington Department of Fish and Wildlife, and others. The Lower Columbia Estuary Partnership coordinates much of the overall LCRE ecosystem restoration effort (Figure 2), as described in "*A Guide to the Lower Columbia River Ecosystem Restoration Program*" (Estuary Partnership 2012). The CEERP's three main drivers are as follows:

[1] By definition, the LCRE includes tidally influenced areas of the floodplain from Bonneville Dam to the ocean.

[2] CEERP is an acronym coined in 2011 for the joint BPA/Corps efforts to restore LCRE ecosystems that started with the 2000 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) (NMFS 2000) and now is responsive to subsequent FCRPS BiOps, the Council's Fish and Wildlife Program, and various Corps restoration authorities.

1. Northwest Power and Conservation Council (Council) Fish and Wildlife Program (Council 2009) − the Council's program has strategies for estuary habitat reconnections, long-term effectiveness monitoring, estimation of juvenile salmon survival rates, impacts from estuary stressors, and partnerships.
2. Water Resources Development Acts (Sections 206, 536, and 1135) and the Lower Columbia River Ecosystem Restoration General Investigations Study − the Corps has authorities to restore LCRE ecosystems under various federal laws.
3. Biological Opinions (BiOps) for operation of the Federal Columbia River Power System (FCRPS) (NMFS 2000, 2004, 2008, 2010) − LCRE habitat restoration is an offsite mitigation action to help hydrosystem operations avoid jeopardizing ESA-listed salmonids.



Legend: LCRE restoration funded by…
1 = Entities besides the BPA and Corps for ecosystem restoration, e.g., CREST at Sharnelle Fee
2 = Entities besides the BPA and Corps for recovery actions for listed fish, e.g., LCFRB at Lower Washougal
3 = Corps outside BiOp and recovery, e.g., Johnson Creek springwater
4 = Corps outside BiOp, e.g., Tenasillahe Island
5 = Corps for BiOp, e.g., Post Office Lake
6 = BPA+Corps for BiOp, e.g., Col. Stock Ranch
7 = BPA for BiOp, e.g., Otter Point
8 = BPA outside BiOp, e.g., Duncan Creek
9 = BPA outside BiOp and recovery, e.g., Shillapoo wildlife mitigation

Figure 2. Nested Relationships Among CEERP Drivers and Overall LCRE Ecosystem Restoration. The shaded area represents the CEERP. CREST is the Columbia River Estuary Study Taskforce. LCFRB is the Lower Columbia Fish Recovery Board.

The CEERP is relevant to other programs and needs as well. For example, it is pertinent to recovery plans (LCFRB 2010; ODFW 2010; NMFS 2011) for salmon and steelhead species listed under the Endangered Species Act (ESA), because CEERP restoration actions are intended to benefit ESA-listed fish. CEERP work products (Strategy Report, Action Plan, and Synthesis Memorandum) will be important elements of the BPA/Corps implementation plans required by the 2011 U.S. District Court ruling (U.S. District Court 2011). The 2013 Strategy Report, in fact, will be one component of the response to address the Court's concern,[1] because the report describes the BPA/Corps fundamental strategy for implementing estuary habitat actions and RME. In addition, the CEERP is implementing the Council's RME/Artificial Production Categorical Review Recommendation Report's Recommendation 3 (ISRP 2010) to monitor and evaluate the effectiveness of habitat actions in the LCRE. Finally, the

[1] The Court was concerned about estuary habitat and RME actions and the plan for their implementation. These are described in detail in the 2012 Action Plan (BPA/Corps 2012b).

Council's and Independent Scientific Review Panel's (ISRP's) programmatic issues[1] concerning the LCRE restoration effort (Council 2011) are intended to be addressed by the 2012 and 2013 Strategy Reports, the 2012 and 2013 Action Plans, and the 2012 Synthesis Memorandum (Thom et al. 2012).

The 2013 CEERP Strategy Report has been informed by the Lower Columbia Subbasin Plan (Council 2005), previous synthesis and evaluation conducted in the FCRPS 2007 Biological Assessment and Comprehensive Analysis (Action Agencies 2007), the Council's 2009 Amendments (Council 2009), the ISRP's Final RME and Artificial Production Categorical Review Report (ISRP 2010), the National Marine Fisheries Service's (NMFS's) Estuary Module (NMFS 2011), and the Corps' Anadromous Fish Evaluation Program (AFEP) (Johnson et al. 2012a). The Strategy Report has four main sections after this introduction: CEERP Background, Synthesis and Evaluation Summary, Strategy for Ecosystem Restoration, and Strategy for RME. The report concludes with closing and references sections.

2.0 CEERP Background

In this section we describe the CEERP goal, objectives, and adaptive management process.

2.1 Program Goal and Objectives

The CEERP is founded on a specific goal and associated principles, objectives, and management questions that are pursued within a specially designed adaptive management process. As stated previously, the overall goal of the CEERP is to understand, conserve, and restore ecosystems in the LCRE. The CEERP is also addressing a specific requirement from the 2008 BiOp (NMFS 2008) for the BPA/Corps to provide survival benefit units (SBUs)[2] for salmonids; i.e., 45 units for ocean-type and 30 units for stream-type salmon by 2018. The CEERP seeks to have restoration projects that, from Johnson et al. (2003), "…are founded on the best available ecological restoration science, implemented in an ecosystem context, and developed with the intent to restore relevant ecological processes…incorporate adaptive management practices with testable hypotheses to track ecological responses to a given restoration effort…are implemented in a coordinated, open process and scientific results from monitoring and evaluation are communicated widely and readily accessible." These principles are consistent with guidance from the Expert Regional Technical Group[3] (ERTG 2010a, 2010b, 2011a); a brief summary of the ERTG's guidance on project development to project sponsors is contained in Section 4.3.

[1] The Council was concerned about, "…lack of a clear synthesis or framework in the estuary linking habitat restoration actions to monitoring efforts to action effectiveness evaluations."

[2] A survival benefit unit is an index intended to represent the effect of LCRE habitat restoration on juvenile salmon survival (ERTG 2010a). The SBU method uses an ecosystem-based approach to assess improvements to habitats supporting juvenile salmon and other species. SBUs are assigned on a restoration project-specific basis.

[3] The ERTG for estuary habitat restoration was established by the BPA/Corps in response to the 2008 FCRPS BiOp (Reasonable and Prudent Alternative 37). Its purpose is to provide assessment of the benefits for salmon populations from LCRE habitat restoration actions.

The objectives of the CEERP reflect an ecosystem-based approach. They support and are consistent with the estuary strategies[1] in the Council's 2009 Fish and Wildlife Program (Council 2009) and recommendations[2] from the 2010 Council RME/Artificial Production Categorical Review. The specific CEERP objectives are as follows:

1. Increase the opportunity for access by aquatic organisms to and for export of materials from shallow-water habitats.[3]
2. Increase the capacity and quality of estuarine and tidal-fluvial ecosystems.[4]
3. Improve ecosystem realized functions.[5]

To meet these objectives, the primary CEERP actions are to restore hydrologic connections between the main stem and floodplain, create and/or enhance shallow-water habitat, and reestablish native vegetation. Basically, limiting factors and existing environmental conditions in the LCRE affect juvenile salmonid performance and determine strategic priorities for mitigation actions. An important management concern is how well these actions are working relative to CEERP objectives and, importantly, knowing which projects are the most effective to guide future project development and prioritization. Management concerns are addressed through RME, the results of which are used to adaptively inform CEERP decision-making.

2.2 Adaptive Management Process

The CEERP adaptive management process is described in detail by Thom et al. (2012a). Briefly, this process involves five phases (Figure 3)—decisions, actions, monitoring/research, synthesis and evaluation, and strategy (Thom 2000). The CEERP proceeds through each of these phases adaptively based on the results from the preceding phase(s). Teams of key staff perform specific functions and assume certain responsibilities to produce desired outcomes (Table 1). The adaptive management process informs management decisions that can be reconciled relative to the context of the long-term CEERP goals and objectives. As management questions are answered by RME results, program objectives and strategies will be revised as necessary and inform future restoration and RME actions. The Strategy Report is the deliverable from the Strategize Phase in the CEERP adaptive management process.

[1] The Council's Fish and Wildlife Program estuary strategies include habitat restoration work to reconnect ecosystem functions, long-term action effectiveness monitoring, evaluation of salmon and steelhead migration and survival rates, and evaluation of impacts from flow regulation, dredging, and water quality.

[2] A primary recommendation was, "The Council calls for the responsible entities to complete an estuary-wide synthesis prior to the initiation of the review of habitat actions."

3 Habitat access/opportunity is a habitat assessment concept that "appraises 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).

4 Habitat capacity/quality is a habitat assessment concept involving "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey, temperature, and structural characteristics (cf. Simenstad and Cordell 2000).

5 A category of habitat assessment that includes functional responses, such as 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).

Activities to support all phases of the CEERP adaptive management process are underway in the LCRE, thereby institutionalizing the process regionally across stakeholders/partners. Adaptive management, however, is only successful when the parties to the program commit to sustained cooperation and responsibilities. Adaptive management can be efficient if existing, required reporting functions are adapted to ensure the flow of information from project monitoring staff to project planning staff, and if RME is funded appropriately. The CEERP uses existing regional coordination efforts, such as the Corps' AFEP, the Council's Fish and Wildlife Program, and the Lower Columbia Estuary Partnership's (EP's) programs. Existing work groups contributing to CEERP purposes include the federal Estuary/Ocean Subgroup for Federal RME (EOS), the AFEP Science Review Work Group (SRWG), the EP's Science Work Group (SWG), the ERTG, the ISRP, and others. Many federal, state, and local agencies and non-governmental organizations are working to restore and understand estuarine and tidal freshwater habitats for juvenile salmon in the LCRE and are cooperating and collaborating within the CEERP.

Figure 3. CEERP Adaptive Management Process. Brown and blue boxes signify adaptive management phases and deliverables, respectively. CEERP adaptive management phases, responsible parties, and deliverables are listed in Table 1.

Table 1. CEERP Adaptive Management Phases, Responsible Parties, and Deliverables. See Section 1.3 of the 2013 Action Plan for descriptions of the responsible parties. (Abbreviated terms used in the tables are defined in the list in the front matter of this report.)

Phase	Responsible Parties	Function	Deliverable(s)
Strategize	AA, Council, SRWG, SWG, EOS	Provide strategic priorities on project types that will provide the most benefit	Strategy Report
Decide	AA (final decisions); Council, ISRP, SWG, SRWG, ERTG (inputs)	Select projects and identify RME for a given implementation year	Action Plan, Feasibility Studies
Act (Implementation)	AA; sponsors	Implement restoration projects	Design Memoranda, As-Built Drawings
Monitor and Research	AA; researchers	Study "on the ground" implementation	Site Evaluations, Technical Reports
Synthesize and Evaluate	AA, NMFS, Council, ERTG	Synthesis RME findings and make recommendations to inform following years' strategy	Synthesis Memorandum

3.0 Synthesis and Evaluation – Summary

Over the past 30 years, much has been learned about juvenile salmonid ecology and its ecosystems in the LCRE. During the last decade, much has been done to apply this knowledge to LCRE ecosystem restoration. The NMFS and Pacific Northwest National Laboratory, under contract with the Corps and within the context of the CEERP adaptive management framework (Figure 2), recently synthesized and evaluated information relevant to juvenile salmon in the LCRE (Thom et al. 2012b). The material that follows is reproduced (with permission and without inclusion of references in final section of this document) from conclusions sections in their report and is organized around four key questions.

1. *What are the contemporary patterns of juvenile salmon habitat use in the estuary, and what factors or threats potentially limit salmon performance?*

"Based on evidence to date, the primary direct beneficiaries of restoration of main-stem wetland habitats will be small subyearling Chinook and chum salmon. Juvenile Coho salmon are more prevalent in tidal wetlands within tributary systems than in main-stem sites. Many of the small juvenile salmon are wild spawned, and constitute a life-history type not represented by the hatchery production system. Restoration of main-stem wetland habitats also has indirect benefits to juvenile salmon through export of organic materials, nutrients, and prey resources from shallow-water to main-tem areas. In order to restore life-history diversity to Columbia River salmon populations, it is critical to protect, restore, and enhance the wetland habitat upon which these fish depend."

"Habitat opportunity appears to be a major limitation to salmon performance. Many potential systems are simply unavailable due to migration barriers. Reduced flushing, leading to high-temperature and low-oxygen conditions, appears to limit the time salmon can benefit from wetland habitats during summer months. Tide gates, even those with "fish friendly" designs, are not as beneficial as more open hydraulic reconnections for either salmon movements or for maintenance of adequate water-quality parameters. Conversely, habitat capacity and the limited information about salmon performance in wetland sites indicate salmon are benefitting from wetland food production that results in relatively high growth rates. Wetland-derived insect prey also appears to be regularly transported to the wider ecosystem, where it is available to fish not inhabiting wetlands. However the overall loss of marshes in the LCRE and the reduction of a macrodetritus-based food web may have reduced the overall capacity of the system compared to historical capacities. Competition and predation within wetlands requires more research but present data have not documented adverse effects on salmon performance. Additional research is needed, including potential direct or indirect interactions with non-native species. Predation studies have not been conducted in wetland sites, and bird predation in particular may be significant. Nonetheless, restoration activities that increase habitat opportunity are likely to benefit many salmon populations, and effort should be directed toward targeting sites that can be fully reconnected rather than left with restricted hydraulic connections."

"Contemporary patterns of salmon habitat use must be viewed cautiously and be placed in a broad historical and geographical context when setting restoration targets. Present-day habitat use in the estuary reflects a long history of ecological change that has reduced estuary rearing opportunities, fragmented upriver populations, and simplified salmon genetic and phenotypic diversity. Thus, present areas or time periods of greatest salmon abundance may depict current hatchery production levels or reduced rearing opportunities rather than the "optimal" targets for estuary restoration. Salmon recovery goals involve stocks and life-history types that have been reduced to low abundances and therefore, may be poorly

represented in estuary collections. Estuary restoration thus must consider the historical "tails" of population distributions and life histories and not simply the present peaks. For example, does the lack of subyearling migrants among interior spring Chinook stocks reflect current habitat conditions or was this the norm for all historical populations? Historical data for salmon population structure, abundances, and life histories are needed to provide a context for interpreting contemporary habitat-use patterns and their implications for estuary restoration."

2. *Do factors in the estuary limit recovery of at-risk salmon populations and evolutionarily significant units (ESUs)?*

"Until recently, fish surveys in the LCRE provided general descriptions of the distribution and abundance of juvenile salmon. The upriver sources of estuary-rearing salmon could only be determined for individuals that had been tagged in their natal basins or in hatcheries and later recaptured. Not surprisingly, information about stock-specific rearing and migration behaviors was based primarily on results from relatively large, tagged hatchery smolts. In the last decade, new tagging techniques, otolith chemical analyses, and an improved genetic baseline for Chinook salmon have greatly expanded our capabilities for interpreting stock-specific patterns of estuary rearing and migration. Genetic results have documented variations in the stock composition of Chinook salmon in various estuary reaches and habitats. Tagging studies and otolith chemical methods have described life-history variations for a few genetic stock groups. Overall, limited results to date suggest that estuary residency and habitat use vary among stocks and their associated entry locations, times, and sizes. These findings have important implications for selecting estuary restoration projects that will benefit the diversity of salmon stocks and life histories throughout the Columbia River basin."

"Despite a wealth of new data about stock-specific habitat use, life histories, and performance of juvenile salmon in the estuary, much remains to be learned about the importance of estuary rearing to population viability and salmon recovery. Continued estuary monitoring is needed to more fully characterize juvenile life-history variations within and among genetic stock groups, including at-risk stocks that are in low abundance and often poorly represented in estuary sample collections. Mid- and upper reaches (D – H) of the estuary have been surveyed less intensively than those in the lower estuary. Additional surveys will be required in this region to encompass the full range of habitat types or time periods for different genetic stock groups. Most RME studies have targeted shallow-water and near-shore areas, including habitat types that have been most intensively modified by historical development and that are the primary focus of estuary restoration. Methods for sampling deeper channels further from shore (e.g., purse seine , pair trawl, acoustic–tag monitoring, etc.) often select for high proportions of yearlings and hatchery fish that tend to move most rapidly through the estuary during punctuated migration periods. Additional surveys in deep channel habitats may be useful if the objective is to estimate survivals or migration rates for rapidly migrating stocks (e.g., chum, steelhead, sockeye) or to compare stock-specific life histories (i.e., subyearling and yearling migrants) across a wider range of estuarine habitat types."

3. *Are estuary restoration actions improving the performance of juvenile salmon in the estuary?*

"Of the 56 restoration sites that have been completed in the LCRE since 2004, only a small fraction (n=9) had concomitant AE [action effectiveness] monitoring that directly addressed elements relevant to juvenile salmon ecology; i.e., opportunity, capacity, and realized function. Most AE monitoring has been conducted in the lower 90 rkm of the estuary. In many cases, AE research lacked pre-restoration data, reference sites, and/or statistical analyses aimed at specifically evaluating response of monitored metrics within the context of restoration actions. The paucity of these three components within AE research in

the LCRE presents significant challenges with respect to effectively evaluating salmon performance in restored sites as well as across the landscape."

"Despite the study design limitations noted in several AE research projects, several trends were common across the projects. Hydraulic reconnections appear to increase opportunity for fish to access restored sites. Habitat opportunity for juvenile salmon was also addressed in terms of thermal conditions. Most restored sites yielded water temperatures that are known to be stressful to juvenile salmon. While the timing and magnitude of these elevated temperatures was variable across restored sites, most reported high temperatures, which occurred throughout the summer months. The capacity (e.g., prey availability) and realized function (e.g., fitness, growth, residence time) of restored sites was incorporated into some AE research. However, formal analyses aimed at evaluating the response of these metrics within the context of restoration actions were often lacking, which inhibits the ability to make inferences with regard to salmon performance at site and landscape scales."

4. What is the status of the estuary? Are estuarine conditions improving, declining?

"The physical changes, including floodplain development, dredging of the navigation channel and harbors, and flow regulation, significantly altered the historical geomorphic and ecological state of the LCRE prior to the CREDDP [Columbia River Estuary Data Development Program] studies (Table 6.1). However, the rate of physical alteration has apparently slowed compared to the late 19th and early 20th century. Physical changes are still occurring. The navigation channel was deepened (1−3 ft) early in the present century, and channel maintenance, including dredge material disposal in the estuary is conducted periodically. The habitat complexes within the present floodplain form a highly altered mosaic compared to historical conditions (Simenstad et al. 2011). Non-native species are abundant and dominate vegetation, plankton, fish, and benthos assemblages. Very few "historic" (i.e., late 1800s) wetland habitats remain in the system (Borde et al. 2012). The biological communities and geomorphology of the system are structured by natural disturbances (e.g., floods), with evidence that the habitat mosaic shifts spatially when forced by hydrological conditions and other controlling factors (Simenstad et al. 2011; Borde et al. 2012). Pile dikes, designed to maintain the navigation channel location and depth, have resulted in deposition of sediments and the formation of shallow-water habitats (Kassebaum and Moritz 2012). The rate of introductions of non-native species may be decreasing, but this is difficult to discern. Data show an expansion of invasive, highly competitive, non-native species such as reed canarygrass. There is a legacy of contamination in sediments. Contamination of water and sediment from persistent chemicals is increasing and is of significant concern. Through alteration in river flow dynamics and volumes, increases in water temperature, and sea-level rise, climate change is expected to affect the ecological processes of shallow-water habitats, and the capacity of the habitats to support young salmon."

"Restoration projects focused on floodplain habitats have increased over the past decade (LCREP 2010; Sagar et al. 2012). These actions are showing immediate benefit to juvenile salmon by providing access to habitats as well as processes supportive of ecosystem services of benefit to the entire estuary. Further, natural breaching of levees and dikes has opened areas of former floodplain habitats (Diefenderfer et al. 2010). The land surface formerly behind the levees had obviously subsided and most sites remain dissimilar to nearby reference sites even after several decades (Borde et al. 2012). Hence, the full return of floodplain habitats to their historical state will be protracted, especially those dominated by tidal forested swamps. Yet, these systems will predictably continue to provide services during development phase. Net ecosystem improvement is hampered by development activities such as road

construction and resource extraction in tributary watersheds draining into the lower floodplain habitats and broader LCRE."

Therefore, the CEERP knowledge base concerning juvenile salmon ecology and ecosystem restoration in the LCRE supports actions to restore shallow-water habitats, such as hydrologic reconnections and riparian and channel improvements. Although important uncertainties remain, the existing knowledge base provides a science-based foundation for CEERP restoration and RME actions.

4.0 Strategy for Ecosystem Restoration

The CEERP strategy for ecosystem restoration emphasizes hydrologic reconnections to restore the access to and capacity of habitats that have been cut off from the main-stem river, while also working to improve the quality of existing habitats used by juvenile salmonids and other species (Simenstad and Cordell 2000; Johnson et al. 2003). Other actions are also possible, as described in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011). Johnson et al. (2003) in the "159 Plan" described the theoretical basis for the CEERP strategy, along with guidance for restoration project and program implementation, and included a seven-step ecosystem-based approach to restoration in the LCRE (Table 2). The CEERP strategy, which focuses on the BPA/Corps ecosystem restoration effort, is complementary to the EP's restoration strategy (Estuary Partnership 2012), which covers the broader overall ecosystem restoration endeavor in the LCRE. The material below on the CEERP strategy for ecosystem restoration is organized into three main elements: ecosystem basis, supporting resources, and restoration project development.

Table 2. Seven Steps for an Ecosystem-Based Approach to LCRE Restoration (modified from Johnson et al. 2003)

Step	Description	Comment
1	Describe the fundamentals of restoration science (as they apply to LCRE ecosystem restoration)	See Section 4.1 (ecosystem basis)
2	Determine usage of LCRE habitats by salmonid life-history type, i.e., determine which habitats are most important and why	Ongoing research; see the *2012 Action Plan* (BPA/Corps 2012b)
3	Determine which LCRE habitats have been lost relative to historical conditions (pre-development in 1900s)	See Section 4.2.2 (habitat change analysis)
4	Identify and prioritize restoration strategies for the LCRE and establish a reasonable future condition, given constraints on the system (e.g., flow regulation)	See Section 4
5	Determine which specific habitats can be restored and where, i.e., develop an inventory of possible actions	See Section 4, especially Section 4.3 (restoration project development)
6	Implement locally supported and scientifically based restoration projects	See the *2013 CEERP Action Plan*
7	Monitor actions using standardized protocols and apply the results to adaptively manage future restoration actions	See Section 5 and the *2013 CEERP Action Plan*

4.1 Ecosystem Basis

The CEERP's ecosystem restoration strategy in the LCRE is founded on basic principles of ecological science, in particular, landscape ecology. The National Research Council (NRC 1992, pp. 347–348) viewed landscape ecology as a method for designing integrated aquatic ecosystem restoration projects. It concluded that, "*Wherever possible...restoration of aquatic resources...should not be made on a small-scale, short-term, site-by-site basis, but should instead be made to promote the long-term sustainability of all aquatic resources in the landscape*." Such a landscape approach was recently championed for the Council's Fish and Wildlife Program (ISAB 2011). Johnson et al. (2003) used these principles to develop an ecosystem–based restoration approach in the LCRE. Ecological science, as applied in the CEERP's restoration strategy, includes restoration guidance (Table 3) and the following principles:

Table 3. Restoration Guidance from Ecological Science (derived from Johnson et al. 2003)

Factor	Restoration Guidance
Size	In general, larger size enhances habitat stability, increases the number of species that can potentially use the site, makes it easier for migratory species to find, and increases within-habitat complexity.
Complexity	As the number of habitat types increases, so does the number of species that can occupy the area, and the number of functions supported by the area. Higher complexity potentially results in greater biodiversity, and expression of multiple salmon life-history patterns (Bottom et al. 2005a, b).
Connectivity	Connectivity, the degree of connection and pathways between adjacent habitats or migratory corridors, means that an animal can move between adjacent habitats to derive the benefits of each habitat. It also allows for the flow of material such as organic matter between areas of production (e.g., a salt marsh) and areas of deposition (e.g., tidal channels and creek bottoms where the materials are used by the ecosystem). Connectivity among habitats provides species areas in which to disperse and survive, as well as access to areas of high-quality habitat that is especially valuable to juvenile salmon.
Accessibility	The opportunity to enter and use an off-channel wetland site is fundamental to hydrologic reconnection restoration (Simenstad and Cordell 2002). Projects that restore or enhance access of juvenile salmon to important habitats would potentially enhance the feeding, rearing, and refuge functions of the site.
Areas of historic habitat loss	Areas where habitat loss has been greatest should be considered for restoration, depending on the nature of the loss and current uses at the site. These areas include forested and emergent wetland types that serve salmonids and birds.
Passive habitat restoration over creation	Areas where minor alterations would be needed to maximize ecosystem function should be prioritized over areas where massive alterations or creation of new ecosystems would be required. That said, active restoration in the form of channel excavations, scrape-downs, tide gate and culvert replacements, dike breaches, etc. will be essential actions for CEERP implementation.
Self-maintenance	Self-maintenance addresses the ability of a site to persist and evolve toward a natural (historical) habitat condition without significant human intervention. As a pre-requisite for this to occur, conditions for controlling factors in the reach and in the management unit must be appropriately developed and maintained. Self-maintenance means that the habitat can persist and develop under natural climatic variation, and that the system has a natural degree of resilience to natural perturbations. This criterion also takes into account the need to know the probable historical conditions, and the factors that produced the present conditions. This guideline represents the "areas of historic habitat type loss" theme.

Table 3. (contd)

Factor	Restoration Guidance
Ecosystem functions	This acknowledges that some actions can result in greater enhancement of ecosystem functions than others. These projects may not be the largest or most complex projects. For example, the location may be more important than the size of a project. A medium-sized project in a location where an endangered species can directly benefit because of the proximity to its normal migratory pathway would be more important than a project far outside of the pathway.

- *Re-establishment of natural controlling factors*[1] *is required to build and maintain ecosystem structures,*[2] *processes,*[3] *and functions*[4] *that support juvenile salmon*. Re-establishing the factors that control the development, dynamics, and maintenance of natural habitat structures will result in restoration of natural habitat and ecosystem processes and functions, for example, salmon growth and increased survival/fitness. The CEERP ecosystem-based approach necessarily encompasses juvenile salmon habitats and the supporting ecosystems at site and landscape scales.
- *Returning the LCRE ecosystem to a less altered state is desirable*. The historical condition of the LCRE has been altered by agricultural and industrial development, and its current state is not entirely desirable from an ecological point of view. The structure and function of the LCRE is different than it was prior to hydrological modification and other anthropomorphic changes. The growing body of information indicates that improved survival/fitness of salmon may be dependent on return of the estuary to a less altered state (e.g., Bottom et al. 2005a; Fresh et al. 2005; Karieva et al. 2000), toward which the CEERP is essentially working.
- *The success of a restoration project will vary depending on the level of disturbance (anthropomorphic or natural) of the site and the landscape within which the site resides* (NRC 1992). Using the findings of the National Research Council and a review of the literature on estuarine habitat restoration, Shreffler and Thom (1993) concluded that different restoration approaches, such as enhancement[5] and creation,[6] should be applied depending on the degree of disturbance of the site and the landscape. For example, for sites with a high degree of disturbance, creation of a new habitat may be the only viable approach. In contrast, where the site and landscape are essentially intact, restoration to historical (i.e., humans present, but insignificant disturbance) or pre-disturbance (i.e., before man) conditions would be viable options and the probability of success likely would be high.
- *Most elements within a landscape*[7] *function best when integrated with all other elements of the landscape*. Landscape ecology deals with the effect of the spatial extent, heterogeneity, and geometry

[1] Controlling factors are the basic physical and chemical conditions that construct and influence the structure of the ecosystem.

[2] Ecosystem structures are the types, distribution, abundances, and physical attributes of the plant and animal species composing the ecosystem.

[3] Ecosystem processes are any interactions among physicochemical and biological elements of an ecosystem that involve changes in character or state.

[4] Ecosystem functions are defined as the role the plant and animal species play in the ecosystem, including primary production, prey production, refuge, water storage, nutrient cycling, etc.

[5] Enhancement is any improvement of a structural or functional ecosystem attribute (NRC 1992).

[6] Creation is bringing into being a new ecosystem that previously did not exist on the site (NRC 1992).

[7] Landscapes are spatially heterogeneous geographic areas characterized by diverse interacting patches or ecosystems. The landscape scale is larger than the site scale and smaller than the estuary-wide scale.

of elements (e.g., habitats) of the landscape on the flow of energy, animals, and materials through the landscape (Forman and Godron 1986). One of the fundamental lessons of landscape ecology is that a landscape is a heterogeneous matrix of smaller elements, and that the arrangement, size, productivity, resilience to disturbance, etc. of these elements within the matrix will affect the flow of energy, animals, and materials through the landscape. Removal or degradation of one or more elements may lead to the impaired performance of the remaining elements. In deciding on CEERP restoration strategies and sites, for example, it is useful to identify and consider the dysfunctional or absent elements.

- *Landscape ecology concepts such as minimum area,*[1] *shape,*[2] *corridors,*[3] *and buffers*[4] *are applicable to ecosystem restoration*. Of particular relevance to LCRE restoration are the related concepts of habitat size, accessibility, and capacity (Simenstad and Cordell 2000). These concepts are used by CEERP practitioners and managers to develop and design restoration projects. Also, the ERTG applies these concepts in its scoring process (ERTG 2010b).

4.2 Supporting and Complementary Strategic Resources

During 2012, multiple tools and information resources are being used to support restoration planning and project development for CEERP 2013. These resources vary in their degree of development from completed to under construction. Resources described below are intended to support the CEERP restoration effort now or in the future. Results from these analyses as they become available will be shared with sponsors to ensure they have the opportunity to consider the latest science in determining the best projects to develop. The EP's "*A Guide to the Lower Columbia River Ecosystem Restoration Program*" explains in detail many of these resources, results of analyses, and management implications (Estuary Partnership 2012). As much as the state of the science allows, we will strive to identify the most strategic habitats and locations for restoration.

Overlaying the results of the geographic information system (GIS) analyses will allow managers to map and identify areas critical for restoration and protection. A certain result might be used in combination with the others or be the sole analysis, depending on needs of the user. For example, recovery planners in Oregon and Washington may be mainly focused on priority tributaries for the LCRE salmonid populations or U.S. Fish and Wildlife Service managers may wish to identify specific types of riparian habitats that have been lost since the 1850s. Most of the resources listed below have been or are

[1] Size estimates are a function of the minimum area needed to attract the species of interest, the size of the species, their behavior within the habitat, and required buffers. In addition, the habitat(s) must be stable over time, and with increased size comes stability.

[2] The shape of a patch or contiguous habitat affects the types and number of species in the patch. Species show preferences for edges or interiors of patches. In particular, juvenile salmon are believed to forage at the marsh-mudflat interface and at the edge of habitat patches (Roegner and Dawley 2012).

[3] A corridor is a narrow strip of habitat that differs from the habitats on either side. Corridors form very important routes of migration for many species. Corridors represent a more or less protected route of ingress and egress to habitats. Relative to restoration planning, corridors between sources of recolonizing species and the restored habitat are critical. If corridors are not present, the restoration effort has little chance of success no matter how well it is constructed. Corridors may also function as habitat for some species, and barriers or filters (e.g., riparian buffer zones) (Forman and Godron 1986).

[4] A vegetated buffer surrounding an aquatic habitat reduces disturbances from noise, wind, contaminated runoff, and movement. Without a high-quality buffer, the functions and stability of the aquatic habitat may be compromised.

being developed as a GIS-based platform that can be easily updated as additional analyses come online. In addition, the resulting inventory of identified critical areas can be overlaid with the results of the disturbance analyses and land-use/land-ownership data sets to determine appropriate techniques and levels of effort needed to restore individual sites or combine multiple projects to restore larger areas.

- Characterization of Disturbance Regimes (Estuary Partnership 2012). Characterization of disturbance regimes is based on a landscape- and site-scale disturbance model (Evans et al. 2006). This completed tool (Figure 4) uses existing data about a series of stressors, e.g., diking, toxic contaminants, roads, population, flow restrictions, to categorize disturbances on individual site and landscape scales. This evaluation is useful in determining in general the types of restoration (preservation, conservation, enhancement, restoration, or creation) that are appropriate for a given area.

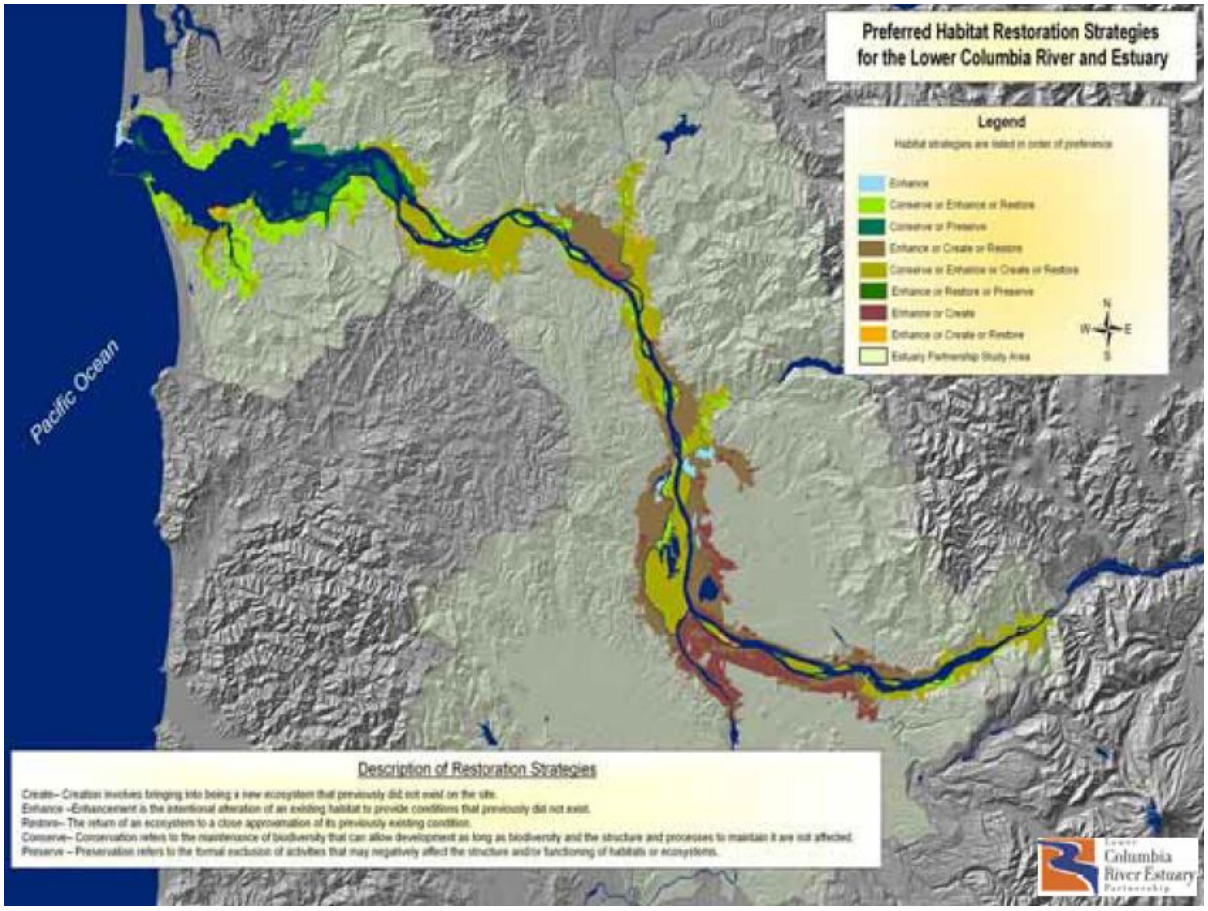


Figure 4. Assessment of Disturbance Across Landscape and Site Scales with Corresponding Restoration Approaches

- Habitat Change Analysis (Estuary Partnership 2012). This analysis compares habitats from historic topographic ("T") sheets and 1850s survey maps to 2010 land-cover data. It assumes historic habitat coverage is a proxy for natural habitat diversity. The results generally showed losses, gains, and changes throughout the LCRE for various habitat types, e.g., tidal and non-tidal herbaceous wetlands, tidal and non-tidal wooded wetlands, forested areas, and shrub-scrub areas. Ongoing analysis is

intended to identify habitat areas where losses are coverable and overlay on public lands to determine potential areas for protection.

- Habitat Suitability Index Model (Estuary Partnership 2012). Focusing on yearling Chinook salmon, researchers used results from the Oregon Health Sciences University's SELFE model to determine the frequencies and locations that meet water temperature, depth, and velocity conditions favorable to yearling Chinook salmon, using criteria adapted from Bottom et al. (2005a). The research is ongoing, but preliminary results are indicating areas in the LCRE where the conditions favorable to juvenile salmon presence are met consistently through time and those areas where they are not. For the latter, the analysis will attempt to identify areas where favorable environmental conditions can be restored.
- LCRE Tributary Deltas as Priority Areas in Recovery Plans (Estuary Partnership 2012). The rationale here is that fall, late fall Chinook salmon, and to lesser degree chum salmon can rear extensively in the tidally influenced habitats of LCRE tributaries. Such areas are important to Oregon and Washington salmon and steelhead recovery plans (ODFW 2010 and LCFRB 2010, respectively), as well as the CEERP. A systematic assessment of LCRE tributaries and their priority for supporting listed salmon and steelhead was conducted. This analysis is complete and produced a map and table of priority tributary habitats that is available from the EP.
- Inventory and Map of Tidally Impaired Floodplain Habitat (Estuary Partnership 2012). This GIS-analysis identified habitat currently disconnected or hydrologically impaired by dikes, levees, tide gates, and other structures. These areas could be reconnected, restoring natural ecosystem controlling factors and corresponding structures, processes, and functions. The results indicated over 63,000 acres of floodplain habitat could be pursued for reconnection.
- Application of the Ecosystem Classification System (Simenstad et al. 2011): The Columbia River Estuarine Ecosystem Classification is a tool that provides an opportunity to use best-science principles, information, and technology to select high-value restoration and protection actions to improve juvenile salmon habitat in the estuary. This application is being developed using the Classification as a foundation with the intent to apply knowledge from the Contributions to Salmon Recovery project by NMFS and collaborators and other projects, such as Historical Linkages (Bottom et al. 2008). For example, the application is intended to help with identification and prioritization of the type, location, and characteristics of estuarine habitat restoration and protection actions that would optimally benefit juvenile salmon of specific ESUs and life-history types.

4.3 2013 Restoration Project Development and Prioritization

Coordinated project development and dynamic prioritization for CEERP relies on both opportunistic and strategic enterprise. During 2012 and continuing in 2013, the approach to project development for the CEERP involves a "targeted" collaborative approach to identifying opportunities to satisfy strategic criteria (Figure 5). The approach was used to develop a living list of specific LCRE ecosystem restoration projects to implement in the 2014−2018 time frame. The result was a new methodology that considers a cost-benefit SBU assessment and allows for improved coordination among sponsors and funding agencies developing projects. As a matter of fact, the BPA/Corps and the EP, in collaboration with CEERP project sponsors, have set up a process to coordinate work to determine project opportunities. A map with relevant GIS layers of all possible sites in the LCRE is used to support this process. To focus the project development process, the EP applies the following layers to an LCRE GIS map: "tidally impaired" (current floodplain), public versus private (generally large tracts only) lands, and

restoration inventory (existing projects already being tracked). A facilitated discussion about each "opportunity area" is then used to determine which sponsors may be already having discussions with the corresponding landowners. If none of the sponsors is holding discussions with the targeted landowners, the group discusses the pros and cons of doing work on that site as well as likely proposed actions. After all project opportunities are identified, the BPA/Corps start the prioritization and assignment stage with the following objectives in mind: identify cost-effective, high-value (SBU) projects; ensure that all partners have a full suite of potential projects based on their capacity; and assign projects that are a good fit for the sponsors' interests and skills. This step includes the following activities:

- Estimate potential SBUs, projected cost, and likelihood of success (see below).
- Prioritize the project opportunities based on cost per SBU, total SBU, and likelihood of completion.
- Request input from sponsors about their interest in the unassigned opportunities.
- Develop a draft version of sponsor (including the Corps through the Water Resources Development Acts Section 536 process) assignments to project opportunities with the goal of delivering the most SBUs in the shortest period of time.
- Where multiple parties are interested in the same projects, consider partnership opportunities.
- Share the draft assignments and then incorporate feedback from project sponsors to determine the final assignments.
- Given the first round of the project development process that was completed in 2012, add new concepts and updates as additional information and experience become available in 2013.

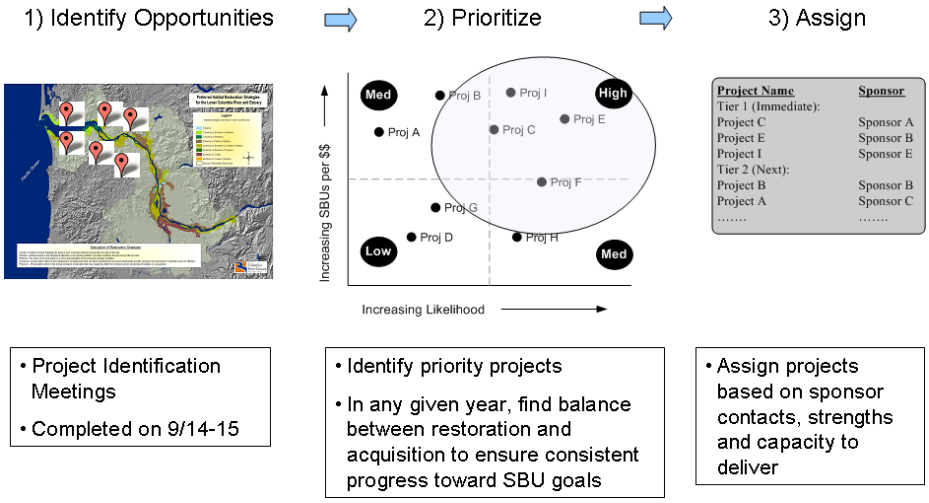


Figure 5. The 2012-2013 Approach for CEERP Project Development

SBU assessment is an important step in the project development process. "Unofficial" SBUs can be calculated by any interested party to gauge benefits from a project. Here, the ERTG approach for calculating SBUs (ERTG 2010a) is used by non-ERTG parties to indicate SBU potential, with the caveat that there is limited information about a project at this early stage in the development process. In cases where the project is relatively costly or risky for other reasons, the ERTG may be asked to assign preliminary "official" SBUs. Preliminary in this case means the project may need to be scored again at a later date if new information becomes available or the project design changes significantly.

The ERTG has provided guidance to restoration proponents that sponsors and the BPA/Corps applied for 2013 project development. This guidance includes (ERTG 2010b, 2011a, 2011b) the following: bigger area is better than smaller area; close to the main stem is better than farther away; restoring remnant channels is better than excavating new ones; natural processes are preferred over engineered processes; and a holistic perspective from a landscape scale is better than narrow, site-specific perspective. Based on this guidance, the BPA/Corps' approach has been modified to focus on restoration projects concerning floodplain reconnections and wetland channel improvements that have a significant footprint in tidally influenced areas relatively close to the main stem. Using a combination of best professional judgment and best available restoration science, the ERTG determined that the aforementioned actions provide the highest juvenile salmonid densities (ERTG 2010a, 2011a). Note that re-vegetation and invasive species removal are important complements to floodplain reconnection and channel habitat restoration actions, but they should not be the primary project focus to ensure delivery of the most cost-effective biological benefit.

In conclusion, the strategy for restoration project development for CEERP 2013 used an ecosystem-based landscape approach (Table 3) and involved a systematic, collaborative identification of potential restoration opportunities using GIS maps and knowledge of local communities to develop a list of potential projects. The list was culled and refined based on SBU assessments and strategic guidance provided by the ERTG and others. This work was fed into the CEERP process to make decisions about which projects to fund; the decision-making process is explained in the 2013 Action Plan.

5.0 Strategy for RME

This section contains a strategy for a programmatic approach to RME that regional stakeholders can implement to support the CEERP and the broader estuary restoration effort. RME is being conducted within the CEERP's adaptive management framework (Section 2.2; Figure 2), within which restoration actions are implemented, RME is conducted, and results are analyzed, synthesized, and reported to decision-makers to evaluate, leading to adjustments in program strategy and subsequent restoration actions in the next cycle. RME is essential to the adaptive management process and the restoration effort.

Two main types of RME are conducted in the LCRE. The first type is action effectiveness monitoring and research (AEMR[1]), which is designed to quantitatively describe the effects of habitat restoration actions on juvenile salmonid performance. The second RME type is ecosystem function monitoring and research (EFMR), which is designed to answer key questions regarding ecosystem functioning (Figure 6). For example, Borde et al. (2012) quantified the ecological and hydrological conditions necessary for development of certain wetland plant communities and tidal channel networks (i.e., EFMR) that were used to inform the effectiveness of wetland restoration actions in the LCRE by comparing restoration and reference site monitoring data (i.e., AEMR). Ecological and hydrological conditions relevant to wetland plant communities and channel networks are also relevant for planning habitat restoration actions, e.g., planning planting lists, designing appropriate elevations and grading within sites.

[1] Action-effectiveness *monitoring* involves spatially extensive sampling of basic restoration indicators, whereas action-effectiveness *research* involves locally intensive sampling at restoration and reference sites to characterize ecosystem structures, processes, and functions.

Traditionally, RME has been divided into several more categories, including implementation and compliance monitoring, status and trends monitoring, AEMR (various scales), and critical uncertainties research (Johnson et al. 2008). The CEERP uses these RME categories as components of its targeted strategy for AEMR and EFMR. The strategy described in this section incorporates the traditional types of RME as they apply to the AEMR and EFMR (Table 4).

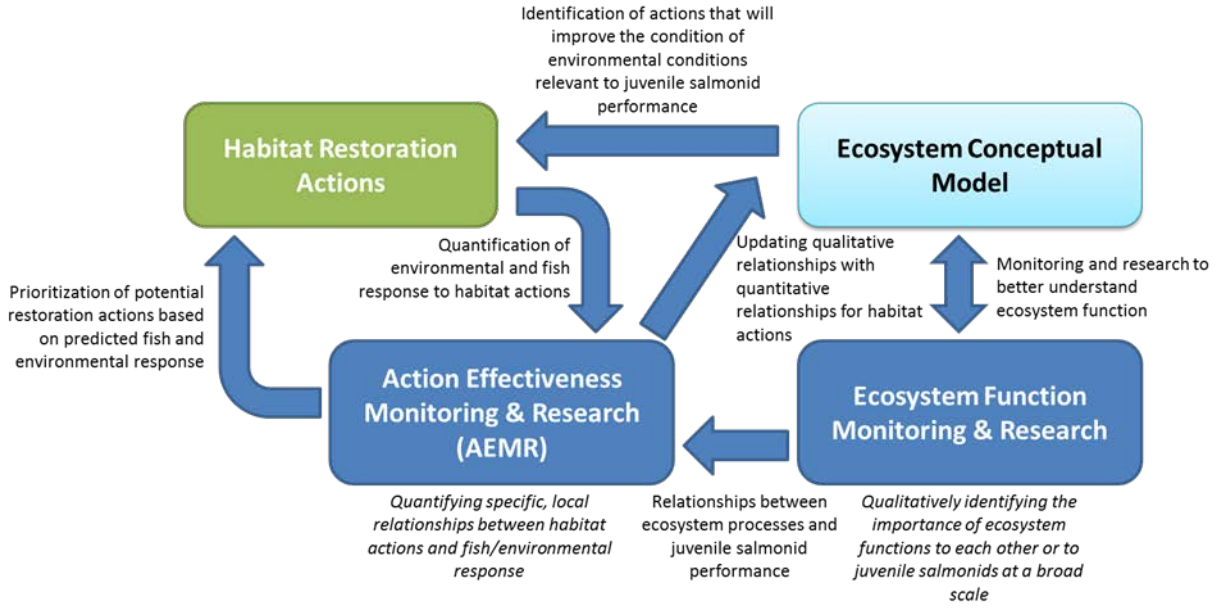


Figure 6. Relationship Between AEMR and EFMR and Connection to Restoration Actions and the Ecosystem Conceptual Model.

Table 4. Traditional RME Types Related to AEMR and EFMR

RME Type	AEMR	EFMR
Status and Trends	Provides broader ecological context and reference conditions from which to assess site-scale action effectiveness results.	Provides broader ecological context for LCRE and through time.
Implementation and Compliance	Provides information on structure or design performance over time to use in association with environmental or fish response.	Not applicable
Critical Uncertainties	Same; although uncertainties research under AEMR is intensive, site-specific study of action effectiveness.	Same; although uncertainties research under EFMR is explicitly tied to potential CEERP actions and thus designed to inform habitat restoration for juvenile salmonid benefit.

5.1 Action Effectiveness Monitoring and Research

The objective of AEMR is to determine the success of restoration actions at site, landscape, and estuary-wide scales in terms of improved ecosystem functionality, especially as it relates to juvenile salmon performance and biological indicators of ecosystem health.

AEMR depends on the attendant restoration actions. LCRE restoration actions involve improving or creating habitat for juvenile salmon in migratory and rearing areas and reconnecting floodplain habitats to the main-stem river (Table 5). To show coordination and communication with RME efforts elsewhere in the Columbia basin, a cross-walk between the LCRE and Columbia River tributary restoration actions reveals mostly commonality between the two areas. The few differences stem from structures and actions that are common in the LCRE, but not the tributaries; e.g., dredged channel material and pile structures. In both areas, actions are undertaken to acquire and protect land, restore riparian habitats, reconnect and restore off-channel and floodplain habitats, and control invasive plant species.

Table 5. Restoration Actions for LCRE and Comparable Fish and Wildlife Program (F&WP) Tributary Restoration Action Categories. LCRE restoration actions and CRE# are from the Estuary Module (NMFS 2011).

LCRE Restoration Actions	CRE#	Comparable F&WP Tributary Restoration Actions
Acquisition and protection	1.3, 9.3	Land acquisition or protection
Restore riparian areas	1.4	Riparian habitat (see invasive plants below)
Create habitat by applying dredged material to beneficial use	6.2, 6.3	Not applicable
Remove or modify pilings	8.2	Not applicable
Restore degraded off-channel habitat	9.4	Reconnection or creation of side-channels, ponds, wetlands and other off-channel habitats. Addition of habitat complexity, e.g., large woody debris, and cover to off-channel habitats
Breach dikes	10.1	Floodplain enhancement/reconnection
Remove tide gates or culverts	10.2	Barrier improvements
Upgrade tide gates or culverts	10.3	Barrier improvements
Control invasive plant species and plant native species	15.3	Plant and plant removal

5.1.1 Previous AEMR Planning

Previous work on programmatic AEMR by the BPA/Corps is built upon for this programmatic AEMR plan. Three sources are particularly pertinent: Johnson et al. (2008), Roegner et al. (2009), and Johnson et al. (2012).

A basin-wide, federal BiOp RME effort commenced in 2000 (NMFS 2000). For the LCRE component of this effort, Johnson et al. (2008) produced a RME plan called the *Research, Monitoring,*

and Evaluation for the Federal Columbia River Estuary Program. This plan developed specific AEMR objectives that were incorporated into the 2008 FCRPS BiOp. At a programmatic level, AEMR was designed to use quantitative studies to demonstrate how habitat restoration actions affect factors controlling ecosystem structures and processes at site and landscape scales and, in turn, juvenile salmonid performance. The plan asserted that data sets developed through status and trends monitoring, implementation and compliance monitoring, critical uncertainties research, and AEMR would need to be established, maintained, analyzed, synthesized, and evaluated at a programmatic level. Data collection methods for action effectiveness, as well as the spatial and temporal scale of monitoring and example protocols, were also recommended, and are carried over in this current programmatic AEMR plan. As an outgrowth of the RME plan, BPA and the EP instituted an intensive AEMR effort at four sites in the LCRE and developed the suite of reference sites.

Standard data collection methods are critical to any programmatic approach to AEMR to ensure the data can be compared and integrated across locations and times. In the LCRE, Roegner et al. (2009a) published *Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary*, including "core metrics," "higher-order" indicators, and sampling designs for AEMR of habitat restoration projects. Categories of methods included hydrology, water quality, landscape, vegetation, and juvenile salmonids. Before -after-reference-impact and "accident response" designs for the purpose of AEMR were described. These protocols and sampling designs are currently being used regionally in project-specific AEMR. The Roegner protocols are available under the "methods" category at https://monitoringmethods.org/.

Johnson et al. (2012b), *Statistical and Other Considerations for Restoration Action-Effectiveness Monitoring and Research*, presented program- and project-level considerations for AEMR. These authors established a methodology for specifying statistical relationships between intensive action effectiveness research and extensive action effectiveness monitoring, including a method to indicate how much AEMR sampling is enough. They also provided a statistical approach for quantitative meta-analysis of AEMR data and offered approaches to prioritizing AEMR and critical uncertainties research. For reporting and documentation, they developed templates for project descriptions, AEMR plans, and site evaluation cards. Below, we apply these program- and project-level considerations for AEMR.

5.1.2 Technical Approach

The technical approach for programmatic AEMR involves AEMR levels, standard extensive monitored indicators, extensive and intensive monitored indicators for ratio estimators, reference and control sites, and sampling design. This material is all site-scale,[1] but we also describe AEMR at landscape[2] and estuary-wide[3] scales.

There are many potential monitored indicators,[4] depending on program needs and project-specific conditions, ranging over a spectrum from extensive monitoring to intensive research (Figure 7). Any monitored indicator must be diagnostic of relevant ecosystem controlling factors, structures, processes, or functions, e.g., elevation, tidal exchange, water temperature, material flux (Thom and Wellman 1996); applicable to all sites with measurements that result in comparable data sets relevant to present and future

[1] Site scale is the footprint of a given restoration project site (approx. 10s to 100s of meters).
[2] Landscape scale is an expanse of the LCRE (approx. 100s of meters to 10s of kilometers).
[3] Estuary-wide scale is from Bonneville Dam to the mouth of the river (235 km).
[4] A monitored indicator is a measurable parameter that is diagnostic of relevant ecosystem features, applicable and comparable across time and space, and practical to implement.

investigations (Tegler et al. 2001); and practical in terms of funding, manpower, and processing and analysis requirements (Callaway et al. 2001). Rice et al. (2005), Thom and Wellman (1996), and Zedler (2001) present fundamental elements of monitoring aquatic habitat restoration projects.

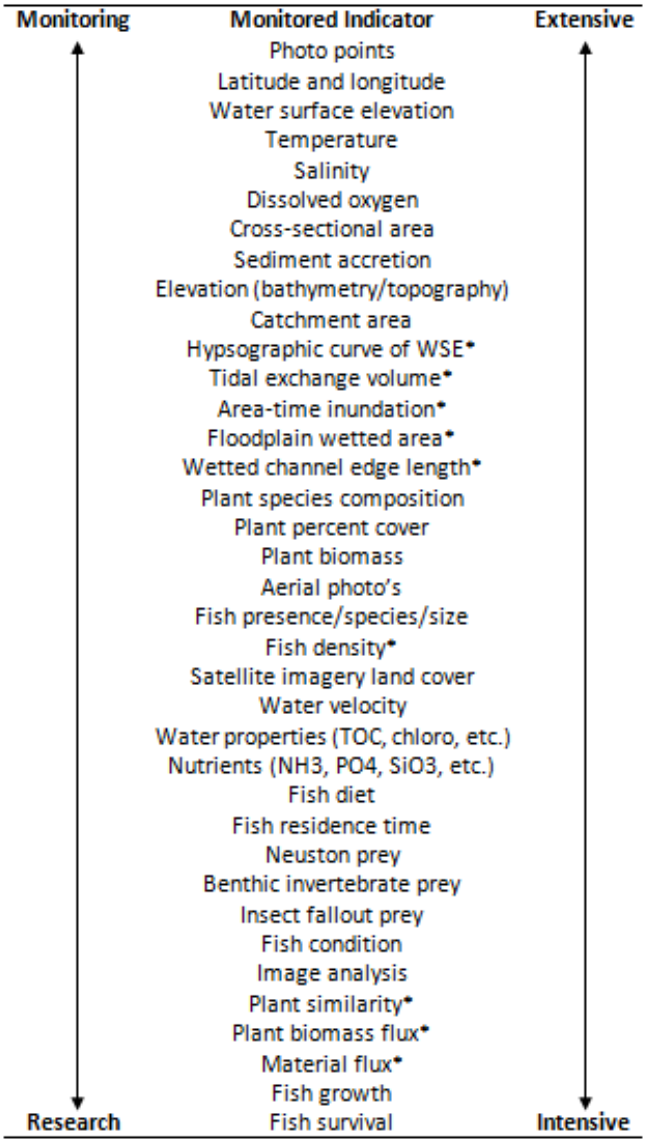


Figure 7. Monitored Indicators for Action Effectiveness Over the Monitoring/Research and Extensive/Intensive Spectrum (modified from Johnson et al. 2012b). *Signifies a derived indicator, i.e., one calculator using data from another indicator.

5.1.2.1 AEMR Levels

Implicit in the development of the programmatic AEMR plan is the spectrum of extensive monitoring to intensive research (Figure 7). We designate AEMR levels (Table 6 and Figure 8) to facilitate communication and prioritization of AEMR activities. Actual AEMR will depend on project and program needs and will likely be a blend of levels.

Table 6. AEMR Levels

Designation	Name	Funding Source	Monitored Indicators	Intensity	Statistical Design	Term/Sampling Episodes[1]
Level 1	Intensive	BPA/Corps	Intensive suite of monitored indicators of ecosystem structures, processes, and functions	Subset of sites	Essential	Long-term; 1-3, 6, and 10 y
Level 2	Core	BPA/Corps	Extensive monitored indicators (core metrics of Roegner et al. 2009)	Subset of sites	Depends on project and program objectives	Medium-term; 1, 3, and 5 y
Level 3	Standard	BPA/Corps or Sponsor	Standard extensive monitored indicators	All sites	n/a (qualitative assessment)	Short-term; 1, 5 y

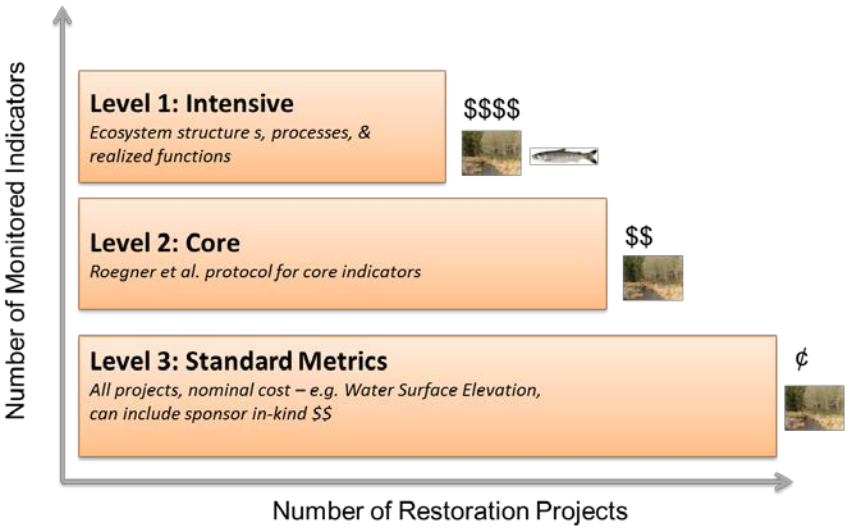


Figure 8. Schematic of AEMR Levels

5.1.2.2 Standard Extensive Monitored Indicators

Data on a subset of standard, extensive monitored indicators (Table 7), dependent on the type of restoration strategy, should be collected at all project sites unless otherwise noted. These data will serve to document key environmental conditions at the site and suggest whether the restoration action is having the desired effect. This standard subset of monitored indicators does not include fish because the intent is to monitor the base physical environment, and minimize impacts on fish populations. As the AEMR database grows, we expect standard monitored indicators will suffice to determine the success of a project in terms of the physical changes realized and in the context of established relationships between extensive

[1] Different indicators may have different frequencies.

and intensive indicators. It is simply not practical for fish data, while very important at chosen priority sites, to be mandatory for all restoration projects. Also, the standard indicators do not cover all "core metrics" from Roegner et al. (2009a), thereby reducing costs and complexity while maintaining data usefulness for action effectiveness assessments. The standard indicators may also be used in intensive to extensive ratio estimators, as explained below, although again this is not mandatory (explained further in the Prioritization and Implementation section).

Table 7. Standard Monitored Indicators by Restoration Action. These are Level 3 monitored indicators (Table 6). Levels 1 and 2 are more intensive and will depend on project objectives.

Monitored Indicator	Data
Photo Points	Discrete
Latitude and longitude	Discrete
Water-surface elevation	Logger
Temperature	Logger
Sediment accretion	Measurement
Elevation (topography)	Existing remote sensing dataset
Wetted area	Derived

5.1.2.3 Extensive and Intensive Monitored Indicators for Ratio Estimators

Relationships between extensive and intensive indicators are being established (Thom et al. 2012b) so that future studies can use measurements of extensive indicators in ratio estimators to predict the responses of related intensive indicators. By developing a proper mix of extensively monitored sites and intensively monitored sites, individual restoration projects may be surveyed with minimal effort while providing maximum opportunities to detect benefits at landscape and estuary-wide scales. Johnson et al. (2012b) established a methodology based on ratio estimation for specifying statistical relationships between intensive action-effectiveness research and extensive action-effectiveness monitoring. Extensive/intensive ratio estimators and predictive relationships are under development for several monitored indicators in the LCRE (Table 8). These relationships, which are being enhanced as new data become available, should be examined during design of new AEMR studies. Given extensive (easy) and intensive (difficult) indicators to sample (X and Y, respectively), the general ratio estimator is of the form (variances of the estimates may be included at a later date):

$$\hat{Y}_{ext} = X_{ext}\left(\frac{\overline{Y}_{\text{int}}}{\overline{X}_{\text{int}}}\right)$$

where $\hat{Y}_{ext}$ = estimated Y at an extensively monitored site

X_{ext} = measured X at the same extensively monitored site

$\overline{Y}_{\text{int}}$ = mean of Y measured at multiple intensively researched sites

$\overline{X}_{\text{int}}$ = mean of X measured at multiple intensively researched sites.

Table 8. Preliminary Data for Relationships Between "Extensive" Monitored Indicator(s) and "Intensive" Monitored Indicator(s) (modified from Johnson et al. 2012). These relationships remain to be fully quantified in the form of ratio estimators to provide statistically valid relationships. *Cross-sectional area is actually an extensive indicator; the relationship with catchment area is what is important.

"Extensive" Indicator(s)	"Intensive" Indicator(s)	Reference
Water-surface elevation + land elevation	Floodplain wetted area; area-time inundation	Coleman et al. (2010)
Water temperature	Juvenile salmon presence	Roegner et al. (2010)
Land elevation + lateral and longitudinal location in floodplain + sediment accretion rate	Plant community composition	Thom et al. (2012b)
Catchment area	Channel cross-sectional area at outlet;* wetted-channel edge length	Diefenderfer and Montgomery (2008)
Wetland area	Plant biomass export	Thom et al. (2012b)
Tidal exchange volume	Material flux (chlorophyll, dissolved organic matter, nutrients, plant biomass, macro-invertebrates)	Woodruff et al. (2012)

5.1.2.4 Reference and Control Sites

Reference and control sites are essential to AEMR studies where the objective is to determine the success or ecological benefits of a particular restoration action. A reference site is similar to the intended eventual outcome at the affected site after restoration, whereas a control site is similar to the affected site before restoration. Using control sites paired with each impact site can add additional statistical power to the analysis when looking to isolate changes in the restoration action compared to changes caused by natural variation or other sources. The use of reference or control sites or both in the sampling design (see next section) will depend on project and CEERP objectives.

AEMR science will benefit from the Lower Columbia Estuary Partnership's Reference Site Study, conducted from 2007 through 2012 (Borde et al. 2011, 2012). This study established a suite of 51 reference sites at relatively undisturbed wetlands for use as appropriate in AEMR work (Figure 9). Borde et al. (2011) provided detailed characterizations of the plant communities, water-surface elevations, water temperatures, and other features. Borde et al. (2012) analyzed these data to address two questions: 1) "What are the ranges of selected environmental factors controlling the establishment and distribution of wetlands in the LCRE, and what vegetation communities are associated with these ranges in different parts of the LCRE?" 2) "Can structural data from multiple reference sites be used to evaluate restoration action effectiveness in the LCRE and if so, what metrics are most useful to this evaluation?" The reference sites provide existing data to use in AEMR comparisons and analyses at site, landscape, and estuary-wide scales.

5.1.2.5 Site-Scale Assessment

At the site-scale, sampling design includes frequency of AEMR sampling and formal statistical designs to evaluate the effects of restoration actions. Johnson et al. (2008) recommend sampling frequencies for many of the monitored indicators in Table 7 and Figure 7. Standard monitoring for action effectiveness will entail deployment of equipment for continuous data logging (e.g., water-surface

elevation and temperature), periodic (once per year for 5−10 y) measurements of sediment accretion and plant composition and percent cover, and photo points and aerial photographs.

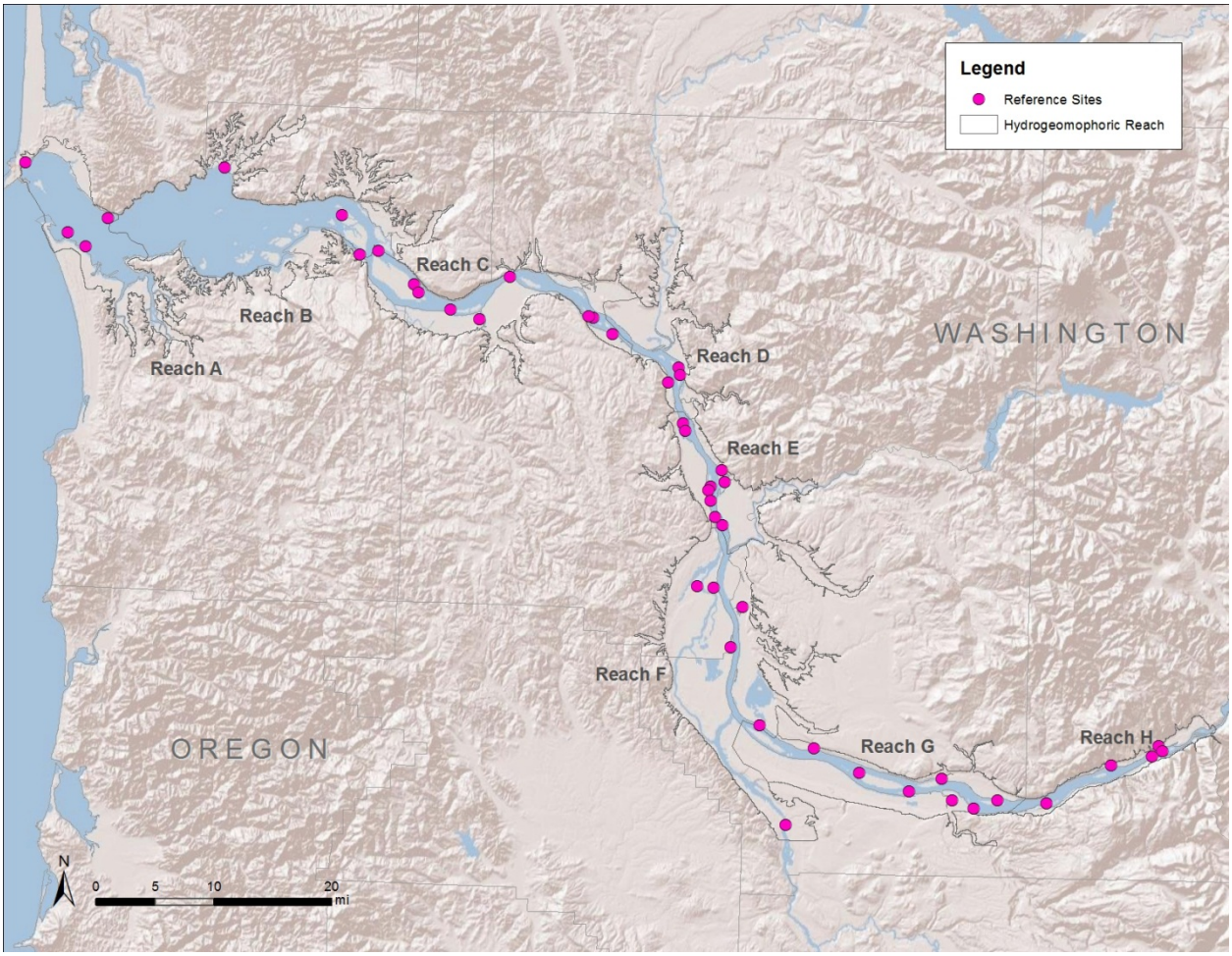


Figure 9. Map of Reference Sites

For more intensive AEMR studies, Johnson et al. (2008) and Roegner et al. (2009) presented designs based on sampling before and after restoration or after restoration only, with both designs involving a comparison of the affected site to an adjacent reference site. Documentation of conditions before a restoration action is warranted to show changes compared to after restoration; however, "before" sampling should be carefully considered because in many cases the restoration causes a profound and obvious change, e.g., breaching a dike to convert a pasture to a wetland. The reference site is essential to designs for intensive AEMR because it allows for analysis of the ecological trajectory of the restoration site. The idea is to assess whether the restoration action produced the desired shift in ecosystem structures, processes, and functions from state A to desired state B. Auxiliary questions could include how rapidly the shift occurred and the relative costs of alternative restoration activities. The sampling designs provided by Roegner et al. (2009) are appropriate for testing these questions in the complex environment of the LCRE. All intensive AEMR studies should be informed by a formal statistical design developed during the study planning stage and customized to meet the project's objectives and monitored indicators, i.e., identify and document reference/control sites, monitored indicators, and analysis methods ahead of time. Recommended sampling episodes for intensive AEMR are 1, 5, and 10 y after restoration,

although timing for actual sampling may deviate from these recommended time steps depending on project and CEERP priorities.

How much AEMR sampling is enough is a common programmatic refrain. With regard to the number of intensively monitored sites, the intent is to select only a sample of the total restoration sites for such effort, say, n of N sites. At these sites, as mentioned above, higher-level ecological responses (i.e., intensive monitored indicators) would be measured along with correlated standard extensive indicators. Then using the standard or extensive data at all or most sites, an estimate of estuary-wide, total higher-level ecological response would be estimated by either ratio or regression estimation (Cochran 1977:150–203). Using the variance formula for regression estimators, the number of intensive monitoring sites that should be sampled can be calculated. The following material is from Johnson et al. (2012b) and was prepared by Dr. J. R. Skalski.

Let $\hat{Y}$ represent the estimate of the estuary-wide, total response and Y be the true value. Furthermore, define precision as

$$P\left(\left|\frac{\hat{Y}-Y}{Y}\right|<\varepsilon\right)=1-\alpha$$

where the desire is for the relative error in estimation $\left(\text{i.e.,}\left(\frac{\hat{Y}-Y}{Y}\right)\right)$ to be less than $\varepsilon, (1-\alpha)$ 100% of the time. For example, if you wish to be within $\pm 25\%$ of the true value 90% of the time, then

$$P\left(\left|\frac{\hat{Y}-Y}{Y}\right|<0.25\right)=0.90\,.$$

Using the above definition of sampling precision, then

$$\varepsilon \doteq Z_{1-\frac{\alpha}{2}}\cdot\frac{\sqrt{\text{Var}\left(\hat{Y}\right)}}{Y}$$

and in the case of regression estimation (Cochran 1977:192)

$$\varepsilon \doteq Z_{1-\frac{\alpha}{2}}\sqrt{\frac{\left(1-\frac{n}{N}\right)\text{CV}_{Y_i}^2\left(1-\rho^2\right)}{n}}\,.$$

Solving for n for given precision defined by ε and α

$$n=\frac{1}{\frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}CV^2_{Y_i}(1-\rho^2)}+\frac{1}{N}}$$

where ε = relative error size

$Z_{1-\frac{\alpha}{2}}$ = *Z*-value for a standard normal distribution at cumulative probability of $1-\frac{\alpha}{2}$

N = total number of potential restoration sites

ρ = correlation between intensive and extensive indicators

CV_{Y_i} = coefficient of variation in the intensive indicator response between restoration areas, i.e., $=\frac{\sqrt{\mathrm{Var}(Y_i)}}{\bar{Y}\ \sqrt{\cdot}}$

Consequently, the number of intensively monitored restoration sites (n) will be a function of the desired level of precision (i.e., ε and $1-\alpha$), how correlated are the intensive and extensive responses (i.e., ρ) and how variable are the restoration sites (i.e., CV_{Y_i}). Robson and Regier (1964) recommended for rough management purposes precision should be ±50%, 95% of the time (i.e., ε = 0.50, $1-\alpha$ = 0.95) and for accurate management, ±25%, 95% of the time (i.e., $\varepsilon = 0.25, 1-\alpha = 0.95$). Using this framework, investigators should use preliminary data to estimate ρ and CV for important higher-level responses and work with management to select useful levels of ε and $1-\alpha$ upon which all parties can agree.

5.1.2.6 Landscape and Estuary-Wide Scale Assessment

AEMR is necessarily conducted at the site scale, as discussed in this section, but the landscape and estuary-wide scales are also important to consider. There are ecological gradients longitudinally, laterally, and vertically in the LCRE that manifest themselves at the landscape and estuary-wide scales. For example, the influence of tides on water-surface elevation decreases as longitudinal distance upstream increases, while the opposite is true for Columbia River discharge (Jay et al. 2012). At a given longitudinal position, plant communities vary laterally as distance from the main stem and land elevation increase (Borde et al. 2011). This multi-dimensional variation in physical and biological features is evident in the LCRE Ecosystem Classification (Simenstad et al. 2011). Location of a restoration site in the landscape and estuary as a whole will affect ecosystem processes and functions at the site and, hence, the restoration design and associated AEMR at the site, landscape, and estuary-wide scales.

Ecosystem restoration strategy in the LCRE is based on a landscape perspective, as recommended by the Independent Scientific Advisory Board (ISAB 2011). As noted by the National Research Council (NRC 1992), the rates and patterns of the recovery of the wetland after hydrological reconnection vary considerably and are likely tied to the restored processes, which are highly dependent on the quality of the surrounding landscape. Therefore, it is appropriate that programmatic AEMR also have a corresponding landscape perspective. At the landscape scale, the working hypothesis is that "restoration actions in the LCRE will produce increased habitat connectivity and an increased area of floodplain wetlands trending toward historical levels present prior to land conversion for agriculture and the construction of dams" (Diefenderfer et al. 2011b). Monitored indicators such as aerial photography and satellite imagery are useful to characterize the landscape setting for a restoration site. Methodologies for landscape-level estimates of habitat connectivity (Diefenderfer et al. 2011a), life-history diversity (Diefenderfer et al. 2011a), and juvenile salmon density (Sather et al. 2012) have been developed and are ready for application to programmatic AEMR. Other methods are being developed to estimate restoration benefits

to juvenile salmon at the landscape scale (Diefenderfer et al. 2011a). Many of these methods can be applied estuary-wide.

A technical approach for AEMR at the landscape or estuary-wide scale developed by Diefenderfer et al. (2011b) is based on levels-of-evidence (Downes et al. 2002). This approach uses analytical results from estuary-wide investigations of net ecosystem improvement (Thom et al. 2005), hydrodynamics (Diefenderfer et al. 2011b), ecological relationships (Thom et al. 2012b), and action effectiveness meta-analysis (Johnson et al. 2012), which are conducted using data from multiple sources, including a suite of reference and restoration sites across the LCRE (Diefenderfer et al. 2011b). The overarching working hypothesis is that "habitat restoration activities in the lower Columbia River and estuary have a cumulative beneficial effect on salmon" (Diefenderfer et al. 2011b). Several ongoing RME projects support analyses at the landscape and estuary-wide scales, e.g., Contributions to Recovery, Multi-Scale Action Effectiveness Research, Synthesis and Evaluation, and Ecosystem Monitoring (see section below on RME Projects). The emphasis currently is on site-scale AEMR, but work is already underway in the CEERP Synthesis Memorandum and the early stage Cumulative Effects Evaluation, among other efforts, to roll up AEMR data at landscape and estuary scales.

5.1.3 Prioritization Strategy

The AEMR data collection effort must be prioritized program-wide to make the best use of limited resources. This programmatic plan presents by topic AEMR criteria and on-the-ground priorities; criteria for prioritization are presented in Table 9.

Table 9. Draft AEMR Prioritization Framework (to be tested in 2012). These are not necessarily the most important restoration actions, but are important elements for restoration implementation and RME.

Topic	Criterion	CEERP Priorities	Weighting	Scoring Measures
Types of restoration actions	Actions important to the restoration program, but whose ecological effects are poorly understood	Hydrological reconnections; habitat creations; pile structure modifications	***	3 = hydrological reconnections; habitat creations; pile structure modifications 2 = riparian improvements 1 = invasive plant control
Landscape locations of AEMR study sites	Locations in landscapes where restoration actions may be concentrated or LCRE areas where little AEMR has occurred; reference site(s) are available	Areas that have been understudied to date; tributary and main-stem confluence areas where multiple salmon populations may benefit from restoration actions	*	3 = Confluence areas; floodplain lakes 2 = Tidal freshwater 1 = Estuary proper
Addresses a key uncertainty in action effectiveness	See list in the section above on State-of-Science	TBD	***	TBD
Project relative	Project size; location	Large project size (>100	*	3 = >100 acres

Topic	Criterion	CEERP Priorities	Weighting	Scoring Measures
impact on ecosystem	relative to main stem; ecological uplift anticipated	acres); near main stem; large ecological uplift anticipated		2 = 10-100 acres 1 = <10 acres
Program management	Impact on program management	Information has high potential to influence decisions	**	3 = High 2 = Medium 1 = Low

5.2 Ecosystem Function Monitoring and Research

This section describes previous and ongoing EFMR efforts funded by BPA or the Corps. The strategy in previous work was to establish a basic knowledge base. The strategy for ongoing work is to focus on key aspects of salmon ecology and ecosystem health to support CEERP decision-making, while continuing to reduce uncertainty and risk in the CEERP effort. The following two subsections contain research objectives and accomplishments for strategic EFMR.

5.2.1 Previous EFMR

2002 – 2008: Estuarine Habitat and Juvenile Salmon: Current and Historical Linkages in the Lower Columbia River and Estuary. The goal of this research was to better understand and define habitat protection and restoration actions for the LCRE. Benefits from and priorities in restoration projects have been hypothesized to be closely related to relationships between estuarine habitat conditions and juvenile salmon life history diversity, abundance, and performance. Specific objectives were to monitor land-scale trends in salmon abundance, population structures, and life histories; measure salmon use of and performance within selected wetlands, and characterize the physical factors impacting habitat availability for juvenile salmon. Data to date have provided insight into juvenile salmon use of the habitats investigated, residence time, prey species and shown positive benefits in the form of increased fitness and growth (Bottom et al. 2008; Roegner et al. 2008).

2004 – 2010: Evaluating Cumulative Ecosystem Response to Restoration Projects in the Columbia River Estuary. The goal of the Cumulative Effects Study was to develop a methodology to evaluate the cumulative effects of individual habitat projects intended to benefit ecosystems supporting juvenile salmonids in the lower Columbia River Estuary (Johnson et al. 2012a). A literature review indicated no existing methods for such an evaluation and suggested that cumulative effects could be additive or synergistic. Thus, a method to evaluate cumulative effects was developed (Diefenderfer et al. 2011b). One of the first products from this study was a standardized set of protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. The protocols ensure monitoring from many different sources (state, federal, etc.) would provide a database with standardized metrics for more regional action effectiveness evaluation (Roegner et al. 2009a).

2009 – 2012: Evaluation of Life History Diversity, Habitat Connectivity, and Survival Benefits Associated with Habitat Restoration Actions in the Lower Colombia River and Estuary. The goal of this study is to evaluate the ability to quantify the benefits to listed salmonids of habitat restoration actions in the LCRE. The proposed methods involve literature review, assessment and pilot testing of available

methods, and, as necessary, develop and testing of new methods with existing data. This study developed and tested with exiting data a quantitative method to index species-specific life history diversity for salmonids in the LCRE; (2) developed and tested with exiting data a quantitative method to index habitat connectivity among the eight reaches in the LCRE; (3) assessed and developed a technical approach to estimate benefits associated with specific habitat restoration actions in the LCRE (Diefenderfer 2011a).

5.2.2 Ongoing EFMR

2003-present: Ecosystem Monitoring Project. This project (BPA 2003-007-00) collects, analyzes, and reports ecological data at sentinel sites that are sampled using rotational panel design. The project assesses trends in ecological conditions in LCRE wetlands. In addition, it produced the Columbia River Estuary Ecosystem Classification System (Simenstad et al. 2011).

2009-present: Contributions to Salmon Recovery. This project (EST-P-09-01) ; synoptic determination of genetic stocks; fish/habitat associations. It will assess the LCRE's contribution to salmon genetic and life-history diversity and have implications for habitat restoration.

In conclusion, beginning in 2001 with the foundation provided by Bottom et al. (2005), the BPA and Corps have been funding research in the LCRE. RME has produced improved understanding of shallow water and wetland habitats lost in the last decades, salmonid use of these habitats, benefits and increased fitness from residing within these habitats, site specific benefits from individual restoration sites, and the cumulative response to multiple individual restoration projects to the ecosystem as a whole. A scientific approach has been applied to evaluate the estuarine habitats and juvenile salmon use and benefits. We have and continue to evaluate quantitative methods to measure the increased benefits from increased ecosystem benefits. Additionally, we have also applied a semi-quantitative levels-of-evidence approach to evaluate the ecosystem restoration program in a cumulative manner. Must of this is new and cutting edge science and it will take time to evaluate all components of these research projects, including addressing remaining uncertainties in the knowledge base.

5.3 Uncertainties

Conceptual models, which are useful tools to discuss ecosystem organization and highlight habitat actions that can address ecosystem concerns (see Figure 10), may be used to highlight any ecosystem processes that are poorly understood and have the potential to improve the effectiveness of habitat restoration actions. For example, the 2012 CEERP Synthesis Memorandum highlighted water temperature as an important factor potentially limiting both habitat capacity and opportunity for juvenile salmonids. However, the official Oregon Department of Transportation criterion for juvenile salmonids was set at 19ºC, yet juvenile salmonids have been found in water hotter than this (Roegner et al. 2010). Further investigation of the relationship(s) between local water temperature and juvenile salmonid performance could yield restoration design recommendations that maximize cooler water temperatures (e.g., via full hydrologic reconnection) in addition to the traditional habitat restoration objectives.

The ERTG, which scores restoration projects based on their projected benefits to juvenile salmonids, developed a list of uncertainties that the Action Agencies will use to prioritize future CEERP RME. Each uncertainty question is further divided into higher resolution sub-questions in the full document (ERTG 2012). The ERTG uncertainty questions include the following:

- What is the ecological role of large woody debris in [a] tidal marshes, [b] river floodplains, [c] floodplain lakes and ponds?
- What is the ecological role and impact of pilings on salmon? Do the pilings need to be removed?
- How do tidal wetlands respond to different types of restoration actions?
- What is the role of floodplain lakes/ponds relative to juvenile salmon?
- What is the role of seasonal floodplains in the upper estuary for juvenile salmon during floods?
- What are the functions of riparian vegetation for juvenile salmon along channel margins?
- Does the spatial organization of restoration projects have non-linear effects (e.g., amounts, synergies, thresholds, cumulative effects) on salmon use, survival, production, and life-history diversity for stocks using those areas?
- How do hatchery-produced stocks affect the benefit of estuary restoration projects to natural stocks?
- What is the stock-specific residency and use of various reaches of the estuary? What ecological measurements best estimate SBUs for various restoration actions?

In addition, ERTG members noted that quantitative predictions of channel geometry, vegetation assemblages and salmon use and productivity (e.g., survival, growth) for restoration actions would be useful for developing design and planning tools. Thom et al. (2012c) also provide recommendations to address uncertainties in the knowledge base. The CEERP is in the process of considering research of these uncertainties, especially those addressing action effectiveness and ecosystem functioning.

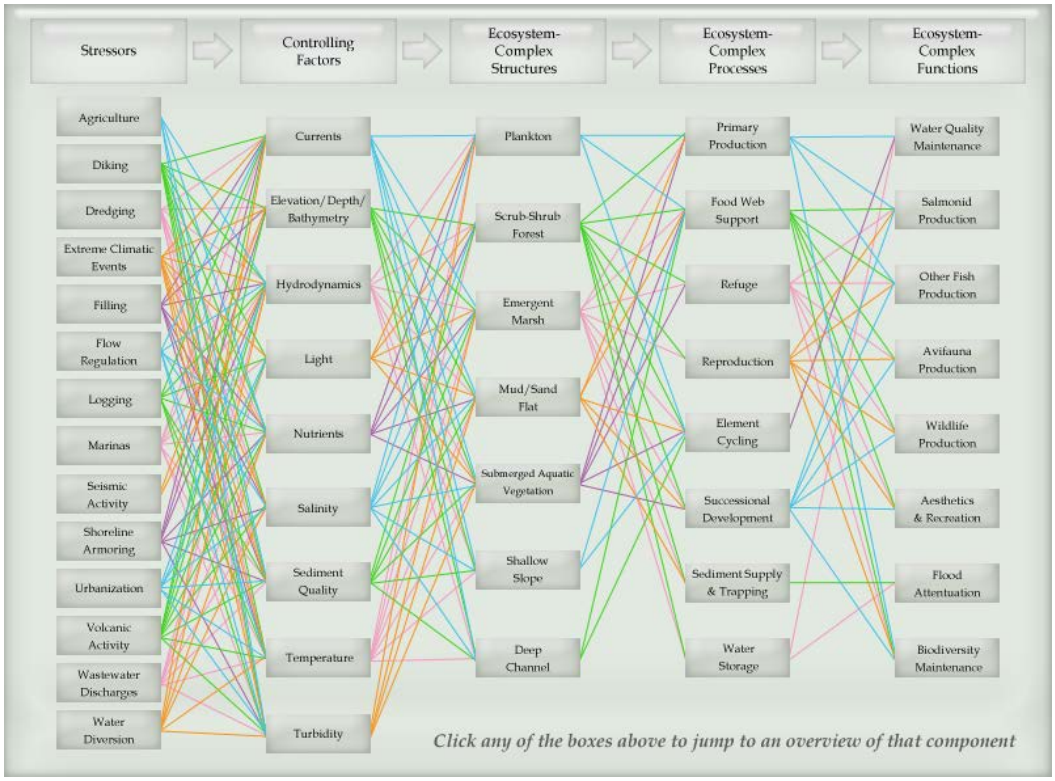


Figure 10. Columbia River Estuary Conceptual Model (Thom et al. 2004)

6.0 Closing

The overall goal of the CEERP is to understand, conserve, and restore ecosystems in the LCRE. The CEERP is a regional, collaborative program that involves using existing processes, programs, technical groups, and plans to avoid redundancy and increase efficiency. A formal adaptive management process is in place involving annual cycles of project development, prioritization, implementation, monitoring and research, and synthesis and evaluation.

This 2013 CEERP Strategy Report describes the BPA/Corps' fundamental strategy for estuary habitat actions and monitoring/research—apply an ecosystem-based approach to restore, enhance, or create ecosystem structures, processes, and functions in the estuary, and perform research, monitoring, and evaluation to assess the effectiveness of these actions, while building our understanding of ecosystems in the LCRE. The CEERP will use, as appropriate, information from projects funded outside the CEERP for external purposes regarding predation, toxic materials, dredging, hydrosystem operations, and tributary habitat improvements, and other topics. The strategy developed in this 2013 Strategy Report was fed by the 2012 Synthesis Memorandum and will drive the actions outlined in the 2013 Action Plan.

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