A Programmatic Plan for Restoration Action Effectiveness Monitoring and Research in the Lower Columbia River and Estuary

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This document presents a plan for a programmatic approach to action effectiveness monitoring and research (AEMR[5]) that regional stakeholders can implement to support the Columbia Estuary Ecosystem Restoration Program (CEERP[6]) and the broader estuary restoration effort. The "actions" are habitat restoration projects in the lower Columbia River and estuary (LCRE). The BPA and Corps are conducting AEMR within the CEERP's adaptive management framework (BPA/Corps 2012), wherein strategic restoration actions are prioritized and implemented, AEMR is conducted, and results are analyzed, synthesized, and reported to decision-makers. This process informs adjustments in program strategy and restoration actions in each subsequent year of the annual cycle.

The purpose of AEMR is to determine the success of restoration actions at site[7], landscape[8], and estuary-wide[9] scales in terms of improved ecosystem functionality, especially as it relates to juvenile salmon performance and the CEERP objectives (Figure 1). Restoration actions will be evaluated from a combination of qualitative and quantitative studies, specified via the structured planning framework herein. To frame this initiative, AEMR addresses two main hypotheses and a series of ancillary hypotheses, which can be addressed by causal or correlative relationships. The main hypotheses are: 1) habitat-based indicators[10] of ecosystem controlling factors, structures, and processes show positive effects from restoration actions, and 2) fish-based indicators of ecosystem functions show positive effects from habitats undergoing restoration. The ancillary hypotheses are reflected in specific analysis questions, which lead to AEMR levels and associated monitored indicators (Figure 1).

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[5] 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.

[6] 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 is responsive to subsequent FCRPS BiOps, the Council's Fish and Wildlife Program, and various Corps restoration authorities.

[7] Site scale is the footprint of a given restoration project site.

[8] Landscape scale is an expanse of the LCRE larger than a site but not estuary-wide.

[9] Estuary-wide scale is the entire LCRE from Bonneville Dam to the mouth of the river, inclusive of the historical floodplain.

[10] Monitored indicators are listed in the Technical Approach section.

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

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AEMR Purpose	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 CEERP objectives

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Main Hypotheses	*Fish-based* indicators of ecosystem functions, including salmon performance, show positive effects from habitats undergoing restoration	*Habitat-based* indicators of ecosystem controlling factors, structures, and processes show positive effects from restoration actions

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Ancillary Hypotheses	At the site scale, the restoration activity results in improved [*monitored indicator*] compared to a baseline pre-restoration condition, or shows a positive trajectory of [*monitored indicator*] from pre-restoration conditions toward those that at a reference site.

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Analysis Questions	*Fish-based* (ecosystem functions, including salmon performance) • Is LCRE ecosystem restoration resulting in improvements in: o juvenile salmon accessing the site? o juvenile salmon performance in terms of condition? growth? life history diversity? o flux of prey , macro-detritus from restoring areas to the main stem? o prey production? • Are listed species from the interior Columbia basin using the site?	*Habitat-based* (ecosystem controlling factors, structures, and processes) • Have hydrological processes been improved (e.g., tidal influence and flood regime) and are they self-maintaining? • Has aquatic connectivity with the main stem river been improved and is it self-maintaining? • Is the rate of sediment accretion at the restoring site at an expected level and is land elevation predicted to be self-maintaining? • Are restored habitats self-maintaining in terms of channel cross-sectional area? percent cover of native versus invasive plant species? • Is LCRE ecosystem restoration resulting in improved water temperatures for shallow water rearing habitats of juvenile salmon relative to surrounding riverine/estuarine environments and/or reference sites?

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AEMR Levels (nested)	Level 1: Intensive monitored indicators of ecosystem controlling factors, structures, processes, and functions (fish- and habitat-based)	Level 2: Extensive monitored indicators of ecosystem controlling factors and structures (habitat-based)	Level 3: Standard monitored indicators of ecosystem controlling factors (habitat-based)

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Monitored Indicators (*examples* of field measurements)	Intensive (fish- and habitat based): juvenile salmon density, condition, growth, genetic stock, diet, residence time, prey production, macro-detritus export	Extensive (habitat-based): vegetation percent cover, plant biomass, dissolved oxygen, water velocity, channel cross-sections	Standard (habitat-based): photo points, water surface elevation, water temperature, sediment accretion

Figure 1. AEMR Cascade from CEERP Objectives to Monitored Indicators

The intended outcome of this programmatic AEMR plan is to achieve efficiency, coordination, and consistent conduct of AEMR across the LCRE over the next six years of the FCRPS BiOp (2013-2018). In addition, programmatic AEMR guidance will be incorporated into technical proposals during the Estuary/Lower Columbia River categorical review within the Northwest Power and Conservation Council's Fish and Wildlife Program in early 2013. Regional stakeholders can use this programmatic approach to provide context for their project-specific AEMR efforts. Stakeholder research, monitoring, and evaluation (RME) plans involve using AEMR to determine if their restoration actions were successful in meeting the project's objectives, identify improvements to restoration design and execution, and recognize cost efficiencies in AEMR efforts. These project-level goals synchronize with the purpose of AEMR at the CEERP program level (Figure 1), where concern is for the collective ecological success of multiple restoration projects across multiple landscapes in the LCRE. Overall, the programmatic approach to estuary AEMR is being coordinated with the broader estuary restoration effort through the Lower Columbia Estuary Partnership, and with Columbia River tributary habitat AEMR and the federal RME effort under the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008).

This plan is organized by the following objectives: 1) summarize key background information; 2) explain technical elements of programmatic AEMR; 3) prioritize AEMR activities, including what, when, where, and how much to monitor or research; and, 4) describe application of AEMR data to adaptively manage the CEERP and broader LCRE ecosystem restoration efforts. The document closes with action items, a conclusion statement, a glossary, and references. The appendix contains a matrix of 2013 site-specific monitoring plans.

Background

In this section, we describe previous AEMR planning efforts, identify common restoration actions, and summarize the state-of-science for AEMR, including important uncertainties in our understanding of the effectiveness of restoration actions in the LCRE.

Previous AEMR Planning

We build upon previous work on programmatic AEMR by the BPA/Corps for this programmatic AEMR plan. Four sources are particularly pertinent: Johnson et al. (2008), Roegner et al. (2009), Diefenderfer et al. (2011, 2012), 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, were also recommended together with example protocols, 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 a suite of reference sites that was monitored for the subsequent several years (Borde et al. 2011, 2012).

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. (2009) 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 being used regionally in project-specific AEMR. The Roegner protocols are available under the "methods" category at https://monitoringmethods.org/.

Early in the CEERP restoration effort, managers realized the need to assess the cumulative effects of multiple restoration projects at landscape and estuary-wide scales. Accordingly, an effort was undertaken beginning in 2004 to develop a methodology to evaluate the cumulative effects of ecosystem restoration projects, as none existed in the ecological literature at the time. This development effort culminated with *A Levels-of-Evidence Approach for Assessing Cumulative Ecosystem Response to Estuary and River Restoration Programs* by Diefenderfer et al. (2011). This approach forms the basis for AEMR evaluations at the landscape and estuary-wide scales (e.g., Diefenderfer et al. 2012a).

Johnson et al. (2012b), *Statistical and Other Considerations for Restoration Action-Effectiveness Monitoring and Research*, presented program- and project-level considerations for AEMR. This report established a methodology for specifying statistical relationships between intensive[11] action effectiveness research and extensive[12] action effectiveness monitoring, including a method to indicate how much AEMR sampling is enough. It 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, templates were developed for project descriptions, AEMR plans, and site evaluation cards. Below, we apply these program- and project-level considerations for AEMR.

Restoration Actions

AEMR methods depend on the attendant restoration actions. In the 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. To illustrate the coordination and communication with RME efforts elsewhere in the Columbia basin, a cross-walk between the LCRE and Columbia River Fish and Wildlife Program (F&WP) tributary restoration actions reveals mostly commonality between the two areas (Table 1). The few differences stem from man-made structures and restoration 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. We adopt the restoration categories from *A Review of Stream Restoration Techniques and Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds* by Roni et al. (2002), presented in their descending order of priority:

- Tier 1 – Actions which are synonymous with protection (e.g., regulations, conservation easements);

[11] Intensive AEMR is research of many core and higher order indicators locally, i.e., over a small spatial scale.
[12] Extensive AEMR is monitoring of a few selected core indicators over a large spatial scale.

- Tier 2 – Actions which deal with restoring habitat connectivity (these could be regulation-based or habitat-improvement-based);
- Tier 3 – Restoring long-term processes: water quality/quantity (e.g., roads, stormwater, instream flows, etc.);
- Tier 4 – Restoring long-term processes: riparian;
- Tier 5 – Restoring short-term processes (e.g., enhancement projects).

Table 1. Restoration Actions for LCRE and Comparable F&WP Tributary Restoration Action Categories. LCRE restoration actions and Columbia River Estuary Code (CRE#) are from the Estuary Module (NMFS 2011).

LCRE Restoration Actions	CRE#	Comparable F&WP Tributary Restoration Actions	Roni Tier
Acquisition and protection	1.3, 9.3	Land acquisition or protection	1
Restore riparian areas	1.4	Riparian habitat	4
Create habitat by applying dredged material to beneficial use	6.2, 6.3	Not applicable	2
Remove or modify pilings	8.2	Not applicable	2
Restore degraded off-channel habitat	9.4	Reconnection and restoration or creation of side-channels, ponds, wetlands and other off-channel habitats. Addition of habitat complexity (LWD) and cover to off-channel habitats	2
Restore high natural hydrologic connection (e.g., breach dikes)	10.1	Floodplain enhancement/reconnection	2
Restore moderate natural hydrologic connection (e.g., remove tide gates or culverts)	10.2	Barrier improvements	2
Restore low natural hydrologic connection (e.g., upgrade tide gates or culverts)	10.3	Barrier improvements	5
Control invasive plants and plant native species	15.3	Plant and plant removal	4

State of AEMR Science in the LCRE

The 2012 CEERP Synthesis Memorandum (Thom et al. 2013) reviewed all available reports, peer-reviewed articles, and other communications concerning AEMR in the LCRE over the past eight years. The memorandum documented that AEMR has occurred throughout most of the LCRE, although emphasis to date has been on the lower 90 km (Figure 2), where a majority of the restoration projects took place. Of the 42 restoration studies reviewed, only nine included fish sampling related to the indicator categories of habitat opportunity, capacity, and realized function (cf. Simenstad and Cordell 2002). Of these nine studies, only one (Crims Island, by Haskell and Tiffan 2011) completed a statistical analysis of before-after restoration-reference data. In general, Thom et al. (2013) concluded that hydrologic reconnections generally seemed to improve access to shallow water habitats for juvenile salmon, but the degree of access depended on the degree of hydrologic reconnection. They noted that few studies examined effects on realized functions for salmon, such as growth rate. These authors recommended that, where appropriate, AEMR include formal statistical study designs, reference and/or control sites, pre-restoration data collection, careful choice of monitored indicators, sampling year-round to capture seasonal changes and fish life history diversity, site evaluation cards, and a central LCRE database. This programmatic AEMR plan incorporates these recommendations and provides specific methods to accomplish them.

Uncertainties remain in the state-of-science for AEMR. The Expert Regional Technical Group (ERTG) recently identified uncertainties from the point of view of scoring restoration projects to assign survival benefit units (ERTG 2012). These are the high-level uncertainties and the ERTG also provided more detailed sub-questions. Uncertainties are considered in the Prioritization and Implementation section below.

- "What is the ecological role of LWD in tidal marshes, river floodplains, and floodplain lakes and ponds in the LCRE?"
- "What is the ecological role and impact of pilings on salmon?"
- "How do tidal wetlands respond to different types of restoration actions?"
- "What is the role of LCRE 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 SBU's [survival benefit units] for various restoration actions?"

Summary

This programmatic AEMR plan is built on the foundation made up of existing AEMR planning documents and CEERP precedents, including AEMR data collection protocols, statistical designs and analysis methods, a suite of restoration actions, and synthesis of the state-of-science for AEMR in the LCRE. The technical approach that follows uses this foundation to refine and specify monitored indicators, sampling designs, AEMR scales, and other features.

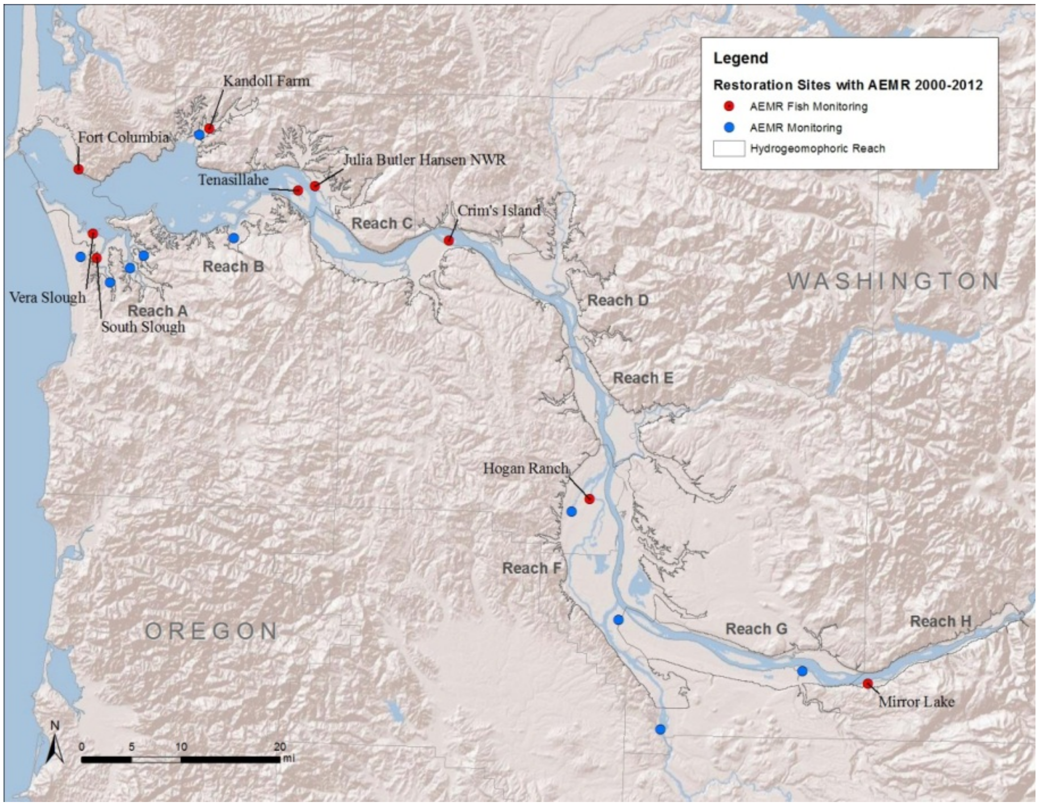

Figure 2. Map of Restoration Project Sites Where Pre- and Post-Construction AEMR Occurred During 2000-2012. Sites where fish were sampled and were included in the 2012 Synthesis Memorandum (Thom et al. 2013) are designated with red dots.

Technical Elements

Technical elements include monitored indicators, AEMR levels, standard monitored indicators, extensive and intensive monitored indicators for ratio estimators, reference and control sites, sampling design, and monitoring and research methods. This material is typically site-scale, although we also describe AEMR at landscape- and estuary-wide scales in the concluding part of this section.

Monitored Indicators

There are many potentially useful monitored indicators[13], depending on program needs and project-specific conditions, which range over a spectrum from extensive monitoring to intensive research (Figure 3). To be recommended, a monitored indicator must be 1) diagnostic of relevant ecosystem controlling factors, structures, processes, or functions, e.g., elevation, tidal exchange, water temperature, material flux (Thom and Wellman 1996); 2) result in comparable data sets relevant to present and future investigations (Tegler et al. 2001); and 3) 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.

[13] 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.

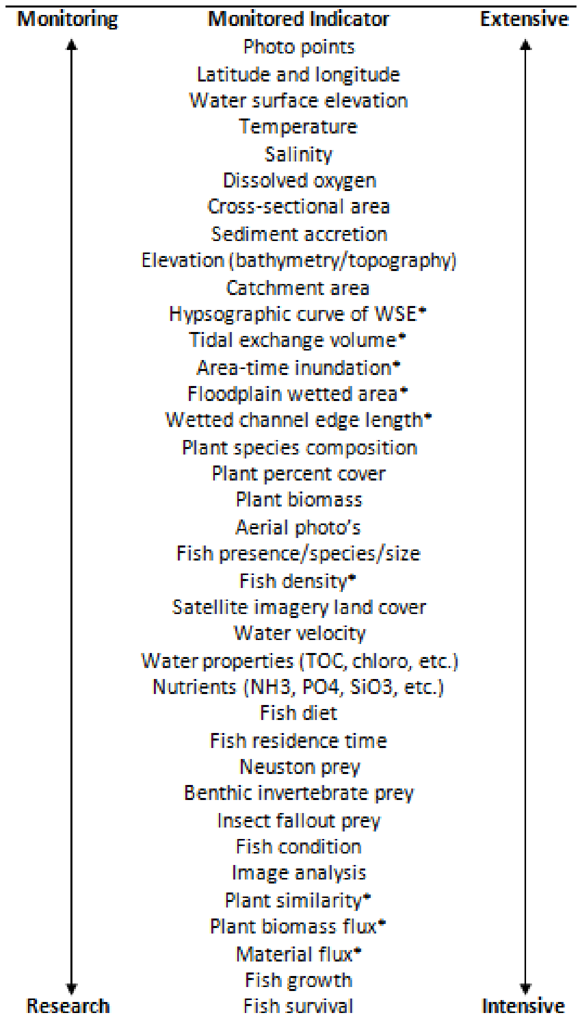

Figure 3. Monitored Indicators for Action Effectiveness across the Spectrum: From Monitoring to Research and Extensive to Intensive Sampling (modified from Johnson et al. 2012). *Signifies a derived indicator, i.e., one calculated using data from another indicator. This list is not exhaustive.

AEMR Levels

Implicit in the development of the programmatic AEMR plan is the spectrum of extensive monitoring to intensive research (Figure 3). Thus, we designate AEMR levels (Table 2) to facilitate communication and prioritization of AEMR activities: Level 1 is intensive AEMR to examine ecosystem processes and functions, along with structures and controlling factors; Level 2 involves extensive AEMR for the core indicators of ecosystem structures and controlling factors from Roegner et al. (2009); Level 3, the most basic level, includes standard AEMR on key controlling factors (Table 3). Thus, the monitored indicators for the AEMR levels are nested. Level 1 AEMR involves a formal statistical design to test difference in responses between the restoration site and control and/or reference sites. Typically, Level 1 will be long term (approx.. up to 10 y) and Levels 2 and 3 short term (approx.. 1-5 y). Because of cost constraints, more projects will have Level 3 AEMR than Level 2 and there will be more Level 2 projects than Level 1 (Figure 4). Actual AEMR will depend on project and program needs and will likely blend the levels.

Table 2. Features of the AEMR Levels

Designation	Name	Funding Source	Monitored Indicators	Intensity	Statistical Design	Term/Sampling Episodes[14]
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	Short-term; 1, 5 y

Table 3. Nested Relationship of the AEMR Levels and the Monitored Indicators

AEMR Level	Standard Monitored Indicators (habitat-based)	Extensive Monitored Indicators (habitat-based)	Intensive Monitored Indicators (habitat- and fish-based)
Level 1	Yes	Yes	Yes
Level 2	Yes	Yes	No
Level 3	Yes	No	No

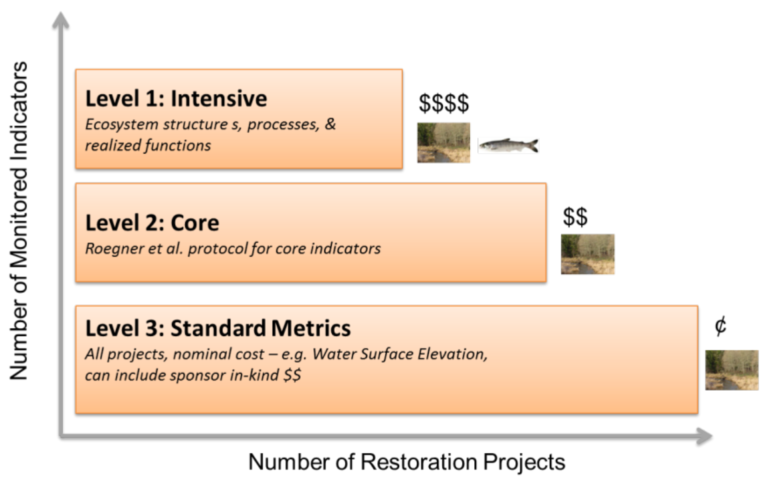

Figure 4. Relationship between Number of Restoration Projects Having AEMR and the Number of Monitored Indicators for the Three AEMR Levels

[14] Term/Sampling Episodes based on recommendations from Thom and Wellman, 1996. However, different indicators may have different frequencies.

To designate AEMR levels for each restoration project, decision-makers will consider additional river and estuary-wide spatial and statistical questions (Table 4). These guidance questions help to incorporate larger spatial and statistical questions in site-scale AEMR planning process and help inform which sites should be considered for more intensive monitoring. Based on project goals, estuary-wide considerations regarding a balanced AEMR program, and available funding, Action Agencies and collaborating partners will make the final determination on AEMR levels for particular restoration sites.

Question 1 establishes whether AEMR related to a specific action has occurred within a reach, with emphasis on monitoring actions in reaches that have had no previous AEMR. Question 2 captures within reach habitat variability, prioritizing the monitoring of restoration actions that may have been monitored within a reach but not in a specific habitat. Question 3 prioritizes sites that provide insight into increased capacity, opportunity, or realized function for juvenile salmonids. In order to strengthen the link between extensive and intensive monitoring, Question 4 supports higher AEMR levels for sites that can provide data to inform intensive/extensive ratio estimators. Question 5 prioritizes sites based on the level of precision required for a given restoration action, with emphasis on sites needed to meet the level of precision specified by Johnson et al. (2012).

Table 4. Guidance questions used to assist in designation of AEMR Levels. CRE subactions refer to the restoration actions in the Estuary Module.

No.	Question
1	Has the action (CRE subaction) previously been monitored in reach?
2	Has action (CRE subaction) been previously monitored in that habitat in that reach?
3	Do data provide insight into increased capacity, opportunity or realized function between habitats or CRE subactions
4	Are more data needed to generate ratio estimator related to action (CRE subaction)?
5	Do sufficient data exist to satisfy AEMR level of precision for a given action (CRE subaction)?

Standard Monitored Indicators

Data on the subset of standard monitored indicators specific to the type of restoration strategy (Table 5) should be collected at all project sites unless otherwise noted in the AEMR prioritization list (see example in the section on AEMR Priorities). Standard monitoring data will serve to document key environmental conditions at the site and may infer 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 changes in the physical environment using relatively inexpensive and easy-to-use methods. 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 when analyzed in the context of established relationships between extensive and intensive indicators (see next section). It is simply not economically feasible for fish data, while very important at chosen priority sites, to be mandatory for all restoration projects. Furthermore, the standard indicators do not cover all "core metrics" from Roegner et al. (2009a), thereby reducing costs and complexity while maintaining the utility of data for action effectiveness assessments.

Given the intent for restoration project sponsors to implement Level 3 standard monitored indicators at all sites, the methods will have to be relatively easy to conduct, inexpensive, and not require a lot of effort to collect, although the level of necessary technical expertise required should not be underestimated. This is not to say, however, that important Level 2 indicators such as channel cross-sections will not be widely collected.

Table 5. Standard Level 3 Monitored Indicators by Restoration Action. Levels 1 and 2 are more intensive and will depend on project objectives.

Monitored Indicator	Data Type
Photo Points	Discrete
Water-surface elevation	Logger
Water Temperature	Logger
Sediment accretion	Measurement
Elevation (topography)	Existing (Lidar)

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. Thus, by developing a proper mix of extensively monitored sites and intensively monitored sites, individual restoration projects may be surveyed with minimal effort while increasing opportunities to detect benefits at landscape and estuary-wide scales.

Johnson et al. (2012b) developed 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 5). 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 takes the following form (variances of the estimates may be included at a later date):

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

where

$\hat{Y}_{ex}$	=	estimated Y at an extensively monitored site
X_{ex}	=	measured X at the same extensively monitored site
$\overline{Y}_{\text{in}}$	=	mean of Y measured at multiple intensively researched sites
$\overline{X}_{\text{in}}$	=	mean of X measured at multiple intensively researched sites.

Table 6. Preliminary Data for Relationships Between "Extensive" (X) Monitored Indicator(s) and "Intensive" (Y) Monitored Indicator(s) (modified from Johnson et al. 2012); Use X to predict Y. These relationships remain to be fully quantified in the form of ratio estimators to provide statistically valid relationships. *Cross-sectional area is an extensive indicator; the relationship with catchment area is the ratio pertinent here.

"Extensive" Indicator(s) (X)	"Intensive" Indicator(s) (Y)	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)

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. Conditions at a reference site are similar to the intended eventual outcome at the affected site after restoration, whereas conditions at a control site are 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. Using reference sites paired with each impact site can help demonstrate the trajectory of development following restoration, relative to target conditions. The use of reference or control sites or both in the sampling design (see next section) will depend on project and CEERP objectives.

AEMR will be informed by results 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 in AEMR work (Figure 5). 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?" At a minimum, the data from the Reference Site Study may be useful for ecological context at future restoration sites nearby, which may also require their own project-specific reference sites.

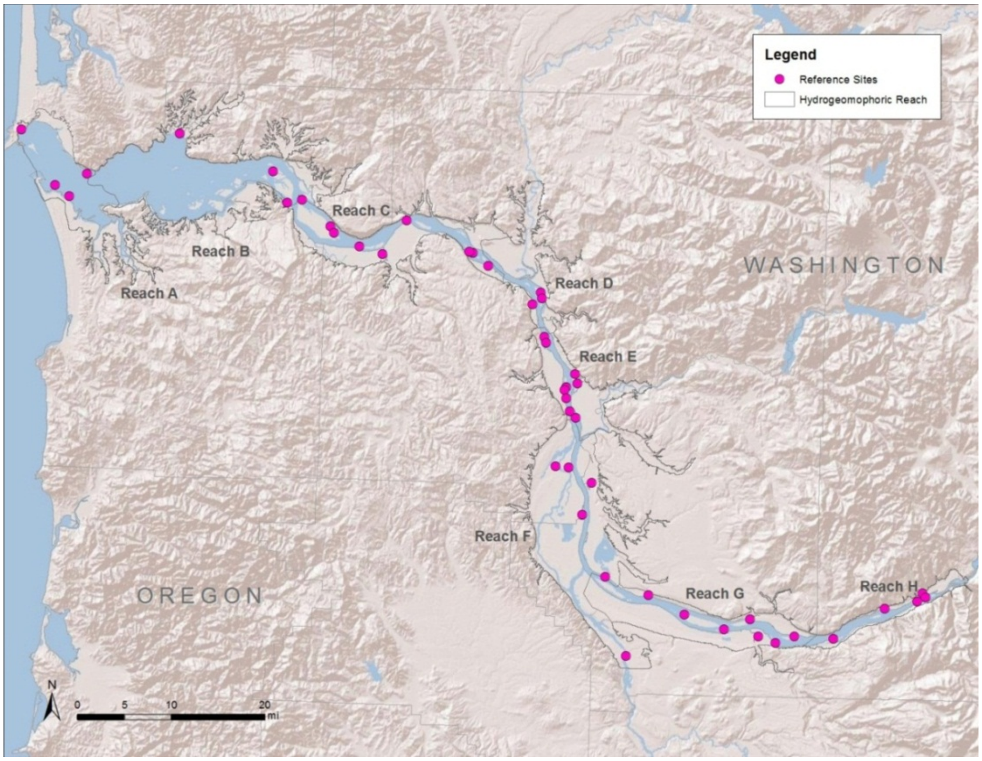

Figure 5. Map of Reference Sites

Sampling Design

Sampling design includes both the frequency of AEMR sampling and selection of a formal statistical design to evaluate the effects of restoration actions. Johnson et al. (2008) recommend sampling frequencies for many of the monitored indicators in Table 2. 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.

For more intensive AEMR studies, Johnson et al. (2008), Roegner et al. (2009), and Diefenderfer et al. (2011) 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 often warranted to show changes afterwards; 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. In comparison, a reference site is essential to designs for intensive AEMR because it allows for analysis of the ecological trajectory of the restoration site. (Such reference sites may or may not come from the Reference Site Study mentioned above.)

In intensive studies, 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. The design serves to 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 because of the pace of ecological 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 collected from all or most sites, an estimate of estuary-wide, total higher-level ecological response would be made using either ratio- or regression-estimation techniques (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. (2012) 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 ε, $(1-\alpha)$ 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

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

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

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

Solving for n for given precision defined by ε and α

$$n=\frac{1}{\dfrac{\varepsilon^2}{Z_{1-\frac{\alpha}{2}}^2 CV_{Y_i}^2(1-\rho^2)}+\dfrac{1}{N}}$$

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., $=\frac{\sqrt{\mathrm{Var}(Y_i)}}{\bar{Y}}$.

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 $1-\alpha$ [that] all parties can agree upon."

Monitoring Methods

Monitoring methods have been developed and field-tested specifically for the CEERP, based on existing methods used in similar restoration and research programs. Information about many monitored indicators is provided in Johnson et al. (2008; Appendix C); the material for each monitored indicator includes a description, the data collection method, and reference(s) for an example protocol.

The monitoring and research protocols developed by Roegner et al. (2009) are an important component of the programmatic AEMR because they will provide a means to analyze data across space and time. Roegner et al. (2009) covered the standard (Level 3) and core (Level 2) indicators, as follows (available at www.monitoringmethods.org):

- Hydrology: water-surface elevation, catchment area, tidal exchange volume, wetland delineation;
- Water Quality: temperature, salinity, dissolved oxygen;
- Topography/Bathymetry: elevation, sediment accretion rate, channel cross-sectional area;
- Landscape: photo points, aerial photos;
- Vegetation: percent cover, species composition, species richness, similarity index;
- Fish: species composition, catch per unit effort, size (length).

Project sponsors and AEMR practitioners will work together to identify the most appropriate methods given the specific monitored indicators and priorities for particular restoration project and programmatic objectives. Every effort will be made to employ standard methodologies at each restoration site to facilitate synthesis and evaluation at the program-level.

Landscape and Estuary-Wide Scales

AEMR is typically conducted at the site scale, but it is also important to consider the landscape and estuary-wide scales, especially as data are synthesized and evaluated. There are ecological gradients longitudinally, laterally, and vertically in the LCRE that are manifested 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 river 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). The 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 recovery of wetlands after hydrological reconnection vary considerably and are likely tied to restored processes, which in turn 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 supposition 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 (Johnson et al. In Preparation), and juvenile salmon density (Sather et al. 2012) are being developed for application to programmatic AEMR. Many of these methods can be applied estuary-wide.

A technical approach for AEMR in the LCRE at the landscape or estuary-wide scale developed by Diefenderfer et al. (2011b) is based on levels-of-evidence assessment (Downes et al. 2002). The approach developed for the LCRE 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). These analyses 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).

Using the levels-of evidence approach, Diefenderfer et al. (2012b) recently completed the first-ever evaluation of the cumulative effects of ecosystem restoration in the LCRE, albeit at an early stage in the CEERP wherein the development of restoration sites is still expected to be limited relative to reference sites. These authors concluded: "…all lines of evidence from the LCRE indicated positive habitat-based and salmonid-based responses, except in cases of tide gate installation on small sloughs. On this basis, we concluded that the habitat restoration activities in the LCRE are likely having a cumulative beneficial effect on juvenile salmonids that access restored shallow-water areas or actively transit main-stem river habitats as they migrate from the hydrosystem and lower-river tributaries to the ocean. In summary, tidal wetlands in the LCRE currently support juvenile salmonids, including interior basin salmonids, and this effect would be expected to increase over time as existing restoration projects mature and new ones are implemented."

Prioritization and Implementation

The AEMR data collection effort must be prioritized to make the best use of limited resources for the CEERP. This section of the programmatic plan provides and implements a prioritization process that we use to plan AEMR for upcoming restoration actions. The studies designated to implement AEMR are described and activity matrices for implementation are presented below, along with a monitoring summary table (Appendix B).

Prioritization Process

The criteria for prioritizing sites for AEMR are focused on elements important to successful multi-scale programmatic RME as opposed to needs of specific restoration projects, and derived from multiple sources (Table 7). The topics are:

- Topic A (**Types of Restoration Actions**) -- We applied the categorization and relative importance tiers given by Roni et al. (2002) to determine scoring levels for AEMR (see "Background" above), as follows: 5=Actions that are synonymous with protection; 4=Actions which deal with restoring habitat connectivity; 3=Restoring long-term processes-water quality/quantity +habitat quality/quality; 2=Restoring long term processes-riparian; 1=Restoring short term processes (enhancement projects). We also associated these priorities with the CEERP restoration actions (see Table 1).
- Topic B (**Landscape Location Related to Density of Restoration**) -- We divided the LCRE into three zones by combining reaches of the Columbia River Estuary Ecosystem Classification (Simenstad et al. 2011): upper zone (Reaches G-H); middle/transition zone (Reaches C-F); and lower zone (Reaches A-B). We examined the concentration of planned restoration actions from the "Get-After-It-List" (GAIL), a list of project identified by project sponsors in summer 2011. We then assigned scoring (3=high; 2=medium; 1=low), depending on the density of planned projects in these three zones.
- Topic C (**Spatial Gaps in Previous AEMR Work**) -- We applied a similar approach by identifying the concentration of previous AEMR (Figure 1) and assigned scoring (3=low; 2=medium; 1= high). Topic 2 may drop in importance over time if sufficient AEMR is undertaken for a given zone, while Topic 3 may gain in priority if spatial gaps continue.
- Topic D (**Addresses a Key Uncertainty**) -- We examined whether the AEMR study addresses uncertainties in the ERTG list (see above) or the recommendations of Thom et al. (2013) in the CEERP 2012 Synthesis Memorandum. These will be prioritized over the next year.
- Topic E (**Survival Benefit Units**) -- Assigned SBUs reflect the project's size, likelihood of ecological success, and anticipated benefits forto fish access and habitat capacity (ERTG 2010b). The scoring measure is based on the average of the SBU values for ocean- and stream-type fish.

The total score for a project is the sum over the five topics of the product of the scoring value and the weighting factor: minimum score = 9 and maximum = 28. The prioritization scores provide one means to rank the restoration projects for AEMR. The prioritization process should be applied periodically (at least once per year) by a committee made of up representatives from BPA, Corps, and EP. It is important to emphasize that this process needs to be responsive to progress in the implementation of restoration actions, and new AEMR developments. The result of this process is a set of recommendations to the AA estuary program leads. The AAs will then consider timing, cost, and certainty of implementation in their final decision.

Table 7. AEMR Prioritization Framework

No.	Topic	Criterion	CEERP Priorities	Weighting Factor	Scoring Measures
1	Types of restoration actions	Actions strategically important to the restoration program	Hydrological reconnections; habitat creations	2	see text
2	Landscape location related to density of restoration actions	Locations in landscapes where restoration actions are concentrated	Results from GAIL (Get-After-It-List)	1	3=high; 2=medium; 1=low
3	Spatial gaps in AEMR	Location in landscapes where little AEMR has occurred	AEMR inventories	1	3=low; 2=medium; 1=high
4	Addresses a key uncertainty in action effectiveness	See list in the section above on State-of-Science	To be determined	3	2=applies; 1=doesn't apply
5	Salmon survival benefit units	ERTG-assigned or preliminary SBUs (Note, ocean- and stream-type SBUs are summed)	Projects with high SBU values	2	3= >3 SBU; 2= 1-3 SBU; 1= 0.3-0.99 SBU; 0=<0.3 SBU

AEMR Priorities

The ongoing and upcoming restoration projects are listed to provide the potential sampling universe of sites for AEMR (Table 8; Figure 6). We set AEMR prioritization levels for these projects using the criteria and priorities above (Table 7). In 2013, pending decisions related to acquisitions and contractual requirements, AEMR is expected to be conducted at approximately 16 sites.

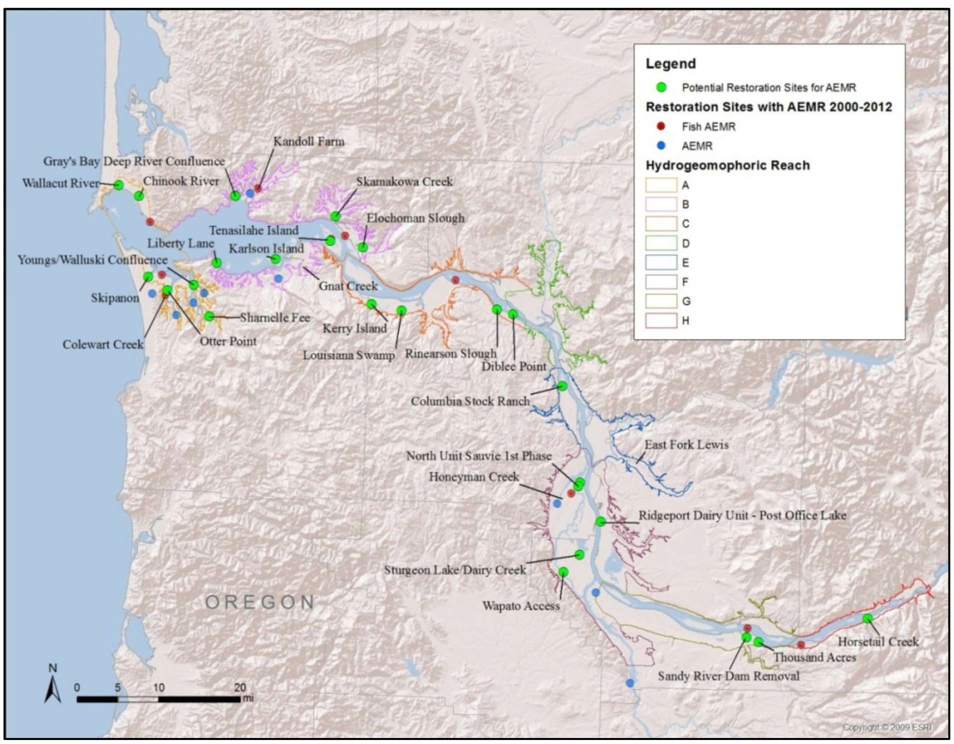

Figure 6. Map of Previous and Potential New AEMR Sites. In consideration of space, only potential new AEMR sites are named.

Table 8. Prioritization of AEMR Level (Table 2) for Ongoing and Upcoming 2012-2014 Restoration Projects. The AEMR level and priority score remain to be determined. The AEMR level and priority score will be determined at a later date. This list does not imply a commitment to fund AEMR. The table continues onto the next page. *Starred sites are located on tributaries, therefore, the distance from the Columbia River mouth represents the distance to the mouth of the tributary, not the distance up the tributary.

Project Name	Rkm	Construction Year(s)	Restoration Action	Proposed AEMR Level	Priority Score
Sandy River	195	2013	Dam removal	1	29
Sauvie Island, North Unit 1st Phase	143	2013	Hydrologic reconnection - remove water control structure	2	29
Kandoll Farm, Phase 2	21*	2013	Hydrologic reconnection – dike breach	2	28
Wapato Access	163	2013	Off/side channel creation/enhancement	2	25
Horsetail Creek	222	2013	Culvert modification - woody debris placement	1	24
Colewort Creek	19*	2013	Channel modification - off/side channel creation/ enhancement	1	24
Louisiana Swamp	77	2013	Hydrologic reconnection - dike breach	2	23.5
Post Office Lake	151	2013	Hydrologic reconnection	1	23
Sharnell Fee - Klaskanie River	19*	2013	Hydrologic reconnection - dike breach	3	20
Dibblee Point	103	2013	Off/side channel creation/ enhancement	3	19
Skamokawa Creek – Dead Slough	53*	2013	Culvert improvements	3	12
Steamboat (JBH)	xx	2013	Dike breach	TBD	TBD
Columbia Stock Ranch	122	2014	Hydrologic reconnection	TBD	34
Dairy Creek/Sturgeon Lake	159	2014	Hydrologic reconnection	TBD	31
Thousand Acre	200	2014	Tide gate removal - off/side channel creation enhancement	2	27.5
East Fork Lewis	138*	2014	Culvert modification - woody debris placement	TBD	27
Tenasillahe Island/ TK Slough	56	2014	Hydrologic reconnection	TBD	22
Karlson Island	42	2014	Hydrologic reconnection - dike breach	TBD	20
Youngs/Walluski Confluence – Restoration Phase	12	2014	TBD	TBD	20
Elochoman	60	2014	Culvert replacement	TBD	17
Kerry Island	43	2014	TBD	TBD	15
Rinearson Slough	100	2014	Tide gate modification	TBD	13
Chinook	8*	2014	Acquisition and tide gate modification	TBD	9

Project Name	Rkm	Construction Year(s)	Restoration Action	Proposed AEMR Level	Priority Score
Port of Astoria (Skipanon)	10	2014	TBD	TBD	9
Gnat Creek	43*	2012	Hydrologic reconnection - dike breach, dam removal	3	23
Otter Point	19*	2012	Hydrologic reconnection - dike breach	3	20
Honeyman Creek	140*	2012	Culvert removal	3	19
Liberty Lane (Tongue Point)	18	2012	Tide gate modification	3	18

AEMR Studies

AEMR will be implemented through ongoing RME studies and as part of particular restoration actions. The following RME studies are described further in the *2012 CEERP Action Plan* (BPA/Corps 2012).

- The Ecosystem Monitoring project (BPA 2003-007-00) is conducting AEMR at selected restoration projects. Four restoration sites have been intensively researched since 2008: Mirror Lake (off-channel and riparian improvements); Sandy River Delta (invasive plant control); Hogan's Ranch (riparian improvements and invasive plant control); Fort Clatsop (hydrological reconnection). This research was completed in 2012.
- The Multi-Scale Action Effectiveness Research project (Corps EST-P-11-01) conducted site-scale AEMR sampling at three sites: Sandy River delta [SRD], Julia Butler Hansen [JBH] National Wildlife Refuge, and Tenasillahe. It also estimated fish density to relate to restoration actions at the landscape scale (St. Helens to Longview). At SRD, pre-restoration sampling was completed in 2012 for planned 2013 dam removal and rechannelization in the delta. At JBH and TEN, post-restoration sampling was completed in 2012. During 2013, researchers will monitor water surface elevation and water temperature at Post Office Lake and perform reconnaissance at Columbia Stock Ranch and the Steamboat Slough breach on JBH.
- The Salmon Benefits project (Corps EST-P-09-01) is a methods-development study that is producing indices for habitat connectivity, early life-history diversity, and restoration benefits to juvenile salmon. The BPA/Corps intend to apply these indices to measure and track restoration action effectiveness at site, landscape, and estuary-wide scales. This project will be closed out in 2013.
- The Synthesis and Evaluation project (Corps EST-P-11-01) is developing a geospatial database for the LCRE (called "Oncor") that will eventually include AEMR data from multiple sites, projects, and researchers to disseminate data and enable comprehensive syntheses and evaluations of AEMR in the LCRE. Data from 2013 AEMR studies will uploaded to Oncor (explained further below under Data Management).

Monitoring Summary

An established AEMR plan for a restoration site (also referred to as an "AEMR template" in Johnson et al. 2012) provides information for the monitoring matrix, which summarizes the monitoring plans for all prioritized sites. Compiling AEMR plans in a systematic format such as the monitoring matrix make it easier to compare intended AEMR at restoration sites, and to evaluate if AEMR plans have considered all appropriate monitoring metrics. The 2013 monitoring matrix is presented in Appendix A. Specifically, the monitoring matrix codifies six elements of AEMR plans:

- limiting factors identified at the restoration site
- specific restoration actions implemented to address those limiting factors
- objectives for addressing the limiting factors through the restoration actions
- metrics for evaluating the success of actions
- whether a reference site or control sites has been identified
- intended statistical design (e.g., BACI).

Application of AEMR within CEERP

Application of AEMR within CEERP incorporates established program infrastructure, clear roles and responsibilities for the participating entities, and a defined schedule of events.

Program Infrastructure

Effective and useful application of AEMR within CEERP requires programmatic infrastructure. Infrastructure entails an adaptive management framework, coordination and peer-review processes, project-specific AEMR plans, standardized data collection and analysis, centralized data management, synthesis and evaluation, reporting and communications mechanisms, and leadership. Most importantly, there must be a commitment from all stakeholders to participate and cooperate in the conduct of AEMR and the overall adaptive management framework to produce AEMR results that are useful to program goals and objectives.

Adaptive Management Framework

AEMR is coordinated, prioritized, implemented, synthesized, and evaluated within the ongoing CEERP adaptive management framework (based on Thom et al. 2012a; application to CEERP explained by BPA/Corps 2012). AEMR, as a component of the overall RME effort in the adaptive management cycle, is critical to determining the success of restoration at site, landscape, and estuary-wide scales. The adaptive management framework provides the foundation of AEMR programmatic infrastructure. Other infrastructure elements, such as coordination and data management, are conducted within this adaptive management framework.

Coordination and Peer-Review Processes

Coordination for AEMR also occurs through existing regional coordination efforts, such as the Corps' Anadromous Fish Evaluation Program (AFEP), the Council's Fish and Wildlife Program (FWP), and the Lower Columbia Estuary Partnership's (EP) programs. Within these programs, work groups contributing to coordination purposes include the federal Estuary/Ocean Subgroup for Federal RME, the AFEP Studies Review Work Group (SRWG), the EP's Science Work Group, and the Expert Regional Technical Group. The Estuary Partnership convenes annual meetings to coordinate on-the-ground RME activities in the LCRE. This meeting in February or March each year focuses on communication among researchers and managers of upcoming field sampling dates and locations.

Peer-review takes place during coordination meetings and reviews. For example, the SRWG provides peer-review of preliminary and final proposals and draft technical reports from the Corps' RME projects in the LCRE. Most importantly, a special AEMR planning prioritization committee with representatives from BPA, Corps, and EP will be established to coordinate the AEMR effort.

Other important peer-review is provided by the Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP) of the Council's FWP. For example, during summer 2012, the ISAB reviewed the draft CEERP 2012 Synthesis Memorandum, which contained AEMR results to date. And, during spring 2013, the ISRP is slated to review the BPA's LCRE habitat restoration projects.

Project-Specific AEMR Plans

Every restoration project will have a written plan for AEMR. Such plans can range from a paragraph describing pre- and post-restoration site conditions coupled with photo points to an intensive research design intended to be carried out over 5 to 10 years. AEMR plans will be restoration project-specific, depending on the local conditions, type of restoration, available funding and time, and other factors. Johnson et al. (2012) provide a template for project-specific AEMR plans consistent with the adaptive management process and the project description templates (ERTG 2010). The point is to document, coordinate, and obtain management review and approval of the plan for site-specific AEMR before field work commences. For a given study-year, AEMR work across the multitude of studies will be summarized in a *Master Monitoring Matrix* (see Appendix A) and a *Matrix of Site-Specific AEMR Hypotheses and Indicators* (see Appendix B). The later two works serve to integrate and summarize the project specific AEMR plans across the CEERP program, and are used in coordination and communication efforts.

Data Flow and Management

AEMR is only as good as the data and information it produces for decision-makers. Coordinated, consistent measures will be employed to ensure proper data flow and ultimate release via a web-accessible database (Figure 7). A geo-spatial database, called Oncor, is being developed to store past and future data, facilitate data sharing among research and restoration practitioners, and be used as the basis for synthesis and evaluation of LCRE data. This database will have the form and function required to relate to other relevant regional data systems (e.g., StreamNet, cbfish.org). The intent is to provide a publicly accessible, interactive map-centered interface to access LCRE AEMR and other data for comprehensive analyses. AFEP project (EST-P-12-01) commenced in 2012 to meet this need. The project's objectives are as follows: 1) coordinate with funding agencies and regional stakeholders to ensure the database system will meet management's needs for ecosystem restoration throughout the floodplain study area of the LCRE; 2) develop and populate a web-based, publicly-accessible geospatial database management and analysis system to support action planning, RME, synthesis and evaluation, strategy development, reporting, public communication, regional and basin review processes, information dissemination, and decision-making, i.e., adaptive management; and, 3) apply data and information within the adaptive management process. During 2013, data reduction protocols, data access and sharing policies, and uploading procedures via Data Exchange Templates will be delivered to AEMR practitioners. The intent is for AEMR data collected during 2013 to be uploaded to Oncor. Once loaded in Oncor, the data along with associated metadata will be available for preparation of Site Evaluation cards and analysis and synthesis. The tentative timeline for CEERP synthesis and evaluation is the have annual updates of new data and complete synthesis every 3-5 years.

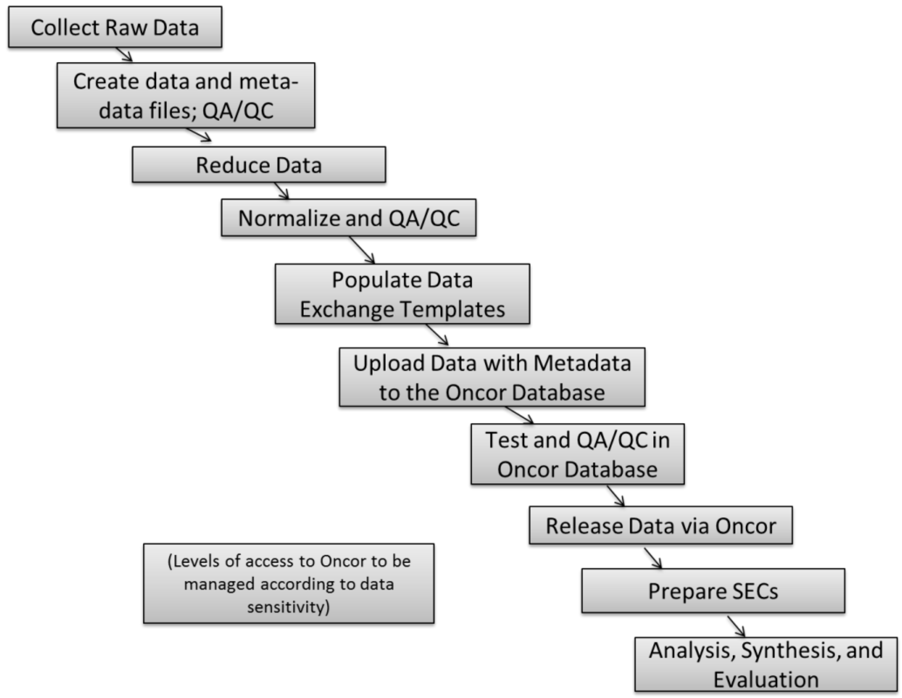

Figure 7. AEMR Data Flow

Reporting and Communication Mechanisms

Reporting of site-specific AEMR will be done using site evaluation cards (SEC). SECs were first proposed by Thom et al. (2008) as a mechanism for systematically recording AEMR data from restoration projects. Information in the project template and the AEMR plan can be copied and pasted directly into the SEC document. The SECs can also be synthesized in periodic meta-analyses. The SEC was designed with the understanding that its utility and value depend on the ability and ease with which it can be accurately completed by a wide range of restoration personnel. If the SEC were too large, too demanding, or too complicated the chances of its being completed would decrease. However, without the SEC, the ability of the CEERP to systematically capture AEMR data, and use the data to respond to reporting requirements, would be greatly diminished. SECs will be required for regular reporting by AEMR practitioners and will be archived in the Oncor database.

RME projects conducting AEMR will produce as appropriate progress reports, technical memoranda, annual reports, and SECs. These reporting documents will be categorized and housed in an electronic library in the central Oncor database. AEMR practitioners will strive to provide timely reporting of findings to facilitate synthesis and evaluation.

The Synthesis Memorandum is one of three inter-related, annual CEERP deliverables; the others are the Strategy Report and Action Plan (BPA/Corps 2012). The Synthesis Memorandum, which is informed by the SECs and various AEMR reports, synthesizes the state of the science on salmon ecology in the LCRE and what was learned from AEMR. It provides a scientific basis for the restoration strategies described in the Strategy Report, which in turn is used to implement restoration and RME actions outlined in the companion Action Plan. In subsequent years, further AEMR is conducted and the results are synthesized in follow-up Synthesis Memoranda. The Synthesis Memorandum provides one main report on AEMR results and management applications that managers can use to make decisions.

The biennial Columbia River Estuary Conference (every even-numbered year) is a useful forum to report and communicate AEMR findings to a wide range of participants. Conference organizers encourage substantial exchange of new data and information among researchers, policy-makers, resource managers, and the public.

Communications that contextualize and summarize the management applications of AEMR findings are essential to foster program support among policy-makers and the public. For example, communications from restoration program managers to a wider, non-technical audience might entail notices of key findings or accomplishments, and implications for society.

Synthesis and Evaluation

Using the Oncor database as a foundation, AEMR results will be "rolled up" in an annual Synthesis Memorandum, or similar synthesis of AEMR results. The synthesis will succinctly summarize the results from the analysis relative to the hypotheses and analysis questions, both at the site and landscape or estuary-wide scales. Meta-analysis of the SECs and other data provide a useful mechanism to synthesize data. Along with the estuary-wide analysis, the Synthesis Memorandum (mentioned above) will include a set of recommendations regarding how to better address the CEERP objectives as well as the critical uncertainties. The synthesis should be concise, specific, and not exceed 10 pages.

Available information from monitoring and research, such as data summaries, data reports, technical reports, and scientific articles, will also be synthesized and evaluated within CEERP adaptive management (BPA/Corps 2012). The levels–of-evidence approach to evaluating the cumulative effects of multiple restoration projects (Diefenderfer et al. 2011), mentioned above, will be applied to the above information summaries to address overall progress toward the management questions for the estuary, critical uncertainties, and hypotheses. The analysis will assess whether there has been an overall net improvement in the ecosystem and the resources it supports, and provide recommendations for adjustments to the program.

Leadership

All successful programs are run by people who provide leadership. This presents a challenge for AEMR in the LCRE, because restoration and RME are conducted by various entities under various authorities and for various purposes. The programmatic AEMR plan herein addresses this challenge in a significant way, but without leadership, it is not likely to meet expectations. Therefore, we propose the creation of an AEMR Leadership Team comprised of three members, one representative each from BPA, the Corps, and the Estuary Partnership. BPA and the Corps, as the primary agencies fiscally responsible for the CEERP, would alternate chairing the team. The Estuary Partnership, as a National Estuary Program body, would represent the views of regional partners to the team. It would be the team's responsibility to ensure that AEMR data are analyzed from an estuary-wide perspective, information is disseminated, and the program is evaluated. The team would also be tasked with ensuring that adaptive management is built into routine, cyclic program management. The first assignment for this team could be to review and approve this programmatic AEMR plan.

Roles and Responsibilities

The roles and responsibilities of various agencies for AEMR coordination and prioritization, implementation, Oncor database management, synthesis and evaluation, and CEERP decision-making are depicted in Table 8. As mentioned above, it is recommended that the BPA, the Corps, and the Estuary Partnership form an AEMR Leadership Team.

Table 8. AEMR Roles and Responsibilities DRAFT

Sector	Agency	Coordination and Prioritization	Implementation	Oncor Database Management	Synthesis and Evaluation	CEERP Decision-Making
Action Agencies	BPA	Co-decision-maker	Overseer	Overseer	Overseer	Co-decision-maker
	Corps	Co-decision-maker	Overseer	Overseer	Overseer	Co-decision-maker
Federal Agencies	NMFS NWFSC	Cooperator	Practitioner	Contributor	Developer; contributor	
	NMFS Portland	Cooperator				Contributor
	PNNL	Cooperator	Practitioner	Developer and contributor	Developer; contributor	
	USFWS	Cooperator	Practitioner	Contributor		
	USGS	Cooperator	Practitioner	Contributor		
State Agencies and Tribes	CIT	Cooperator	Practitioner	Contributor		
	ODFW	Cooperator	Practitioner	Contributor		
	WDFW	Cooperator	Practitioner	Contributor		
Non-Governmental Organizations	CLT	Cooperator	Practitioner	Contributor		
	CREST	Cooperator	Practitioner	Contributor		
	LCEP	Lead coordinator	Practitioner	Developer and contributor	Developer; contributor	
	LCFRB	Cooperator				
	NPCC	Cooperator	Overseer		Overseer	
	Watershed Councils	Cooperator	Practitioner	Contributor		

Key Event Schedule

Key events for AEMR will occur throughout 2013 (Table 9). Early in the year, planning and prioritization will take place. Coordination will occur throughout the year; however, a key event is the AEMR coordination meeting of AEMR stakeholders in March. Coordination meetings for the Oncor database will be convened every four months as needed. AEMR preliminary results will be presented at a workshop or other mechanism in the fall and be applied to the 2014 CEERP Strategy and Action Plan.

Table 9. Key AEMR Event Schedule for CY 2013

AEMR Event	Date	J	F	M	A	M	J	J	A	S	O	N	D
Prioritization completed	31 Jan												
Coordination and communication with researchers	28 Feb												
AEMR plans completed	28 Feb												
Coordination meeting	15 Mar												
Oncor database coordination meetings	various												
CEERP 2013 Synthesis Memo (or equivalent)	30 Jun												
CEERP 2014 Strategy Report and Action Plan (draft)	31 Aug												

Preliminary results workshop and SECs (draft)	10 Nov												
CEERP 2014 Strategy Report and Action Plan (final)	30 Nov												
Selection and date for CREEC 2014	5 Dec												

Action Items and Conclusion

The following list summarizes action items from the programmatic AEMR plan. [Will be update in 2013]

- establish an AEMR Leadership Team to lead implementation of AEMR within the existing CEERP adaptive management framework.
- update and refine the Roegner protocols and develop a “wiki” for them;
- quantify the extensive/intensive monitored indicator relationships in the form of ratio estimators;
- develop data reduction protocols to accompany the Roegner protocols;
- write restoration project-specific descriptions (ERTG 2010), AEMR plans, and site evaluation cards, and disseminate them via the Oncor database;
- develop and operationalize the Oncor database in coordination and integration with other Columbia basin database efforts such as cbfish.org;

Action effectiveness is a critical element of the CEERP adaptive management process. It is important to monitor the effectiveness of restoration actions to know how well they are performing relative to their intended purpose. Funds for AEMR, however, are limited and must be spent wisely to obtain useful, cost-effective information for management. This programmatic AEMR plan helps address this need.

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.”

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

***census* -** A complete and thorough collection of data on the population at hand.

***conceptual ecosystem model* –** A graphical representation or a simple set of diagrams that illustrate a set of relationships among factors important to the function of an ecosystem or its subsystems (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. 2009). They must be relevant to the objective.

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

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

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

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

evolutionarily significant unit – A population that 1) is substantially reproductively isolated from conspecific populations and 2) represents an important component in the evolutionary legacy of the species (Johnson et al. 1994). Seventeen ESUs have been designated and mapped in the Pacific salmon range in California, Washington, Oregon, and Idaho. Each unit generally includes a major river basin such as the Snake or Sacramento Rivers or a section of coastline that may include several river basins as in the California Central Coast ESU.

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 habitats are.

***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 research – research 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 one 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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Appendix A: Master Monitoring Matrix for 2013

1/25/13

Caveat: This table is an example intended to show potential information and presentation format.

		Standard Indicators (Level 3)					Extensive Indicators (Level 2)						Intensive Indicators (Level 1)									
Site	Month	Photo Pt	WSE	Temp	Sed Acc	Elev	Salinity	D.O.	X-sec	Water velocity	Plant %cover	Plant biomass	Water prop	Nut's	Fish presence	Fish density	GSI	Fish Diet	Fish growth	Fish res time	Macro-inverts	Material flux
North Unit	Jan		x	x																		
	Feb	x	x	x																		
	Mar		x	x					x		x											
	Apr		x	x																		
	May	x	x	x											x							
	Jun		x	x																		
	Jul		x	x											x							
	Aug	x	x	x					x		x											
	Sep		x	x																		
	Oct		x	x																		
	Nov	x	x	x																		
	Dec		x	x					x													
SRD	Jan		x	x																		
	Feb		x	x																		
	Mar		x	x																		
	Apr	x	x	x																		
	May	x	x	x																		
	Jun	x	x	x																		
	Jul	x	x	x																		
	Aug	x	x	x																		
	Sep	x	x	x																		
	Oct	x	x	x																		
	Nov		x	x																		
	Dec		x	x																		

Appendix B: SummaryTable of 2013 Site-Specific AEMR Indicators

1/25/13

Caveat: This table is work in progress intended to show potential information and presentation format. Not all of the material has been reviewed by restoration sponsors or monitoring practitioners.

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
Sauvie Island - North Unit	Removal of water control structures	H1-Reconnecting floodplain lakes and sloughs back to tidal influences will expand shallow water habitat, improve water quality, and reduce potential fish stranding.	Hydrologic connection during salmonid outmigration period will be sufficient to provide access to off lacustrine habitat	BARI The reference site for the project is at Triangle Lake, near the mouth of Cunningham slough. It is an unobstructed tidal slough. The marsh plain is higher at Triangle than the other sites, so vegetation communities are different from the target plant communities within the restoration work area.	Water Surface Elevation	Vegetation Surveys	Fish Access (and where do they go in flood plain lakes)
			Water quality (temperature and DO) conducive to juvenile salmonid use during periods of outmigration		Water Temperature	Channel Cross Sections	
			Monitor timing and duration of hydrologic connection		Photo points		
	Soil Scrape down	H2-Scrapedown of soils will remove the rhizome layer of the invasive Reed Canary Grass and lower the marsh plain elevation, which	The site will remain underwater during the early germination months of February and March. This is anticipated to curtail the growth				

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
		will result in longer inundation periods.	of invasive species, while creating growing conditions more suitable for native species.				
			More closely match natural inundation patterns				
	Channel connections to Cunningham Slough and/or mainstem Columbia	H3-Increased connectivity to the mainstem Columbia and Cunningham slough will expand access points and increase frequency of overtopping events.	Increased ingress/egress points means greater access to available juvenile salmonids				
			Food web productivity will be enhanced as the marsh plain is more directly connected to surrounding waterways, increasing nutrient exchange				
			Increase channel edge densities				
Sandy River Dam Removal	Remove the dam that plugs the old Sandy River distributary to reestablish connectivity of the old channel to its historic confluence	H1- Improve access for juvenile salmon, including upriver stocks, to the shallow water habitats in the SRD, i.e., increase unmarked CH	Increase unmarked Chinook salmon densities	BARI – Reference sites on Gary Island and Chatham Island	Water Surface Elevation	Vegetation Surveys	Fish density, Genetic Stock Id'
			Increase in prey densities			Macroinvertebrate Sampling	Fish Diet, prey avail.
			Increase Juvenile salmon growth				Bioenergetics

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
	with the Columbia River	salmon densities H2 - Improve prey availability for juvenile salmon, i.e., increase prey densities. H3 - Increase juvenile salmon growth rates	rates				
			Water quality will improve for salmonids		Water Temperature, Photo points	DO	
			Channel cross sections will increase and stabilize			Channel Cross Sections	
			Juvenile salmon accessing the will feed on prey at the site				
Kandoll Farm Phase 2	Breach Dike along Grays River	H1-Restored tidal exchange and greater inundation will improve access to emergent wetland habitat	Tidal Prism/exchange similar to reference site	BARI - Same reference site as Kandoll Farm Phase 1	Water Surface Elevation	Vegetation Monitoring	
		H2- Restored tidal exchange will improve water quality for juvenile salmonids	Water quality conducive to juvenile salmonid use		Water Temperature	Macro Invertebrate Sampling	
	Native Revegetation	H3- Restoration of tidal, fluvial processes will result in promotion of native freshwater wetland emergent, scrub-shrub, and forested wetland	Vegetation communities should be similar to reference site at same elevations		Sediment Accretion	Channel Cross Sections	

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
		H4- Edge habitat will result in improved macroinvertebrate prey availability	Increased macroinvertebrates				
	Topographic complexity o Channel excavation o Large wood debris	H5- Restored tidal exchange and greater inundation will result in accretion and aggradation in tidal marsh areas.	Restored topography will approach similar topography in reference area				
		H6- Large woody debris will increase channel complexity	Channel cross sections will be similar to reference site				
Thousand Acres	Remove water control structure and tide gate	H1- Fish able to access habit during periods of hydrologic connection and water quality will be conducive for juvenile salmonids	Hydrologic connection during salmonid outmigration period will be sufficient to provide access to off channel habitat	BACI Sundial island - Hourglass slough	Water Surface Elevation	Vegetation Monitoring	
			Water quality conditions within acceptable ranges during periods of hydrologic reconnection		Water Temperature	DO	
	Invasive vegetation management/Native revegetaion	H2- Improving native vegetation diversity will promote native vegetation	Vegetation communities with similar percent cover of native and invasive plants as		Photo points		

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
		assemblages, decrease invasive plants	reference site				
Wapato Access	Excavate connection channel	H1- Fish able to access habit during periods of hydrologic connection and water quality will be conducive for juvenile salmonids	Hydrologic connection during salmonid outmigration period will be sufficient to provide access to off channel habitat	BARI -- Sauvie Slough (Willow Bar)	Water Surface Elevation, Water Temperature	Vegetation Monitoring, Channel Cross Sections	Nutrients (NH_3 PO_4 SiO_3) (2013/2014)
		H2- Increased flushing will change available nutrients which will alter ecosystem food web.	Water quality conditions within acceptable ranges during periods of hydrologic reconnection			DO	
	Invasive vegetation management Topographic complexity o Increase depth of pond o Large wood debris	H3- Improving native vegetation diversity will promote native vegetation assemblages, decrease invasive plants	Vegetation communities with similar percent cover of native and invasive plants as reference site				
		H4- Diversity of wetland/riparian habitat types should evolve with changes in topography	Increase in edge and habitat diversity and an increase in native plants will increase food web productivity		Photo points	Macro Invertebrate Sampling	

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
Horsetail Creek	Eliminate Diversion of Oneonta Creek	H1- Oneata Creek discharge should be roughly equal in reaches located upstream and downstream of existing diversion	During the months of July and August, discharge downstream of current diversion should be at least 80%of that measured upstream of diversion	Accident Response Design - - Target restoration values for Flow and Temperature related to juvenile salmonids are established for ODEQ and ODFW. Vegetation restoration values are based on values for PNNL Reference Site study for marshes in reach H	Water Surface Elevation	Vegetation Monitoring	Pit Tag Array
		H2- Increases in Horsetail Creek temperatures between railroad and pond outlet stations should be roughly the equal to those observed between the pond outlet and Horsetail Creek outlet stations	7-day average maximum temperature measured at Horsetail Creek outlet should be ,.5 higher than 7-day average maximum temp. measured upstream of confluence with pond outlet.		Water Temperature	Water Velocity	
	Retrofit I-84 Culvert to improve fish passage	H3- Retrofit to culvert will improve flow through culvert by diverting majority of low flows into western-most barrel.	During the months of July and August, discharge through the western-most culvert should be 75% or greater of combined discharge of Horsetail and Oneonta Creeks		Photo points	Channel Cross Sections	

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
		H4- Constructed "swim-through" diversion riffle at culvert inlet will allow fish passage	From November through June, constructed riffle should have surface water depths, slope, thalweg and water velocities suitable for passing adult and juvenile salmonids.				
	Install LWD structures and regrade constructed channels	H5- Increase in channel complexity will provide habitat opportunity for juvenile salmonids	Pool depth typically greater than 2ft in portions of Horsetail creek				
	Construct Native vegetation marsh	H6- Restoration of fluvial and sediment processes will promote the establishment and propagation of natural plant community	• Plant community in constructed wetland should have no less than 28.58% native cover and no more than 26.36% non-native plant cover after 5 years. • Seasonal inundation of constructed wetland should correspond with salmonid spawning and outmigration periods				

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
Colewort Creek	Channel creation and enhancement of existing ditches, marsh plain elevation lowering, large woody debris placement, invasive species removal	H1- Habitat opportunity should be increased with additional channel area and sinuosity	Water quality conditions should be similar to well-developed tidal channel present	BARI -- A reference site has been identified, however with limitations.	Water Surface Elevation	Macro Invertebrate Sampling	PIT tag array
	Diversify topography adjacent to created channels and replant with native vegetation	H2- Diversity of wetland/riparian habitat types should evolve with changes in topography	Increase in edge habitats and diversity in native plants will increase food web productivity		Water Temperature	Vegetation Monitoring	
LA Swamp	Dike Breach	H1- Restored tidal exchange and greater inundation will improve access to emergent wetland habitat	Depth and timing of tidal prism similar to reference site	BACI - Vegetation, similar hydrology (used to create grading plan)	Water Surface Elevation	Channel Cross Sections	
			Water quality suitable during juvenile salmonid during outmigration periods		Water Temperature	Vegetation Monitoring	
	Create Tidal Channels o Large wood Debris o Remove levee along Tandy Creek	H2- Diversity of wetland/riparian habitat types should evolve with changes in topography	Increase in edge habitats and diversity in native plants will increase food web productivity		Photo points	Macro Invertebrate Sampling	
	Native Re-vegetation o Exotic Control o Planting	H3- Soil scrape down to promote native vegetation diversity and assemblages,	Plant native vegetation communities at similar elevations as reference sites		Sediment Accretion		

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
		decrease invasive plants	5-year maintenance of plantings to promote establishment				
Post Office Lake	Remove a broken tide gate and associated culvert to reconnect Post Office Lake to mainstem	H1- In terms of ecological benefit*, pre-restoration conditions will not equal post-restoration conditions; juvenile salmon density, stock composition, and seasonal distribution will change over time at the site related to restoration actions.	Channel cross-sections will increase then stabilize	BARI - Campbell Lake for fish community, habitat characteristic's flux, etc. BACI -- Green Lake (Base habitat features (WSE and temperature)	Water Surface Elevation	Channel Cross Sections	Fish Community Data Collection
			Sediment will accrete in the wetlands adjacent to Post Office Lake following reconnection		Water Temperature	Macroinvertebrate Sampling	Genetic Stock Identification
			Water temperature regime in Post Office Lake will improve (reduced temp. fluctuations)		Photo points	aerial photography	Pit Tag Array
			Opportunity for juvenile access to Post Office Lake rearing will increase		Sediment Accretion	Water Velocity	Drift Prey
			Juvenile salmon will feed on prey at the site			DO	Benthic-invertebrate prey and benthic TOC
			Juvenile salmon accessing the site will show positive				Fish Diet

Site	Restoration Actions	Hypothesis	Objectives	Statistical Design/Reference Site	Level 3 Indicators	Level 2 Indicators	Level 1 Indicators
			growth				
			Native fish species richness will increase				Fish Condition
			Material flux to main stem will increase				Nutrients (NH_3 PO_4 SiO_3)
			Invertebrate prey density in the main stem immediately outside Post Office Lake will increase				
Columbia Stock Ranch	TBD						
Dairy Creek - Sturgeon Lake	TBD						
East Fork Lewis	TBD						
Steamboat Slough	TBD						
Youngs Walluski	TBD						