EcoRestore Adaptive Management Program White Paper

DRAFT 3/7/2017

Executive Summary

The California EcoRestore (EcoRestore) initiative calls for the restoration and enhancement of 30,000 acres of habitat, primarily floodplain and tidal marsh, by 2020. As part of this initiative, EcoRestore has committed to "leverage collaborative science efforts … and undertake investigations that support adaptive management and long-term understanding of Delta systems" (EcoRestore 2015).

This white paper proposes recommendations to develop a complete, integrated, and financially supported adaptive management program for habitat restoration in the Delta and Suisun Marsh. While the scope of this paper is limited to integration of current EcoRestore projects, implementation of the recommendations will provide a strong foundation for a robust, long-term habitat restoration adaptive management program that is based on scientifically rigorous modeling, monitoring, research and assessment methods. The desired outcome of implementing the recommendations is an EcoRestore Adaptive Management Program that 1) supports individual restoration projects, 2) considers local and system-scale effects, 3) sets a stage to evaluate impacts of restoration actions at multiple time and spatial scales, and 4) has an organization structure wherein acquired knowledge is effectively communicated and used for development of subsequent goals, objectives and management actions. The EcoRestore Adaptive Management Program described in this paper would have an emphasis on tracking and evaluating program-wide progress and would also provide resources to support effective implementation of adaptive management at the project level.

Chapter 2 of this white paper identifies existing resources and missing pieces needed to support adaptive management, and is organized according to the three phases of adaptive management: Plan, Do, and Evaluate and Respond, with special discussion of Data Management as a cross-cutting element that spans all phases of adaptive management. This chapter provides rationale and justifications for the recommendations at the program-wide and project-level scales. Having the EcoRestore Adaptive Management Program to support adaptive management at both program-wide and project-level scales, the expectation is that implementing agencies will save time and money while still ensuring the use of best available science and compliance with regulatory requirements.

Chapter 3 lists a set of specific recommendations for an adaptive management program that supports EcoRestore, as well as outlines a structure to aid and improve individual restoration projects. These recommendations integrate existing adaptive management efforts to enhance coordination, integration, synthesis and evaluation, information sharing, and communication. Implementation of these recommendations would establish a robust adaptive management program for habitat restoration in the Delta and Suisun Marsh. Below is a short summary of the recommendations.

Governance

G1 Develop a governance framework for an EcoRestore Adaptive Management Program

G2 Establish a position for an Adaptive Management Science Coordinator

G3 Maintain the position of EcoRestore Director

G4 Maintain the Interagency Adaptive Management Integration Team as a technical team

G5 Maintain the EcoRestore Adaptive Management Steering Committee

Conceptual models and key uncertainties

CM1 Update and develop additional conceptual models for all EcoRestore project types

CM2 Develop a strategy to curate conceptual models

CM3 Develop a common list of key uncertainties and identify those to be addressed through active adaptive management and applied studies

Quantitative modeling

QM1 Develop additional tools and staff capacity to support integrated modeling, scenario analysis, and decision making

QM2 Provide well-documented access to models and their updates

QM3 Provide venues for modeling experts from public, private, academic, and NGOs to do community modeling

QM4 Develop predictive models of restoration trajectories and expected restoration outcomes

QM5 Develop system-wide physical-chemical-biological models for each project type

Shared system-wide resources

SR1 Identify data resources of universal benefit for restoration planning, fund the data collection, and share the data

Data management

DM1 Establish a position for an EcoRestore Data Manager

DM2 Develop an open data strategy and strategic plan for data management

DM3 Identify data science resources at participating agencies and allocate additional resources for web-servicing and data access

Performance Measures

PM1 Develop performance measures to track system-wide progress resulting from restoration

Project-level support

PS1 Develop specific guidance for project-level adaptive management plans

PS2 Identify resources and support for planning and implementing adaptive management and long-term monitoring
PS3 Ensure adequate funding for long-term management and stewardship
PS4 Develop a suite of shared tools and infrastructure to support decision making and scenario analysis

Monitoring and research

MR1 Develop and implement monitoring frameworks for each project type
MR2 Develop and implement a system-wide integrated research and monitoring framework to evaluate system-wide effectiveness of restoration
MR3 Secure long-term funding for project-level monitoring
MR4 Identify funding and technical support for active adaptive management experiments
MR5 Identify funding and contracting support for mechanistic studies

Analysis and synthesis

AS1 Devote staff to analysis and synthesis to do program-wide evaluations
AS2 Perform system-wide synthesis and feedback into updated conceptual models and evaluating program-wide adaptive management triggers
AS3 Fund and facilitate peer-review

Communication

C1 Develop a communication strategy
C2 Hold an annual adaptive management forum
C3 Develop outreach materials or venues to improve practitioners' and managers' awareness of, support for, and capacity to implement adaptive management priorities
C4 Develop outreach materials or venues to inform scientists and regulators on the practical considerations involved in restoration

Regulatory flexibility

RF1 Advise projects to identify potential adaptive management changes in their original permits
RF2 Work with fisheries regulatory agencies to balance take limitations with needs for effectiveness monitoring for fish benefits
RF3 Encourage regulatory agencies to make use of effectiveness monitoring and targeted research to satisfy permit monitoring requirements
RF4 Encourage project proponents to design monitoring plans that integrate effectiveness monitoring and targeted research with permit compliance monitoring

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Chapter 1: Introduction

Background

The California EcoRestore initiative (hereafter EcoRestore) calls for the restoration and enhancement of 30,000 acres of habitat, primarily floodplain and tidal marsh, by 2020. As part of this initiative, EcoRestore has committed to "leverage collaborative science efforts … and undertake investigations that support adaptive management and long-term understanding of Delta systems" (EcoRestore 2015). EcoRestore is developing an adaptive management program (hereafter the EcoRestore Adaptive Management Program) to achieve its habitat restoration goals and increase restoration success for the benefit of the long-term health of the Sacramento-San Joaquin Delta and Suisun Marsh's native fish and wildlife species.

In the face of uncertainty, adaptive management is the preferred approach to implementing management actions. It emphasizes acquisition and use of new knowledge in management of natural resources under changing conditions, leading to continuous improvements in management, planning, and implementation to accomplish specified objectives. Adaptive management is called for in the Delta Reform Act and is required for compliance with multiple regulatory processes. However, despite copious information generated from numerous research and monitoring projects in the Delta and Suisun Marsh, a full adaptive management cycle is rarely completed at either the project- or system-level (Delta Independent Science Board 2016).

Currently there is no system-wide adaptive management program for the Delta and Suisun Marsh, and various gaps and inefficiencies exist throughout the adaptive management cycle (see Figure 1 for the adaptive management cycle as depicted in the Delta Plan [2013]). Impediments to implementation of adaptive management have been recently reviewed by the Delta Independent Science Board and others (Delta Independent Science Board 2016; Nagarkar and Raulund-Rasmussen 2016). This white paper builds off these previous reviews and provides a set of recommendations to integrate existing resources and fill gaps in infrastructure in order to establish an adaptive management program for EcoRestore. These recommendations are not in and of themselves an adaptive management framework or plan; rather, they set the stage for establishing a robust program that largely builds off of existing efforts (Appendix 1) to improve our collective understanding of management actions and to improve achievement of desired outcomes. The EcoRestore Adaptive Management Program described in this paper would have an emphasis on tracking and evaluating program-wide progress and would also provide resources to support effective implementation of adaptive management at the project level.

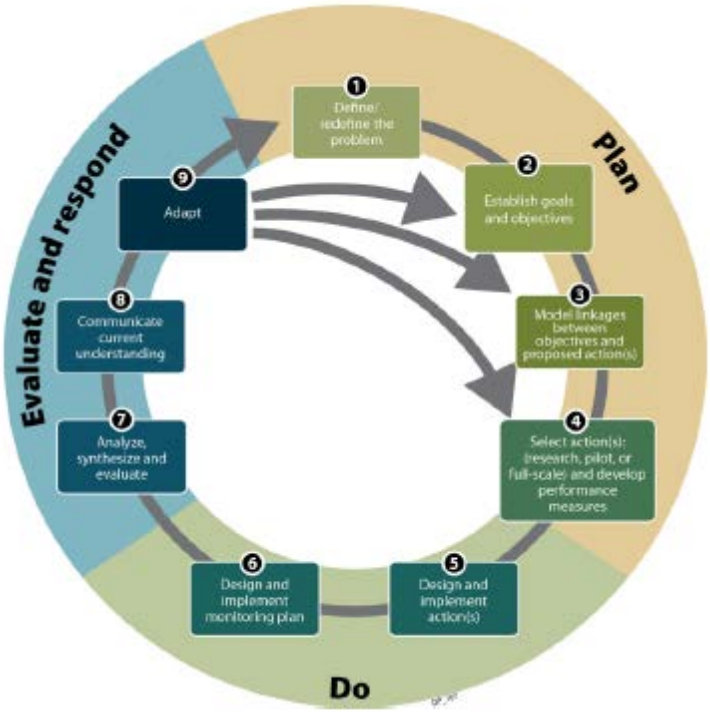

Figure 1. The 3-phase, 9-step adaptive management cycle (Delta Stewardship Council 2013a).

Problem statement and need

The Delta Science Plan (Delta Stewardship Council 2013b) provides the following problem statement, which frames the need for this paper: "Past attempts to adaptively manage Delta water operations and habitat restoration have rarely covered the full adaptive management cycle, and have not considered the appropriate time frame and spatial scale required for changes to occur as a result of management actions. System-wide progress toward achieving the coequal goals will not be possible if multiple adaptive management efforts are incomplete, nonintegrated, fail to consider system-wide and local effects, or are unable to respond within the time frame of management actions" (Delta Stewardship Council 2013b).

The problem is well defined and the legislative mandate (i.e., Delta Reform Act, Biological Opinions, NMFS Recovery Plan, USACE permitting) and political commitment by EcoRestore to address the problem are clear. The necessary next steps are to:

1. Develop an organizational structure for the EcoRestore Adaptive Management Program,
2. Integrate existing elements that support adaptive management (see Appendix 1) and add missing elements (see Appendix 2), and
3. Obtain sources of dedicated funding.

Goal and objectives

The goal of this white paper is to identify the necessary components of a complete, integrated, and financially supported adaptive management program for habitat restoration in the Delta and Suisun

Marsh. Establishing an integrated program is recommended because it provides an otherwise absent system-wide approach to improving our understanding of progress made towards achieving desired outcomes from the multitude of individual projects planned or in-process in the Delta and Suisun Marsh. This paper focuses on EcoRestore projects and proposes recommendations for putting such a program into practice. To be clear, the envisioned program and its components would not supersede the existing authority of agencies or regulations. While the scope of this paper is limited to current EcoRestore projects, implementation of the recommendations will provide a strong foundation that would support a future, more broadly focused, Delta and Suisun Marsh habitat restoration program.

The specific paper objectives are as follows:

1. Document existing parts of the adaptive management cycle (Figure 1) that are currently being implemented and are relevant to EcoRestore projects (Chapter 2 and Appendix 1).
2. Identify elements of adaptive management in need of additional support and/or areas where integration of existing efforts is possible (Chapter 2 and Appendix 2).
3. Produce a set of recommendations that support and enhance adaptive management for EcoRestore projects, and for the EcoRestore program as a whole, while leveraging and optimizing existing adaptive management efforts (Chapters 2 and 3).
4. Identify programmatic needs (e.g., staffing, funding, and infrastructure) and approaches for implementing the EcoRestore Adaptive Management Program (Chapter 3).

Outcome

The intent of this white paper is to deliver recommendations (Chapter 3), with sufficient background information (Chapter 2), that when funded and implemented will result in a robust habitat restoration adaptive management program based on rigorous research, monitoring, and assessment methods. The desired EcoRestore Adaptive Management Program will 1) support individual restoration projects, 2) consider local and system-scale effects, 3) set a stage to evaluate impacts of restoration actions at multiple time and spatial scales, and 4) have an organizational structure wherein acquired knowledge is effectively communicated and used for development of subsequent goals, objectives and management actions. The program should be focused on expediting and supporting projects by addressing areas that currently limit or impede implementation of adaptive management of restoration projects in the Delta and Suisun Marsh.

Methods

The Interagency Adaptive Management Integration Team (IAMIT) was established to serve as an interagency technical coordinating body to strengthen collaborations and discuss strategies for implementing adaptive management for habitat restoration in the Delta and Suisun Marsh. The IAMIT includes science managers and technical staff from agencies and representatives from local governments. The California Natural Resources Agency requested that the IAMIT develop a white paper, along with the EcoRestore Adaptive Management Steering Committee, to advise on the development of a habitat restoration adaptive management program and to provide specific recommendations on how such a program could be implemented. Key to this task is determining how existing planning,

159 monitoring, analysis, and communication efforts can contribute to an EcoRestore Adaptive Management
160 Program.

161 The IAMIT (see list of IAMIT members and their affiliations in Appendix 3), with support and leadership
162 from staff at the Delta Science Program, developed this white paper by first considering the
163 contributions of existing programs, then brainstorming other necessary elements of adaptive
164 management at the program and project levels and identifying "gaps" affecting successful
165 implementation of adaptive management. Recent reviews describing impediments to implementation of
166 adaptive management in the Delta and Suisun Marsh were used to support this assessment (Delta
167 Independent Science Board 2016; Nagarkar and Raulund-Rasmussen 2016). Staff also reviewed
168 examples of adaptive management programs in other systems, including the South Bay Salt Ponds
169 (South Bay Salt Pond Restoration Project 2007), the Everglades (LoSchiavo et al. 2013; Gunderson and
170 Light 2006; National Research Council 2014), and the Kissimmee River (Dahm et al. 1995; Whalen et al.
171 2002). Finally, the group worked from those identified gaps to develop specific recommendations for
172 designing and implementing the adaptive management program. Delta Science Program staff took the
173 lead on drafting the paper, with multiple rounds of review from IAMIT members and the EcoRestore
174 Steering Committee, and input from other invited reviewers.

Chapter 2: Elements of the EcoRestore Adaptive Management Program

This white paper identifies existing resources and missing pieces in support of adaptive management at both the program-wide and project-level scales, focusing on the EcoRestore project types (see Box 1, "EcoRestore project types"). The paper is organized according to the three phases of adaptive management: Plan, Do, and Evaluate and Respond, with a special discussion of Data Management as a cross-cutting element that spans all phases of adaptive management. Existing resources and gaps for adaptive management vary across habitat and project types; more details and specific examples are provided in Appendices 1 and 2. The EcoRestore Adaptive Management Program should build off these existing resources and find ways to bridge gaps in order to create system-wide support for adaptive management.

The program envisioned in this white paper will require dedication of staff and financial resources, and the development of some additional plans, strategies, and venues. Much of this could be accomplished in phases, first by redirecting efforts of existing agency staff, then over time by hiring additional dedicated individuals to sustain implementation of the EcoRestore Adaptive Management Program in the long-term. A more specific vision for the program's structure and relationships to existing entities needs to be developed and articulated in a governance framework (Recommendation G1). Among the roles identified, perhaps the most urgent is for one or more coordinators to help set direction for the program, organize the priorities of other staff, and facilitate communication. The South Bay Salt Ponds Restoration Project provides an example of such an organizational structure; the project employs two full-time coordinators, one "lead scientist" focused on science and monitoring activities and one "executive project manager" focused on management activities across the project (South Bay Salt Pond Restoration Project 2007). Both coordinators share duties in facilitating communication between scientists, decision-makers, and other stakeholders. The recommended structure for the EcoRestore Adaptive Management Program considers this model, with a Science Coordinator (Recommendation G2) focusing on science activities and EcoRestore Director (Recommendation G3) focusing on implementation and management.

In addition to the coordinators, there is a recognized need for technical and policy guidance for the program, and two interagency groups have already formed to help address these needs for EcoRestore. The Interagency Adaptive Management Integration Team (IAMIT), made of up agency scientists, technical management staff, and local government representatives, started meeting in March 2016 with the mission to assist EcoRestore in developing a Delta habitat restoration adaptive management program. The goal of the IAMIT is to provide technical and scientific recommendations on how a habitat restoration adaptive management program for the Delta and Suisun Marsh can be developed and implemented. The first task of the IAMIT was to develop this white paper, but there are many recommendations in this paper for which the IAMIT would be an ideal body to implement or advise on. Therefore, one of the recommendations of this paper is to maintain the IAMIT as a technical team for implementing the white paper (Recommendation G4), which will require continued commitment from

the participating entities to dedicate staff time to this effort. The other body is the EcoRestore Adaptive Management Steering Committee (Steering Committee), made up of agency leaders and resource managers involved in habitat restoration and adaptive management efforts. In particular, agencies participating in this group either have direct responsibility over resources to support the EcoRestore Adaptive Management Program or are key stakeholders, such as local governments. As with the IAMIT, the Steering Committee's first task was to help develop the white paper, but they may also be an ideal body to help implement some of the other recommendations of the paper and we advise that they continue to stay active in the formation of the Adaptive Management Program (Recommendation G5).

Box 1. EcoRestore project types

Tidal wetlands: EcoRestore calls for restoration of 9,000 acres of tidal and sub-tidal habitat to benefit fish species, the majority of which is intended to fulfill the 8,000 acres of tidal marsh restoration called for by the 2008 Delta Smelt biological opinion (BiOp).

Floodplains and fish passage: EcoRestore calls for restoration and/or enhancement of over 500 acres of floodplain habitat and for securing planning, permitting, and financing for an additional 17,000 acres. EcoRestore's main floodplain restoration and fish passage project is a USBR/DWR-led effort to implement the 2009 salmon BiOp in the Yolo Bypass: the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project.

Levee-related habitats: EcoRestore includes levee setbacks and levee strengthening projects that incorporate improvements to habitats along levees, such as creation or enhancement of riparian habitat, shaded aquatic habitat, and/or channel margin habitat.

Subsidence reversal and carbon sequestration projects: EcoRestore calls for restoration of 3,500 acres of managed wetlands, which includes subsidence reversal and carbon sequestration projects.

Other project types: Several EcoRestore restoration projects include improvements to upland habitats (e.g., grasslands), and some include restoration or enhancement of other types of wetlands (e.g., vernal pools, alkali wetlands). These habitats are relevant to many special status species, such as giant garter snake.

Phase 1: Plan

Phase 1 of the adaptive management cycle involves defining the problem, establishing goals and objectives, modeling linkages between objectives and proposed actions, selecting the scale of the project actions (research, pilot, full-scale), and developing performance measures (Figure 1).

Program-wide

Defining problem statements and setting goals and objectives for the EcoRestore Adaptive Management Program begins with a basic understanding of the system and desired outcomes. System-wide goals and objectives are described in several management plans for the Delta and Suisun Marsh, such as the Delta Plan, the Central Valley Project Improvement Act (CVPIA) Final Restoration Plan, the Suisun Marsh Plan, the Central Valley Flood Protection Plan Conservation Strategy (CVFPPCS), and the California Department of Fish and Wildlife's forthcoming Delta Conservation Framework, among others (see Appendix 1). Establishing an EcoRestore Adaptive Management Program should begin with defining

EcoRestore's goals and objectives, including those listed in Box 1, and identifying integration points between these and existing goals and objectives from other programs.

System-wide planning efforts in the Delta and Suisun Marsh are informed by several existing resources (see Appendix 1), including historical ecology accounts that suggest possibilities for restoration strategies and trajectories. The Sacramento-San Joaquin Delta Conservancy Board recently approved funding for Phase 1 of the Cache Slough Region Regional Restoration Strategy, a collaborative process to develop a restoration strategy that complements other ongoing efforts. The EcoRestore Adaptive Management Program should build on this pilot effort to develop a common set of decision support tools, including modeling of restoration trajectories and expected outcomes, to support adaptive management of the system as well as aid project-level design (Recommendations QM3, QM4, and PS3). Quantitative models greatly improve the potential for objective comparisons of management actions, and can be used to identify the data gaps that matter the most through sensitivity analyses (U.S. Fish and Wildlife Service 2016). Predictive models simulating restoration trajectories and expected restoration outcomes for each project type should incorporate relevant spatial and time scales and integrate physical, chemical, and biological (fish, avian, and terrestrial) modeling as appropriate (Recommendations QM4 and QM5).

Models, from simple conceptual models to complex numerical models, are useful in evaluating consequences of alternative management actions and weighing trade-offs between potential decisions. Conceptual models are critically important for linking goals to objectives using the best available science, and can guide adaptive management at multiple levels and scales. In the Delta and Suisun Marsh, numerous conceptual models have been developed to describe ecological function for some habitat types, species, and regions (Appendix 1); however, conceptual models for certain important habitat types, species, and processes are lacking or out of date. To be effective, the EcoRestore Adaptive Management Program should support the development and updating of conceptual models (Recommendation CM1) and include a strategy to curate conceptual models (Recommendation CM2).

Furthermore, the EcoRestore Adaptive Management Program should use existing and new conceptual models to identify key uncertainties in our knowledge of ecosystem function. While addressing uncertainties is largely done at the project level, identifying system-wide uncertainties provides the opportunity for a coordinated approach to address areas where significant gaps in knowledge hinder restoration or management actions (LoSchiavo et al. 2013). Key uncertainties associated with tidal marsh restoration for fish benefits have been identified (Brown 2003; Herbold et al. 2014), and uncertainties associated with system function in Suisun Marsh were identified from conceptual models in the Suisun Marsh Plan (USBR et al. 2013). However, there is a need to identify key uncertainties for other regions and project types (Recommendation CM3).

Performance measures provide a means to understand ecosystem function and progress made through restoration efforts. In the Delta and Suisun Marsh, there are no system-wide performance measures in place to address restoration effectiveness, though habitat-relevant performance measures are included in the Delta Plan (Delta Stewardship Council 2013a), CVPIA, CVFPPCS , species recovery plans, and individual projects. The EcoRestore Adaptive Management Program should develop a robust set of

performance measures to track program-wide restoration effectiveness (Recommendation PM1). Subsequent project and monitoring efforts should be designed in such a way to adequately report progress on the performance measures.

Project-level

Project-level planning needs for adaptive management depend on many of the same resources as program-wide needs described above. Adaptive management plans are required for compliance with multiple regulatory processes (e.g., Delta Plan consistency, Fish Agency Strategy Team crediting, and various US Army Corps of Engineers permits). Staff members from multiple agencies develop adaptive management plans for individual projects. Adaptive management liaisons from the Delta Science Program provide advice and guidance on use of best available science, availability of conceptual models, regional monitoring activities, and relevant research, and can help with integrating individual adaptive management projects, plans, and programs across the system (Delta Stewardship Council 2013b). To further assist adaptive management planning efforts, specific guidance that integrates various regulatory and funding agencies' requirements for project-level adaptive management plans should be developed (Recommendation PS1).

Phase 2: Do

Phase 2 of the adaptive management cycle includes design and implementation of restoration actions and project-level monitoring plans (Figure 1).

Program-wide

For many EcoRestore projects, desired outcomes should emerge at larger spatial and temporal scales than individual projects can feasibly measure. Several groups conduct research and perform system-wide monitoring in the Delta and Suisun Marsh, including Interagency Ecological Program (IEP) member agencies, the Delta Regional Monitoring Program, and university researchers. However, the Delta and Suisun Marsh lacks a monitoring framework by which these various existing efforts can be integrated and connected to provide system-wide assessment of restoration effectiveness. The EcoRestore Adaptive Management Program should develop a system-wide restoration research and monitoring framework that crosses projects and project types to fill this gap (Recommendation MR2). Such a framework would allow for a unified approach to monitoring the region and provide a potential mechanism for resource sharing and joint monitoring that pools resources from individual projects. The framework could also be a centralized place to discuss system-wide scientific considerations, such as prioritization of restoration-related research and sequencing of restoration project implementation.

Certain fundamental environmental datasets are missing that could improve project planning and evaluation. Specific examples of these datasets include Digital Elevation Models (DEMs), tidal benchmarks, tide gauges, salinity models, channel bathymetry, aerial elevation imagery, and aerial vegetation imagery. The first step in addressing this need should be to obtain feedback from those staff involved in Delta restoration about what resources would be useful to support habitat restoration planning or evaluation. These datasets need to be better defined, and then funding must be allocated to collect and process the data and make it available to all EcoRestore project proponents and analysis staff to aid their planning and evaluation (Recommendation SR1).

Modeling and monitoring provide a way to formally anticipate and prepare for environmental changes, and adaptive management provides a framework for responding to change. For example, adaptive management plans may incorporate model projections of sea-level rise, a plan for monitoring the impacts of sea-level rise, and potential management scenarios to respond if rising sea-level is threatening desired functionality of the restoration project. Some changes, such as extreme weather events or large-scale management actions, will have system-wide effects and may provide unique opportunities to learn and test hypotheses about the functioning of natural and restored habitats. Having contingency plans, quick-to-mobilize funding and staff for additional research (Recommendation MR5), monitoring protocols (Recommendation MR1), and modeling capability (Recommendations QM1 and QM 3) in place will allow the program to capitalize on these opportunities, as recommended by the Delta Independent Science Board (Delta Independent Science Board 2016).

Project-level

Project-level actions are designed by individual project proponents and should be informed by resources described above for project planning efforts as well as by lessons learned from other projects. For Fish Restoration Program (FRP) projects, the Fish Agency Strategy Team (FAST) crediting process requires review of project designs by an external science team in addition to technical review by the FAST (FRP Implementation plan). Similar support is provided by various interagency review teams (e.g., Suisun Marsh Adaptive Management Advisory Team [AMAT], Yolo Bypass Fisheries and Engineering Technical Team [FETT]), though not all project types are supported equally (Appendix 1).

Where possible, EcoRestore projects should incorporate "active adaptive management" (Williams 2011) principles in project designs, whereby experimental elements allow for actively testing key uncertainties identified by conceptual models (Recommendation MR4). However, one of the challenges faced by individual restoration projects is that staff has limited time to work on incorporating experimental design, because regulatory permitting is a priority. Another issue is that project implementers often avoid experiments because of the risk that it could prevent them from meeting their project goals and objectives (Delta Independent Science Board 2016). There is a perceived need to "check all the boxes" and concern that adding experimentation will derail the process. Because permit conditions can sometimes inhibit flexibility to change project direction or management (Delta Independent Science Board 2016), the EcoRestore Adaptive Management Program should encourage regulatory agencies to build adaptive management actions into permits, to allow for flexibility and ability to take risks (Recommendation RF1). In addition, distinction by regulatory agencies between performance measures necessary for permit compliance (or FAST crediting) and other indicators of project effectiveness (e.g., success or failure of specific design elements) could encourage projects to be more experimental (Recommendations RF3 and RF4).

Monitoring should be consistent with each project's stated goals and objectives, designed to test hypotheses and uncertainties based on conceptual models, and include social and economic metrics (e.g. evidence of human uses, impacts to adjacent landowners). When feasible, monitoring from individual projects should also be designed with system-wide goals and performance measures in mind (Recommendation CM3). Monitoring frameworks, such as the one recently developed for tidal wetlands by the Interagency Ecological Program Tidal Wetlands Monitoring Project Work Team (IEP TWM PWT,

http://www.water.ca.gov/iep/about/tidal_wetland_monitoring.cfm), provide guidance for developing project monitoring plans that use standardized methods to allow for comparability across projects for larger-scale analysis, synthesis, and evaluation efforts and should be emulated for other project types (Recommendation MR1). The development of these frameworks is a challenging and complex exercise; when recommending monitoring protocols there is a need to balance scientific and economic considerations, and anticipate different scientific needs of individual projects. Currently, tidal wetland projects being implemented for Biological Opinion compliance (FRP projects) are the only EcoRestore project type that has both a monitoring framework (in-development) and a monitoring program with dedicated funding. Non-FRP projects typically do not have these resources, which leaves significant challenges for implementing adaptive management.

One of the most difficult challenges for monitoring projects is balancing conflicting regulatory priorities in a single monitoring program (Nagarkar and Raulund-Rasmussen 2016). For example, many EcoRestore projects are meant benefit for endangered fish species; however, constraints on "take" for Endangered Species Act listed fish species can limit some aspects of fish monitoring. To address this problem, it is important for EcoRestore to work with fisheries regulatory agencies to determine appropriate ways to conduct effectiveness monitoring with consideration for listed fish and then support implementation of those suggestions (Recommendation RF2). This may require scientific innovation for restoration monitoring such that sampling designs and/or methods have reduced or minimized impacts to listed species. Having EcoRestore determine how to collect data on listed fish in a consistent way, acceptable to regulatory agencies, will also facilitate comparability of data across projects.

A way that EcoRestore projects can enhance monitoring efficiency is by combining compliance monitoring with targeted research or effectiveness monitoring, resulting in much greater information gain per monitoring dollar invested but requiring more up-front planning (Recommendations RF3 and RF4). The South Bay Salt Ponds Restoration Project has successfully worked with regulatory agencies to accept applied studies as meeting compliance monitoring requirements, which means investments in monitoring also support gathering data to address key uncertainties identified during project planning (L. Valoppi, personal communication).

Changes to the landscape resulting from habitat restoration can often take multiple years to detect. Thus, long-term monitoring for status and trends will be required to adequately measure effects relative to certain metrics. Unfortunately, the duration of project level monitoring is often limited and monitoring is completed only to the extent provided by short-term grants or required by regulatory mandates (Delta Independent Science Board 2016). To be effective, the duration of monitoring programs should be determined based on the specific metrics and performance measures to be informed by the monitoring. Long-term monitoring requires dedicated commitment of resources and stable internal priorities from project proponent agencies (Recommendations PS2 and MR3).

Phase 3: Evaluate and Respond

Phase 3 of the adaptive management cycle includes evaluating and communicating the data generated by the monitoring plan to create information that can be used to evaluate progress towards goals, refining conceptual models, and adapting (Figure 1).

Program-wide

Data collected from individual restoration projects need to be analyzed according to relevant objectives and hypotheses and compared across projects in the context of system-wide monitoring programs and targeted research (Recommendations MR2 and AS2). Dedicated staff with a range of technical expertise are needed to perform system-wide analyses of the effects of habitat restoration in the Delta and Suisun Marsh and to generate reports on restoration effectiveness and changes in the state of knowledge. While various technical staff with appropriate expertise are currently employed by agencies (e.g., California Department of Fish and Wildlife, Department of Water Resources, Delta Science Program, etc.), the scope of their current work is either too broad or too narrow for them to produce the information needed for adaptive management of ecosystem restoration program-wide. For EcoRestore to have a robust analysis, synthesis, and evaluation component, additional dedicated staff whose duties are specific to habitat restoration projects is recommended (Recommendation AS1). Furthermore, synthesis products developed by these staff should be peer reviewed by high-level scientists who have experience and expertise in large-scale restoration programs (Recommendation AS3). Peer review will improve the robustness and credibility of science generated by the EcoRestore Adaptive Management Program. Experts from other large-scale restoration programs may provide valuable input on approaches to monitoring, research, and adaptive management that could accelerate and enhance learning from restoration in this system. In the Everglades, peer review facilitated buy-in on the adaptive management approach from agency managers and other stakeholders (LoSchiavo et al. 2013). The Delta Independent Science Board provides oversight and periodic reviews of a broad range of scientific programs that support adaptive management of the Delta and Suisun Marsh and can complement peer review specific to restoration effectiveness of EcoRestore.

Formal communication is essential to bridge technical and management teams. Two-way communication is necessary; science-based information must be reported by those who plan and implement projects to those who make higher-level management or regulatory decisions, and information from agency and project managers must be communicated to the scientists so that their efforts can be tailored to best serve management needs. There are existing venues where communication takes place, such as seminars, workshops, conferences, workgroups, and interagency coordination meetings. However, there is no formal, cross-cutting, or consistent venue for communicating information between scientists and managers. An annual adaptive management forum, such as is called for in the Delta Science Plan (Delta Stewardship Council 2013b), could provide a targeted venue for the timely sharing of ideas relevant to adaptive management of restoration projects (Recommendation C2). It would also be useful to have the Science Coordinator and EcoRestore Director ensure that information relevant to evaluating habitat restoration is being shared (Recommendations C3 and C4). The approaches for utilizing and enhancing existing venues and strategies should be formalized in a communication strategy for EcoRestore (Recommendation C1).

Decision makers should periodically re-examine program-wide problem statements, goals and objectives, and key uncertainties based on new results and understanding. Technical staff should update conceptual models and use them to generate key uncertainties and hypotheses to inform the design of future restoration projects (Recommendation AS2).

Project-level

Information from an individual project may inform actions at that project site, plans for future projects, or changes to the conceptual models that guide restoration in the system. As restoration project managers work to build new projects, they often play a key role in overseeing synthesis of existing data from other projects to inform the design of their own. As mentioned above, there are various forums for communicating information about restoration projects, but the onus is on the project managers to compile and synthesize the relevant information from a wide variety of venues. A more formal mechanism for restoration-relevant syntheses to be recorded and shared could be of great benefit to project managers, save agencies time and money, and help ensure that the best available science is used to plan projects (Recommendation AS2).

Opportunities to address key uncertainties during project planning should be identified and communicated to the relevant agencies and project managers (Recommendations C1 and C3). Facilitating communication between scientists and managers through email updates and phone meetings as well as more formal meetings and workshops could be a role of the Science Coordinator (Recommendation G2), following the model of the South Bay Salt Ponds Lead Scientist (South Bay Salt Pond Restoration Project 2007), and is an integral part of the communications strategy (Recommendation C1). An annual adaptive management forum would provide an opportunity for practitioners, managers, scientists, and funders, both local and from other systems, to exchange ideas and discuss challenges in more depth (Recommendation C2).

Decisions on changes to constructed restoration projects should be made based on new information, if deemed appropriate by the project teams and regulators, and with regard for available funding. A potential impediment for project-level adaptation is the regulatory challenge of implementing changes once a project has been constructed. For example, new permits for impacts to wetlands may be needed to dredge a channel that has filled in with sediment post-construction. A common concern of project managers is that obtaining permits to make any changes on a constructed site is infeasible (Nagarkar and Raulund-Rasmussen 2016). In these cases, an alternative strategy to completing the adaptive management cycle is to incorporate lessons learned at one project into planning for future projects (Delta Independent Science Board 2016).

Cross-Cutting: Data Management

Data management is common to multiple phases of the adaptive management cycle and includes activities to not only to collect and store data, but also to make data accessible and transparent. The EcoRestore Adaptive Management Program is envisioned as a data-driven effort that relies on access to key datasets in order to inform and adapt.

Many state and federal data management systems offer central access to datasets of regional interest (Appendix 1). These datasets are usually developed for specific purposes, such as assessment of water quality, biological species, habitat quality, or hydrology. All of these datasets are essential for planning and evaluating habitat restoration, but it is not always clear how to relate these data resources to each other.

Program-wide

For program-wide evaluation, data from multiple projects must be accessible, reviewed in the context of long-term monitoring and other regional datasets, and linked with results from targeted research. An overall strategic plan for data management for the EcoRestore Adaptive Management Program should be developed to serve these analytical needs (Recommendation DM2). The strategic plan for data management should be consistent with the Environmental Data Summit white paper (Environmental Data Summit Organizing Committee 2015) and address the following principles:

- Compatibility among EcoRestore projects in database structure and database platforms
- Comparability among EcoRestore projects in specific data types
- Quality assurance and quality control, and
- Accessibility of data.

This strategic plan for data management should identify how data from different agencies and consultants can be brought together and made compatible for broad-scale assessments, and who will be responsible for data management (Recommendation DM2). A recently established California Water Quality Monitoring Council (CWQMC) Steering Committee of management-level decision makers will guide the development of an implementation plan that will help integrate data from different agencies, set standards and develop plans for a federated system to accelerate knowledge discovery, and guide resource management in the Delta and Suisun Marsh. The EcoRestore Data Manager who develops this strategic plan should work in close coordination with the CWQMC Steering Committee (Recommendation DM1) and should leverage existing staff resources at participating agencies to improve web-services and data access for new and existing datasets (Recommendation DM3).

Project-level

During the planning phase, it is important to consider what types of data are needed and how data will be managed, stored, and accessed. Data management plans should be developed early-on for individual restoration projects, and they should address both immediate needs and long-term archiving of data for future uses. Project-level data management plans should be developed to be consistent with the EcoRestore strategic plan for data management (Recommendation DM2); this will help ensure that they can support timely analysis, synthesis, and evaluation at the system-wide scale. Support from EcoRestore for project-level plans should leverage existing resources, such as the technical guidance provided by the CWQMC Data Management Workgroup regarding data management plans, web services, and data federation. Additional guidance may need to be provided to projects in order to cover specific data management needs.

Projects should share data using a common data platform so that data from multiple projects can be accessed, reviewed, and linked with data from other projects. For example, online data visualization tools can help support the needs of technical teams and resource managers to evaluate trends or phenomena in environmental conditions. Bay Delta Live is an example of a web-based access point that integrates over 300 datasets relevant to the Delta and Suisun Marsh and provides simple data visualization tools. Online portals may also serve as useful tools for communication and outreach.

Chapter 3: Recommendations for EcoRestore Adaptive Management Program Implementation

Recommendations in this chapter support the development of a complete, integrated, and effective EcoRestore Adaptive Management Program. This program will support the success of the EcoRestore initiative, as well as provide support that aids and improves individual restoration projects. These recommendations were developed by evaluating existing resources and current efforts, identifying current gaps and needs, and gathering examples from other systems. Once a basic program was envisioned, additional recommendations were formulated to make that program robust. The recommendations integrate existing adaptive management efforts to enhance coordination, integration, synthesis, evaluation, information sharing, and communication. Implementation of these recommendations will establish a well-founded adaptive management program for habitat restoration in the Delta and Suisun Marsh.

Governance (G)

G1. Develop a general governance framework for the EcoRestore Adaptive Management Program with clearly defined relationships to relevant entities (e.g., Natural Resources Agency, Delta Stewardship Council (Planning Division and Delta Science Program), Department of Water Resources, California Department of Fish and Wildlife, Interagency Ecological Program, local governments, State and Federal water contractors, NGOs, etc.) and decision roles. The governance framework will incorporate science and technical teams, decision-makers and restoration implementation agencies. New staff and governance structures will not supersede authority of project proponent agencies or of local governments

G2. Establish a position for an Adaptive Management Science Coordinator for EcoRestore (Science Coordinator) to coordinate and champion adaptive management science activities. Clearly define his/her roles, responsibilities, communication strategies and relationships to IEP and Delta Science Program Lead Scientists. Among those roles will be to:

- chair the IAMIT (G4)
- guide and secure resources for projects undertaken by the IAMIT (perhaps CM3, SR1, PS1, MR2, C1, etc.)
- coordinate communication between restoration practitioners and scientists (C3), and
- represent science needs of EcoRestore with high-level managers (such as with the EcoRestore Steering Committee, the DPIIC, and the IEP Directors).

The Science Coordinator will work closely with the EcoRestore Director (G3), modeling staff (QM1), the data manager (DM1), and analysis and synthesis staff (AS1).

G3. Maintain the position of Director of Ecosystem Restoration for EcoRestore (EcoRestore

Director) to coordinate and champion adaptive management implementation activities. The EcoRestore Director will work in close association with the Science Coordinator (G2), and facilitate implementation of adaptive management approaches by serving as a liaison to restoration project proponents.

G4. Maintain the Interagency Adaptive Management Integration Team (IAMIT) as a technical team for EcoRestore to:

- guide coordination among restoration practitioners, scientists, communication staff, and decision makers
- provide a venue to discuss high-level technical issues and integration of adaptive management elements across projects, and
- address challenges and barriers to implementing adaptive management.

The Science Coordinator (G2) will chair this group. The IAMIT should include members of federal, state, and local agencies involved in implementation or regulatory oversight of EcoRestore projects. The IAMIT will give high-level recommendations for system-wide analysis, synthesis, and evaluation (see AS1 and AS2). The IAMIT will advise on or undertake implementation of various other recommendations in this white paper.

G5. Maintain the EcoRestore Adaptive Management Steering Committee as a high-level decision making body that can assist in directing resources for implementing recommendations of this white paper.

Conceptual models and key uncertainties (CM)

CM1. Update existing and develop additional conceptual models and restoration-relevant hypotheses for EcoRestore project types.

CM2. Curate conceptual models, either in a new or existing program.

CM3. Develop a common list of key uncertainties based on existing conceptual models and identify those that can be addressed through adaptive management experiments and applied studies in EcoRestore projects.

Quantitative modeling (QM)

QM1. Develop additional tools and staff capacity for integrated modeling (Modeling Workshop 2015), alternative scenario analysis, and structured decision-making to guide project design.

QM2. Provide access to models and their updates, including model documentation and reviews.

QM3. Provide venues to leverage modeling expertise from public, private, NGOs, and academic researchers to address complex issues and encourage community modeling connecting multidisciplinary experts.

QM4. Develop predictive models of restoration trajectories and expected restoration outcomes at appropriate spatial and time scales for each project type.

QM5. Develop system-wide physical-chemical-biological models for each project type.

Shared system-wide resources (SR)

SR1. Identify fundamental environmental data resources of universal benefit to improve project planning and evaluation. Once the resources are identified, pursue funding for obtaining

those data, and make those resources available to all EcoRestore projects.

Data management (DM)

DM1. Establish a position for an EcoRestore Data Manager (Data Manager). This person's charge is to identify, develop, curate and publish the critical datasets needed to inform the EcoRestore Adaptive Management Program. The Data Manager will serve as the data librarian for the Science Coordinator (G2) and the IAMIT (G4) and will be responsible for coordinating, implementing, or advising on the other recommendations in this section. The Data Manager will participate in and coordinate with relevant monitoring and data management initiatives already underway across California's natural resources and environmental protection agencies, such as the CWQMC Steering Committee for Data Management and the efforts to implement the Open and Transparent Water Data Act of 2016 (AB 1755).

DM2. Develop an open data strategy that drives a strategic plan for data management for EcoRestore. The open data strategic plan establishes the goals and tactics to be used to ensure there is sustained availability of the critical datasets for the EcoRestore Adaptive Management Program to succeed. The strategic plan must include actions to:

- implement shared data standards across restoration projects
- identify, develop, curate and publish the critical datasets for EcoRestore,
- establish and sustain processes for efficient and effective data flow, both in and out of their source databases,
- address data sharing issues and associated agreements, and
- ensure long-term archival of datasets

DM3. Identify data science resources at participating agencies and allocate additional resources to develop, publish, and maintain application program interfaces (APIs), web-services, and open data access to the key EcoRestore datasets. Support the development of project-level data management plans that align with the EcoRestore open data strategy (DM2).

Performance measures (PM)

PM1. Develop a robust set of performance measures to track system-wide progress resulting from restoration. These performance measures should be developed (and updated periodically) collaboratively by interested agencies, and reported on by analysis and synthesis staff (AS1). Performance measures should be based on best available science and link to individual project, species, or habitat objectives as well as other parallel efforts (e.g., Delta Plan, CVPIA, species recovery plans, among others).

Project-level support (PS)

PS1. Develop specific guidance for project-level adaptive management plans that integrates various regulatory and funding agencies' requirements. A consistent approach to adaptive management should be developed for all EcoRestore project types to ensure compatible links to program-wide and project performance measures.

PS2. Identify additional resources (e.g., funding, staff) and support (e.g., tools, templates) for

planning, implementing, and managing project-level adaptive management elements, including sufficient funding for adaptive management. Ensure adequate funding and staffing at all federal, state, and local agencies to cover responsibilities for long-term management and stewardship of constructed sites.

PS3. Develop a suite of shared tools to support decision-making and use of science in planning and implementing restoration projects, including modeling, data analysis, decision-support, and visualization tools. Establish a venue with infrastructure and staff expertise to utilize these tools for science-based evaluation of alternative project designs (e.g., DRERIP Action Evaluation Procedure).

Monitoring and research (MR)

MR1. Develop and implement monitoring frameworks for each EcoRestore project type, following the example of the Tidal Wetlands Monitoring Framework developed by the IEP TWM PWT. These frameworks should include monitoring protocols to allow for data comparability between projects (consistent with DM2), and consider options to consolidate monitoring across individual projects to improve planning (i.e., to consolidate expertise and resources), reduce costs, or streamline permitting requirements.

MR2. Develop and implement a system-wide integrated research and monitoring framework to evaluate system-wide effectiveness of restoration (AS2). This framework should build on existing monitoring programs (e.g., IEP, FRP) and identify ways in which programs can be coordinated or augmented. It should be developed in coordination with and consideration of the strategic plan for data management (DM2). This framework will need to consider all types of EcoRestore projects, and all species that could benefit from restoration.

MR3. Secure dedicated, long-term funding to support monitoring of projects to address project-level and program-wide performance measures. Funding for monitoring should cover all habitats on a project site, not just target habitats (e.g. terrestrial monitoring for upland habitats at FRP tidal wetlands sites).

MR4. Identify funding and technical support for projects to incorporate active adaptive management experiments, or design features that test key uncertainties relevant to project objectives.

MR5. Identify funding and contracting support for collaborations between agencies and universities, consultants, or NGOs to incorporate targeted research that complement or supplement restoration monitoring.

Analysis and synthesis (AS)

AS1. Devote staff with expertise in: biostatistics, modeling, ecology, climatology, fish biology, and other fields to perform program-wide integrated analysis and synthesis. These staff will perform analyses using a variety of data sets (e.g., project monitoring, regional monitoring, long-term and continuous monitoring stations, targeted research, etc.) to generate presentations, reports, and peer reviewed publications.

AS2. Support system-wide synthesis to address key uncertainties and hypotheses, generate the information needed to update conceptual models and guide the next generation of

restoration projects. Synthesis and evaluation will lead to meaningful revision of system-wide goals, objectives, and performance measures and potentially to adaptive management actions. This analysis, synthesis, and evaluation will be guided by the Science Coordinator (G2) and the IAMIT (G4).

AS3. Fund and facilitate periodic peer review (every two to five years) of synthesis products by high-level scientists that have experience and expertise in large-scale restoration programs.

Communication (C)

C1. Develop a communication strategy for the EcoRestore Adaptive Management Program, with oversight from the EcoRestore Director (G3) and Science Coordinator (G2), and with guidance from the IAMIT (G4) and communication staff from participating agencies. The strategy should address:

- existing venues where restoration information can be shared,
- strategies for communicating scientific information to decision-makers, scientists, project managers, and agency managers,
- strategies for communicating the needs and constraints of project managers to scientists and decision makers,
- strategies for ensuring that information gets shared in a timely manner, and
- methods to publicize adaptive management results to inform the public and to garner support for the program.

C2. Hold an annual adaptive management forum (Delta Science Plan action 3.4, Delta Stewardship Council 2013) to share lessons learned, communicate ideas and information on adaptive management, and provide a networking venue for project implementers, managers, and scientists.

C3. Develop outreach materials or venues to improve restoration practitioners' and agency managers' awareness of, support for, and capacity to implement identified adaptive management priorities. This will include outreach concerning system-wide key uncertainties (CM3), active adaptive management experiments (MR4), and mechanistic studies (MR5).

C4. Develop outreach materials or venues to inform scientists and regulators on the practical considerations involved in restoration. This effort will inform the practical development of the research framework (MR2) as well as improve the integration of adaptive management with regulatory permits (RF1-4).

Regulatory flexibility (RF)

RF1. Advise projects obtaining permits to proactively include adaptive management-driven components in their permit applications, to potentially avoid the need for re-permitting when adaptive changes are warranted.

RF2. Work with fisheries regulatory agencies to develop sampling strategies, methods, and technologies that will be most appropriate to balance incidental take limitations with effectiveness monitoring for fish benefits. For example, using existing monitoring data to gauge the risk of incidental take, environmental DNA sampling (eDNA) to detect target species without take, and using surrogate species to examine the effects of contaminants.

RF3. Encourage regulatory agencies to work with project proponents to allow effectiveness monitoring and targeted research to satisfy permit compliance monitoring requirements.

RF4. Encourage project proponents to design monitoring plans such that they efficiently integrate effectiveness monitoring and targeted research with required permit compliance monitoring.

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Abbreviations and Acronyms

753	AMAT	(Suisun Marsh) Adaptive Management Advisory Team
754	BiOp	Biological Opinion
755	CDFW	California Department of Fish and Wildlife
756	CWEMF	California Water and Environmental Modeling Forum
757	CWQMC	California Water Quality Monitoring Council
758	CVFPPCS	Central Valley Flood Protection Plan Conservation Strategy
759	CVPIA	Central Valley Project Improvement Act
760	DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
761	DSC	Delta Stewardship Council
762	DWR	California Department of Water Resources
763	FAST	Fish Agency Strategy Team
764	FETT	(Yolo Bypass) Fisheries and Engineering Technical Team
765	FRP	Fish Restoration Program
766	IEP	Interagency Ecological Program
767	MAST	IEP Management, Analysis, and Synthesis Team
768	NGOs	Non-governmental organizations
769	NMFS	National Marine Fisheries Service
770	NOAA	National Oceanographic and Atmospheric Administration
771	SFEI	San Francisco Estuary Institute
772	SFSU	San Francisco State University
773	TWM PWT	IEP Tidal Wetlands Monitoring Project Work Team
774	UC Davis	University of California, Davis
775	USACE	United States Army Corps of Engineers
776	USBR	United States Bureau of Reclamation
777	USGS	United States Geological Survey
778	USFWS	United States Fish and Wildlife Service

Glossary

Adaptive management: A framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives (Water Code section 85052).

Biological Opinions: The USFWS 2008 Delta Smelt Biological Opinion and the NMFS 2009 Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations, Criteria and Plan.

Channel margin habitat: In-water habitat along the channel margin which generally range from perennial aquatic wetlands to floodplain and riparian habitats. This habitat type generally includes shaded riverine aquatic habitat at upper elevations. It is also referred to as Fish Friendly Levee Habitat.

Compliance monitoring: Monitoring conducted to evaluate compliance with permits and/or regulations.

Data Management System: A structural organization and defined set of principles, practices, rules and coordination processes to establish integration of monitoring data into a program-wide data management that supports timely modeling, analysis, synthesis and evaluation at the system level.

Delta Conservation Framework: A long-term (25-year) implementation framework for ecosystem conservation in the Sacramento-San Joaquin Delta and Suisun Marsh and Yolo Bypass currently under development by DFW.

Effectiveness monitoring: Monitoring specifically to address effectiveness of restoration actions. Effectiveness monitoring includes monitoring of pre-project conditions and monitoring to measure achievement of targets.

Fish passage projects: Projects that include removal or modification of fish barriers, improving migration by preventing fish stranding and migratory delays (Wallace Weir, Lisbon Weir), installation or modification of fish ladders which facilitate upstream migration (Fremont Fish Ladder), and installation of fish screens, which facilitate downstream migration. For the purpose of this white paper, fish passage projects are described in conjunction with floodplains as they are functionally linked.

Floodplain: The area at low to mid elevations adjacent to and transitioning between fluvial, or riverine, and tidal areas, that is subject to flooding during periods of high discharge.

Framework: A set of ideas, facts and principles that provide an integrative and coordinated approach.

Integrated modeling: A set of models spanning multiple disciplines, connected to clear questions that require the coordination of data, assumptions, and uncertainty analyses. An integrated modeling system requires access to data from many sources, including field data and modeling outputs.

Levee-related habitat: Includes riparian habitat, shaded riverine aquatic habitat, and channel margin habitat**.**

Program-wide: Covers the EcoRestore Program scope, which is a subset of the Bay-Delta system.

Riparian habitat: Habitat at the interface between land and rivers, channels, creeks or streams characterized by a woody vegetation community.

Recovery Plan: A document that describes the current status, threats and research and management actions to increase endangered species population sizes.

Regional: Within the context of this paper, 'regional' means a smaller unit of the Delta wide system that has similar ecological processes and functions (e.g., Suisun Marsh, Cache Slough Complex, Yolo Bypass).

Regional restoration strategy: An implementable suite of potential multi-beneficial programmatic solutions and projects that produce a strategy that identifies opportunities for a landscape-level integrated approach to habitat restoration while avoiding and/or minimizing impacts on existing land use, agriculture, regional economics, local values, and continued operation and maintenance of critical water supply and flood management infrastructure.

Shaded riverine aquatic habitat: Aquatic edge habitat that is shaded by adjacent riparian vegetation.

System-wide: Within the context of this paper, the system is defined as the legal Delta, Suisun Marsh, and the Yolo Bypass. System-wide refers to processes or programs that span the system.

System-wide monitoring: Long-term and integrated monitoring across the whole system. In some other programs, this level of organization is referred to as 'regional' (e.g., Delta Regional Monitoring Program).

Target: A measurable value of an indicator at a defined point in time that reflects a desired outcome.

Targeted Research: Studies designed to test the understanding of linkages in conceptual models.

Tidal and sub-tidal wetlands: Perennially wet habitats subject to tidal influence and dominated by emergent vegetation and shoals; often freshwater in the Delta or brackish in Suisun Marsh. Sub-tidal habitat occurs below mean low low water (MLLW) and is therefore submerged the majority of the time; this habitat is generally reflected in EcoRestore projects as open water (e.g. channels) associated with intertidal habitats. Also referred to as tidal perennial aquatic habitat.

Upland habitat: Generally non-wetland habitats occurring above mean high high water (MHHW); can include seasonal wetlands like vernal pools.

Appendix 1: Existing Resources Supporting Adaptive Management

Table A1. Existing resources relevant to the EcoRestore Adaptive Management Program, sorted by phase or component of the adaptive management cycle. For each project type, full circles (●) indicate existing resources that are either completed and up-to-date or currently active teams/forums, half circles (◒) indicate existing resources that are either currently in development or are completed but may need updating and/or expanding to cover additional needs, and empty circles (○) indicate areas where few to no resources exist. Shaded cells indicate when a particular resource is not applicable to an EcoRestore project type. A discussion of how these resources fit within the EcoRestore Adaptive Management Program can be found in Chapter 2 "Elements of the EcoRestore Adaptive Management Program."

Significant Existing Resources for Adaptive Management of EcoRestore Projects		Project types				
		Tidal Wetlands	Floodplains & Fish Passage	Levee-related habitats	Subsidence reversal & C sequestration	Other habitats
Plan	The San Francisco Estuary Institute (SFEI) **Delta Landscapes Project** provides information about historical ecological function and suggests possibilities for restoration strategies and trajectories. Publications from this project include **Sacramento-San Joaquin Delta Historical Ecology Investigation**, **A Delta Transformed**, and **A Delta Renewed**.	●	●	●	●	●
	The **Cache Slough Region Regional Restoration Strategy** is a collaborative process to develop a restoration strategy that complements other already ongoing work. The project currently has funding to develop a baseline assessment, which will lead into phase 2 strategy development that will integrate ecological restoration and existing land use.	◒	◒	◒	◒	◒
	The **Delta Plan** includes system-wide goals and objectives, an adaptive management framework, and performance measures.	●	●	○	◒	○
	The **California Department of Fish and Wildlife Conservation Framework will guide long-term implementation of strategies and actions for the protection, enhancement, restoration and adaptive management of the Delta.**	◒	◒	◒	◒	◒
	The **Central Valley Project Improvement Act Implementation Plan for Fish Programs** integrates a decision-making framework to prioritize and implement anadromous fish-related provisions under the CVPIA over the next 5-10 years.	●	●	●		

Significant Existing Resources for Adaptive Management of EcoRestore Projects	Project types				
	Tidal Wetlands	Floodplains & Fish Passage	Levee-related habitats	Subsidence reversal & C sequestration	Other habitats
The **Central Valley Flood System Conservation Strategy** identifies specific tools and approaches to restore natural areas to benefit fish and wildlife as part of a sustainable flood management plan.			◒		
Conceptual models relevant to habitat restoration, including: • **Tidal wetlands monitoring framework models** • **Delta smelt MAST report model** • **DRERIP models** • **Suisun Marsh Plan models** • **Salmon Assessment of Indicators by Life Stage (SAIL)**	●	◒	○	○	○
Key uncertainties identified for: • **Fish benefits from tidal restoration (e.g., Brown et al. 2003, Herbold et al. 2014)** • **Suisun Marsh ecological function**	●	◒	○	○	○
Regional teams and forums, including: • **FRP coordination team meetings** • **Suisun Marsh AMAT** • **Yolo Bypass FETT** • **Yolo Basin and Cache Slough Collaborative**	●	●	○	○	○
The **Delta Science Program**'s adaptive management liaisons are available to provide support and advice to all project proponents on adaptive management planning	●	●	●	●	●
The **California Water and Environmental Modeling Forum (CWEMF)** facilitates an open exchange and pooling of models, promotes consensus, mediates technical disputes, and maintains a modeling clearinghouse.	●	●	●	●	●
Existing projects that can be studied to develop lessons learned.	◒	○	◒	◒	○
For FRP projects, **consultation with the FAST**, including the use of expert panels to review project objectives, existing scientific information, and site specific design options is a key component to provide guidance on project implementation. This approach is designed to allow for identification of potential adaptive management actions and collecting/communicating lessons learned for future FRP projects.	●				
IEP studies (long term and special study)	●	●	○	○	○

	Significant Existing Resources for Adaptive Management of EcoRestore Projects	Project types				
		Tidal Wetlands	Floodplains & Fish Passage	Levee-related habitats	Subsidence reversal & C sequestration	Other habitats
	Ecohydraulic predictive tools developed by the Fisheries Engineering Technical Team (FETT) for evaluating fish passage and habitat restoration alternatives.		●			
	Existing **multi-year studies by the Department of Water Resources in the Yolo Bypas**s.		●			
	The **DSC levee habitat issue paper** (Davenport et al. 2016) reviews effectiveness of habitat improvements along Delta levees and provides recommendations to improve future habitat project siting and evaluation of project effectiveness.			●		
	Significant body of **peer reviewed literature** evaluating multiple research and pilot-scale subsidence reversal and/or carbon sequestration projects in the Delta.				●	
	Delta Conservancy's **Carbon Workshops**				◒	
Do	Several groups conduct **research and system-wide monitoring in the Delta and Suisun Marsh**, including IEP, USGS, DWR, CDFW, and researchers from universities (e.g., UC Davis, SFSU).	●	●	○	●	○
Do	The **Delta Regional Monitoring Program** is a stakeholder-directed effort to coordinate water quality monitoring activities in and around the Delta.	●	●			
Do	The **Wetlands and Riparian Area Monitoring Plan (WRAMP)** provides a framework and toolset (e.g., EcoAtlas and California Rapid Assessment Method [CRAM]) for assessment and monitoring, with an emphasis on water quality and regulatory compliance.	●	●	●	●	●
Do	The **DRERIP action evaluation procedure** uses a standardized set of steps to evaluate proposed restoration actions based on information in DRERIP conceptual models and peer reviewed literature.	●	●	●	●	●
Do	The **IEP TWM PWT tidal marsh monitoring framework** identifies hypotheses associated with restoration actions and provides guidance for developing project monitoring plans that use standardized methods to allow for comparability across projects for larger-scale analysis, synthesis, and evaluation efforts.	●				
Do	The **FRP monitoring program** performs integrated aquatic habitat monitoring for FRP tidal wetland projects system-wide; this group has dedicated funding and will follow the standardized protocols described in the IEP TWM PWT's monitoring framework.	●				

	Significant Existing Resources for Adaptive Management of EcoRestore Projects	Project types				
		Tidal Wetlands	Floodplains & Fish Passage	Levee-related habitats	Subsidence reversal & C sequestration	Other habitats
Evaluate and Respond	Staff from the **IEP Management, Analysis and Synthesis Team (MAST)** synthesize data from various monitoring efforts and targeted research.	◒	◒	◒	◒	◒
	Peer reviews facilitated by Delta Science Program	●	●	●	●	●
	Delta Independent Science Board (Delta ISB) standing board of 10 nationally and internationally prominent scientists to provide broad oversight and periodic reviews of science underlying Bay-Delta programs.	●	●	●	●	●
	Regional or project-specific forums include: • **FRP coordination team meetings** • **Yolo Bypass FETT** • **Suisun Marsh AMAT**	●	●	○	○	○
	Interagency workgroups such as IEP TWM PWT and CEMW where project proponents can share results.	●	●	○	○	○
	Data from completed and active restoration projects.	◒	○	○	◒	○
	Seminars and symposia, including those facilitated by the Delta Science Program	●	●	●	●	●
	Locally-focused workshops and conferences, including: • **Annual IEP Workshop** • **Bay-Delta Science Conference**	●	●	●	●	●
Data Management	"**Enhancing the Vision for Managing California's Environmental Information**" white paper: this vision document seeks to chart a course towards a more evolved data stewardship strategy, broader uses of data visualization, and more sustainable business models to foster new and productive relationships across all sectors.					
	California Water Quality Monitoring Council (CWQMC) and its **Workgroups** • **Bioaccumulation Oversight Group** • **Data Management Workgroup** • **California Estuaries Monitoring Workgroup (CEMW)** • **California Wetland Monitoring Workgroup (CWMW), and** • **California Cyanobacteria and Harmful Algal Bloom**					
	IEP and **IEP Data Utilization Work Group**					
	Digital repositories, including: • **BIOS**, Biogeographic Information and Observation System					

Significant Existing Resources for Adaptive Management of EcoRestore Projects	Project types				
	Tidal Wetlands	Floodplains & Fish Passage	Levee-related habitats	Subsidence reversal & C sequestration	Other habitats
• **CalFish**, A California Cooperative Anadromous Fish and Habitat Data Program • **CDEC**, California Data Exchange Center: network of hydrologic data • **CEDEN**, California Environmental Data Exchange Network: water quality, bioassessment, habitat and toxicity data • **DEDUCE**, Delta Environmental Data for the Understanding of a California Estuary, Delta Conservancy: estuary wide data center and repository • **NWIS**, USGS data on water use, water quality, surface water flow and groundwater levels • **STORET** and **WQX**, Storage and Retrieval and Water Quality Exchange, EPA • **SFEI CD3** (Water Quality Data) for contaminant data					
Data portals and dashboards: • **Bay Delta Live** • **MyWaterQuality portals (**MyWaterQuality Portal, California Estuaries Portal, Harmful Algal Blooms (HABs) Portal, **and** California Wetlands Portal) • **State of California Geoportal**: catalog and access to State geospatial data resources • **State Open Data Portals** (data.ca.gov) • **California Pilot Open Data Portal** (govtech.com) • **US Government Open Data** (data.gov)					
California **EcoAtlas** for restoration project tracking and wetland and riparian restoration monitoring data, and displaying SFEI's Delta Historical Ecology maps					
Federal Geographic Data Committee					
Open Geospatial Consortium					

Appendix 2: Key Gaps and Needs for Adaptive Management

Table A2. Significant gaps and needs identified as being essential to address in order to set up an EcoRestore Adaptive Management Program. Relevance of each gap to the major EcoRestore habitat or project types is noted by shaded cells. The relationship of each gap to recommendations presented in Chapter 3 is noted in parentheses.

Key Gaps and Needs for Adaptive Management of EcoRestore Projects	
Plan	**A system-wide adaptive management program structure for the Delta (G1, G2, G3)**
	Program-wide goals and objectives (AS2)
	Performance measures to assess & track system-wide outcomes **(PM1)**
	Decision support tools that allow for assessment of alternative scenarios in regional restoration strategies **(PS3)**
	Conceptual models for habitats other than tidal wetlands and for non-fish species in tidal wetlands **(CM1)**
	Centralized location and staff resources to update, house & curate models (AS2)
	Identified **system-wide key uncertainties** concerning ecological function and responses to restoration **(CM3)**
	Incorporation of **targeted research** (e.g., mechanistic monitoring) into project designs **(RF3, RF4, MR4)**
	Flexible regulatory requirements that support adaptive management approaches **(RF1, RF3, RF4)**
	Monitoring techniques that balance sampling with take for listed fish species (RF2)
	Tools, staff capacity, and access to integrated modeling, alternative scenario analysis, and structured decision-making (QM1, QM2, QM3, QM4, QM5)
	System-wide physical-chemical-biological models for each project type **(QM5)**
Do	**Adaptive Management plan guidance** for all project types **(PS1, PS2)**
	Monitoring frameworks for all project types (except tidal marsh) **(MR1)**
	Mechanism to integrate monitoring across projects **(MR2)**
	Framework for integrated monitoring for all project types **(MR2)**
	Consistent **long-term funding and/or staffing for monitoring** that would also allow for monitoring of habitat/species condition to inform adaptive management **(MR3, MR4)**
	Non-aquatic habitat/species monitoring of FRP projects **(MR1)**
	Easily accessible **monitoring data (DM3)**
	Inventory of **regional high-value datasets and tools to access these datasets (SR1, SR2)**

Key Gaps and Needs for Adaptive Management of EcoRestore Projects	
Evaluate and Respond	**System-wide analysis and synthesis**, including staff to perform the tasks **(AS1)**
	External **expert peer review (AS3)**
	Venues to communicate, particularly for habitats other than tidal marsh and floodplain **(C1, C2, C3)**
Data Management	**Project data management plans** with standards for interoperability **(DM3)**
	Staff to manage data (DM1)
	Overall data management system defining a unified approach and principles for project data integration, data governance and data federation (consistent with the Environmental Data Summit white paper) **(DM2)**
	Data sharing agreements for compatibility, comparability, quality assurance and accessibility of project data **(DM2)**
	Long-term repositories and dedicated data portal to access aggregated and system-wide data relevant to the EcoRestore program (complementing already existing resources) **(DM3)**
	Data capacity for projects (e.g. resources, tools, hardware & software, staff) **(DM1, DM2, DM3)**

Appendix 3: List of IAMIT Members

Table A3. List of IAMIT participants as of 2016.

Agency	Representative
CDFW	Jacobs, Brooke
CDFW	Low, Alice
CDFW	Sherman, Stacy
CDFW	Sloop, Christina
Contra Costa County	Fateman, Abigail
Delta Conservancy	Jensen, Laura
Delta Conservancy	Stanton, Beckye
Delta Science Program	Adelson, Annie
Delta Science Program	Austin, Darcy
Delta Science Program	Christman, Maggie
Delta Science Program	Kayfetz, Karen
Delta Science Program	Koller, Martina
Delta Science Program	Hastings, Lauren
Delta Stewardship Council	Davenport, Jessica
Delta Stewardship Council	Huang, Daniel
DWR	Conrad, Louise
DWR	Jones, Gardner
DWR	Jones, Kristopher
DWR	Loboschefsky, Erik
DWR	Melcer, Ron
NGO	Luoma, Samuel N
NOAA	Johnson, Rachel
NOAA	Sawyer, Evan
NOAA	Wulf, Ryan
On behalf of SWRCB	Connor, Valerie
Sacramento County	Thomas, Don
San Joaquin County	Mayo, Steve
SFCWA	Cowin, Kelsey
SFCWA	Fong, Stephanie
Solano County	Goulart, Roberta
Solano County	Miljanich, Peter
Solano County Water Agency	Lee, Chris
USBR	Israel, Josh
USBR	Smith, Ian
USFWS	Swinney, Heather
USFWS	Turner, Kim
USGS	Ruhl, Cathy
Yolo County	Marchand, Petrea