Adaptive Management Program for the Long-term Operations of the Central Valley and State Water Projects

Deleted: California Water Fix and Current Biological Opinions on the Coordinated Operations of the

Contents

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1 Executive Summary

Adaptive management is a science-based, flexible approach to resource management decision-making. When correctly designed and executed, adaptive management programs provide the ability to make and implement decisions while simultaneously conducting research to reduce the ecological uncertainty of a decision's outcome. These characteristics facilitate a management regime that is transparent, collaborative, and responsive to changes in scientific understanding.

The Federal and State water operations agencies (Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR)) and the State and Federal fisheries agencies (U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (CDFW)) (collectively the 'Five Agencies') adaptively manage the Endangered Species Act Section 7 compliance for the continued Long-Term Operation (LTO) of the Central Valley Project (CVP), for its authorized purposes, and the State Water Project (SWP), for its authorized purposes. This document sets forth the Adaptive Management Program (AMP) to to reduce uncertainty and improve the performance of Central Valley Project and State Water Project water operations under new Biological Opinions. This document highlights areas under the Proposed Action for the LTO that will require investments in research, monitoring, and modeling, while explaining how each (existing efforts and new) will build on each other.. This document will be used by the five agencies for the purposes of coordinating with stakeholders and making decisions within each agencies respective regulatory and statutory requirements.

This Adaptive Management Program includes a framework for a structured decision-making process with four overarching phases: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt.

- During **Phase 1: Plan**: Management and research priorities are set through operational criteria established through in the Proposed Action for LTO, BiOps, CESA authorizations and Science plans. The operations criteria set water management objectives while the science plans address how uncertainties associated with the operational and stressors affecting covered species will be addressed. Science Plans will be developed collaboratively using multi-agency and stakeholder forums such as the CSAMP/CAMT process and/or local watershed groups. The Science to be conducted to address uncertainties will undergo peer review consistent with the standards established by the appropriate decision making entity.

- Through **Phase 2: Assess**, the products developed through the Science plans, and the subsequent synthesis will undergo independent review, and the outcomes of this research will provide the basis for future proposals for management adjustments developed during Phase 3.

- In **Phase 3: Integrate**, interagency and agency-stakeholder discussions (based on the results of Phase 2's scientific assessments) will inform development of management adjustment proposals and additional research alternatives through a structured decision making process. This 'scoping' process will also lead to the development of additional adaptive management questions an alternatives to continue to address covered species and operational needs, assess benefits and identify uncertainty.

- During **Phase 4: Adapt**, the agency or agencies with final decision-making authority decide whether to adopt or reject a management adjustment proposal. Decisions will be evaluated to determine whether reinitiation of consultation and/or permit amendments are required.

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Deleted: This document describes how efforts to avoid jeopardy in the Section 7 consultation for the LTO may interface with other programs and efforts in the Central Valley and Delta, including collaborative science enterprises seeking to recover listed species and restore ecosystem functions outside of the Section 7 requirements on the LTO. However, many of the collaborative science enterprises include entities other than the 5 agencies and have decision making processes beyond the direct control of the 5 agencies.

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A Biological Opinion Coordination Team (BOCT) will be co-led by Reclamation and DWR. Members of the BOCT will include a designated representative[1] each from Reclamation, USFWS, NMFS, DWR, and CDFW. CVP and SWP Public Water Agencies (PWAs) may provide a designated representatives to participate in the BOCT. Reclamation and DWR shall be responsible for managing the representation of their respective PWAs and shall endeavor to manage number of representatives and their conduct to achieve effective coordination. The BOCT's role in implementing this AMP is described in Section 4.1.1. One or more project-specific teams will be required to implement the actions in the Science Plans. These project teams shall allow for the participation of a representative from each of the 5 agencies and will include stakeholders.

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Success of the adaptive management process outlined within this AMP hinges upon continued investments in research, monitoring and modeling. These investments address key uncertainties related to water operations and threatened and endangered species that have been raised in a number of different venues (e.g., the IEP Management, Analysis, and Synthesis Team and Salmon and Sturgeon Assessment of Indicators by Lifestage and the Collaborative Science and Adaptive Management Program (CSAMP) Salmon Scoping Team, CVPIA Science Integration Team, the Delta Science Program Structured Decision Making efforts, the Winter-Run Chinook Salmon Life Cycle Model, and the Delta Smelt Life Cycle Model) as well as during the development of a Proposed Action for the LTO. The Implementing Entities are committed to leveraging the expertise found in these different venues; filling critical data and information gaps in the areas of integrated monitoring and research, mechanistic studies and models, information synthesis, and data access from their respective resources. The agencies are committed to using structured decision making process to provide a proven transparent collaborative framework for the incorporation of science into decisions.

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Working through the collaborative process outlined herein, the Five Agencies commit to reach a common understanding of the Proposed Action for the LTO and associated regulatory requirements, to the maximum extent possible, while still retaining individual agency discretion to make decisions. To that end, the Implementing Entities seek to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with taking actions in the face of uncertainty and achieving the best near-term outcomes possible for all the authorized purposes of the CVP and SWP.

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[1] "Designated Representative" means in the case of DWR and CDFW the official representative designated by the Governor to act on his behalf, and in the case of the SWP/CVP contractors the official representative designated by an elected board of directors to act on their behalf.

2 Introduction

"Adaptive Management" is defined in California Water Code, section 85052, as "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives." The Department of Interior's Adaptive Management Application Guide (Williams and Brown, 2012) cites the National Research Council (2004) definition for adaptive management as a decision process with "… flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process." At its most basic level, adaptive management is a learning cycle and feedback loop whereby resource managers may simultaneously make management decisions while gathering further knowledge and information about a single resource or set of natural resources. Adaptive management is inherently collaborative, requiring "communication and transparency among all interest groups as well as a willingness to overcome the institutional barriers to collaborative decision-making," (Luoma *et al.* 2015). Starting with Holling (1978) and Walters and Hilborn (1978), a general framework for adaptive management has emerged as a as a structured decision-making process that incorporates uncertainty by recognizing there are different possible outcomes to management actions. Adaptive management then relies on flexible decision-making that is adjusted as outcomes from management actions and other events become better understood.

Defined objectives and clearly identified expectations of management outcomes are critical to the adaptive management process (Williams, 2011). Based on objectives (and allowing for uncertainty), resource managers can then develop hypotheses about potential resource responses to various management actions and implement the selected action(s), while collecting information to compare the outcomes expected to those observed (Williams *et al.* 2009). The goal of any adaptive management program is to incrementally reduce uncertainty and management risks by learning more about how the target resource responds to the management regime being evaluated. The challenge becomes how to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with achieving the best near-term outcome possible (Allan and Stankey, 2009). In practice, the bigger challenge has been reaching general agreement among parties about management tactics and their efficacy. Conroy and Peterson (2013) developed formal practices for Structured Decision Making that is currently being applied for the Central Valley Project Improvement Act with representatives from the 5 Agencies, PWAs, and NGOs.

Commented [A3]: Conroy, M.J. and J.T. Peterson. 2013. Decision Making in Natural Resource Management: a structured adaptive approach. Wiley-Blackwell.

3 Intent and Objectives

Through the Adaptive Management Program described in this document, the Implementing Entities are committing to the ongoing adaptive management for the LTO of the CVP and SWP. The intent of this AMP is to guide the Implementing Entities as they:

1. Create an adaptive management plan for long-term operations of the CVP and SWP that is consistent with state and federal endangered species laws and the co-equal goals of the Delta Reform Act.

2. Identify the key uncertainties about how Central Valley water operations and other management actions to benefit the species can be implemented to avoid jeopardy and meet other regulatory standards applicable to state and federally-listed fishes, including future effects associated with the CWF.

3. Describe the basic processes and governance principles that will be needed to ensure the application of best available scientific information to all aspects of decision-making on multiple time scales (*i.e.*, multi-year, annual planning/forecasting, and even real-time operations considered within the bounds of annual planning[2]).

4. Report upon the compliance with Incidental Take Statements and Permits under the Biological Opinions.

5. Work within the regulatory requirements necessary to avoid jeopardy while adaptively managing operations alternatives and performance metrics necessary to state and federally-listed species and critical habitat.

6. Develop and implement conservation measures under the Proposed Action.

7. Develop and implement Science Plans consistent with potential revisions to the Proposed Action under this adaptive management plan.

8. Describe how the proposed adaptive management program integrates with existing efforts, including those of the Central Valley Project Improvement Act (CVPIA), Interagency Ecological Program (IEP), Collaborative Science and Adaptive Management Program (CSAMP), Delta Stewardship Council/Delta Science Program (DSP), and individual agency science initiatives.

A preliminary set of objectives associated with the application of this Adaptive Management Program are included in Appendix 1. Final objectives for this adaptive management program will be developed using collaborative structured decision making processes and be limited to those actions necessary to achieve applicable regulatory standards.

Key Uncertainties

With regard to CVP and SWP water operations, there remain a number of key uncertainties associated with identifying biological response to potential management actions. These uncertainties have been raised in a number of different venues (e.g. by the Long-term operations biological opinions independent review panel (LOBO IRP), Interagency Ecological Program (IEP) Management, Analysis, and Synthesis

[2] As described in Section 5.2, below, the adaptive management and decision making processes described in this Program are not applicable to real-time operations. However real-time operations are mentioned in this Program to provide context.

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Team (MAST) & Salmon and Sturgeon Assessment of Indicators by Lifestage (SAIL), and CSAMP Salmon Scoping Team (SST)) as well as during the development of a Biological Assessment for the LTO.

Through IEP, the MAST and SAIL reports provide recommendations to fill critical data and information gaps, enhance the existing monitoring network and improve quantitative modeling capability to support transparent decision-making. Key recommendations from the MAST report related to the Proposed Action on the LTO include:

- Refine entrainment and transport estimates of all life stages of Delta Smelt to quantify their effect on overall population viability,

- Develop estimates of predation loss to quantify its effect on Delta Smelt viability, and salmonid survival.

- Study the toxicity of delta contaminants related to vegetation management on the health and viability of Delta Smelt and health and survival of salmonids.

- Develop tools to better evaluate and monitor Delta Smelt food availability and composition, and

The SAIL report reviews multiple qualitative, statistical, and numerical approaches and summarizes how they may be applied to improve the scientific understanding of how water operations decisions affect salmonids and sturgeon (IEP SAIL 2016). The SAIL report further illustrates how the existing Delta monitoring network can be leveraged with the inclusion of updated technologies to improve data collection and analysis. The following list from the SAIL report identifies five system-wide recommendations to enhance the existing monitoring network and enable information to be incorporated into salmonid and/or sturgeon lifestage models:

- Incorporate genetic information to identify individual runs of Chinook Salmon,

- Develop juvenile abundance estimates for salmonids and sturgeon,

- Collect data associated with different life history metrics at multiple life stages for salmonids and sturgeon,

- Expand, enhance, and integrate fish survival and water quality monitoring, and

- Collect fish condition data on salmonids and sturgeon.

The CSAMP SST also prepared a report on the key findings of historical research and monitoring efforts and provided a gap analysis of existing and missing data that are critical to our understanding of salmon and steelhead survival in the Delta in the context of hydrodynamic conditions and water exports. Like the SAIL report, the SST report, *Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta* (CSAMP SST 2016), recommends building on the current and substantial body of scientific understanding. This CSAMP SST report also highlights key information gaps, which, if filled would likely improve our ability to more effectively manage operations and hydrodynamics to increase survival of salmonids emigrating through the Delta. These information gaps include our understanding of the role of factors influencing salmonid survival through the Delta, the role of Delta conditions in salmonid fitness at the individual and population level, and opportunities to improve salmonid population abundance and viability through changes to Delta conditions and water project operations. The SST's report recommendations are broken into four categories of action:

- Continue existing survival studies, monitoring, and analysis of data
- Implement short-term actions to improve salvage facility operations
- Develop a long-term monitoring, research and adaptive management plan
- Implement the long-term monitoring, research and adaptive management plan

Collectively, these efforts and others have sought to assess the current state of Delta science and highlight opportunities to assess the value of taking or modifying certain actions, reduce environmental uncertainty, and inform future management actions and decisions.

- Shasta Spring Pulse Flows
- Shasta Spring Management of Spawning Location and Timing
- Delta Smelt Subadult Habitat (Suisun Marsh Salinity Control Gates and modification to the 2008 RPA Fall X2 Action)

The Proposed Action further includes the following conservation measures:

- Salmonid Spawning and Rearing Habitat
- Small Screen Program
- Food web Subsidies
- Winter-Run Conservation Hatchery
- Fish Conservation and Culture Laboratory
- Shasta Cold Water Management Tools
- WRCS Adult Rescue and Juvenile Trap and Haul
- Folsom Cold Water Management Tools
- Stanislaus Temperature Study
- San Joaquin Basin Steelhead Telemetry Study
- Predator Hot Spot Removal
- Salvage Facility Improvements

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4 Conceptual Framework: Decision Making, Process, Governance

Given the uncertainties involved in assessing the effects of water operations and restoration activities on listed species, the Five Agencies coordinate on management actions that comply with applicable federal and state legal requirements intended to protect species listed as threatened or endangered while giving due consideration to new scientific and operational information. The proposed approach outlined in this Adaptive Management Program incorporates aspects of adaptive management that are both "active" (where managers and operations are pushed in a process of experimentation to explore the benefits, limits and response to management actions) and "passive" (which lacks explicit experimentation and is instead more an assessment of existing and future conditions and circumstances). Ultimately the approach used in this Adaptive Management Program will proceed with an iterative development of management alternatives whereby managers will use a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a management decision.

Participants:
Decision Making Action Agencies: Reclamation and DWR
Coordinating Regulatory Agencies: USFWS, NMFS, CDFW, SWRCB, ACOE, DSC
Coordinating Stakeholders: Public Water Agencies

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4.1 Decision-Making

This Adaptive Management Program outlines a collaborative process that is intended to address areas of uncertainty related to the ongoing operation of the CVP and SWP for their authorized purposes. Under the adaptive management program, new information gained during implementation will inform operational decisions within the ranges of criteria and effects analyzed in applicable BiOps and CESA authorizations. Each agency retains discretion to make decisions as appropriate within its authority and within its role in a Section 7 consultation. If the effects of any operational decisions are not within the ranges of criteria and effects analyzed in applicable BiOps or CESA authorizations, Reclamation will reinitiate formal consultation under ESA section 7 and implementing regulations (50 CFR 402.16), if necessary, and/or DWR will commence a permit amendment process under California law, if necessary.

Nothing in this AMP modifies the rights and responsibilities of the Participants. Decisions shall be made consistent with the authorizing legislation and the regulations and policies under the federal and state Endangered Species Acts, as appropriate.

Reclamation and DWR shall retain sole discretion for:

- Water Operations of the CVP and SWP, including Allocations, under Reclamation Law and the State Water Project, as appropriate
- Agency Appropriations (budget requests, fund alignment, contracting, etc.)
- Section 7 Action Agency and Applicant (consultation)
- Coordination and cooperation with PWAs as required by Contracts and Agreements

CDFW, FWS, and NMFS shall retain sole discretion for:

- Consultation under Section 7 of the federal ESA and California Fish and Game Code, as appropriate and the associated Incidental Take Statements/Permits

- Agency Appropriations

State Water Resources Control Board:
- Enforcement as allowable under federal and state law.

Operating Entities other than CVP and SWP shall retain sole discretion for:
- Operation of Non-CVP and Non-SWP Diversion Facilities
- Contract and/or Agreement Terms
- WIIN Act Requirements

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Reclamation, at its sole discretion, will be responsible for changes to the Proposed Action and the requirements to fulfill its NEPA and ESA obligations. Reclamation will coordinate with the 5 Agencies and within the BOCT to the extent practicable and allowable by law.

Additional efforts or groups will be needed to fulfill all aspects of this Adaptive Management Program and support the decision-making process by the 5 Agencies Descriptions of certain groups and how they will be involved in the various phases of this Program may be found in *Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*.

Deleted: USFWS and NMFS, at their sole discretion, will be responsible for considering updates to their effects analyses, jeopardy determination, and may make changes to their Incidental Take Statements and the necessary measures to fulfill their ESA requirements. USFWS and NMFS will coordinate with the 5 Agencies and within the BOCT to the extent practicable and allowable by law.

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4.1.1 Biological Opinion Coordination Team (BOCT)

The BOCT, co-led by Reclamation and DWR, will include a representative of Reclamation, USFWS, NMFS DWR, CDFW, and one or more PWAs from the SWP and CVP. These representatives will likely be senior managers. Additional staff from any of the BOCT members and/or consultants may also participate to provide technical assistance or other support.

Commented [A10]: Suggest bounding this participation. As written its rather open ended.

The BOCT shall have primary responsibility for support, coordination and implementation of the AMP and shall:

1. Be responsible for funding and permitting the priority science needs identified by Collaborative Science Workgroups necessary to carry out the Adaptive Management Program.

2. Identify priority science needs not addressed by Collaborative Science Workgroups, and route requests for those science needs with, if necessary, appropriate funding to the appropriate entity with the capacity to complete them, or at its discretion, the IICG may initiate work to address priority science needs using its own staff, staff from its members, or any appropriate entity.

3. Establish mechanisms for developing and agreeing to Adaptive Management Changes, such as through preparation of an annual adaptive management work plan or development of specific proposals that identify the compliance implications of the proposed change.

4. Promote, fund and permit scientific activities/monitoring that the IICG determines are necessary to carry out the Adaptive Management Program.

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5. Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency.

6. Refer management related actions or proposals, as appropriate, for review by an independent science panel for example, the Long-term operations biological opinions independent review panel (LOBO IRP).

7. Assure transparency consistent with the requirements of the Delta Plan.

8. Identify and secure needed infrastructure and resources to support scientific activities/monitoring.

9. Review and approve the Annual Monitoring and Research Plan and progress reports.

4.2 Relationship of Adaptive Management to Real-Time Operations

Under the current BiOps, a "real-time operations" mechanism allows for adjustment of water operations, within established parameters, to respond in real time to changing conditions for the dual purposes of increasing fish protection when it is warranted and for increasing water exports within established bounds for fish protection (Figure 5-1).The adaptive management and decision-making processes described here do not apply to real-time operations; where individual real-time operations decisions must be made on a daily, weekly or monthly time scale; because new research efforts cannot be developed and deployed in that same window of time. However, changes to operational criteria in the BiOps and associated CESA authorizations may be changed over time through the adaptive management process. The need for additional Section 7 Consultation would be determined based on reintiation triggers.

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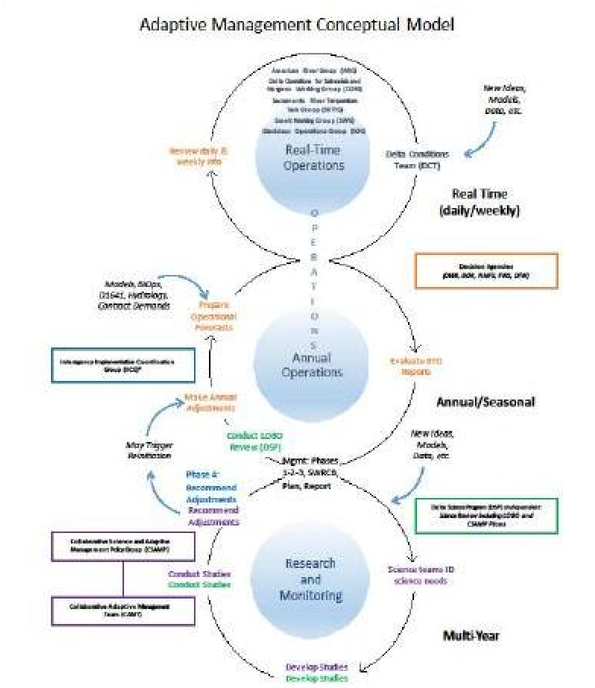

Figure 5-1. Describing the multiple time-scales of adaptive management of current USFWS and NMFS Biological Opinions on the coordinated operations of the Central Valley and State Water Projects

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4.3 Adaptive Management Program

Under this Program, adaptive management changes to operations and other implementation actions would occur on an annual or longer (multi-year) basis, and are not intended to apply to seasonal nor real-time operations.

Commented [A14]: Most of this language came over from the CWF AMP but I would think AMP WOULD apply to seasonal and real-time ops. Seeking Maria's thoughts on this.

Four process diagrams, referred to here as "phases," illustrate the major components of the proposed adaptive management process: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt. The four diagrams (Figures 5-2 – 5-5) describe each phase of the process as well as how each phase relates to one another.

Certain analytical tools are useful during implementation of the phases of adaptive management, and are described below. Section 5.4.5 describes structured decision making and its utility in formulating research, monitoring and adaptive management actions at multiple scales, from the individual study up to overall program management. Section 5.4.6 describes the use of conceptual models in adaptive management and provides examples of how such models are already in use to address ecological questions in the Delta. Further evolution of these models will be an integral part of the adaptive management process.

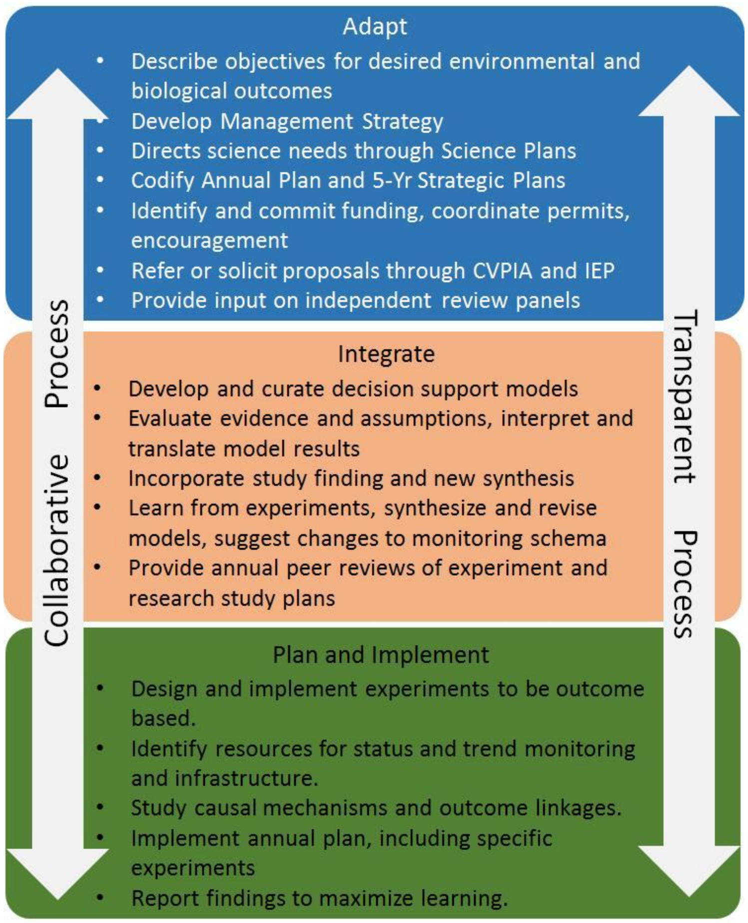

Figure 5-X. The four phases of the adaptive management process.

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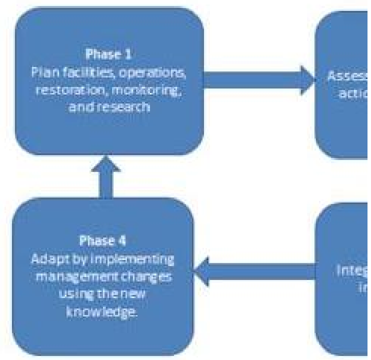

4.3.1 Structured Decision Making

Structured decision making (SDM) is a general term used for a suite of analysis tools that can help inform useful, robust decisions. Every decision consists of several primary elements: management objectives, decision options, and predictions of decision outcomes. By analyzing each component separately and thoughtfully within a comprehensive decision framework, it is possible to improve the quality of decision making. The actions identified as requiring adjustments due to uncertainty, will be addressed in this Adaptive Management Program through the steps outlined in Table 1 below.

Table 1. Structured Decision Making

Step	**Information to be Developed**	**Responsible Party(ies)**
1. Define the problem	What specific decision has to be made? What is the spatial and temporal scope of the decision?	Implementing Entities , other stakeholders
2. Define issues and objectives	What are the management objectives? Ideally, these are stated in quantitative terms that relate to metrics that can be measured. Setting objectives falls in the realm of policy, and should be informed by legal and regulatory mandates, as well as stakeholder viewpoints.	BOCT?
3. Develop alternatives	What are the different management actions from which we can choose? This element requires explicit articulation of the alternatives available to the decision makers. The range of permissible options is often constrained by legal or political considerations, but structured assessment may lead to creative new alternatives.	Implementing Entities , other stakeholders
a. Understand the uncertainty associated with each alternative	Because we rarely know precisely how management actions will affect natural systems, decisions are frequently made in the face of uncertainty. Uncertainty makes choosing among alternatives far more difficult. A good decision-making process will confront uncertainty explicitly, and evaluate the likelihood of different outcomes and their possible consequences.	Implementing Entities
b. Identify risk tolerance	Identifying the uncertainty that impedes decision-making, then analyzing the risk that uncertainty presents to management is an important step in making a sound decision. Understanding the level of risk a decision-maker is willing to accept, or the risk response determined by law or policy, will make the decision-making process	Implementing Entities

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	more objectives-driven, transparent, and defensible.	
c. Identify linked decisions	Many important decisions are linked over time. The key to effectively addressing issues associated with linked decisions is to isolate and resolve the near-term issues while sequencing the collection of information needed for future decisions.	Implementing Entities
4. Quantify the consequences of alternative management actions	What are the consequences of different management actions? To what degree would each alternative lead to successfully reaching a given objective? Depending on the information available or the quantification desired for a structured decision process, consequences may be modeled with highly scientific computer applications, or with personal judgment elicited carefully and transparently. Ideally, models are quantitative, but they need not be; what is most important is that they link actions to consequences.	Implementing Entities
5. Understand the tradeoffs	If there are multiple objectives, how do they trade off with each other? Numerous tools are available to help determine the relative importance or weights among conflicting objectives; this information is used to compare alternatives across multiple attributes to find the 'best' solutions.	Implementing Entities, other stakeholders
6. Decide, take action, and monitor	For those decisions that are iterated over time, actions taken early on may provide a learning opportunity that improves management later. Decisions should be well-documented outcomes of steps 1-5 above.	Agency or agencies with final decision-making authority

4.3.2 Conceptual Models

In the history of Delta ecosystem research, the term "conceptual model" has generally been used to refer to a process-based diagrammatic conceptual model that identifies sensitive resources and physical or biological processes that determine their state. An early example was the suite of models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), ca. 2008. An example dealing with factors affecting fish habitat is shown in Figure 56.

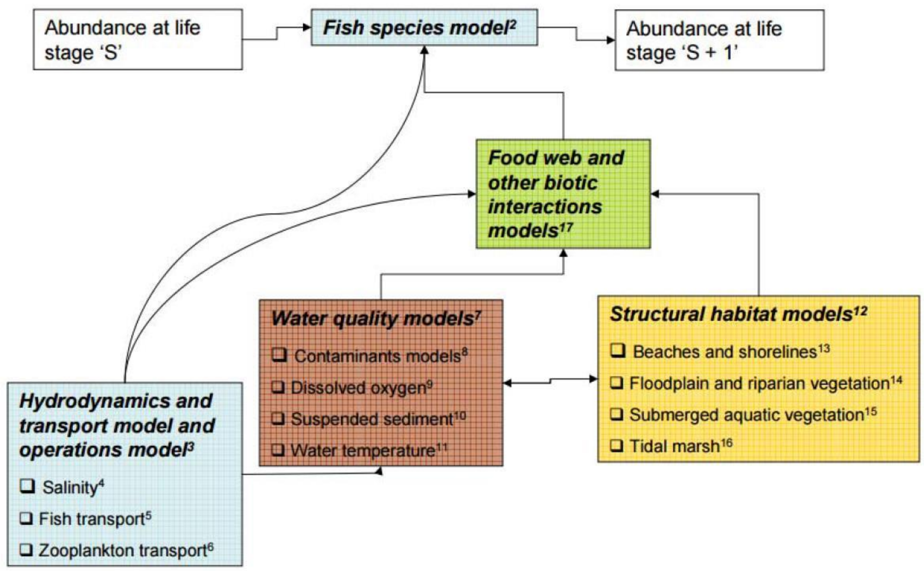

Figure 5-6. The Delta Aquatic Habitat Linkage Model of Nobriga (2008), an example DRERIP model.

Since this early example, there has been considerable development in the number and complexity of conceptual models being used to study Delta ecosystems. The 2015 annual report of the Collaborative Adaptive Management Team (CAMT 2015), for instance, refers to the use of conceptual models for the following:

- A life cycle model for winter-run salmonids in the south Delta
- A process model for Delta Smelt entrainment risk with reference to Old and Middle River flows
- An approach to aggregating study a suite of hydrodynamic, water quality, and particle tracking models, referred to collectively as an individual-based model (IBM), to identify adult Delta Smelt behaviors that best explain movement towards SWP and CVP, and entrainment.
- A re-evaluation of the re-examine life cycle model results of Maunder and Deriso (2011) using updated data sets and revised assumptions.
- Critically review the conceptual models that underlie adult Delta Smelt salvage and determine through multi-regression models the best suite of variables that explain historical salvage patterns.
- Use an existing life cycle model to understand the effects of entrainment on the Delta Smelt population.
- Perform a gap analysis evaluating the analytical tools currently in place to evaluate water project effects on salmonid survival.

Efforts under the Central Valley Project Improvement Act, CSAMP, and with the Delta Stewardship Council's Delta Science Program have developed DSMs to support SDM. These and similar efforts illustrate the utility of conceptual modeling tools to formalize understanding of how water operations affect fish, to assess the accuracy of these concepts in the context of information acquired through monitoring, research, and numerical modeling tools, and to formulate proposals to further test and improve the conceptual models.

Phase 1: Plan

During **Phase 1**, research priorities are set through the identification of the scientific uncertainties most likely to influence a course of action. Science plans address how uncertainties associated with the operational and other stressors affecting covered species will be addressed.. Science Plans will be developed collaboratively using multi-agency and stakeholder forums. Changes to the Science Plans beyond year-1 could incorporate management adjustments made in **Phase 4: Adapt**, A diagram of the decision-making process for effecting an adaptive management change under the Program is described in Appendix 7.

4.3.3 Phase 1: Plan

Define the bounds of the management problem and set management and research objectives.

As recommended in the 2016 Independent Science Board (ISB) report, an iterative learning cycle will be applied throughout the implementation of CVP and SWP water operations, associated habitat restoration actions, and other management actions. Successfully bounding ecological uncertainty with regard to management outcomes must include clearly defined problem statements (objectives that will be used to inform decision points) and the means to address those questions (the suite of actions under consideration).

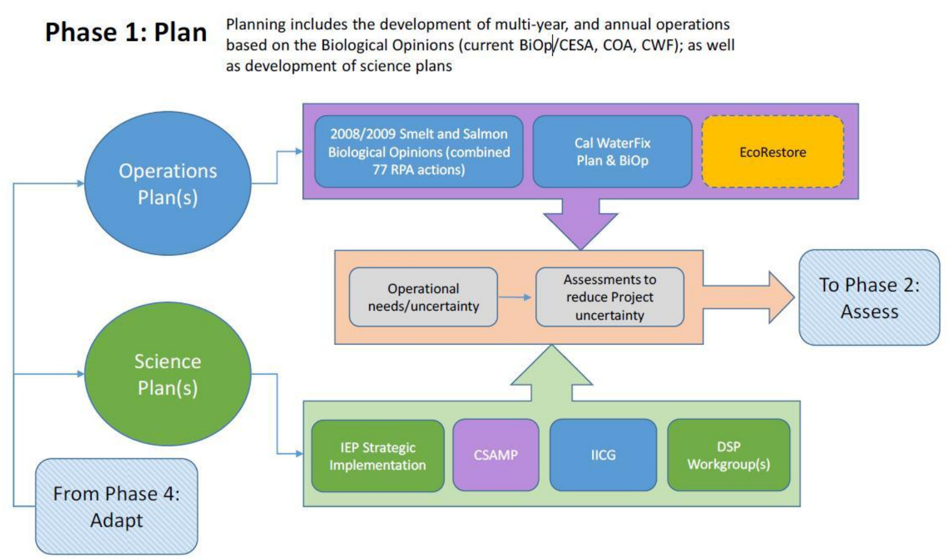

Figure 5-2 Phase 1, Plan: Facilities and operations, restoration/ecosystem management, and monitoring and research.

4.3.3.1 Design and Operations Planning in the Context of the ESA and CESA

4.3.3.1.1 Multi-year Planning:

The basic flow of the planning phase is shown in Figure 5-2. The CVP and SWP operate under the U.S. Army Corps of Engineers (USACE) flood control rules, State of California water quality standards, current BiOps and CESA authorizations, Memorandums of Understanding between Reclamation, DWR, and DFW, as well as other statutory and regulatory requirements. The BiOps include some conditional elements intended to be implemented in an adaptive management framework.

The IICG anticipate continuing to explore many of the questions and uncertainties related to the effects for LTO of the CVP and SWP on listed species and the efficacy of actions such as Old and Middle Rivers (OMR) flow restrictions, fall outflow and other requirements.

4.3.3.1.2 Setting Objectives and Triggers:

While the Proposed Action and associated BiOps generally contain rationales and conceptual foundation for individual actions, many actions do not explicitly contain measureable objectives needed for the design and planning of an adaptive management program. Species specific objectives included in *Appendix 1—Initial Objectives Derived From the Proposed Action, BiOps/CESA* are adopted into the framework document as an initial set of objectives, against which performance of operations and other management actions can be assessed. These initial objectives are subject to further refinement as the process continues.

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Given that adaptive management is intended to accommodate change both in the management of a resource and the corresponding response, objective triggers are an essential component of this Adaptive Management Program to signal when an alternative management action may be warranted. Triggers are defined, pre-set and measurable conditions that prompt evaluation of information collected to that point in the context of current conditions and considering whether potential alternative approaches are warranted. For the purposes of this Adaptive Management Program, triggers will be focused on longer term outcomes. The BiOps are expected to specify the amount or extent of incidental take that will trigger reinitiation of consultation as described within their respective incidental take statements. Reinitiation of ESA consultation is also required under 50 CFR 402.16 if the action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that had not been considered; if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; or if a new species is listed or critical habitat designated that may be affected by the identified action.

Phase 2: Assess Through **Phase 2: Assess**, identified uncertainties are translated into research studies designed to reduce these uncertainties. Agency and stakeholder groups conducting research and modeling to answer adaptive management questions will vary depending on the logistics involved (e.g., major field studies will probably require the IEP). The Proposed Action includes specific opportunities to vary operations within the year in order to better understand the relationship between water operations and fish requirements. Products pertinent to annual operations and assessments to reduce operational uncertainty will be peer-reviewed to improve the quality of research proposals. The results of these products will provide the basis for future management proposals developed during the scoping process of **Phase 3: Integrate**.

4.3.4 Phase 2: Assess

Represent existing scientific understanding through current operational decisions while continuing to identify uncertainty and alternate hypotheses as a result of ongoing monitoring and research.

The 2015 ISB report, *Fishes and Flows in the Sacramento-San Joaquin Delta* (ISB 2015) recommended implementation of integrative scientific approaches grounded on management questions and focused on processes, drivers and predictions. The approach outlined in Figure 53 reflects the complexities of the ecological responses being examined by individual research projects and tracked by system-wide monitoring.

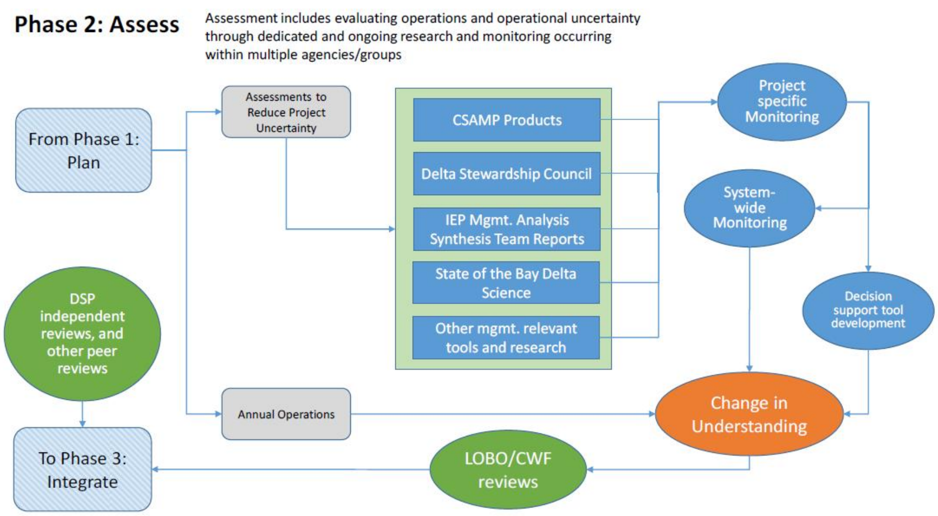

Figure 5-3. Phase 2, Assess: Collaborative Science, synthesis and performance assessment to inform management direction and change as uncertainty is addressed

An essential element of this Adaptive Management Program is the development and execution of a scientifically rigorous research, monitoring and assessment program to provide a robust information base, as well as the synthesis of the resulting information to analyze and understand responses of the ecosystem to a particular management regime. This requires the implementation of an integrated core monitoring network for water operations that also incorporates many project specific monitoring actions (See Section 6: *Tools and Scientific Support*). The scientific and technical information generated from this comprehensive program will be organized to provide a process to assess progress against the triggers and objectives.

4.3.4.1 Annual Review

In order to ensure the realization of objectives of the LTO and Biological Opinions, the BOCT will annual review the status of implementation. These reviews will include an evaluation of operations and the latest scientific, technical, and planning information (*i.e.*, Phase 3: Integration). This integrative adaptive management approach supports iterative improvement in the Proposed Action and system performance as science and knowledge of the system advances. When appropriate, results of these evaluations will be used to inform the potential modification of the Proposed Action by Reclamation to address action-specific performance metrics within Phase 3 (Integrate) and the consideration of those alternatives in Phase 4 (Adapt).

Major findings and updates may require a targeted independent review separate from the annual evaluation. Additionally, a comprehensive Independent Review would be anticipated at least every 5 years to provide technical assessments regarding ongoing and future research priorities, science plans, study designs, water operations, other management actions, or habitat restoration actions. Together these independent reviews, along with the research products from the many Delta science-related groups, will provide greater understanding to inform new management and research options as detailed in Phase 3 (Integrate).

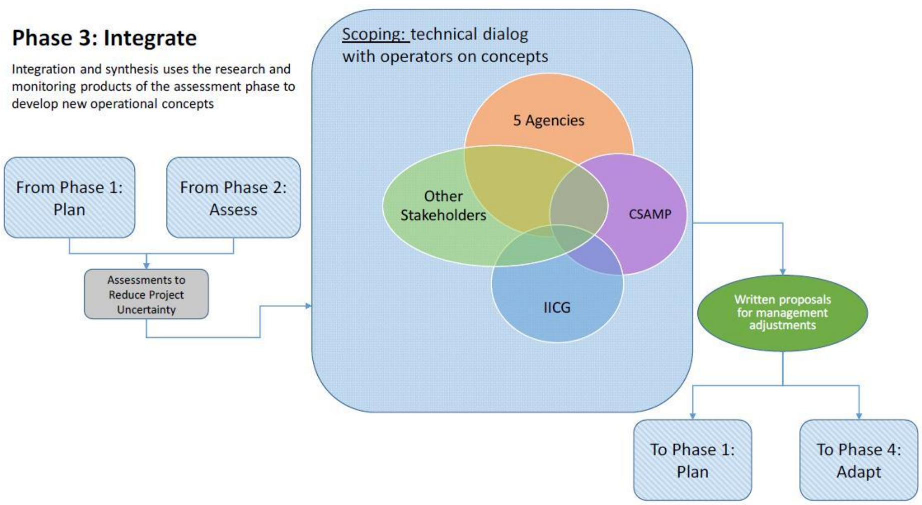

Figure 5-4. Phase 3, Integrate: Management and Science Integration

Phase 3: Integrate

The development of new executive level adaptive management alternatives to address operational needs and uncertainty occurs via several pathways and at multiple levels; these are generally described as scoping in **Phase 3: Integrate**. Through the structured decision making process, designed to test management strategies and data collection, interagency and agency-stakeholder discussions inform management and research alternatives based on the results of scientific assessments from **Phase 2: Assess**.

The results of both science products and their independent reviews are considered at multiple levels and at multiple venues including: between the Five Agencies, within CSAMP, and with the BOCT. Determinations regarding whether the results of studies (e.g. monitoring post-construction performance of refugia areas) constitute a significant enough change in understanding to trigger changes to the management of the refugia or their monitoring and research will be made as part of a formal response to independent review and through the structured dialog of the scoping process. In this example, if the monitoring and research indicate that a management adjustment could improve the performance of the predator refugia, proposals to make said adjustment will be developed through the same scoping process.

4.3.5 Phase 3: Integrate

Reflect on outcomes and consider new approaches to management and research based on new understanding.

During the integration phase, which occurs on a continuing basis, the Implementing Entities will develop alternatives for adaptive changes to management actions within their scope of authority and, in some cases, may also recommend changes to monitoring and research approaches (Figure 5-4). In the development of these recommendations, the Implementing Entities will engage stakeholders, academic scientists and other relevant groups through a scoping process to collaborate on the development of management actions and research projects stemming from Phase 2. The scoping process will use a structured decision making approach to analyze key uncertainties and maximize the transparency of decisions. Key structured decision making concepts include making decisions based on clearly articulated objectives, addressing uncertainties, and responding transparently to legal mandates and the public in decision making. The CSAMP, in coordination with the BOCT provides an example of a venue in which to collaboratively define management relevant problems, establish objectives, define potential available alternatives, and evaluate uncertainty and identify research needs. New knowledge revealing a potential opportunity to improve conditions or operations in the Delta and/or its tributaries could then lead to Reclamation proposing a modifications to the Proposed Action for CVP/SWP operations within the performance standards analyzed in the biological opinions, in Phase 4 (Adapt).

Within Phase 3, the objective of scoping is to first determine whether information developed in Phase 2's assessment is significant enough to trigger consideration of changes to a management action or a Science Plan, and, if so, to determine the resources needed to implement the change. Scoping via structured decision-making will involve operators and scientists from the Implementing Entities with input from participating science and stakeholder groups. Through scoping dialogue, experts, stakeholders and agency managers seek to develop a common interpretation and understanding of the monitoring and research products. If, through structured decision-making, it is determined that a change in a management action is appropriate, the appropriate Agency will then develop options or approaches to modify the management action to more effectively achieve its desired objectives. It is expected that the appropriate agency develop options in an transparent and collaborative manner and provide for soliciting and incorporating input.

The primary products envisioned for Phase 3 are written proposals for adjustment of management actions within established performance metrics that will describe the anticipated effects of the recommended management change on listed species and water supply reliability and describe the actions necessary to implement said change within legal and regulatory documents consistent with Section 7 and NEPA. Further, because the issues that trigger written proposals for management adjustments may have far-reaching effects, participation by Agency managers is a necessity during Phase 3, Peer review of proposed management actions and their scientific basis will be essential prior to making any decisions related to recommendations for a major management adjustment.

An element of Phase 3 will be to communicate the results of implemented actions, research, and monitoring to policy makers, managers, stakeholders, the scientific community, and the public, so that they can understand and evaluate progress toward addressing uncertainties and respond as necessary. The BOCT will prepare communications from time to time, as needed, and develop materials regarding adaptive management and monitoring matters for communication with a broader range of interests as part of the scoping process. The BOCT will ensure that study products are unbiased and explicitly and evenhandedly deal with uncertainty and disagreement in the analysis and interpretation, and that opposing points of view are clearly and evenhandedly presented in materials presented to stakeholders, external review bodies, and the public. The BOCT may work with CSAMPIEP, DPIIC, and CVPIA to develop reports that serve the following purposes.

- Provide the necessary data and information to demonstrate compliance biological opinions.
- Identify the performance of action components of the Proposed Action on covered species and the effectiveness of conservation measures and established performance objectives and metrics
- Disclose planned annual and long-term science priorities and programs and the synthesis of the information developed through the science program and their relevance to project operations and the requirements of the BiOps and CESA authorizations.
- Document actions taken under the adaptive management program (e.g., process, decisions, changes, results, or corrective actions).
- Disclose issues and challenges concerning implementation of the LTO and identify potential modifications or amendments that would increase the likelihood of meeting the purpose and need for the LTO.

To demonstrate compliance with the biological opinions, an Annual Report will be prepared by Reclamation with input from the BOCT. The Annual Report will be made available to the public.

Phase 4: Adapt

The decision and final authority regarding whether to adopt or reject a management adjustment lies with the agency or agencies with decision-making authority (most often, the Bureau of Reclamation or Department of Water Resources in their respective capacities as operators of the CVP and SWP), and occurs during **Phase 4: Adapt**. Management decisions consider the proposals developed during **Phase 3: Integrate** and are based on the assessment and review of **Phase 2: Assess**. Depending on whether or not the proposed modification is considered within the adaptive limits of operations, changes to the operations criteria established through the BiOps, CESA authorizations, Bay Delta Water Quality Control Plan and Science Plans, the proposed modification may require reinitiation of consultation or permit amendment.

4.3.6 Phase 4: Adapt

Revise models and/or management actions based on information gained.

The fourth phase of this Adaptive Management Program encompasses the decision to implement a management change through adjustments in water operations, restoration tactics, or monitoring (Figure 5-5). The responsible agency from Phase 3 will use the written proposals and recommendations from Phase 3 to make recommendations and management decisions based on their authorities.and consistent with the requirements of all relevant laws and regulations, including ESA, CESA, NEPA, the California Environmental Quality Act, Clean Water Act, Delta Plan, and the Bay Delta Water Quality Control Plan.

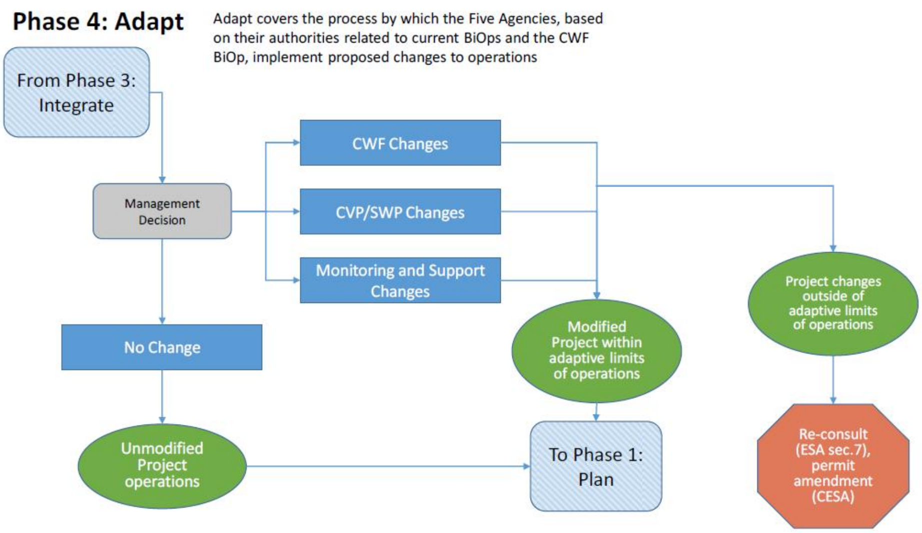

Figure 5-5. Phase 4, Adapt, Process for making an adaptive management change

5 Research and Scientific Support

The current understanding of research needs that support adaptive management is listed within the Proposed Action. In assembling information regarding future research needs, agencies will rely as much as possible on peer-reviewed published literature. When such literature is not available, the Implementing Entities will utilize agency reports that are available to the public (e.g., the MAST and SAIL reports). In some cases, the Implementing Entities will also rely on information from reports or articles that have been submitted to scientific journals but that have not yet been accepted for publication. The below sections outline a commitment from the Implementing Entities to invest in more robust tools, monitoring and research efforts to support this Adaptive Management Program.

5.1 Delta Smelt Research and Understanding

Much of our current understanding of Delta Smelt is summarized in a synthesis report developed by the IEP MAST (IEP 2015). The MAST summary is structured around a conceptual model that includes a suite of hypotheses that outline the majority of the knowledge base for current Delta Smelt management efforts. The overall conceptual model is organized in a tiered structure and describes how Landscape, Drivers, and Habitat Attributes successively affect Delta Smelt survival, growth, health and reproduction. Moreover, more detailed models nested within the conceptual model describe how these factors are thought to affect individual Delta Smelt lifestages. Specific to avoiding jeopardy under Section 7 compliance to the ROC on LTO; these include:

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Entrainment and Transport: Improved entrainment estimates will more accurately depict how entrainment affect key population attributes (e.g., population dynamics and viability). In order to avoid under- or over-estimating these effects, more precise estimates of entrainment losses of all life stages are needed.

Food: Poor feeding conditions can affect Delta smelt health and even increase the rate of predation on fishes; as such, food availability must be a critical aspect of Delta Smelt habitat that could be affected by several management actionstools that can be used to evaluate the impact of different invertebrate restoration strategies (e.g., tidal marsh, wastewater treatment, overbite clam control, suppressing competition from other fishes, etc.). The development of such tools would benefit from improved sampling of prey in under sampled regions (e.g., Cache Slough complex);

5.2 Salmonid and Sturgeon Research and Understanding

Water project facilities and their operations, coupled with other management actions (e.g., flood management, navigation, local water users, habitat restoration, fish passage, invasive species, waterwater treatment, and harvest/hatchery management both salmonid and predator species) have profound and complex effects on migratory fish and their habitats. There is high uncertainty in how native and migratory fishes will respond to these large changes in physical and biological conditions.

Using the recommendations of the SAIL report and the CAMT SST report, we focus here on identifying long-term integrated core monitoring, research efforts, and synthesis tools that will be necessary to reduce uncertainties about how current and future water project operations impact migratory fish populations. The prioritized items below are not a comprehensive list of the science necessary for successful adaptive management. Rather, they are intended to highlight strategic system-wide science efforts that would benefit from integration into a broader management and regulatory context to facilitate funding security and consistency in implementation at the appropriate scales. Much of our most valuable monitoring and analytical tool development suffers from a lack of long-term funding security and fragmented implementation, which together lead to inefficiencies in applied science to better inform management decisions.

5.2.1 Integrated Scientific and Management Information System

Enhanced integrated core water quality and biological monitoring designed with adequate precision to support information needs on salmon, steelhead, and sturgeon abundance, movement, and/or survival at critical life stages linked to factors that have immediate effects on fishes' behavior and vital rates. Information needs more specifically include:

Quantify stock-specific juvenile salmon abundances

The current salmon monitoring network provides information on the presence and timing of salmon at various monitoring locations. However, more informative monitoring metrics, such as the abundance of individual salmon runs or populations, are required. Non-lethal genetic sampling coupled with new approaches to estimating trawl and seine efficiencies (e.g., paired coded wire tag and acoustic releases, multi-pass beach seining) can provide accurate information on stock-specific abundances of salmon at strategic locations of scientific and management value (e.g., Sacramento Trawl, Chipps Island, salvage, others). Specific guidance on how to implement this recommendation for juvenile salmonids is provided in the SAIL (IEP 2016).

Expand and integrate electronic tagging with water quality monitoring

A collaboratively designed and implemented expanded tagging program in the Sacramento River system would provide a better understanding of how water project operations influence Chinook salmon survival. This expanded tagging will require increased capacity for data management and capture-recapture modeling. The data generated from this program will build our understanding of how hydrologic variation, water project operations, habitat restoration and other management actions influence salmon survival. Real time monitoring of acoustic tags (in concert with representative tagging) will improve our understanding of where fish are in the system, potentially increasing operational flexibility and an increased ability to meet the Delta's co-equal goals.

Monitor and manage for life history diversity at multiple life stages

Maintenance and regeneration of life history diversity is central to salmon recovery plans and restoration actions, yet it is one of the most challenging metrics to monitor. Genetic, otolith, and passive integrated transponder (PIT) tagging tools will assist in the development of diversity indicators and insights into how to manage water project operations and restoration efforts to support life history diversity and long-term resilience. In order to inform management decisions for the protection of life history diversity, it would be valuable to enhance the current monitoring network with both parentage-based tagging (PBT) and otolith collection from adult spawners with funding and protocols for long-term archiving (i.e., the DFW Tissue Archive). Though relatively new, both of these technologies are well-tested, and would provide substantial management-relevant information. A complementary approach to assess the lifetime survival of the diversity of salmon outmigrants, many too small to acoustically tag, is to tag representative sizes of juveniles with PIT tags throughout the monitoring program to be sampled in downstream monitoring surveys or upon return in adult carcass surveys.

Develop Green Sturgeon dynamic rate functions and abundance

A number of key parameters regarding green sturgeon spawning distribution and indices of juvenile abundance are in need of further development. With significant improvement, these parameters could be compared to environmental conditions to identify those conditions associated with green sturgeon production. Further developing an index of age-0 juvenile green sturgeon abundance; juvenile green sturgeon telemetry studies; run size and spawning distribution estimates; and quantitative modeling methods to generate estimates of life stage abundance and survival; will greatly improve our understanding of biology, habitat preference, and potential effects of large-scale projects and restoration actions on life stage. Specific guidance on how to implement this recommendation has been investigated and can be led by IEP affiliated scientists investigating sturgeon, and as identified in the SAIL (IEP 2016).

Develop marking/tagging program to identify all hatchery salmonids at Nimbus

To ensure our ability to estimate the proportion of natural origin fall-run and the impacts of hatchery practices on the viability of Central Valley fall-run Chinook salmon and ESA-listed stocks, we will need a long-term marking/tagging program of all hatchery salmonids and tag recoveries in the ocean and escapement surveys, as was recommended by the California Hatchery Scientific Review Group (2012). The ability to identify a hatchery fish allows greater flexibility to take actions similar to what is implemented through hatchery reform in the Pacific Northwest to minimize domestication or fitness reduction in salmonid populations (e.g., segregation weirs). A universal hatchery marking/tagging program would allow for focused research on understanding impacts of hatcheries on naturally-reproducing salmonid populations.

Implement steelhead monitoring plan to assess factors influencing anadromy

The status of the anadromous life history in natural *O. mykiss* remains largely unmonitored with current, extremely limited population trend data. This limitation can begin to be addressed by PIT tagging juvenile *O.mykiss* and quantifying river residency, response to temperature management, and the proportion that outmigrate and survive to adulthood as a means to determine whether management actions aimed at supporting the contribution of anadromy to the population are effective. DFW has developed a steelhead monitoring plan which is being implemented and will provide valuable data to initiate a systematic and deeper understanding of steelhead in the Central Valley. NMFS SWFSC has also been conducting genetic analyses of above-barrier hatchery broodstock and Central Valley floor populations of *O.mykiss* to better understand genetic structure and genes relevant to the expression of anadromy. These actions, combined with genetic analyses and acoustic tagging studies could provide valuable insights into the genetic and environmental factors favoring the different life history forms.

5.2.2 Mechanistic Studies

Field, laboratory and modeling research that focuses on understanding mechanisms (e.g., habitat carrying capacities, disease, predation, food availability, contaminants) linking flow and temperature to different life stages of salmon is required. Specific studies include those that:

5.2.2.1 Assess impacts of predation

Salmon mortality varies across locations in a way that strongly suggests that predation by other fish is the proximate cause. Salmon survival also appears to have declined over time, concurrent with an increase in predatory fish such as large-mouth bass. Recent CAMT and SAIL technical teams working on south Delta salmonid survival and life cycle mechanisms, respectively, highlight that little is known about what ecological mechanisms are directly impacting salmon and sturgeon migration behavior and survival. These analyses and early modeling results indicate predation is non-random in the environment, happening mostly in a small percentage of a river system at "hotspots". From these data, predictive models can be developed to determine hotspot locations. These models require regional calibration, so surveys throughout the Delta as well as the Sacramento River basin will be needed.

5.2.2.2 Investigate salmon route selection and fish guidance technology

Landscape-scale survival studies suggest that the route a fish uses during outmigration strongly influences their survival to the ocean. Factors including distance to ocean, habitat quality, and predatory density, differ among routes and these differences affect overall salmon survival. Two-dimensional fish tracking suggests that routing of fish at channel junctions is determined by their position relative to a demarcation of flow divergence (i.e., the critical streak line). It is important to continue these studies of fish behavior at junctions and the extent to which engineering solutions can enhance fish survival/growth benefits. Current efforts evaluating the use of guidance structures to influence the proportion of fish diverted towards a higher survival route are underway. The CSAMP SST report suggested a broad suite of studies that may be needed to assess fish behavioral responses to various drivers (e.g., velocity, salinity gradients, tidal fluctuations, etc.) which will be important to adapt key operational parameters such as Old and Middle River flow (OMR) and the Inflow to Export ratio (I:E). Engineering solutions may also prove valuable depending on the extent to which the reach containing the NDD of CWF becomes a lower survival reach than alternative routes.

5.2.2.3 Implement restoration science and effectiveness monitoring

Focused research on how freshwater habitats influence salmonid size and timing of ocean entry and how this freshwater experience influences their overall ocean performance is needed. Floodplain and shallow water habitats, such as tidal marshes, and bays are not well-sampled by existing monitoring programs. Targeted studies are needed to examine the predicted benefits and risks of these habitats and the influence of associated restoration actions on Chinook salmon and sturgeon populations. Additionally, the benefits of restoration will likely be in fish quality (e.g., condition and growth), diversity in outmigration timing, and delayed survival benefits (e.g., ocean survival) rather than a potential direct increase in juvenile abundance in the freshwater.

5.2.3 Modeling and Synthesis

This category includes life-cycle models that integrate core monitoring and mechanistic study data to evaluate the influence of management actions (e.g., water operation, restoration, reintroductions, harvest, hatcheries, invasive species, climate change) into changes in the future viability of fish populations. Specific studies needed include those that:

5.2.3.1 Support system-wide physical models

Water project facilities and operations, by design, alter the timing and amounts of water flows, and thus water depth and velocities. The development and refinement of process-based model frameworks that track the movement of water and relevant constituents (e.g., heat, particles, contaminants, dissolved oxygen, etc.) throughout the entire Central Valley system would be very useful. The CSAMP SST report highlighted the need to update the Delta Simulation Model II (DSM2) as a critical step to better assessing the effect of Delta water operations.

5.2.3.2 Support system-wide ecosystem models

Biological models, coupled to physical models, are the basis for making the quantitative predictions required for effective adaptive management of anadromous fish and water resources. The development of process-based model frameworks to capture the fundamental biological processes (e.g., growth, survival, reproduction, evolution, movement, interactions with predators, competitors, prey, parasites, and pathogens, etc.) at each domain, and how the biotic components (e.g., prey, predators) move between domains. A variety of modeling frameworks should be developed and tailored to accommodate different management questions and biological endpoints.

5.2.3.3 Support salmon and sturgeon life cycle models

Develop a salmonid life cycle model tailored expressly to assist with evaluating salmonid responses to the long-term operations of the state and federal water projects as mandated by the courts and echoed by the Delta Science Program's panel review (NMFS 2009; Rose et al, 2011). While significant progress has been made in the development, refinement, documentation, and implementation of the life cycle model (LCM) for winter-run Chinook salmon, the modification to water project infrastructure and operational decisions as part of CWF will continue to generate new information that can be used to further refine our understanding and the models.

5.2.3.4 Develop winter-run Chinook salmon ocean forecast model

Salmon populations are also highly responsive to changes in ocean conditions, which may obscure population responses to management if not accounted for. The development of an ocean forecast model will determine if ocean ecosystem metrics (coupled with stock-specific abundance estimates at ocean entry) can be used to forecast abundance of age 2 and 3 Sacramento River winter-run Chinook salmon in the mixed-stock fishery. Directly quantifying juvenile Chinook salmon in the coastal ocean is virtually impossible due to low population size, and yet understanding early ocean mortality may be the missing gap necessary to better evaluate how different sources of mortality impact the larger population of winter run.

5.2.3.5 Develop real-time salmon movement and survival model

The Delta Operations of Salmon and Sturgeon (DOSS) team uses multiple sources of information to infer the likely proportion of a stock that remains in the river vs. in the Delta during that stock's outmigration. The DOSS team provides managers with a weekly outlook regarding the vulnerability of ESA-listed stocks to Delta water project operations, yet this outlook is based on the judgement of experts and does not have a quantitative tool to assist in this evaluation and integration of information. The development of a statistical GIS movement and survival framework to process real-time salmon acoustic detections to better quantify salmon distribution and movement would further validate DOSS advice.

5.2.4 Data Access

Improved data availability, consolidation, and statistical support for real-time water project operations is critical, and key to this effort is data access.

The majority of biological monitoring data (except salmon escapement in Grandtab) is not readily available to the public or agency scientists. Staff members have to be contacted individually to acquire basic monitoring information which makes synthesis efforts challenging and laborious. In addition, identifying the point of contact for data can also be challenging. The development of a centralized accessible network for relevant physical and biological data necessary for management decisions related to salmon and water resource management would provide for more effective access and enhanced transparency.

6 Funding

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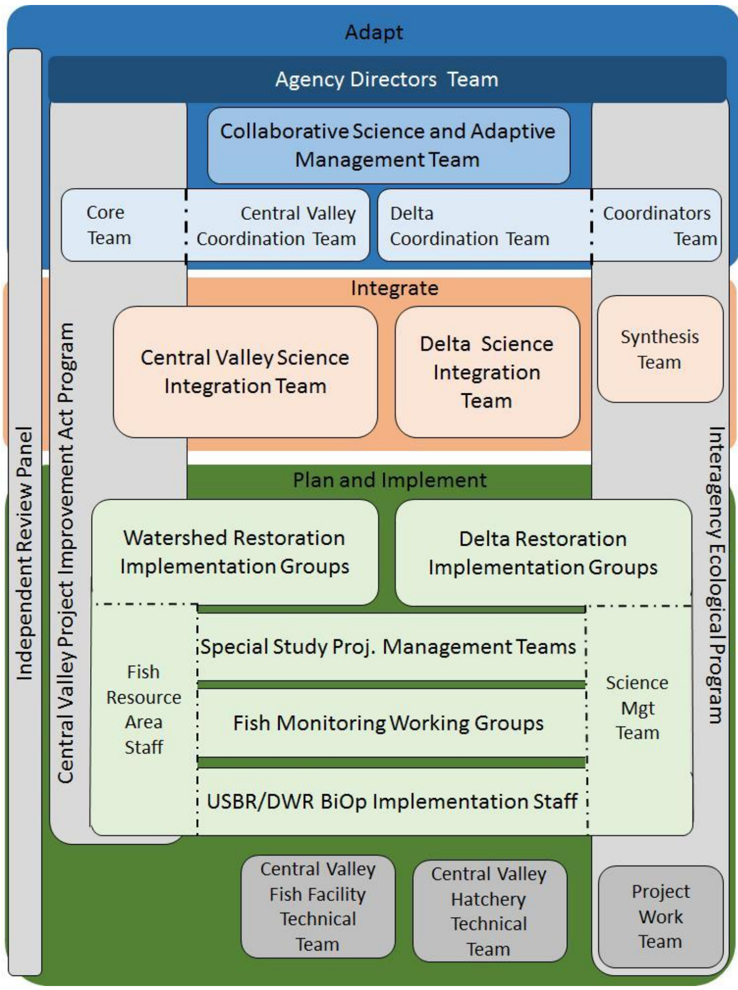
As part of the current BiOps and CESA authorizations and the Bay Delta Water Quality Control Plan, a number of monitoring and research actions in the Delta are currently being implemented through the IEP and south Delta fish facilities management and enhancement efforts, as well as through the Fish Restoration Program Tidal Restoration Monitoring Program. IEP continuously reassesses its monitoring and research efforts to address management specific actions. Most recently, the SAIL has identified actions to improve tracking and real time decision support monitoring. Upstream monitoring on the Sacramento, Feather, American and Stanislaus rivers related to upstream reservoir management actions to protect listed fish species is also conducted. CSAMP has developed study plans and budgets for specific research efforts to address south Delta operational effects on salmon, Delta Smelt entrainment, and the Fall X2 action in the FWS 2008 OCAP BiOp. CSAMP is also developing study plans to address additional areas of scientific uncertainty related to operation of the SWP/CVP in the Delta. DFW as part of a settlement agreement with water agencies has created a Longfin Smelt technical team to address uncertainties related to current sampling approaches and how Longfin Smelt abundance is characterized, as discussed above this effort is expected to expand in the future.

Additional CWF scientific research and monitoring (identified in sections above) will be required to address the effects of water operations with North Delta Diversions in place, as well as questions related to the design and operation of the facilities themselves to minimize effects on listed species. During implementation of the current BiOps and CESA authorizations it has become apparent that additional resources for monitoring and research are need to address uncertainties and to provide better information upon which to base management decisions. Further, the additional work identified through the SAIL effort and the CSAMP Salmon Gap Analysis will need additional funding.

Appendix 8, presents an estimate of the potential future annual costs for implementing the monitoring and research necessary to support the Adaptive Management Program. Current and anticipated funding requirements and timelines will be determined by the IICG.

7 Summary of Relationships to Other Programs

Important efforts are underway to implement science-based adaptive management to improve the scientific basis of operational decisions on annual or multi-year time scales. The Adaptive Management Program will integrate with the existing and planned efforts summarized below, and others, that are developing and implementing science to apply adaptive management principles to the Delta ecosystem. As the Adaptive Management Program is developed, specific linkage to each of these efforts will be defined. The proposed action will make use of the existing CVPIA and IEP programs and augment those programs with stakeholder involvement, see figure XX.



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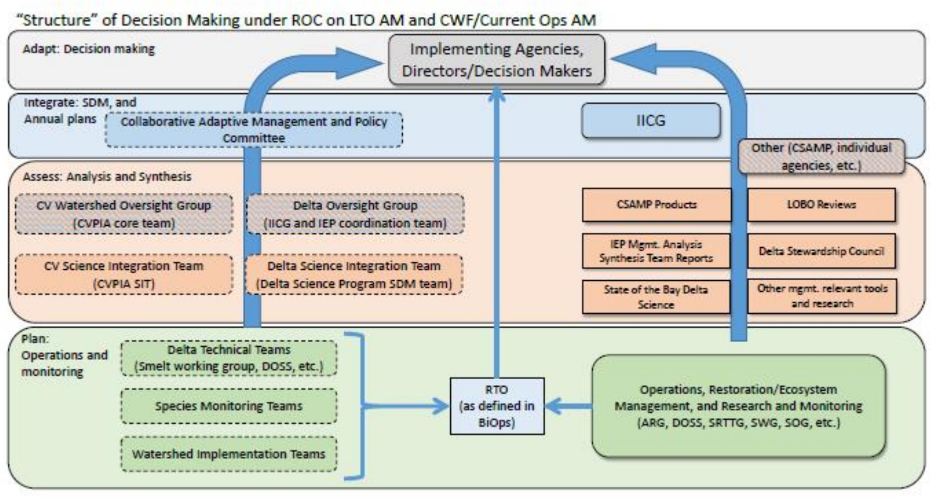

Figure XX. **Primary components of the CVP/SWP Adaptive Management governance structure (not intended to represent a hierarchy).**

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7.1 Current Efforts

The original IEP studies of the influence of Delta flows on the recruitment of striped bass and the function of their supporting food web were an ambitious interagency attempt at an "adaptive management" program that pre-date the current definition of the phrase adaptive management (used in this Program). In this context, the IEP program has expanded and morphed as agency priorities have evolved. As a result of this cooperative history, there are several very important efforts already underway to implement science-based decision support tools that seek to thereby improve the scientific basis of operational decisions at an annual or multi-year time scale (*Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*).

To be most successful, this Adaptive Management Program will build on and augment the existing efforts that have been developing and implementing science to apply adaptive management principles to the Delta ecosystem since the 1960s. In particular, this Program will incorporate many elements of the process and structure of the IEP and the Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team (CSAMP/CAMT), and the State and Federal Contractors Water Agency Science Program, and will continue to rely on the Delta Science Program for peer review and research support. Because these existing efforts will form core elements of this Program, each effort is described below.

7.1.1 Central Valley Project Improvement Act, Anadromous Fish Restoration Area

The CVPIA includes a requirement for reasonable efforts to double anadromous fish populations in the Central Valley by 2002 (fish doubling goal). Recommendations were made to update and improve the science-based framework for priorities, reorganize the program structure and management, improve implementation by making full use of CVPIA water operations authorities, and improve collaboration with all related programs in the Central Valley. As a result, in 2015, Reclamation and the USFWS established an organization structure consisting of:

- Core Team: Senior agency program managers providing input on CVPIA's program;
- Science Integration Team: Data scientists and modelers to develop decision support models open to stakeholder participation; and
- Project Management Teams: agency and stakeholder scientists that design and implement specific restoration projects and science studies.

The CVPIA Core Team coordinates annual priorities, projects, and funding. The CVPIA Science Integration Team consists of a collaborative group of Central Valley river and Delta experts from agencies, water users, NGOs, and consultants, with a science facilitator from the U.S. Geological Survey. The current CVPIA Science Integration Team developed DSMs for Chinook salmon, steelhead, and sturgeon which will be used in the ROC on LTO SDM process. Project Management teams and interagency and stakeholder teams that participate in designing and implementing project charters, which are developed annually as part of the Fisheries Resource Area's annual work planning efforts. Because of the history, size, and scope of this program's restoration, monitoring and research efforts in the Sacramento and San JOaquin rivers and their tributaries, it will continue to be a primary component in the implementation of LTO's adaptive management and monitoring program.

7.1.2 CSAMP

The CSAMP was launched following decisions by the United States District Court for the Eastern District of California to remand the current BiOps to the USFWS and NMFS for further consideration in accordance with the decisions (*San Luis & Delta-Mendota Water Authority v. Salazar*, 760 F.Supp.2d 855 (E.D. Cal. 2010); *Consolidated Salmonid Cases*, 791 F.Supp.2d 802 (E.D. Cal. 2011)), and more specifically following a decision by that court on April 9, 2013 (*In re Consolidated Delta Smelt Cases*, 2013 WL 1455592 (E.D. Cal. 2013) (2013 Court Order)). The 2013 Court Order was issued in response to a motion to extend the court-ordered remand schedule for completing revisions to the current BiOps and completing review under the National Environmental Policy Act (NEPA).

The 2013 Court Order allowed the parties making the motion (i.e., Reclamation, USFWS, NMFS, and DWR) additional time for the development of a proposed robust science and adaptive management program, with collaboration of the scientists and experts from the Public Water Agencies ('PWAs') and the non-governmental organization (NGO) community with the intent to inform the management actions incorporated into the current BiOps (and Reasonable and Prudent Alternatives) and consideration of alternative management actions.

The 2013 Court Order granted a one-year extension of time to deadlines associated with the cases' remand. The parties filed an annual progress report in February 2014, and the court granted a second one-year extension in March 2014. The parties prepared a second annual progress report in February 2015, requesting a third one-year extension. However, the Ninth Circuit Court of Appeals reversed the court's decisions that remanded the current BiOps to USFWS and NMFS (*San Luis & Delta-Mendota Water*

Authority v. Jewell, 747 F.3d 581 (9^{th} Cir. 2014), *cert. denied* 135 S.Ct. 950 (2015); *San Luis & Delta-Mendota Water Authority v. Locke*, 776 F.3d 971 (9^{th} Cir. 2014)).

After reversal of the court's decisions requiring remand of the current BiOps, in 2015, all parties agreed to continue the CSAMP to promote the collaborative development of scientific information to inform sound decision-making in the future.

7.1.2.1 Organization

The CSAMP is structured as a four-tiered organization comprised of:

1. Policy Group consisting of agency directors and top-level executives from the entities that created CSAMP;

2. CAMT made up of managers and staff scientists that serve at the direction of the Policy Group;

3. Scoping Teams created on an as-needed basis to scope specific science studies; and

4. Investigators contracted to conduct studies.

7.1.2.2 Mission Statement

The CAMT mutually agreed on the following mission statement at its July 23, 2013 meeting:

> *The Collaborative Adaptive Management Team (CAMT) will work, with a sense of urgency, to develop a robust science and adaptive management program that will inform both the implementation of the current Biological Opinions, including interim operations; and the development of revised Biological Opinions.*

CAMT expects to revisit its mission statement (by increasing its scope) as it develops its Five Year Plan for CAMT. In the meantime, CAMT intends to remain focused on completing the studies initiated in 2014 and identify new initiatives based on the results of these studies.

Current products that are being developed by the CAMT scoping teams and principle investigators include analysis and synthesis tools and reports concerning Delta Smelt Entrainment, Gear Efficiency, Fall Habitat, and Salmonid survival. These reports from the two scoping teams will identify key findings, issues and recommendations for next steps. The next steps recommended in the two scoping teams' reports will be evaluated and prioritized by CAMT members. The highest prioritized efforts will be presented to the CAMT Policy Group and will be incorporated into the CAMT five year plan that CAMT is currently developing.

Items in the CAMT Five Year Plan may also support and contribute to advancing the objectives of other efforts including CWF and IEP. The CWF Five Agencies will ensure that efforts being implemented via CAMT or IEP are integrated and continue to move forward in those forums.

7.1.3 Interagency Ecological Program

The IEP has brought state and federal natural resource and regulatory agencies together to monitor and study ecological changes and processes in the Delta since 1972. The IEP currently consists of nine member entities: three state agencies (DWR, DFW, and the State Water Resources Control Board), six federal agencies (USFWS, Reclamation, USGS, USACE, NMFS, and U.S. Environmental Protection

Agency), and two (current) partners: the San Francisco Estuary Institute and the Delta Science Program. These agencies and partners work together to develop a better understanding of the estuary′s ecology and the effects of the SWP/CVP operations on the physical, chemical, and biological conditions of the estuary. The 2014 IEP Strategic Plan describes IEP's goals and strategies to achieve them (http://www.water.ca.gov/iep/docs/IEP_Strategic_Plan102214.pdf).

7.1.3.1 Organization

The IEP is structured as a four-tiered organization comprised of:

1. Member agency directors;
2. IEP Coordinators made up of senior level managers who oversee the program
3. Science Management Team made up of managers and staff scientists that serve at the direction of the Coordinators to scope specific science studies. The IEP Lead Scientist provides strategic direction for, and oversight of, IEP science efforts, acts as the chief science advisor to the IEP Coordinators and Directors, chairs the Science Management Team, and serves as the primary scientific voice to all the groups;
4. Ad hoc project work teams that also develop scientific study concepts that can be recommended to the Science Management Team. The project work teams have included not only agency staff but have had extensive participation from academics and stakeholders; and
5. Investigators who are either agency staff or are academics or consultants contracted to conduct studies.

The IEP has coordinated Bay-Delta monitoring and research activities conducted by state and federal agencies and other science partners for over 40 years (*Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*). IEP monitoring activities are generally carried out to document CVP and SWP compliance with water rights decisions and California Endangered Species Act (CESA) authorizations and/or current BiOp conditions. Most of the monitoring under the IEP focuses on open-water areas and the major Delta waterways conveying water to the SWP/CVP facilities in the south Delta and downstream, including the entire Bay-Delta and portions of its watershed. The IEP produces publicly accessible data that include fish and invertebrate status and trends, water quality, estuarine hydrodynamics, and foodweb monitoring. Because of the history, size, and scope of this program's monitoring and research efforts in the Delta, it will continue to be a primary component in the implementation of CWF's adaptive management and monitoring program.

Although IEP member agencies have varying priorities, IEP provides a common ground for shared science priorities to come together and focus on supporting management needs for the Bay-Delta ecosystem and the water that flows through it. Some priorities are very explicit, such as monitoring specified in a permit or agreement. Others are focused on informing pending decisions or seeking new understandings that allow better decision making in water project operations or prevent new challenges such as invasive species.

Science Agenda

To meet anticipated science needs of the member agencies and provide the scientific tools and advice that resource managers can rely upon, the IEP has developed an IEP Science Agenda to focus on overarching management challenges anticipated in the next 3-5 years (http://www.water.ca.gov/iep/docs/2016_IEP_Science_Agenda_FINAL.pdf). The agenda serves as an outline for achieving important objectives by identifying and organizing science needs in the context of conceptual models, related information gaps and uncertainties, and strategies and priorities. The IEP Lead Scientist and IEP Coordinators have guided the development of the agenda, while drawing insights from the program scientists, project work teams, managers, and stakeholders particularly via the CSAMP.

7.1.4 Delta Stewardship Council, Delta Independent Science Board (DISB) and Delta Science Program (DSP)

Established by 2009 Delta Reform Act, the Delta Stewardship Council is charged with achieving the co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The DISB provides a standing board of nationally or internationally prominent scientists with appropriate expertise to evaluate the broad range of scientific programs that support adaptive management of the Delta. The DISB will provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs and reports to the Delta Stewardship Council. The Delta Science Program's mission is to provide the best possible unbiased scientific information to inform water and environmental decision making in the Bay-Delta region. The Delta Science Program's objectives are to:

- Initiate, evaluate and fund research that will fill critical gaps in the understanding of the current and changing Bay-Delta system.
- Facilitate analysis and synthesis of scientific information across disciplines.
- Promote and provide independent, scientific peer review of processes, plans, programs, and products.
- Coordinate with agencies to promote science-based adaptive management.
- Interpret and communicate scientific information to policy- and decision-makers, scientists, and the public.
- Foster activities that build the community of Delta science.

The Delta Science Program has particular expertise and experience organizing and facilitating independent scientific reviews. It also has primary responsibility for developing and implementing the Delta Science Plan. The Delta Science Program may review monitoring and research methods and results to provide technical support to the adaptive management process.

In its January 2016 review, *Improving Adaptive Management in the Sacramento-San Joaquin Delta*, the Delta Independent Science Board (ISB 2016) provided a number of insights regarding the way adaptive management has been applied to the Delta ecosystem as well as a number of recommendations for future implementation. Key findings and recommendations included:

- Agencies must become more actively engaged in collaborations;
- Adaptive Management must be identified as a high priority;
- Supporting Adaptive Management with dependable and flexible funding;

- Design and support monitoring to fit the magnitude of management actions and timing of ecosystem processes;

- Develop a framework for setting decision points or thresholds that would trigger a management response;

- Use restoration sites to test adaptive management and monitoring protocols.

The Delta Science Program has also identified a nine step adaptive management process. This Program proposes to use a four-phase approach to adaptive management which has been described in Section 5. Figure 8-1 describes how this Program's approach relates to the nine-step process.

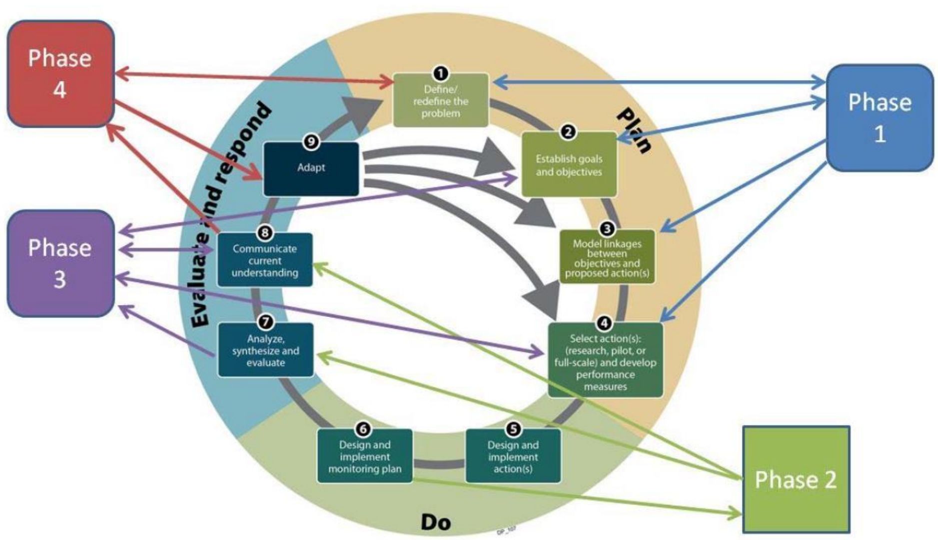

Figure 8-1. Describing the relationship between the DSP's nine step adaptive management process and the four phase process described in this Program

Arrows "from" a phase means that particular step is contained within the phase, where arrows "to" a phase mean that that step influences a phase. Double arrows are both within and influencing the phase.

The overarching objective of the BiOps and CESA authorizations is to avoid jeopardy or adverse modification of critical habitat for the covered species. During Phase 1 the development of management actions to be tested via the science plans/priorities is similar to Step 4 and based on the problems defined by Step 1. In the development of management actions and science plans objectives (*i.e.* Step 2) will be clearly defined and modeled linkages of Step 3 will be created between proposed actions/studies and the objectives. Phase 1 results in the Operations plan and Science plan, as well as their implementation (*i.e.* Steps 5 & 6).

8 Reporting

Reports and plans will constitute the most visible documentation of the adaptive management process. In general, each adaptive management action will be proposed in a plan and its outcomes described in a report. Reports will take into account other existing processes and augment those efforts.

8.1 Annual Work Plan and Budget

On an annual basis, the IICG will prepare an Annual Work Plan and Budget for the upcoming year. The Work Plan will describe the proposed activities of the adaptive management and monitoring program. The Budget will set out projected expenditures and identify the sources of funding for those expenditures.

The IICG will develop and approve the Annual Work Plan and Budget.. As part of this process, the Five Agencies will participate in developing the draft plan. As part of their participation on the IICG, the Five Agencies will ensure the draft plan accurately sets forth and makes adequate provision for the implementation of the applicable permit terms under which the CVP and SWP operate.

A draft of the Annual Work Plan and Budget will be developed by the IICG, working with the Collaborative Science Workgroups, and posted for review and comment. A final Annual Work Plan and Budget will be completed no later than 1 month prior to the beginning of the activities described therein.

At a minimum, the Annual Work Plan and Budget will contain the following information.

- A description of the planned actions under the adaptive management processes.
- A description of the planned monitoring actions and the entities that will implement those actions, based on the structured decision-making described below.
- A description of the anticipated research studies to be undertaken and the entities that will conduct the studies.
- A budget reflecting the costs of implementing the planned actions.
- A description of the sources of funds that will be used to support the budget.

8.2 Annual Progress Report

At the end of each implementation year, Reclamation and DWR, through the BOCT, will develop an Annual Progress Report. The report will be based upon existing information, data, and analysis. The report will provide an overview of the activities carried out during the previous implementation year and provide information sufficient to demonstrate that the proposed action is being implemented consistent with the provisions of the BOs.

The BOCT shall solicit input on the draft of the Annual Progress Report from its members prior to its review and approval. The IICG shall finalize and approve the Annual Progress Report within six months of the close of the reporting year.

The annual progress report will include, among other things, the following types of information.

- Documentation of the implementation of habitat restoration and protection measures specified in the Proposed Action in relation to their schedule and performance specifications, including the following components.

  - A summary of the habitat protection and restoration actions that have been initiated, are in progress, or have been completed, including information regarding the type, extent, and location of protected and restored habitat for listed species. The report will document these actions on an annual and cumulative basis.

  - A general summary of all land management activities undertaken on protected and restored habitat, including a description of the management issues associated with each habitat protection or restoration site.

  - Identification of actions that have not been implemented on schedule and an explanation for the deviation from schedule. For actions that are behind schedule, a suggested schedule or process for completing them will also be included.

- Descriptions of actions taken pursuant to the adaptive management programs.

  - Documentation of the results of monitoring and research actions prescribed in the PA. This is to include a summary of the actions that have been initiated, are in progress, or have been completed for each conservation measure, including information related to type, location, and method of implemented actions. The report will document this on an annual and cumulative basis.

  - Adaptive management decisions made during the reporting period, including the scientific rationale for the action.

  - Use of independent scientists or other experts in the adaptive management decision-making processes.

  - Changes in the manner in which conservation measures are the proposed action is implemented, based on interpretation of monitoring results and research findings, or other information.

- An accounting of the funding provided to support the monitoring, research, and adaptive management programs. The accounting will identify the source of the funds, the annual and cumulative expenditures to support the programs by cost category, and any deviations in expenditures from the associated ***Annual Workplan and Budget***.

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10 APPENDICES

Appendix 1—Initial Objectives and Management Questions

Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species

Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass

Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Habitat Restoration

Appendix 6—Delta Outflow

Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program

Appendix 8- Estimated funding needed to support the Adaptive Management Program

Appendix 1—Initial Objectives and Management Questions

This appendix and the table below describes preliminary species-specific objective. Final objectives for this adaptive management program will be developed using collaborative processes and limited to those actions necessary to achieve applicable regulatory standards. The BOCT will consider those final objectives when implementing this AMP.

Objectives (Triggers for Adaptive Management action)	Management Question
Shasta Division (Taken from Shasta RPA Draft Science Plan)	
Forecasting	
Ascertain and establish the appropriate biological objectives for use in the environmental watering approach to water management.	What is a reasonable biological objective for temperature-dependent mortality to maintain (protect and restore) the winter-run Chinook population (percentage and year-to-year frequency)? o What levels of storage and releases are required from a prior year to achieve the biological objectives for a subsequent year? o What are the probabilities that different storage and releases from the prior year lead to successful attainment of biological objectives? What are the bounds of feasibility (Shasta storage, climate) driving cold-water volume and storage? o What are the effects of a changing climate? How do we prioritize biological needs in situations of limited cold water?

Commented [A23]: Need to develop an appendix for Uncertainties Related to Water Operations. We already have some uncertainties drafted and there is lots to draw from in the NMFS Effects Analyses sections from the draft BiOp.

Commented [A24]: I changed the format of this appendix to follow the objectives and management questions format from the 2018 RPA Amendment Draft Science Plan.

Deleted: *Derived From Current Biops/CESA and CWF*

Commented [A25]: Deleted by Reclamation, need to add back in and make it more ROC focused

Commented [A26]: Not sure if this is needed since Yolo is not being consulted on as part of ROC.

Commented [A27]: Suggest updating this from Channel Margins to the more general category of Habitat Restoration to fit the Conservation Measures that are part of the ROC PA.

Deleted: *Channel Margin*

Commented [A28]: Not sure if this is necessary for ROC LTO as currently proposed in the BA PA

Commented [A29]: These appendices were deleted by Reclamation. Need to work back in.

Deleted: *for the Existing Biological Opinions and CESA Authorizations for the Longterm Operations of the CVP and SWP and for CWF*

Commented [A30]: This is a first cut with objectives and management questions pulled from January 24, 2019 Shasta RPA Amendment Draft Science plan and a CAMT Delta Salmonid Research Workshop Group May 18, 2018. Need to add objectives for other Divisions but have not had time to do this yet.

	o What are the population level risks from different balances on the downstream compliance location, water temperature targets, and risk of running out of cold water at the end of the season? o What practices for managing pre-spawning flows and temperatures minimize later risks to populations? o What is the relationship between pre-spawn flow, storage, temperatures, spawning location and density-dependent effects? o What are the trade-offs between temperature management and other flow-related survival?
Species Viability and Variability	
Identify species and life-stage specific criteria on which to base biological objectives and metrics.	What are the appropriate egg-to-fry survival biological mechanisms to model? Have we appropriately characterized background mortality? Spatially, seasonally, and year to year? Can the endangered winter-run Chinook salmon species be managed to have temperature dependent mortality that would lead to recovery years, versus protection only years, per the Victorian model, and still allow for recovery? o What level of productivity is necessary to mitigate high temperature dependent mortality (i.e. critical years)? o What amount of optimal carrying capacity is necessary to support a viable population? o What can existing management tools, such as the NMFS Southwest Fisheries Science Center Central Valley Chinook Life Cycle Model, provide in understanding and crafting temperature-dependent survival targets?
Interactions between Stressors	
Explore and refine the practicable management criteria and the (interaction with other) physical/environmental conditions that may influence the biological objectives.	What is the relative significance of temperature-dependent mortality compared to other sources of mortality? o Are the eggs or fish oxygen deprived? o How does substrate influence egg-to-fry survival? Does substrate size affect the sensitivity to temperatures? How can the following non-temperature dependent factors relieve (or increase) pressures on cold water management? o Disease o Predation

	○ Spawning Habitat Quality ○ Rearing Habitat (Improve survival) ○ Migration Cues (Improve Survival) ○ What about multiple stressors interacting: temperature and pathogens; temperature and predation, temperature/food/energy
Structural Modification of Facilities	
Consider the existing and potential facilities that could be used to achieve any biological objectives.	Are there any further structural modifications to reduce temperature dependent mortality? What additional reservoir cold-water pool conditions may see improved temperature performance through structural modifications or adjustments used during the recent drought (i.e. tarping the TCD, penstock operations)? What benefits to volume, and length and duration of gate operation of the TCD, can be achieved by these structural modifications?
Delta Division (Taken From CAMT Delta Salmonid Research Workshop Group May 18, 2018	
Condition, Behavior and Hydrodynamics	How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by hydrodynamics (tidal influence, inflows)? What are the ways (e.g. habitat creation, landform changes, hydraulic residence time/water quality) that hydrodynamics in the Delta affect fish behavior?
Operations and Behavior	Where in the Delta are operations (see list below) changing hydrodynamics, and how are salmon behaviors changing given those changes? a. DCC operations b. OMR regulated operations c. I:E regulations affecting hydrodynamics d. Differential pumping at facilities – are there differences in hydrodynamics e. Other operations
Condition, Behavior and Water Quality	How is salmon condition and behavior (e.g. rearing, active swimming, lateral distribution within the channel, passive displacement, diel movements, energy expenditure, growth, timing of ocean entry, selective tidal stream transport, migration, routing) affected by water quality drivers (i.e. Temp, DO, primary productivity, turbidity, salinity)?

Commented [A31]: These categories are directly from the CAMT workshop report and are not described as objectives, but they are a good start. Suggest developing objectives statements for each category

	How do operations affect water quality?
Flow Metrics and Thresholds	Is there a channel velocity or flow direction threshold at which salmonids change their migration behavior or routing? o If so, what is it, how long must it be sustained, how frequently must it occur and would the change in behavior or routing be observable in an acoustic telemetry study?
Alternative Flow Metrics	To what extent can alternative flow metrics (identified in SST Question 5 as: Qwest; hydraulic residence time in south Delta; percentage of positive flow; proportion of CVP exports; and proportion of Sacramento River water at CVP/SWP) provide better management of south Delta water operations than existing metrics (OMR, I:E) intended to support behavior and migration that results in increased survival of salmonids?
Biological Response Metrics	The SST identified eight biological response metrics that would be useful for assessing the effectiveness of RPA actions. The metrics included: o Proportion of test fish at specific channel junctions that enter the Interior Delta; o Survival within specific reaches or to specific locations within the Delta; o survival through the Delta; o Condition of fish sampled above, within (at salvage facilities), and below the Delta; o Proportion of returning adults that display extended Delta rearing as fry based on otolith analysis; o Predicted risk that a juvenile salmonid would be entrained at the export facilities based on models; o Percentage of direct (salvage) mortality relative to estimated population abundance; and o Abundance of salmon populations leaving the Delta, or locations further downstream (e.g., Benicia or Golden Gate bridge). Are any of the metrics listed above more effective than what is currently used to manage and assess the effects of water project operations on salmonids?
Monitoring and Decision Support Tools Real- time monitoring and predictive modeling of juvenile salmon distribution in the South Delta could allow for more effective water project operations.	To better inform water project operations, what locations in the South Delta should be monitored/modeled, what metrics should be monitored/modeled, and what monitoring/modeling tools should we invest in? How could these data be used to inform water project operations?
Achieving Recovery	What are the optimal conditions in the Delta for salmon recovery?

	a) in the near term (given existing upstream conditions and population size), and b) under proposed restored conditions in the upper watershed What are the dominant conceptual models/ hypotheses describing 1) how salmon behave in the Delta now, and 2) how we anticipate salmon would behaving once populations targets are met and environmental/ habitat objectives in the upstream tributaries achieved? a. What are the dominant conceptual models/ hypotheses related to desired conditions to support those behaviors? b. What are the major areas of uncertainty around those conceptual models? c. What are the most important actions or experiments that could be taken to resolve those areas of uncertainty? How can operations, in combination with targeted restoration and other management actions, be optimized to achieve desired conditions for the range of salmon behaviors the delta will need to support in the near-term and the long-term? a. How can we design operations to test key hypotheses and resolve core uncertainties? b. What metrics should be used to measure the success of management actions

Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Key Uncertainty	Potential Research Actions
How does tidal marsh restoration affect production of food suitable for listed fish species both within and outside of the restored sites?	Quantify primary and secondary production, including food suitable for listed species, both within restored tidal marsh natural communities and transported from restored areas to adjacent open-water habitat and the fate of that production.
How have hydrodynamic changes associated with tidal restoration affected organic carbon transport and fate?	Quantify the flux of organic carbon produced in restored tidal marsh plain into existing channels in the Action Area.
How has tidal marsh restoration affected benthic invertebrate communities? In particular, how are invasive mollusks affecting zooplankton production in restored tidelands?	Document and evaluate water quality conditions in restored subtidal aquatic habitats.
Do juvenile sturgeon use restored tidal wetlands?	Capture and acoustically tag juvenile sturgeons in Action Area, then track movement using existing hydroacoustic array. Assess fraction of time in or adjacent to restored tidal wetlands. Begin the 3-5 year-long study when 20% of the tidal wetland restoration acreage is achieved.

Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Habitat Restoration

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Commented [A32]: Need to develop more statements to address the habitat restoration measures that are part of the PA…gravel, side channels, riparian, small screens, etc…See BA table 4-6 for details. Also the Effects Analyses for each division discusses uncertainties.

Key Uncertainty	Potential Research Actions
How is predation affecting listed fishes in restored channel margin habitat?	Quantify abundance of nonnative fishes in restored channel margins. Assess effects of nonnative fish predation on listed species in restored sites. Identify ways to avoid and minimize those impacts.
Does channel margin enhancement contribute to an increase in survival of fry-sized Chinook salmon in restored river reaches?	At representative channel margin enhancement sites, mark and recapture fry-sized Chinook salmon. This work should include collection of 3-5 years of data before implementation at the site in order to establish a baseline condition capturing years with varying hydrology and an additional 3-5 years of data collection after the channel margin enhancement has been constructed.

Delta Smelt Pre-Adult Habitat

The integration of Suisun Marsh Salinity Control Gate operations in the late summer and manipulation of salinities into the fall is proposed based on the recruitment of Delta Smelt.Table 1. Key Questions and Possible Investigative Approaches to Address Delta Smelt Pre-Adult Habitat Management

Commented [A33]: FWS and Reclamation have been working on the replacement action for fall X2 and it is being written as an AMP. Suggest having FWS and Reclamation add that program here in some form.

Key Questions	Possible Investigative Approaches
Under what circumstances does survival in the fall affect subsequent winter abundance?	Quantitatively determine the contribution of Delta Smelt survivorship in the fall to inter-annual population variability. Review available lifecycle models for applicability.
Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of Delta Smelt?	Investigate the relationship between fall outflow and the relative change in Delta Smelt abundance using univariate and multivariate and available historic data.
Under what circumstances is survival of Delta Smelt through the fall related to survival or growth rates in previous life stages?	Compare Delta Smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data are being collected as part of the Fall Outflow Adaptive Management Plan (FOAMP).
Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of Delta Smelt during the fall?	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Another option is to test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, as well as work by Kimmerer, Burnham & Manly.
Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on Delta Smelt survival?	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of Delta Smelt during the fall.
Source: Collaborative CAMT (2014)	

Appendix ? Monitoring Groups for Core Operations

Monitoring Program for Core CVP and SWP Operation

Commented [A34]: This is a good list of existing monitoring programs, but it is not clear how these monitoring programs will be used to support operational decision making…needs more work to integrate into the AMP above

This monitoring program for the Core Water Operation of the CVP and SWP identifies the information required for:

- Real-time water operations,
- Demonstrating compliance with Core Water Operation commitments in the Proposed Action, and
- Evaluating re-initiation triggers.

Additional monitoring to determine status and trends of species and understanding ecosystem interactions may occur through other processes, such as Voluntary Agreements and/or existing water quality permits , are listed, but are not explicitly relied upon for the Core of the Proposed Action. Reclamation and DWR may accomplish the monitoring through agreements with other agencies, partnerships with local water users, and/or contracts with private entities.

This Core Monitoring Program considers the information developed by the Salmon and Sturgeon Assessment of Indicators by Lifestage (SAIL) Program (Johnson et al. 2017) and the Enhanced Delta Smelt Monitoring (EDSM) Program (cite). This Core Monitoring Program focuses on the functions met by the different efforts and use the current technologies as examples that meet the functions. Additionally, the Core Monitoring provides support for the necessary studies to develop annual incidental take limits. Monitoring methodologies may change as technology advances or research supports better protocols.

Core Water Operations

Core water operations include Shasta and Folsom Cold Water Pool Management, Delta Cross Channel Gate Operations, Old and Middle River Reverse Flow Management, and Delta Smelt Fall Habitat. Physical information for real-time operations includes:

- Delta Flow, Temperature, Turbidity, and Salinity Stations
- Tributary Flow and Temperature Stations
- Folsom Reservoir Temperature Profiles
- Shasta Reservoir Temperature Profiles

Biological information required for real-time operations includes:

- Chinook Salmon
  - Redd Timing and Location: Provides the spatial and temporal risk of mortality for the different flow and temperature regimes as well as the potential for dewatering. Currently accomplished through weekly visual surveys that identify new redds by reach.
  - Carcass Surveys: Supplements the redd surveys to account for unobserved redds to help assess the significance of individual redds. Currently accomplished by field crews per well established protocols on the number of adults and the proportion that are female.
  - Juvenile Abundance and Timing: Identifies the production of juveniles salmonids (Red Bluff Diversion Dam), migration of salmon for operation of the Delta Cross Channel (Knights Landing Rotary Screw Trap), and the implementation of OMR reverse flow actions (Sacramento Trawl and Chipps Island Trawl).
  - Delta Distribution: Informs OMR actions and is currently supported through beach seines, acoustic tagging, and some EDSM.
  - Salvage Count: Informs the direct effects on listed fish
  - Genetic Identification: Informs the salvage of listed Chinook salmon species versus non-listed Chinook salmon species.
- Delta Smelt
  - Turbidity Stations: Informs the potential for a “turbidity bridge” that would inform OMR Actions.
  - Temperature Stations: Informs the transition between life stages and the need for protective measures.
  - Water Quality Stations: tracks the movement of the low salinity zone and parameters associated with the food web, e.g. chlorophyll.
  - Delta Distribution: Informs the entrainment risk due to OMR actions and is currently would be supported by EDSM.
  - Fish Condition: Informs when adults have spawned and the need for larval protections.
- Steelhead
  - American River and Clear Creek Redd Surveys

- o Salvage Count
- Sturgeon
  - o Salvage Count

Table C-1 lists the current programs in place that would support Core Water Operations for the ROC on LTO.

Table C-1. Real-time monitoring

ID	Monitoring Program	Typical Time Of Year Operating	Target Species/ Parameter	Site/Region
1	Adult Spring Chinook Escapement Monitoring in Clear Creek.		Chinook carcass and weir abundance counts	Clear Creek
2	Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Program	January - December	Juvenile Chinook salmon productivity	Red Bluff Diversion Dam, American River, Stanislaus River
3	Juvenile Salmon Emigration Real-time Monitoring (Seines and Trawls)	October 1- November 30	Juvenile Chinook and steelhead relative abundance	North Delta
4	Juvenile Salmon Delta Abundance Trawling (expanded DJFMP trawling)	December-May	Juvenile Chinook salmon abundance and condition	Sacramento and Chipps trawl
5	Genetic Identification of Salmonids and Smelt to Inform Central Valley Project Operations and Bay-Delta Monitoring	January- December	Chinook salmon and Smelt diversity	Central Valley (RBDD to Chipps Island)
6	Lower Sacramento River Juvenile Salmon and Steelhead Monitoring Project	August - June	Juvenile Chinook salmon and Steelhead distribution and productivity	Middle Sacramento River at Knights Landing
7	Winter-run Chinook Salmon Escapement Monitoring	May-August	Winter-run Chinook carcass and redd abundance and distribution	Sacramento
8	Fish Salvage Operations	January - December	Juvenile Fish abundance	CVP and SWP Delta Fish Protection Facilities
9	Enhanced Delta Smelt Monitoring	January- December	Delta Smelt abundance, distribution, condition, and productivity	San Francisco Estuary
10	Delta Flow Measurement and Database Management	January - December	Flow and water quality	Bay-Delta
11	Operation of Thermograph Stations	January - December	Temperature and sediment loads	
12	Hatchery Marking (100% Tagging)		Winter-run Chinook, Spring-run Chinook Salmon, Late-Fall Chinook salmon, Steelhead	Livingston Stone National Fish Hatchery, Feather River Hatchery, Coleman National Fish Hatchery, Nimbus Hatchery

Effects to listed fish due to CVP and SWP operations would be expected from decisions on winter-run temperature dependent mortality to preserve future year classes, redd dewatering to preserve fall-run future winter-run year classes, habitat parameters within the Delta, and salvage at the Delta pumping facilities of all species. As many effects depend upon hydrology and meteorology beyond the control of Reclamation and DWR, effects would be compared based on the range of conditions within a water year.

Status and Trend Monitoring

Status and trend monitoring characterizes the population of species and their environments over time include the effects of stressors from sources other than the CVP and SWP. Recovery plans characterize the status and trends differently depending upon the species in the general categories of abundance, production, life history diversity, and geographic diversity. In addition to the Core Monitoring, a number of additional programs are anticipated to continue, the majority of which are supported by Reclamation and DWR for CVP, SWP, and Delta watersheds:

- Hatchery Proportion (Constant Fractional Marking)
- Genetic Analyses of California Salmonid Populations: Parentage Based Tagging (PBT) of salmonids in California Hatcheries
- Fall Midwater Trawl
- 20-mm Survey monitoring to determine distribution and relative abundance of Delta Smelt and Longfin Smelt
- Spring Kodiak Trawl
- Estuarine and Marine Fish Abundance and Distribution Survey
- Smelt Larva Survey (SLS)
- Summer Townet Survey
- Environmental Monitoring Program (EMP)

Commented [A35]: Copied over from Appendix C

Adaptive Management Special Studies

Ongoing research programs to improve the state of science and address questions by one or more managing agencies occur on an ongoing basis.

Table C-3. Adaptive Management Program Monitoring

ID	Monitoring Program	Typical Time of Year Operating	Target Species/ Parameter	Site/Region
1	Estuarine and Marine Fish Abundance and Distribution Survey (Bay Study)	January - December	Fish and macroinvertebrates	San Francisco Bay and lower Sacramento and San Joaquin Rivers
2	Bay Salinity Monitoring	January - December	Conductivity and water temperature	Bay-Delta
3	Directed Outflow Project	April-November	habitat condition, water quality, food web	Bay-Delta

Description of Programs

Monitoring of the Central Valley and Bay-Delta Watershed requires extensive coordination across multiple agencies and offices within the different agencies as well as academia and private entities. The following sections describe the organization into various programs in more detail.

Real-Time Monitoring

Adult Spring Chinook Escapement Monitoring in Clear Creek

The goal of this program is to estimate population size and distribution of adult spring Chinook holding and spawning in Clear Creek. This monitoring information is used to inform Clear Creek in-season operations like spring attraction pulses. This monitoring activity produces annual adult escapement of spring Chinook into Clear Creek using two methods: video counts and snorkel-based estimates. Count data will be posted on the publicly accessible USFWS website for interested parties.

Objectives:

- Operate a video weir station to count and identify fish entering and leaving the watershed
- Index adult holding population size by visual counts made during snorkel surveys
- Estimate the spatial and temporal distribution of holding and spawning through snorkel surveys
- Estimate spawning population size using redd counts produced during snorkel surveys Spawning success is an indicator of the effectiveness of water and temperature management especially during the summer holding period when reservoir management is particularly important
- Obtain genetic samples, scales, and otoliths to determine run, age, natal origin, and juvenile life history of Chinook spawning in Clear Creek

Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Project

This program quantifies passage and production of juvenile salmonids produced in the upper Sacramento River. This project allows for evaluation of flow and temperature operations from Whiskeytown and Shasta/Keswick reservoirs and provides real-time information to fishery monitoring team to inform fishery and water operations management. Data on the production trends of endangered winter-run Chinook Salmon, threatened spring-run Chinook, the Central Valley ESU of Steelhead as well as the Southern Distinct Population Segment of the North American Green Sturgeon will be derived. Biweekly catch data and passage estimates will be posted on the publicly accessible USFWS website for interested parties.

Objectives:

- Estimate total annual production of juvenile winter-run Chinook Salmon produced in the mainstem Sacramento River and compare these data to adult escapement estimates.

- Estimate juvenile production of fall, late-fall, and spring-run Chinook Salmon.
- Measure relative abundance of Lamprey and Green Sturgeon passing Red Bluff Diversion Dam.

Juvenile Salmon Delta Emigration Real Time Monitoring (expanded DJFMP seines and trawls)

This Delta Juvenile Fish Monitoring Program (DJFMP) monitoring project includes expanded beach seining and surface trawling 3 additional days/week from October 1st to November 30 near Sacramento (Sacramento and Chipps Island) to detect the arrival of older juvenile Chinook Salmon entering the Delta. Monitoring data are used to inform Delta Cross Channel Gate closure decisions from October 1st to November 30 to minimize the diversion and mortality of emigrating juvenile winter-run sized Chinook Salmon. Catch data will be posted on the publicly accessible USFWS website for interested parties.

Objective:

- Provide data for Delta Cross-channel Gate operational triggers.

Juvenile Salmon Delta Abundance Trawling (expanded DJFMP trawling)

This program involves surface trawling (Sacramento and Chipps Island) for increased capture of specific CWT groups released with acoustically tagged releases of juvenile hatchery salmonids during the winter and spring. This includes expanded surface trawling to achieve daily trawling at these sites for at least 5 days/week during the period these groups are likely to be encountered. This period is flexible dependent on the requirements of the releases, but typically runs from early December until early May, approximately five months. If acoustic tag groups are not released, this monitoring study should not be undertaken.

Objective:

- Provide CWT recapture data for estimating the number of juvenile salmonids entering and exiting the Delta.
- Collect tissue samples for genetic stock identification of fish at Chipps and Sacramento trawl.

Genetic Identification of Salmonids and Smelt to Inform Central Valley Project Operations and Bay-Delta Monitoring

Project operations requires accurate information regarding what species are being encountered at various locations in the Central Valley. Historically, juveniles salmonid have been identifed based on two length-at-date models, which have been demonstrated to be inaccurate. The population-of-origin is determined for juveniles by comparing their genotypes to reference genetic baselines in order to quantify the number and distribution of true ESA-listed (genetic) winter and spring runs categorized by length-at-date criteria models. The overarching goal of this work is to directly target (and reduce) one source of uncertainty in the estimation of loss for listed Chinook Salmon (but primarily winter run) at South Delta fish salvage facilities and from other CVP monitoring sites. Also, this study provides genetic information at various locations in the Delta to improve accuracy of identifying juvenile salmonids and larval fishes to inform operations and monitoring activities. Species identification information is relied upon to estimate the effects of project operations. Annual genetic identification data will be incorporated into the annual incidental take report for interested parties.

Objectives:

- Genetic classification of Chinook salmon captured from SWP and CVP fish protection facilities for improved estimation of facility loss. This information is provided through multiple potential time steps including: rapid (<48hours), biweekly, and seasonally.
- Genetic classification of Chinook salmon in monitoring programs (e.g., RBDD, Sacramento Trawl, Chipps Island Trawl, Knights Landing, Upper Sacramento stranding surveys). These data are required for agency estimates of juvenile production at Red Bluff Diversion Dam and Sacramento and Chipps trawls.
- Assist with species identification of fish larvae or other difficult to identify samples collected at the fish protection facilities.

Lower Sacramento River Juvenile Salmon and Steelhead Monitoring Project

This program monitors out-migrant juvenile Sacramento River Chinook salmon and steelhead utilizing rotary screw traps located near Knights Landing on the Sacramento River. Juvenile salmonid monitoring in the upper Sacramento River between Red Bluff Diversion Dam and confluence with the Feather provide an early warning of increases in emigration rates of listed salmonids out of the upper Sacramento River toward the Sacramento-San Joaquin Delta. This near real-time data and early warning information provided by the program allows for data related triggers for the operation of the DCC. Daily catch data are posted on the publicly accessible CalFISH website for interested parties.

Objectives:

- Monitor and report the outmigration of juvenile salmonids from the Sacramento River as they move toward the Sacramento-San Joaquin Delta on a real-time basis.
- Monitor, record and compare movements of emigrating salmonids during specific environmental conditions.
- Estimate emigrating salmonid numbers and composition in the lower Sacramento River above the Delta.
- Examine the influences of Sacramento River flood relief structures on emigrating juvenile salmonids.

Winter-run Chinook Salmon Escapement Monitoring

This project monitors the annual abundance, timing, distribution, and several life history characteristics of naturally spawning winter Chinook salmon. Estimates of abundance of Sacramento River Winter Chinook

Salmon provide the basis for monitoring the population status and trends of this endangered species. Information generated from this project also provides the basis for evaluating the supplementation program at the winter run Chinook salmon conservation propagation program at Livingston Stone National Fish Hatchery. Recoveries of coded-wire tags from this project feed into cohort reconstructions, which provide the basis for estimating survival rates and evaluating the effects of ocean harvest upon this endangered species. Recoveries of coded-wire tags will be reported to the Regional Mark Information System for use in a cohort reconstruction analysis. Weekly carcass data are posted on the publicly accessible CalFISH website for interested parties.

Objectives:

- Estimate of winter Chinook spawner abundance generated based on carcass mark-recapture estimation methods.
- Estimate escapement and contribution to natural spawning by natural and hatchery origin winter Chinook.
- Estimate of pre-spawning mortality

Fish Salvage Operations

Sampling of entrained fish at the Tracy Fish Collection Facility (TFCF) and Skinner Delta Fish Protective Facility (SDFPF) is the source for CDFW's daily salvage and loss estimates for the monitoring of incidental take of listed fish species.

Fish salvage and loss information at the SDFPF and TFCF is used extensively in water project monitoring and planning. The Fish Facilities Monitoring Project manages the data collected on fish entrained and salvaged at the SDFPF and TFCF. This project maintains one of the largest historical databases on Delta species available and has been used in assessing the effects of new facilities and programs, water project operations proposals, and evaluation of proposed CALFED alternatives. Daily data can be obtained via the California Department of Fish and Wildlife’s Bay-Delta FTP server.

Objectives:

- Report fish salvage count data for regular operations and special studies
- Report physical and operational conditions at SDFPF and TFCF including temperature, bypass operations, facility flows, primary and secondary channels flows and depths, and holding tank flows.
- Collect tissue samples for distribution to Agency tissue archives.

Enhanced Delta Smelt Monitoring

High-frequency sampling of the Enhanced Delta Smelt Monitoring (EDSM) program is stratified by regions that, based on differences in hydrodynamics, differ in Delta Smelt density and risk of entrainment. The EDSM program provides an early warning of entrainment events in a broader context than the previous Early Warning Survey and employs a stratified sampling design that includes multiple crews trawling concurrently at multiple sites in pre-defined density strata within the low- and/or high-risk zones of entrainment in the San Francisco Estuary. Stopping rules were developed to minimize the impact of take on the population and effort can be modified to adapt to changing management needs and priorities.

For real-time purposes, EDSM may replace a number of historic trawls. However, for Delta species status and population trends, the long-running trawls may provide useful comparative information. These trawls have been included below in the Status and Trends Monitoring section.

Objectives

- Biweekly estimates of life stage specific abundance
- Biweekly estimates of distribution within different regions of the Bay-Delta.

Delta Flow Measurement and Database Management

The Delta Flow Network consists of 35 flow and water quality monitoring stations located throughout the Sacramento-San Joaquin Delta; eleven of these stations are supported by the IEP. Data from this network of stations are used by Delta managers and scientists to make real-time decisions and plan for future events such as climate change, water operations, restoration projects, evaluate fish transport, and migration issues. In addition, these data are used to calibrate and validate numerical models that are used to predict water levels, flow speeds, and spatial and temporal evolution of salinity in the Delta. The data collected at these stations are critical for understanding the circulation and mixing patterns in the complex and interconnected channels that comprise the Delta region. Understanding Delta hydrodynamics is imperative to understanding the impacts of proposed major infrastructure projects and regulatory actions being taken to protect endangered species in the Delta.

Objective:

- Provide accurate continuous flow data throughout Bay-Delta.

Operation of Thermograph Stations

This program provides continuous information on the temperature and sediment regimes in the rivers in order to evaluate effects on the restoration of native species fisheries, amphibians and other aspects of the aquatic ecosystem. An additional goal is to better understand the transition from cold water to warm water regimes and how flow magnitude interacts to control the transition.

Objectives:

- Provide accurate continuous temperature readings.
- Provide data regarding sediment loading.

Status and Trends Monitoring

Existing monitoring techniques below assist in understanding species status and population trends. The information may also be useful in annual reporting and demonstrating compliance with ESA. However, they do not necessarily provide real-time operational benefits.

Commented [A36]: Many of the monitoring programs below are used for informing and managing real time operations.

Genetic Analyses of California Salmonid Populations: Parentage Based Tagging (PBT) of salmonids in California Hatchery Programs.

The purpose of this task is to collect tissue samples and conduct the genetic analyses necessary to evaluate the genetic pedigree relationships of California salmonid hatchery broodstock. This information is used to inform hatchery broodstock management, including supporting recovery actions for ESA listed Central Valley salmonids stocks.

California hatcheries release a large number of juvenile salmonids every year, and genetic parentage based tagging (PBT) of adult spawners provides critical information about spawner age distribution, inbreeding, distribution of reproductive success among spawners, migration among Central Valley hatcheries, and other population parameters. The California Hatchery Scientific Review Group recommended PBT as an effective monitoring tool for the management of hatchery broodstock programs.

Objectives

- Genotype samples
- Use broodstock PBT to support Central Valley salmon and steelhead monitoring programs and hatchery broodstock management by identifying hatchery-of-origin and brood year for field caught and hatchery return samples and monitoring inbreeding and migration among Central Valley salmon and steelhead hatcheries.
- Evaluate genetic data for special hatchery broodstock projects to improve broodstock management

Fall Midwater Trawl

Fall Midwater Trawl Survey (FMWT) sampling began in 1967 to measure the abundance and distribution of age-0 Striped Bass and has since collected similar information on a suite of pelagic fishes including Delta Smelt and Longfin Smelt. Survey staff calculates annual abundance indices based on September through December monthly sampling data collected from San Pablo Bay through the Delta. The survey sampling has expanded into Cache Slough and the Sacramento Deepwater Ship Channel and may include zooplankton sampling and processing.

The survey's catch data provides means to calculate adult Delta Smelt incidental take at the export facilities. The State Water Project Incidental Take Permit for Longfin Smelt requires the FMWT Longfin Smelt abundance index to calculate the incidental take limit for the salvage facilities.

Objectives:

- To annually measure the relative abundance and distribution of selected species of pelagic fishes in the estuary.
- To detect introductions of new exotic fish and invertebrates.
- Provide baseline data to evaluate management plans and habitat restoration projects.
- To measure availability of fall planktonic food resources (since 2010).

20-mm Survey monitoring to determine distribution and relative abundance of Delta Smelt and Longfin smelt

The 20-mm Survey monitors juvenile Delta and Longfin Smelt distribution and abundance throughout their historic spring range in the Sacramento-San Joaquin Delta and upper Estuary. This survey monitors Delta Smelt around 20 mm TL in size which is the size that larval "take" is counted against the SWP and CVP. This information allows managers to vary water operations and provide sufficient flows to maintain Delta Smelt rearing habitat away from the south and central Delta and minimize entrainment.

Objectives:

- Determine the distribution of juvenile Delta and Longfin Smelt in relation to the major water diversions
- Compare current relative abundance to historical relative abundances
- Provide concurrent zooplankton density information to monitor the suitability of their food supply

Spring Kodiak Trawl

The Spring Kodiak Trawl (SKT) began in 2002 and is designed to provide information on the distribution of pre-spawning and spawning Delta Smelt, to improve our ability to detect adult Delta Smelt, obtain maturity status data, and provide results on a near "real-time" basis to assist in water management and export decisions. The survey is designed to determine pre-spawning and spawning distribution of adult Delta Smelt in relation to the CVP and SWP water export facilities. Due to its superiority in sampling efficiency to the earlier Fall Midwater Survey, the early results of the SKT are also been used to help estimate the relative abundance of adult Delta Smelt at extremely low population levels.

Objectives:

- Determine the distribution of maturing Delta Smelt during the period of December through May
- Evaluate the sexual maturation of Delta Smelt during this period and detects the start of spawning migration
- Report current relative abundance compared to historical estimates

Estuarine and Marine Fish Abundance and Distribution Survey

Since 1980, 52 channel and shoal stations from South San Francisco Bay to the lower Sacramento and San Joaquin rivers have been sampled monthly with a midwater and otter trawl. In addition to tracking abundance trends and distributional changes of individual species, data from this study is used to determine changes in the fish communities over time.

Objectives:

- Determine the effects of outflow related mechanisms on the abundance and distribution of estuarine and marine fishes.

Smelt Larva Survey (SLS)

This survey provides near real-time abundance and distribution data for Longfin (LFS) Smelt larvae in the Delta, Suisun Bay and Suisun Marsh. Data are used by agency managers to assess vulnerability of Longfin Smelt larvae to entrainment in south Delta export pumps. Sampling begins within the first two weeks in January and repeats every other week through the second week in March. The data is used to assess the risks of entrainment by the SWP and CVP and to determine OMR levels designed to minimize take of juvenile LFS at these facilities.

Summer Townet Survey

Summer Townet Survey (STN) is a long-term effort to monitor young pelagic fishes in the upper San Francisco Estuary. Since 1959, STN has sampled fixed locations from eastern San Pablo Bay to Rio Vista on the Sacramento River, and to Stockton on the San Joaquin River; and a single station in the lower Napa River. The study area was expanded in 2011 to include the Sacramento Deep Water Ship Channel and Cache Slough. Currently, 40 stations are sampled every other week June through August using a conical, fixed-frame net, which is pulled obliquely through the water column 2 to 3 times at each station. Data collected at 31 stations are used to calculate annual relative abundance indices for age-0 Striped Bass (*Morone* saxatilis) and Delta Smelt (*Hypomesus transpacificus*). The remaining 8 stations are sampled to increase our understanding of juvenile fish abundance and distribution in the lower Napa River and the north Delta. In 2005, STN added a zooplankton net to assess fish food resources at each station. A subset of the fish collected are retained for diet analysis. The STN also measures water temperature, water clarity and specific conductivity. Managers and researchers use the data collected by STN to inform decisions and improve our understanding of the health of the upper San Francisco Estuary.

While the original intent was to monitor the population of age-0 Striped Bass throughout the upper San Francisco Estuary, its scope has broadened to include other species of fish such as Delta Smelt and the food resources they rely upon.

Objectives:

- Measure annual abundance of selected age-0 fish
- Measure factors affecting abundance and distribution of age-0 Striped Bass, Delta Smelt and other fish in the estuary
- Measure availability of summer planktonic food resources
- Examine summer diets of young Striped Bass, Delta Smelt, and other pelagic fishes

Environmental Monitoring Program

The Environmental Monitoring Program (EMP) was established in 1971 to collect environmental data for resource management, to better understand estuarine processes, and to document compliance with State Water Resources Control Board Water Right Decision D-1379. This program collects water quality, chlorophyll, phytoplankton, benthic, and zooplankton samples at fixed locations in the Sacramento-San Joaquin Delta, Suisun Bay, and San Pablo Bay. Two of the program's strengths are continuity and data integration; the EMP is one of the nation's oldest environmental monitoring programs and has compiled over four decades of consistent and comprehensive water quality and biological data.

This is a comprehensive monitoring program that helps to ensure compliance with water quality objectives and standards, which were established to protect the beneficial uses of water in Sacramento-San Joaquin Delta and Suisun Marsh.

Objectives:

- Provide accurate and validated water quality and biological information to managers for real-time and adaptive management of the SWP and CVP
- Document and evaluate long term water quality and ecological trends in the San Francisco Estuary
- Detect and document invasive species, such as *Microcystis aeruginosa* and *Potamocorbula amurensis*, and conduct specials studies to discern their impact on native species, the food web, and human health.

Delta Juvenile Salmon Monitoring (DJFMP seines and trawls)

This program involves year-around beach seining and surface trawling (Mossdale, Sacramento, and Chipps Island) throughout the San Francisco Estuary to monitor the relative abundance and distribution (spatial and temporal) of juvenile Chinook Salmon and other native species in the Central Valley of California.

Objectives:

- Determine the status and trends of juvenile Chinook Salmon in the San Francisco Estuary.
- Examine factors influencing the status and trends of juvenile Chinook Salmon.

Juvenile Spring-Run and Steelhead Production Monitoring in Clear Creek

The goal of this program is to estimate production of juvenile salmonids in Clear Creek. Clear Creek juvenile salmon and steelhead production estimates are used to guide and evaluate the effectiveness of proposed actions. It also serves a status and trend purpose to provide information for ESA status consideration. This monitoring activity results in juvenile production estimates for spring-run and steelhead in Clear Creek. Biweekly count and passage estimates data will be posted on the publicly accessible USFWS website for interested parties.

Objectives:

- Operate a rotary screw trap to catch, identify, and count juvenile fish leaving Clear Creek.
- Use rotary screw trap capture-efficiency trials to transform juvenile counts into total production estimates for salmon and steelhead.
- Estimate spawning success by combining juvenile production estimates with adult population estimates. Spawning success can be an indicator of the effectiveness of water management, habitat restoration and environmental variables.

Adult Steelhead and Late-fall Chinook Escapement Monitoring in Clear Creek

The goal of this program is to estimate population size and distribution of adult steelhead and late-fall Chinook spawning in Clear Creek. This monitoring activity is used to guide and evaluate the effectiveness of the proposed actions. It also serves a status and trend purpose to provide information for ESA status consideration. The activity estimates annual adult populations of steelhead and late-fall Chinook in Clear Creek using two methods: video counts and kayak-based redd counts. Count data will be posted on the publicly accessible USFWS website for interested parties.

Objectives:

- Operate a video weir station to count and identify fish entering and leaving the watershed.
- Estimate spawning population size using redd counts produced during kayak surveys.
- Estimate spawning success by combining redds counts with estimates of the number of juvenile fish produced. Spawning success can be an indicator of the effectiveness of water management and habitat restoration.
- Collect spawning habitat data for use as an indicator of the effectiveness of habitat restoration.
- Estimate the spatial and temporal distribution of spawning through kayak-based surveys.

Spring, Fall, and Late-fall Chinook Salmon and Steelhead Escapement Monitoring in the Upper Sacramento River Basin

Conduct mark-recapture carcass surveys, aerial and wading redd surveys, video counts, and snorkel surveys of the mainstem Sacramento River and its major tributaries (Battle Creek, Cow Creek, Bear Creek, Antelope Creek, Mill Creek, and Deer Creek) to estimate adult salmon and steelhead escapement. Data collected may include: hatchery mark status, gender, tag status, carcass condition, spawning status, fork length, and disposition, from all or a subset of carcasses handled. Other samples may include biological samples, such as: head, fin tissue, otoliths, and scales, from a subset of carcasses handled during the survey. Annual data are posted on the publicly accessible CalFISH website for interested parties.

Objectives:

- Estimate of spring run, fall run, and late-fall run Chinook and steelhead spawner abundance generated based on carcass mark-recapture or Vaki/video count estimation methods on the mainstem Sacramento River.
- Estimate escapement and contribution to natural spawning by natural and hatchery origin winter Chinook.
- Estimate of pre-spawning mortality in upper Sacramento River

American River Chinook Salmon and Steelhead Escapement Estimation

Conduct mark-recapture carcass surveys, aerial and wading redd surveys and snorkel surveys of the American River to estimate fall run Chinook and steelhead escapement. This activity generally runs mid-September through March. Data collected may include: hatchery mark status, gender, tag status, carcass condition, spawning status, fork length, and disposition, from all or a subset of carcasses handled. Other samples may include biological samples, such as: head, fin tissue, otoliths, and scales, from a subset of carcasses handled during the survey. Weekly carcass data are posted on the publicly accessible CalFISH website for interested parties.

Objectives

- Estimate the number of Chinook salmon spawning in the lower American River on an annual basis, beginning in mid-September.

- Estimate of escapement and contribution of hatchery-origin fish

- Estimate of pre-spawning mortality

Stanislaus River Chinook Salmon and Steelhead Escapement Estimation

Conduct mark-recapture carcass surveys, aerial and wading redd surveys and snorkel surveys of the American River to estimate fall run Chinook and steelhead escapement. This activity generally runs mid-September through March. Data collected may include: hatchery mark status, gender, tag status, carcass condition, spawning status, fork length, and disposition, from all or a subset of carcasses handled. Other samples may include biological samples, such as: head, fin tissue, otoliths, and scales, from a subset of carcasses handled during the survey. Weekly carcass data are posted on the publicly accessible CalFISH website for interested parties.

Objectives

- Estimate the number of Chinook salmon spawning in the Stanislaus River on an annual basis, beginning in mid-September.

- Estimate of escapement and contribution of hatchery-origin fish

- Estimate of pre-spawning mortality

Enhanced Acoustic Tagging, Analysis, and Real-time Monitoring

This monitoring program supports an acoustic receiver network and associated real-time and retrospective modeling of the data. This monitoring may include (1) the deployment of real-time receivers that will provide timely information on migrating salmon smolt and green sturgeon location and timing, (2) expansion of the existing autonomous acoustic array to increase the coverage and detection efficiency; (3) development of new metrics for the real-time data for key management relevant questions such as entrainment estimates at critical junctions (Georgiana Slough and Delta Cross Channel); and (4) retrospective analyses directly geared toward improving the quality and robustness of forecasting models (e.g., enhanced particle tracking models, fish migration models). Survival modeling and forecasting will be posted on the publicly accessible NOAA-Fisheries website for interested parties.

Objectives:

- Real-time estimates of reach-specific survival for juvenile salmonids in the Sacramento River and Delta

- Real-time estimates of route-entrainment for juvenile salmonids in the Delta

Mossdale Spring Trawl

This monitoring program is a long-term San Joaquin River basin juvenile Chinook salmon monitoring using a trawl net. The project samples on San Joaquin River near Mossdale County Park. This program identifies annual juvenile Chinook salmon production in the San Joaquin River Basin. Catch data will be posted on the publicly accessible CalFISH website for interested parties.

Objectives:

- Determine annual juvenile Chinook salmon production in the San Joaquin River Basin
- Determine how water quantity and quality conditions affect smolt production trends and *Oncorhynchus mykiss* passage at Mossdale trawl.

Adaptive Management Program Monitoring

Tidal Wetland Monitoring Studies

This program collects fish and invertebrate data near existing and tidal wetlands and planned tidal wetland restoration sites. These data provide information on how fish and invertebrate communities change pre-/post-restoration. Tidal wetland habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh is important for improving habitat and food web resources for threatened fishes. This program is responsible for biological monitoring in these restored tidal habitats to assess their success for providing benefits for at-risk native fishes. Pre-project monitoring data allows project managers to evaluate the effectiveness of tidal wetland restoration projects.

Objectives:

- Determine the extent to which long-term sampling reflects conditions in nearby shallow water and wetland habitats.
- Determine whether gear efficiency evaluations are feasible using new sampling technology
- Determine the level of spatial and temporal replication necessary to make sampling design recommendations for long-term monitoring.
- Continue developing a baseline of biomass, community composition, and fish condition for fish and invertebrates near planned tidal restoration and comparison sites. This will allow us to make pre-and-post-restoration comparisons for evaluating restoration progress.

Bay Salinity Monitoring

Salinity and water temperature are collected in San Francisco Bay. Data are used to better understand the hydrodynamics of the estuary and calibration of multi-dimensional flow and transport models. Understanding how these variables are distributed around the Bay leads to a better understanding of habitat types and distribution in the Bay. Time series of water temperature and specific conductance (salinity is calculated from conductivity and water temperature) are needed (1) to improve our understanding of the hydrodynamics of the estuary (e.g., gravitational circulation), (2) for calibration of multi-dimensional flow and transport models of the Bay, (3) to better understand the distribution of physio-chemical habitat types throughout the Bay, and (4) to provide supporting data for numerous estuarine studies of the Bay and Delta.

Upper Estuary Zooplankton Sampling

The Zooplankton Study has estimated the abundance of zooplankton taxa in the upper San Francisco Estuary since 1972 as a means of assessing trends in fish food resources and is part of a D-1641 mandate to monitor water quality and related parameters. Sampling with three gear types occurs monthly at 22 stations located throughout San Pablo Bay, Suisun Marsh, Suisun Bay, and the Delta. Zooplankton are an important trophic link between primary producers and fish. The Zooplankton Study provides abundance estimates and distributional data for fish food resources in the upper San Francisco Estuary. This information is used by aquatic ecologists to understand the lower food web and some biological drivers of the Delta Smelt population. The study also detects and monitors zooplankton recently introduced to the estuary and determines their effects on native zooplankton species.

Objectives:

- Determine abundance and distribution of zooplankton in the upper San Francisco Estuary
- Determine the relationships between species abundance and temperature, salinity, turbidity, and chlorophyll
- Determine long-term abundance trends for all species and if these trends show significant declines or increases
- Determine if introduced species becoming established in the estuary

Upper Sacramento River Habitat Restoration Monitoring Project

Sacramento River Spawning and Rearing Habitat Restoration Monitoring Program

- Determine the effectiveness of habitat improvement project sites at improving habitat for adult and juvenile Chinook salmon and steelhead trout.
- Determine species presence assemblage and density over time through repeated surveys.
- Collect spatial fish data by snorkel, videography, seine, or electrofish surveys.
- Compare habitat attributes between control and treatment sites before and after project implementation. Metrics can include water temperatures, velocities, depths, substrates, cover, vegetation, temperature stratification in backwaters, hyporheic conditions, and macroinvertebrate metrics.

Reporting

Various reporting is completed by the multiple agency and consultants completing the monitoring describe above. The Real Time Monitoring activities currently provide their data through various sites. Communication of these data has typically been supported through email, and more recently through web-based aggregation and visualization sites such as Bay-Delta Live, SacPAS, and SHOWR. These sites will continue to support the needs for rapid analytical and reporting of Real Time Monitoring data.

Commented [A37]: Is this reporting intended to be separate from Reclamation's reporting? Not sure how this fits into the Core Water Operations planning and AM (if we agree to modify this to be AM-like)

Bay-Delta Live

Bay-Delta Live is a collaborative community of interests with the goal of expanding open and transparent sharing of information essential in understanding the complex and dynamic ecosystem of the Sacramento-San Joaquin Bay Delta. Bay-Delta Live provides information from multiple sources using enhanced visual interfaces. Bay-Delta Live is used by resource managers, scientists, conservationists, policy makers, academics, and others local community interestes. BDL is supported through contributions from federal and state agencies, as well as community and agency information.
https://www.baydeltalive.com/

SacPAS

This website provides monitoring, evaluation, and web-based data products and services for primary and associated activities funded by the U.S. Bureau of Reclamation (USBR) and mandated by the Endangered Species Act (ESA). It serves as a means by which information integration services can be provided to the Central Valley Project Improvement Act (CVPIA) and ESA participants. Web-based services relate fish passage to environmental conditions and provide resources for evaluating the effects of river management and environmental conditions on salmon passage and survival. This website is maintained by University of Washington with funds from US Bureau of Reclamation.
http://www.cbr.washington.edu/sacramento/

Objective

- Provide a publicly accessible, web-based query and reporting system of historical and current fish, environmental, and hydrologic information, vital to year-round planning and adaptive management of the Central Valley Project and State Water Project.

- Provide basic conditions, performance measures, and threshold-based alerts are available through data aggregation and analysis of environmental conditions.

SHO-WR

SHOWR is designed to help decision makers and interested stakeholders understand and engage in the complicated process of managing Shasta Reservoir operations to protect Winter Run Chinook Salmon.The SHO-WR application demonstrates the power of open data paired with open source analytics and visualization tools for California water resources management. The application has been developed iteratively as part of a demonstration project led by the Sacramento River Settlement Contractors (SRSC). The primary objective of this demonstration project is to integrate diverse flow, water operations, fishery, and water quality data into a single, open data environment that facilitates more data-driven and timely decision making. On the section of the Sacramento River immediately below Lake Shasta, the fishery agencies have targeted water temperature as the most critical resource to successful spawning of winter-run Chinook salmon from late April through September. This single parameter controls the operation of Shasta Reservoir, SRSC diversions, the Central Valley Project (CVP), other project reservoirs, and the Bay Delta.

https://flowwest.shinyapps.io/showr/

Table C-4: Availability of data generated by Real Time Monitoring Projects.

Id	Monitoring Program	Bay Delta Live	Sacpas	Showr
1	Adult Spring Chinook Escapement Monitoring in Clear Creek.		Adult escapement	
2	Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Program		Juvenile Production	
3	Juvenile Salmon Emigration Real-time Monitoring (Seines and Trawls)	Abundance Index, Distribution	Abundance Index, Distribution	
4	Juvenile Salmon Delta Abundance Trawling (expanded DJFMP trawling)			
5	Genetic Identification of Salmonids and Smelt to Inform Central Valley Project Operations and Bay-Delta Monitoring			
6	Lower Sacramento River Juvenile Salmon and Steelhead Monitoring Project	Abundance Index, Distribution	Abundance Index, Distribution	
7	Winter-run Chinook Salmon Escapement Monitoring			
8	Fish Salvage Operations	Daily Loss	Daily Loss	
9	Enhanced Delta Smelt Monitoring	Daily distribution		
10	Delta Flow Measurement and Database Management	Flow Characteristics	Flow Characteristics	
11	Operation of Thermograph Stations	Temperature Characteristics	Temperature Characteristics	Temperature Characteristics
12	Hatchery Marking (100% Tagging)		Smolt-to Adult Return ratios, Daily Loss	

References

Johnson, RC, S. Windel, PL Brandes, JL Conrad, J Ferguson, PAL Goertler, BN Harvey, J Heublein, JA Israel, DW Kratville, JE Kirsch, RW Perry, J Pisciooto, WR Poytress, K Reece, BG Swart. 2017. Science Advancements Key to Increasing Management Value of Life Stage Monitoring Networks for Endangered Sacramento River Winter-Run Chinook Salmon in California. San Francisco Estuary and Watershed Science. 15: 1-41.

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