APPENDIX A
CONCEPTUAL FOUNDATION AND
ANALYTICAL FRAMEWORK FOR EFFECTS ANALYSIS

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BAY DELTA CONSERVATION PLAN

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Appendix A
Conceptual Foundation and Analytical Framework for Effects Analysis

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Acronyms and Abbreviations

af	acre-feet
BA	biological assessment
BDCP	Bay Delta Conservation Plan
BO	biological opinions
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cm	centimeters
CVP	Central Valley Project
Delta	Sacramento–San Joaquin River Delta
DFG	California Department of Fish and Game
DPM	Delta Passage Model
DPS	distinct population segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DRMS	Delta Risk Management Strategy
DSC	Delta Stewardship Council
DWR	California Department of Water Resources
EBC	existing biological condition
ELT	Early Long-Term
ESA	Endangered Species Act
ESU	evolutionarily significant unit
HCP	habitat conservation plan
IOS	Interactive Object-Oriented Salmon Simulation
LLT	Late Long-Term
LSZ	Low Salinity Zone
$m^3 s^{-1}$	cubic meters per second
NCCP	natural community conservation plan
NCCPA	Natural Community Conservation Planning Act
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
LLT	Late Long-Term
OBAN	Oncorhynchus Bayesian Analysis
OCAP	operating criteria and plan
POD	Pelagic Organism Decline
PP	Preliminary or Proposed Project
PSU	practical salinity unit
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROA	Restoration Opportunity Areas
OCAP	operating criteria and plan

SB	Senate Bill
SRWQM	Sacramento River Water Quality Model
State Water Board	State Water Resources Control Board
SWP	State Water Project
USWFS	U.S. Fish and Wildlife Service
VSP	Viable Salmonid Population

Appendix A
Conceptual Foundation and Analytical Framework for Effects Analysis

A.1 Introduction

This appendix provides background and describes the overall approach to the effects analysis in Chapter 5 and the subsequent appendices.

This appendix has two closely related components:

- The Conceptual Foundation describes the scientific, legal, and social setting and assumptions for the effects analysis.
- The Analytical Framework describes the development of the effects analysis, including the subsequent appendices.

A.2 Conceptual Foundation

An ecosystem conceptual foundation is a set of scientific theories, principles, and assumptions that describe how an ecosystem functions. The conceptual foundation is derived through the synthesis of scientific information and peer review (Lichatowich 1998:5). It determines how information is interpreted, what problems are identified, and as a consequence, the range of appropriate solutions (Williams 2006). For the Bay Delta Conservation Plan (BDCP), the conceptual foundation is the scientific outline of the biological effects analysis that guides how the analysis is organized and displayed.

Lichatowich (1998) describes the value of a clear conceptual foundation as:

> "…an analog to the picture that comes with a jigsaw puzzle. The picture, usually on the box lid, illustrates what all the pieces will look like when placed in their proper order. Each piece of the puzzle is a small data set containing information, which is interpreted by continually comparing or referencing back to the picture. Assembling the puzzle without the guidance of the picture or with the wrong picture would be extremely difficult if not impossible. Unfortunately, biological systems do not come with a single clear picture or conceptual foundation we can use to interpret the information contained in the various pieces of the salmon management puzzle. The conceptual foundation must be constructed by biologists using a combination of information specific to the watershed, scientific theory and reasonable assumptions."

The BDCP is a very complex jigsaw puzzle with numerous pieces. Considerable effort and expense have been devoted to studying and describing the details on each puzzle piece. Assembling these pieces into a useful depiction of the Sacramento–San Joaquin River Delta (Delta) ecosystem requires reference to a "picture" that allow us to organize and assemble the pieces. The conceptual foundation provides that reference picture. However, as Lichatowich (1998) points out, the jigsaw puzzle metaphor is imperfect because we do not know the single overall picture that correctly describes and helps us to assemble all the pieces of the Delta. Further, that picture is constantly changing because of variation in the environment and as understanding of the Delta ecology improves. For these reasons, the conceptual foundation for the Delta is best viewed as a hypothesis that identifies our assumptions and knowledge at this point in time.

The BDCP conceptual foundation allows us to assemble the scientific and management pieces into a coherent plan. The conceptual foundation applies to both aquatic and terrestrial environments; however, much of the emphasis of the BDCP to date has been on changes to the aquatic environment and so this conceptual foundation emphasizes impacts on aquatic species. The conceptual foundation is based on the work of scientists and managers working in the Delta, Suisun Bay, Sacramento River, and San Joaquin River. It especially reflects input from the BDCP Science Advisors (BDCP Science Advisors 2007), the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), and the Interagency Ecological Program Pelagic Organism Decline (POD) work group (Baxter et al. 2010). DRERIP has produced conceptual models (referred to as the *Delta conceptual models*) for several key aquatic species and ecological processes (DFG undated). These models have been consulted and incorporated into the conceptual foundation to the extent appropriate. The BDCP conceptual foundation, however, is developed specifically to aid the analysis of the impacts of the BDCP on covered fish and wildlife species.

The conceptual foundation describes the purpose, vision, and strategy for the BDCP and the structure of biological goals and objectives. It provides the ecological setting for the BDCP as well as the legal setting and applicable laws. Finally, the conceptual foundation describes an overall conceptual model for the BDCP and the effects analysis including the geographic structure of the analysis. Collectively, these elements create a conceptual basis for the BDCP effect analysis. Related to the conceptual foundation is the analytical framework that describes the models, data, and analyses that correspond to relationships described in the conceptual foundation. The analytical framework describes the overall analytical scheme for the effects analysis that is detailed in the methods section of each appendix. However, the conceptual foundation is developed independent of the analytical framework and is not driven by the availability of data or quantitative models or tools.

A.2.1 Vision and Strategy

A.2.1.1 Vision

The BDCP is intended achieve two goals: (1) provide for the conservation and management of aquatic and terrestrial species, including the restoration and enhancement of ecological functions in the Delta, and (2) improve current water supplies and the reliability of delivery of water supplies conveyed through the State Water Project (SWP) and the Central Valley Project (CVP). The BDCP envisions the integration of water operations and restoration activities that meet both ecosystem and human needs for Delta into a comprehensive plan addressing a wide range of issues. The BDCP contributes to recovery of native species listed under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA), and would establish a more reliable source of water supply for human needs. Unlike regulatory approaches that have focused on narrow resource protection measures, the BDCP integrates actions to address multiple species, habitats, and water supply needs to produce fundamental, systematic, and long-term physical and biological improvements in the Delta ecosystem. To achieve these goals, the BDCP makes substantial alterations to water conveyance infrastructure and water management regimes in combination with extensive restoration and improvement of habitat as well as actions to reduce the impacts of various biological stressors. It is expected that these actions would significantly enhance Delta ecosystems to support the conservation of multiple species and natural communities, while improving water supply and reliability for contractors that export water from the Delta. To further advance this holistic approach and enhance opportunities for success, the BDCP includes mechanisms to accommodate and respond to new information and greater scientific understanding of the Delta.

The BDCP vision incorporates values advanced by the State of California in the Delta Vision process (State of California 2008). Delta Vision was a state-led effort employing a blue-ribbon panel to articulate a direction for management of the Delta and a process to reconcile conflicting human needs for ecological health, economic, and other natural resources in the Delta. The Delta Vision established the health of the Delta ecosystem and a reliable water supply for California as the primary and equivalent goals for sustainable management of the Delta. The BDCP will contribute to achievement of these goals.

A.2.1.2 Strategy

The BDCP has been developed by a broad consortium of interests, including state and federal water managers, state and federal water contractors, fish and wildlife managers, the environmental community, and stakeholders. The parties have constructed an integrated plan to balance the dual planning goals of the BDCP. The plan is based on consideration of the environmental requirements of listed fish species, the shared vision for a future environment, water use needs, and a host of applicable regulations, laws, and policies.

The goals of the BDCP address a number of issues associated with restoring the ecological health of the Delta and ensuring a reliable system to meet the water needs of the State of California (Table A-1). Success of the BDCP relies on a commitment by the parties to improve both ecological conditions and water supply reliability. The BDCP provides an integrated solution that addresses issues associated with restoration of species, the Delta ecosystem, and the regional water supply (Table A-1).

Table A-1. Issues Addressed by the BDCP

Issues addressed by the goal of improving the ecological health of the Delta	Issues addressed by the goal of improving reliability of water supplies from the Delta
• Loss of wetland environments • Loss of floodplain environments • Degradation of water quality • Reduction and change in food for pelagic fish species • Entrainment of fish in SWP and CVP pumps	• Reduced water supplies under current regulatory restrictions • Reduced water management flexibility due to environmental constraints

Although the BDCP is a large and complex plan with a number of conservation measures and covered activities, the overall strategy is relatively simple and consists of two major categories of actions along with other actions to address other specific stressors[1]: First, construction of a new water intake on the Sacramento River that would be connected, via a canal or tunnel, to the CVP and SWP pumping facilities in the south Delta (dual conveyance); and second restoration of aquatic, wetland, floodplain and upland areas to provide habitat and ecological benefits for fish and wildlife. Dual conveyance would provide increased flexibility in water operations by allowing water to be

[1] The BDCP actually contains 19 distinct conservation measures, not all of which are captured by these two major action categories.

diverted at two points (Sacramento River and south Delta) rather than the current single diversion point. This would reduce reliance on the south Delta facilities, which would increase the reliability of the water supply system in the face of sea level rise or earthquakes (DWR 2009a). By reducing the use of the south Delta facilities, dual conveyance would reduce entrainment of fish at the SWP and CVP facilities. This should allow increased export of water beyond the current levels and allow for this portion of the Delta to improve ecosystem functions.

Table A-2. BDCP Conservation Measures that Address the Goals

Conservation measures that address the goal of improving the ecological health of the Delta	Conservation measures that address the goal of improving the reliability of water supplies from the Delta
• Restore 133,000 acres of total habitat, including 65,000 acres of aquatic habitat • Improve access to floodplain, including the Yolo Bypass • Improve food supply by restoring wetlands • Improve water quality • Reduce fish entrainment at CVP and SWP facilities • Improve aquatic ecosystem health via flow management and invasive species control	• Increase flexibility for water exports • Increase reliability of water supply • Increase total amount of water exports (relative to currently constrained export levels)

The BDCP would restore or protect up to 133,000 acres of aquatic and terrestrial habitat, including 65,000 acres of tidal marsh in the Delta, and would improve floodplain environments on the Sacramento River, especially floodplains in the Yolo Bypass. These actions would approximately double the amount of tidal and intertidal wetland habitat in the Delta. Restoration of wetland and floodplain environments would provide key habitat for some life stages of native fish species such as delta smelt, Sacramento splittail, and salmonids. In addition to the direct value of increasing the quantity of aquatic and terrestrial environments, restoration of wetlands and nearshore aquatic environments would address other ecological problems affecting listed fish species in the Delta. Loss of wetlands contributes to the decline in quantity and quality of food for native fish species; restoration of the wetlands would improve the food supply. The restored wetlands would also provide habitat for a variety of resident and migrant waterfowl, as well as key mammal, reptile, and amphibian species. Restoration of large portions of the Delta to tidal habitat would affect the hydrodynamics and water quality in immediately surrounding channels and, in some cases channels distant from the restoration site, by increasing the tidal prism and reducing the tidal range. Reduced contamination from pesticides and herbicides that would result from restoring habitat on agricultural lands would interact synergistically with improvements in organic and nutrient input from restored tidal marsh and floodplains to benefit the aquatic foodweb.

A.2.2 Biological Goals and Objectives

Specific biological goals and objectives can be found in Chapter 3. This section discusses goals and objectives generally and their relationship to the effects analysis.

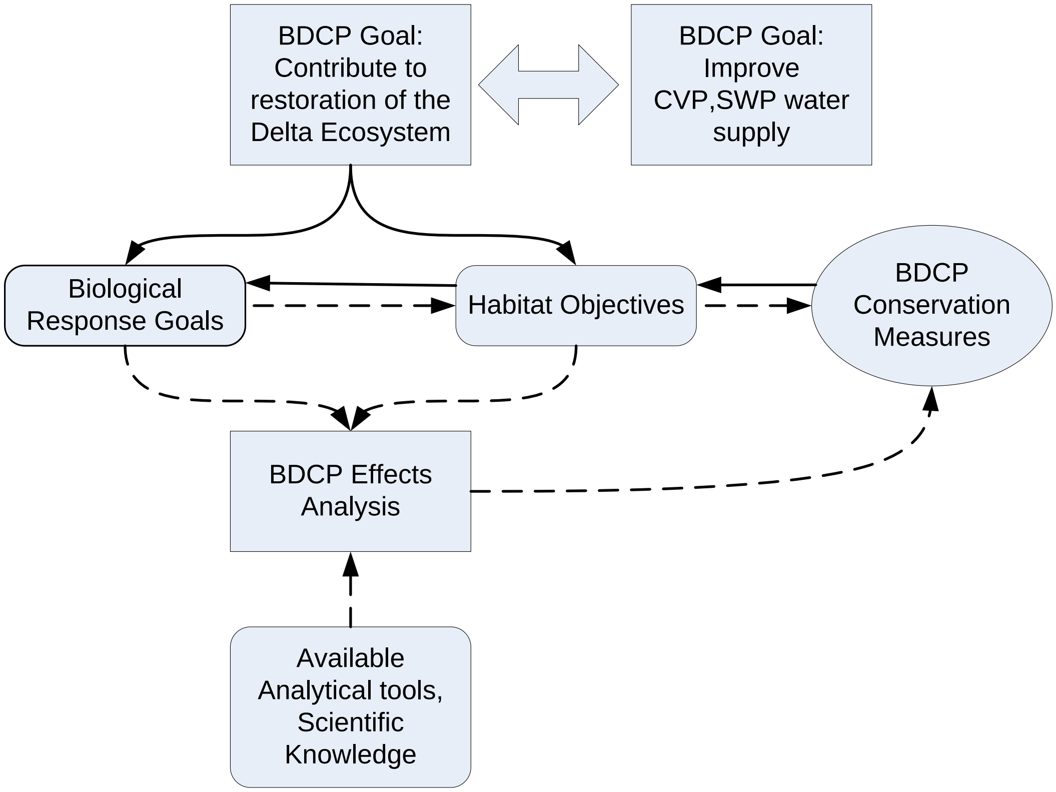
The biological goals and objectives are organized hierarchically:

- **Landscape Goals and Objectives.** Ecosystem goals and objectives are focused on the extent, distribution, and connectivity among habitats and improvements to the overall condition of hydrological, physical, chemical, and biological processes in the Plan Area in support of achieving goals and objectives for natural communities and covered species.
- **Natural Community Goals and Objectives.** Natural community goals and objectives are focused on maintaining or enhancing ecological functions and values of natural communities. Achieving natural community goals and objectives also serve to conserve habitat of associated covered species and other native species.
- **Species-Specific Goals and Objectives.** Species-specific goals and objectives address species-specific stressors and habitat needs that are not addressed under the higher order ecosystem and natural community goals and objectives. For covered fish species, goals and objectives may be life stage specific.

Goals and objectives describe the desired future conditions of the Plan Area and serve as benchmarks for evaluating BDCP performance relative to ecological health. Goals and objectives are intended to be attainable and directly relevant to BDCP conservation measures. When possible, goals and objectives are quantitative and specify a timeframe.

Goals and objectives relate to the overall biological goal of the BDCP and define qualities of an ecologically healthy Delta. They reflect the relationship between species response and environmental change discussed under the conceptual model for the effects analysis in Section A.2.7. Objectives capture the direct changes to the environment expected from the conservation measures and provide measurable targets. Goals are measures of species and natural community responses that are often indirectly tied to conservation measures but are inferentially linked to the objectives through qualitative and quantitative models. Because most BDCP conservation measures act on the environment to change habitat for species, the objectives are often expressed in measures of habitat such as acres of habitat restored, changes in entrainment, and changes in zooplankton food sources. Goals can be expressed in terms of habitat but more often express desired measures of species performance such as increased growth, abundance, or population growth. Either goals or objectives may be linked to the conservation measures. A conservation measure to restore a given acreage of a specified natural community would be linked to a corresponding objective that would quantify the amount and type of habitat to be restored. A conservation measure to implement more sweeping changes would be linked to a variety of both goals and objectives.

The structure of biological goals and objectives for BDCP and their relationship to the effects analysis are illustrated in Figure A-1. This conceptual model is based on the premise that habitat (biotic and abiotic) constitutes the primary control on the biological performance of species (Southwood 1977) and that actions, including BDCP conservation measures, change habitat to achieve species and ecosystem goals. Goals and objectives define the conditions of the restored Delta ecosystem called for in the overall BDCP goal of contributing to ecosystem restoration. During preparation of the BDCP (dashed lines in Figure A-1), biological goals and habitat objectives inform the crafting of conservation measures through the analysis of effects. The effects analysis is based on the best available scientific information, models, and analyses. During implementation of the BDCP (solid lines in Figure A-1), conservation measures change habitat, which results in a species response such as an increase in growth, abundance or survival.



Dashed lines indicate BDCP planning and preparation while solid lines indicate implementation of conservation measures.

Figure A-1. Conceptual Model of Relationship between BDCP Conservation Measures and Biological Goals and Objectives

The BDCP effects analysis links conservation measures and expected species response based on best available science applied through conceptual and quantitative models (Figure A-1). Because of the complexities of biological responses, environmental variability, and limitations in scientific understanding, it is often difficult to directly link conservation measures to species response and then to biological goals. Hence, the conceptual and quantitative analyses in the effects analysis create an expectation of biological response based on the information available. These expectations represent a working hypothesis of the relationship between actions, stressors, and biological performance. These working hypotheses will be tested and refined through experimentation and adaptive management over the term of the BDCP.

The effects analysis captures current scientific understandings of how environmental conditions relate to the biological response of covered fish species (Figure A-1). However, analytical methods are expected to improve in the future, new information will be collected, and environmental conditions will change. These changes in conditions and current knowledge would be incorporated through the scientific synthesis step in adaptive management.

A.2.2.1 Relationship to the Effects Analysis

The effects analysis helps the fish and wildlife agencies and the public evaluate the expected outcomes of the BDCP. The effects analysis examines the effects of BDCP actions on parameters that can be related to the biological goals and objectives, including habitat availability, habitat quality, and population response for covered species.

When analyses and data are available, the effects analysis will attempt to match the numeric, geographic, and temporal units incorporated in the models underlying the biological goals and objectives, to provide conclusions about likely consequences of BDCP implementation. However, in some instances that precision may not be possible because of the high variability of the environment, the inadequacy of modeling tools, the disparity between the scale of modeling or temporal analysis reflected in the effects analysis and that used to frame the objectives, or a combination of factors. In some cases, only a qualitative effects analysis may be available to help evaluate a quantitative biological objective. In other cases, the effects analysis may draw conclusions on a geographic or time scale that is broader than the biological objective. Despite these challenges, the effects analysis will describe the relationship between the BDCP's conservation measures and the habitat and species performance metrics, as far as available data support such a description.

A.2.3 Uncertainty and Adaptive Management

Ecological systems such as the BDCP Plan Area are inherently complex and subject to high levels of uncertainty. Complexity arises from the numerous biological, physical, chemical, and social pathways linking many elements of the Study Area. Uncertainty over the life of the project implementation comes from several sources:

- Natural variability in environmental conditions caused by local, regional, and global factors.
- Change in environmental conditions (e.g., climate change).
- Limitations in scientific knowledge regarding key factors and pathways.
- Unforeseen human and natural events (e.g., earthquakes).

The effects analysis in Chapter 5 is based on the best information available but knowledge and analytical techniques will improve over time while the other sources of uncertainty will continue. In other words, the BDCP addresses a dynamic system of natural and cultural elements that must be accommodated in the adaptive implementation of the program over the permit term.

Adaptive management is a "formal, systematic and rigorous program of learning from the outcome of management actions, accommodating change and thereby improving management "(National Research Council 2011). Adaptive management allows managers to deal with the uncertainties inherent in ecological systems and not be paralyzed by lack of complete knowledge and ability to accurately forecast future events (Holling 1978). Successful adaptive management requires acceptance of natural events, uncertainty, and resulting change in analytical tools, goals, objectives, or management actions.

The BDCP adaptive management process is described in Chapter 3, Section 3.6. Adaptive management in the BDCP has also been discussed in previous versions of the BDCP and summarized in the review of the topic by the National Research Council (2011); the figure in Appendix E of that review is especially relevant to the structure of adaptive management in the BDCP. Here the focus is on the general concept of adaptive management and how it relates to the biological goals and objectives and the effects analysis.

Implementation of the BDCP in an adaptive management framework extends the effects analysis outlined in Figure A-1 to implementation (Figure A-2). The effects analysis uses conceptual and quantitative models to synthesize the available scientific information to determine expectations regarding the relationship between conservation measures, habitat objectives, and biological response goals leading to the achievement of the overall BDCP biological goal. Adaptive management of the BDCP will refine and test those expectations require monitoring, research and management experiments designed to test and refine the working hypothesis posed by the BDCP and allow the region to navigate through an uncertain future (Lee 1993) .

Monitoring is designed to answer the following types of questions:

- Are actions being implemented consistent with the plan? (Compliance monitoring)
- Is habitat for covered species changing as expected as a result of BDCP actions (e.g., zooplankton communities are improving, entrainment declining, and habitat being restored)? (Effectiveness monitoring)?
- Are covered species responding to habitat changes as expected (e.g., growth is increasing, abundance is increasing, populations are expanding)? (Effectiveness monitoring)
- How are baseline conditions for covered species and their habitats changing, independent of the BDCP? (Status and trend monitoring)

Monitoring of indices and metrics appropriate to these questions can provide relatively rapid feedback on the implementation and provides the first level of adaptive response.

Directed research focuses on the relationship between actions (conservation measures), habitat objectives, and biological responses to test the fundamental hypotheses and assumptions of the BDCP and to refine the expectations of biological response. For example, research might address how different types of restoration of tidal marshes might add to detrital food sources and increase turbidity or how different configurations of screens might affect the biological impacts of the new north Delta intakes. Directed research will also be focused on filling critical gaps in our knowledge about a covered species or its habitat (i.e., critical uncertainty studies). For details of the adaptive management and monitoring program, see Chapter 3, Section 3.6, Adaptive Management and Monitoring Program.

To deal with the need to provide certainty and predictability for the BDCP, the parties are discussing the concept of *adaptive limits*. Adaptive limits provide an acceptable and agreed upon range for management experimentation within which adaptive management can adjust to unforeseen circumstances but still achieve the overall goals and objectives of the BDCP while providing assurances to the regulated entities.

An adaptive approach requires that information is effectively fed back into the BDCP program management structure so that an adaptive response can be made. The results from research, monitoring, and experimentation feed back into a scientific synthesis process in which information becomes knowledge to inform management decisions (Figure A-2). This synthesis is analogous to the BDCP effects analysis in which available information is analyzed to create working hypotheses regarding the outcomes of BDCP actions. Synthesis also develops and uses new models and working hypotheses to guide management actions.

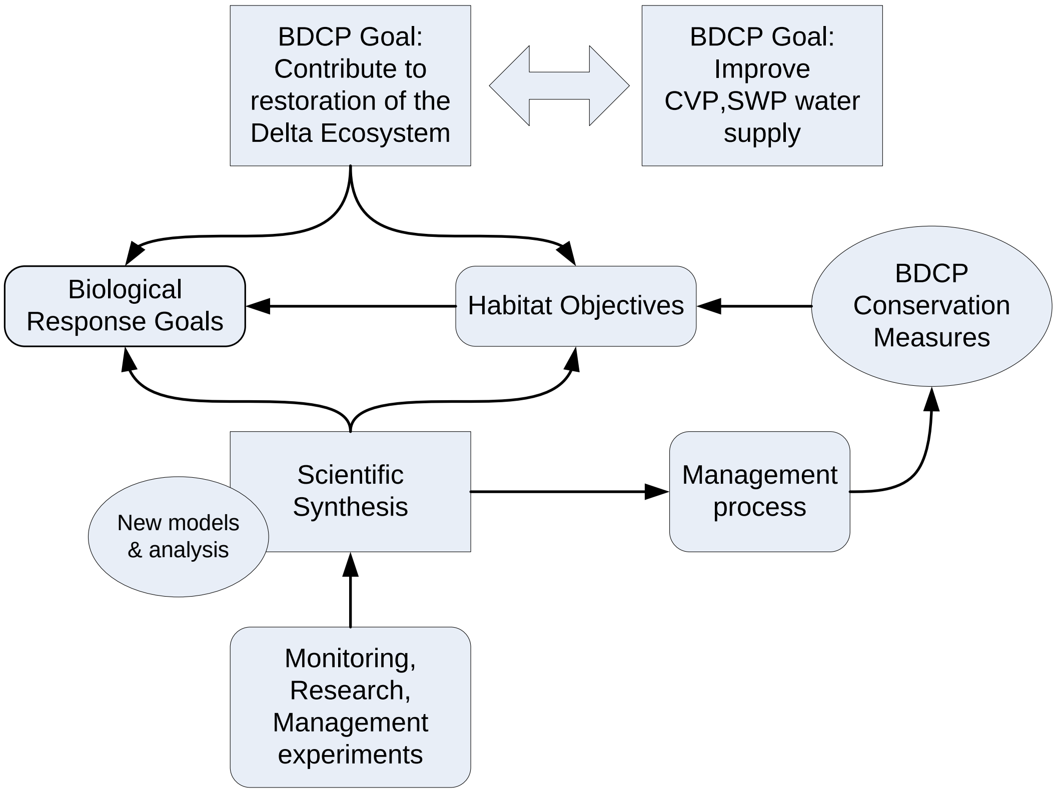


Figure A-2. Role of Adaptive Management in the BDCP

Finally, the information from the scientific synthesis feeds back to inform managers about progress in meeting the BDCP goals at broadest scale (e.g. restoration of the Delta ecosystem) as well as biological response goals and habitat objectives (Figure A-2). As long as the conservation strategy is properly implemented, the permittees would be fulfilling their obligations in compliance with their federal and state permits. However, if monitoring data or other scientific information suggests that inadequate progress is being made toward the biological goals and objectives, decisions would be made about refining the monitoring program, conservation measures, conceptual models (including hypotheses on which the models are based), and/or biological objectives in the context of the BDCP adaptive management and monitoring programs.

A.2.4 Legal and Regulatory Context

The BDCP is expected to result in long-term regulatory authorizations under state and federal endangered species laws for the operations of the SWP and CVP. Specifically, the goal of the BDCP is to serve as a natural community conservation plan (NCCP) under the state's Natural Community Conservation Planning Act (NCCPA),[2] and as a habitat conservation plan (HCP) under Section 10 of the ESA. The BDCP will also provide the basis for biological assessments (BAs) that support new ESA Section 7 consultations between the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS). The BDCP is further intended to meet the standards set out in the recently enacted

[2] The BDCP has also been designed to meet the regulatory standards of the California Endangered Species Act (CESA).

Sacramento–San Joaquin Delta Reform Act, which provides for the incorporation of the BDCP in a comprehensive management plan for the Delta (known as the Delta Plan).

A.2.4.1 Compliance with Endangered Species Act, California Endangered Species Act, and the California Natural Community Conservation Planning Act

Consistent with the overall intentions of the BDCP, the design of the effects analysis supports evaluation of the BDCP conservation measures with regard to state and federal regulatory criteria. The analysis is designed to address the requirements of Sections 7 and 10 of the ESA and NCCPA. Section 10 of the ESA requires that HCPs identify the impacts likely to result from the incidental taking of species covered by the plan. To issue permits, USFWS and NMFS must find that the BDCP conservation strategy minimizes and mitigates the impacts of this taking to the maximum extent practicable for each of the covered species. The effects analysis will characterize the adverse, beneficial, and net impacts of the covered activities on each of the covered species to support that determination.

Under the Section 7 formal consultation process, the federal action agency prepares a BA that includes an evaluation of the potential effects of the proposed federal action on listed and proposed species and designated and proposed critical habitat. On the basis of the BA and other information, USFWS and NMFS prepare biological opinions (BOs) to determine whether the proposed federal action is likely to jeopardize listed species or result in the adverse modification or destruction of critical habitat. The BDCP is intended to support the Section 7 consultations necessary for both issuance of the incidental take permit under Section 10 of the ESA by USFWS and NMFS, and consultation between Reclamation and USFWS and NMFS for continued operation of the CVP, incorporating the BDCP. To support these consultations, the BDCP effects analysis will also evaluate all direct, indirect, and cumulative effects on the covered species and effects on designated and proposed critical habitat.

The BDCP effects analysis also will provide the basis for the California Department of Fish and Game (DFG) to make their findings under the NCCPA. The analysis supporting the NCCPA will address whether the BDCP conserves the covered species; maintains ecological integrity of habitat, ecosystem functions, and biological diversity; establishes linkages to habitat areas outside the Plan Area; protects and maintains habitat areas of sufficient size to support sustainable populations of covered species; incorporates a range of environmental gradients and habitat diversity; and sustains movement and interchange of organisms to maintain the integrity of habitat areas within the Plan Area.

For the BDCP to be adopted and permitted, as described above, the California Department of Water Resources (DWR) and DFG must comply with the California Environmental Quality Act (CEQA); and Reclamation, USFWS, and NMFS must comply with the National Environmental Policy Act (NEPA). Table A-3 shows the compliance requirements for each agency under CEQA, NEPA, ESA, and NCCPA, and the trigger for each compliance action.

Table A-3. Environmental Regulation Requirements for Each BDCP State and Federal Agency

Agency	Required Regulation Compliance	Trigger for Compliance
California Department of Water Resources	ESA (Section 10, incidental take) NCCPA (incidental take) CEQA	Approval and implementation of the BDCP; SWP potential for take of federally listed species; SWP potential for take of state-listed species
Bureau of Reclamation	ESA (Section 7) NEPA	Incorporation of BDCP into CVP; potential to adversely affect federally listed species
U.S. Fish and Wildlife Service	ESA (Section 10 permit process, Section 7) NEPA	Issuance of Section 10 permit and internal Section 7; issuance of biological opinion to Reclamation
National Marine Fisheries Service	ESA (Section 10 permit process, Section 7) NEPA	Issuance of Section 10 permit and internal Section 7; issuance of biological opinion to Reclamation
California Department of Fish and Game	NCCPA (NCCP approval process) CEQA	Fish & Game Code Section 2835 issuance of take authorization and approval of NCCP. (CESA 2081 permit not required if NCCP permit issued for state-listed species)

Notes:
CESA = California Endangered Species Act; ESA = Endangered Species Act; NCCPA = Natural Community Conservation Planning Act; CEQA = California Environmental Quality Act; SWP = State Water Project; NEPA = National Environmental Policy Act; CVP = Central Valley Project; Reclamation = Bureau of Reclamation; NCCP = natural community conservation plan.

A.2.4.2 Relationship to Other Plans and Policies

The BDCP addresses many of the Delta's resources, but other plans and policies also address similar resources and have the potential to influence or interact with the BDCP. These include the Delta Vision (Delta Vision 2008), the Delta Plan (Delta Stewardship Council 2011) (to be implemented per the Delta Protection Act by the Delta Stewardship Council), the Delta Risk Management Strategy (DWR 2008), and the Suisun Marsh Plan (Bureau of Reclamation et al. 2011). Although both the 2008 USFWS BO and the 2009 NMFS BO require revision based on federal court directive, it is expected that the revised BOs will have the potential to interact with the BDCP.

A.2.4.3 Delta Vision

In September 2006, then-governor Arnold Schwarzenegger signed Executive Order S-17-06, which established the Delta Vision process to be carried forth by an independent Blue Ribbon Task Force, whose charge was to develop a "durable vision for the sustainable management of the Delta" with the goal of "...managing the Delta over the long term to restore and maintain identified functions and values that are determined to be important to the environmental quality of the Delta and the economic and social wellbeing of the people of the state." The Delta Vision was designed to coordinate and build on the many ongoing but separate Delta planning efforts and assess the risks and consequences to the Delta's many uses and resources in light of changing climatic, hydrologic, environmental, seismic, and land use conditions. The Delta Vision focused on a wide range of resources and issues, including aquatic and terrestrial functions and biodiversity; land use and land use patterns; transportation corridors; utilities, including aqueducts; water supply and quality, including runoff and discharges; recreation; flood risk and management; emergency response; and local and state economies.

As discussed in Section A.2.4, Legal and Regulatory Context, the goals of the BDCP relate to the recommendations of the Delta Vision process.

A.2.4.4 Senate Bill 7X 1 (Delta Protection Act), Delta Stewardship Council, and the Delta Plan

Partially in response to the Delta Vision Final Report, Senate Bill 7X 1 (Delta Protection Act) was passed in November 2009, which established a new legal framework for Delta management, emphasizing the equal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem" as foundation for state decisions regarding Delta management. A major component of the Delta Protection Act included the creation of the Delta Stewardship Council (DSC) and directed the DSC to prepare and adopt the Delta Plan.

DSC is a seven-member council charged with developing, adopting, and implementing the Delta Plan by January 1, 2012. The Delta Protection Act requires the Delta Plan to further the equal goals of restoring the Delta ecosystem and a providing a reliable water supply. These goals are supported by promoting statewide water conservation, water use efficiency, and sustainable use of water; improving water conveyance and storage; and reducing risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments. One objective of the Delta Plan is to promote new and improved infrastructure relating to water conveyance and storage in the Delta, and for operating both to achieve the equal goals (Water Code Section 85304). As such, there is particular interest in incorporating the BDCP in the Delta Plan.

After the Department of Fish and Game approves the BDCP as an NCCP and determines that the US Fish and Wildlife Service has approved the BDCP as an HCP, the DSC is to incorporate the BDCP into the Delta Plan. The Delta Protection Act re-affirms CEQA compliance, real-time SWP-CVP project operations, and consultation with the Delta Independent Science Board as conditions of permit approval. The DSC may hear appeals of the DFGs decision to grant the NCCP and its determination that HCP permits have been obtained. The DSC also has separate authority to determine if covered actions in the Delta are consistent with the Delta Plan. However, individual BDCP projects are not covered actions reviewable by the DSC in the consistency process after the BDCP is incorporated into the Delta Plan. DWR, DFG or any successor implementing entity is to report to DSC annually regarding plan implementation and status of monitoring and adaptive management programs. The DSC may make recommendations to the DCP implementing agencies, but they cannot change the terms and conditions of the permits.

A.2.4.5 Delta Risk Management Strategy

The Delta Risk Management Strategy (DRMS) was developed by DWR to assess the risks of flooding in the Delta and to develop a strategy to manage those risks. Phase 1 was published in 2009 and outlines the flooding hazards and risks related to Delta resources, specifically levees and other infrastructure, ecosystem values and functions, water supply and exports, and people working and/or residing in areas subject to flooding. DRMS Phase 2, published in 2011, builds on the knowledge gained in Phase 1 and presents a suite of options to reduce these risks (DWR 2008, 2009a, 2011). These options for risk reduction were considered in the development of the BDCP. In particular, the DRMS recommended developing an isolated conveyance facility or dual conveyance approach as the best ways to minimize risks to water supply. DRMS also recommended implementing restoration and other environmental enhancements to minimize risks to ecosystem resources. These recommendations closely mirror the goals and structure of the BDCP.

A.2.4.6 Suisun Marsh Plan

The Suisun Marsh Habitat Management, Preservation, and Restoration Plan was developed by DFG, DWR, USFWS, NMFS, Reclamation, and the Suisun Resource Conservation District as a comprehensive 30-year land management plan for the entire Suisun Marsh. The plan allows a managed wetland operator to manage properties for the purposes of waterfowl habitat, and includes a tidal wetland restoration goal of 5,000 to 7,000 acres, consistent with the near-term restoration activities included in the BDCP for Suisun Marsh. Adoption of the plan by each of these agencies is expected in late 2011.

A.2.4.7 Biological Opinions on the Long-Term Operations of the Central Valley Plan and State Water Project

Both the 2008 USFWS BO and the 2009 NMFS BO for the long-term operations of the CVP and SWP (USFWS 2008; NMFS 2009) require revision based on federal court directive. The 2008 USFWS BO and the 2009 NMFS BO set requirements for changes in flows to minimize effects on covered species. These included a fall X2[3] requirement, a limitation on the reverse flows in Old and Middle River from December through June, a requirement to restore 8,000 acres of tidal marsh habitat in the north Delta and Suisun Marsh, and other environmental improvements, including those in the Yolo Bypass. The north Delta intake proposed by the BDCP would address the issues related to the Old and Middle River flows by reducing reliance on the south Delta facilities. Similarly, the BDCP proposes substantial restoration of tidal marsh habitats that would contribute to compliance with these BOs. The BDCP would also improve passage in the Yolo Bypass, which would address many actions called for in the NMFS BO.

A.2.5 Ecological Background

The Delta is part of the overall San Francisco estuary, the largest estuary on the U.S. Pacific Coast (Sommer et al. 2007). The estuary has three distinct parts: San Francisco Bay, the Delta, and lower portions of the Sacramento and San Joaquin Rivers. The BDCP Plan Area encompasses the legal Delta and additional areas in which conservation measures may be implemented pursuant to the Plan (e.g., the southern portion of the Yolo Bypass and Suisun Bay and Marsh), and is the focus of the effects analysis. The BDCP Study Area includes the Plan Areas as well as substantial portions of the Sacramento River and San Joaquin River watersheds that may be affected by BDCP actions. San Francisco Bay connects to the Pacific Ocean through the Golden Gate and has a more marine character. The Delta is the estuary and tidal marsh at the confluence of the Sacramento and San Joaquin Rivers. The Sacramento River enters from the north and the San Joaquin River from the south to drain the California Central Valley.

The Delta is the nexus of freshwater and marine, and aquatic and terrestrial environments. Ecological conditions in the Delta are defined by the way in which environmental gradients interact

[3] X2 is the distance from the Golden Gate Bridge up the axis of the estuary to where tidally averaged bottom salinity is 2 practical salinity units (PSUs) (Jassby et al. 1995).

across these environments. Two of the most influential gradients in the Delta are tidal exchange and salinity, which are influenced by distance from the ocean and flow into the Delta; and the extent of water inundation of nearshore lands influenced by elevation along with tidal and riverine flows (BDCP Science Advisors 2007; Moyle et al. 2010) (Figure A-3).

Tidal exchange and salinity produce a gradient delineated into four zones from ocean to rivers, including:

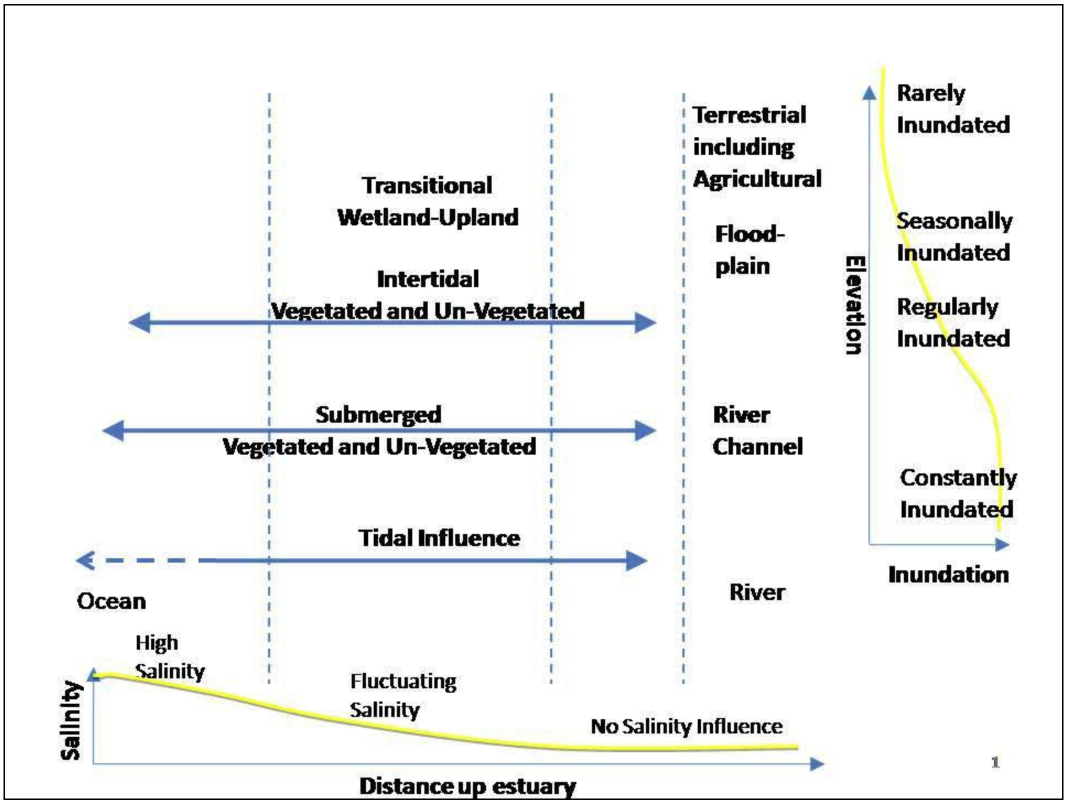
- High salinity with tidal exchange
- Fluctuating salinity with tidal exchange
- Fresh water with tidal exchange
- Fresh water with no tidal exchange

The borders of these zones are dynamic and depend on Delta inflows, the range of oceanic tides (mainly spring vs. neap), and regional weather. Zone 1 describes the San Francisco Bay, Zones 2 and 3 are the Delta, and Zone 4 describes the Sacramento and San Joaquin Rivers above the limit of tidal exchange.

In Zones 2 and 3 (the Delta), the elevation gradient produces four distinct environments (Figure A-3):

- Constantly inundated
- Inundated and exposed on tidal time scales
- Seasonally inundated
- Infrequently inundated

Although the elevations are fixed, the inundation areas vary according to water levels. Water levels in the Delta are a function of river flows and tides as well as atmospheric pressure and winds. Structures such as levees, barriers, and tidal gates modify gradual gradients of tidal exchange and salinity, creating abrupt shifts in environmental conditions (e.g., in elevation or salinity). Subsidence changes gradient and the pattern of inundation during floods. These alterations can disrupt the transport and exchange of chemical and biological materials along these gradients.



Source: (BDCP Science Advisors 2007).

Figure A-3. Horizontal and Vertical Gradients that Control Environmental Conditions in the Delta

Elevation, flow, tides, and subsidence along with diking and channelization produce the pattern of sloughs, channels, islands, and open water that characterizes the Delta environment today. Historically, the Delta was a much more complex array of channels and flooded marsh formed by tules and other plants at the interface of freshwater inflow and marine waters. Extensive intertidal wetlands were present across the Delta dissected by sloughs, channels, and open water areas (Kimmerer 2004). Since the mid-19th century, the Delta has been modified extensively through diking and draining of marsh lands that removed 95% of the historical wetlands in the estuary (Sommer et al. 2007) and through management of inflow by upstream water storage projects.

A.2.5.1 Pelagic Organism Decline

The significant decline in abundance of several delta fish species in recent years has been alarming to fishery managers. This decline has been termed the *pelagic organism decline* (POD). The reasons for POD are complex and not completely understood (Sommer et al. 2007; Baxter et al. 2010) but have been the focus of numerous scientific studies. In response to the decline in pelagic fish species, an interagency POD work group was formed to oversee studies and summarize current information related to the decline in Delta fish species (Baxter et al. 2010).

In their most recent synthesis, the POD work group proposed the hypothesis that the decline in pelagic fish species is an indicator of a fundamental regime shift in the Delta ecosystem (Baxter et al. 2010). The POD conceptual model incorporates the ecological concept that ecosystems can initially absorb the effects of environmental changes because of the resilience of the system. However, changes accumulate to eventually cause a more-or-less abrupt shift in the character and functioning of the system (Ludwig et al. 1997). Thus, the cause of the shift in Delta fish species may not be the proximal circumstances observed in any year but the incremental effects of numerous changes over a longer time frame.

The current POD conceptual model links the long-term decline and recent collapse of pelagic fishes to multiple and often interactive drivers, the effects of which can be grouped into four major categories (Baxter et al. 2010) (Figure A-4):

- Prior fish abundance (e.g., stock-recruitment effects)
- Habitat effects (e.g., loss of key species habitat)
- Top-down effects (e.g., predation, entrainment)
- Bottom-up effects (e.g., food availability and quality)

Top-down effects refer to mortality from predation and entrainment by water diversions, while bottom-up effects refer to food availability and quality. Bottom-up effects have received significant attention in recent years because of increasing evidence that changes in the pelagic foodweb have reduced both the quantity and quality of food available to pelagic fishes (Jassby et al. 2003). Primary productivity and phytoplankton biomass in the upper San Francisco estuary (measured by chlorophyll-*a* concentration) is low compared to other estuaries and has declined over the last 4 decades (Jassby et al. 2003). This long-term decline has been linked to shifts in nutrient ratios and concentrations (especially increasing ammonium concentrations associated with changes in sewage treatment), grazing by the overbite clam (*Corbula amurensis*), and changes in composition of the phytoplankton community (Jassby et al. 2003; Baxter et al. 2010; Glibert 2010). These changes have been linked to changes in zooplankton communities and overall declines in food availability for pelagic fishes. The sharpest declines have been observed among calanoid copepods, a primary prey for the early life stages of pelagic fishes (Kimmerer 2004). The cyanobacteria *Microcystis* has become common. This species forms dense blooms but is of lower food value than native phyto- and zooplankton (Baxter et al. 2010). Long-term trends in pelagic fish populations show a correlation to these changes in food supply (Glibert 2010). Thus, bottom-up food limitation is likely an important driver influencing long-term fish trends in the upper estuary and has been identified as a potentially significant factor in the recent POD. However, it is likely not the sole driver of the POD, based on analysis of the long-term monitoring data and review of the recent time series data associated with the POD (Baxter et al. 2010).

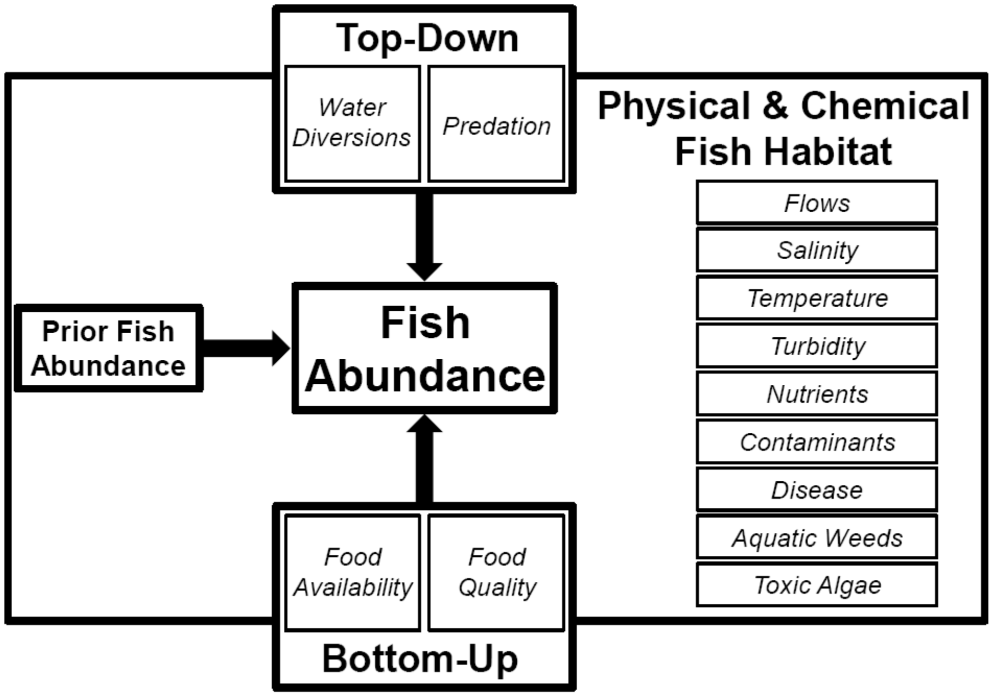


Figure A-4. Conceptual model for Pelagic Organism Decline (POD) developed by the POD Interagency Work Group (Baxter et al. 2010)

A.2.5.2 Ecological Drivers

The intrinsic ecological character of the Delta is set by large-scale drivers of climate, geology, marine conditions, and biogeography. Land use has fundamentally altered the Delta ecosystem and is now an important driver of ecological processes as well. Land use may have forced a regime shift in the system and fundamentally altered biological community and ecological processes. This change may be exacerbated by regional and global climate change that may affect precipitation and marine drivers. BDCP is an ecological program designed to address many of the proximal constraints on native fish and wildlife communities; however, the ultimate success of the program will reflect the character of the new Delta regime that will continue to change over the 50-year life of the BDCP.

A.2.5.2.1 Climate

Climate refers to the long-term pattern of precipitation and temperature produced by global, regional, and local factors. Acting with the drivers of geology (topography) and land use, climate (precipitation and temperature) creates flow patterns and quantities that affect conditions throughout the Study Area. The Sacramento and San Joaquin River watersheds encompass climates ranging from the alpine high sierra to the more Mediterranean climate of the valley floor. These discrete watersheds and the Study Area in general are fundamentally influenced by climate variability from seasonal to millennial scales. The water supply of the Central Valley is strongly dependent on snowmelt from high elevation portions of the watersheds. Temperature and precipitation vary considerably by season, location, and elevation. Warmest temperatures in the Central Valley are in the San Joaquin and Tulare Basins in summer and coolest in the high elevation of the southern Sierra Nevada during the winter.

Precipitation in most of California is dominated by extreme variability— seasonally, annually, and over decadal time scales. Precipitation is greatest in the northern Sierra, Cascade Range, and north coast and lowest in the southern San Joaquin Valley and Tulare Basin. Nearly all of the precipitation in the watershed falls during the winter-spring wet season, mostly as a result of cold fronts sweeping in off the Pacific Ocean. Most of the freshwater flow into the estuary occurs in winter and spring, although extensive water development projects have reduced the winter-spring flow into the estuary and increased flow in summer and early fall. Summer temperatures are generally hot inland of the Coast Ranges and cool and foggy to the west because of cool, southward-flowing coastal currents and coastal upwelling. The summer temperature gradient produces a large-scale east-west pressure gradient across California, resulting in strong westerly afternoon winds across much of the estuary. The principal meteorological effect on the estuary occurs through the timing and quantity of precipitation and freshwater flow, which has seasonal, interannual, interdecadal, and longer-term patterns, while the shorter-term patterns have been altered by dams and diversions. The seasonal pattern of winter precipitation, spring snowmelt and runoff, and the dry summer and fall is altered by variations in large-scale climate. The timing and amount of spring runoff are a function of spring temperature, which depends on the distribution of regional high- and low-pressure centers in the northern Pacific. Snowmelt runoff, which supplies most of the water for human use in the Central Valley, has occurred in earlier months of recent years owing to a trend toward higher spring temperatures (Kimmerer 2004).

Because of cool winter temperatures at the higher elevation of the Sierra Nevada, much of the precipitation in the Study Area falls as snow. At lower elevations, warmer conditions exist and rain is the dominant precipitation. Precipitation in the Study Area peaks in January and declines to very low levels in the summer (Figure A-5). Precipitation is strongly dependent on elevation with valley floor precipitation less than one third of that at higher elevations. Warmer temperatures in the late spring and summer induce snowmelt at the higher elevations. The summer precipitation tends to be short and intense at high elevations but does not contribute a significant portion of annual total. Temperatures in the valley floor are high in the summer, although buffered by ocean breezes in regions near the Delta. Daytime high temperatures in excess of 37°C (100°F) are not uncommon in the summer.

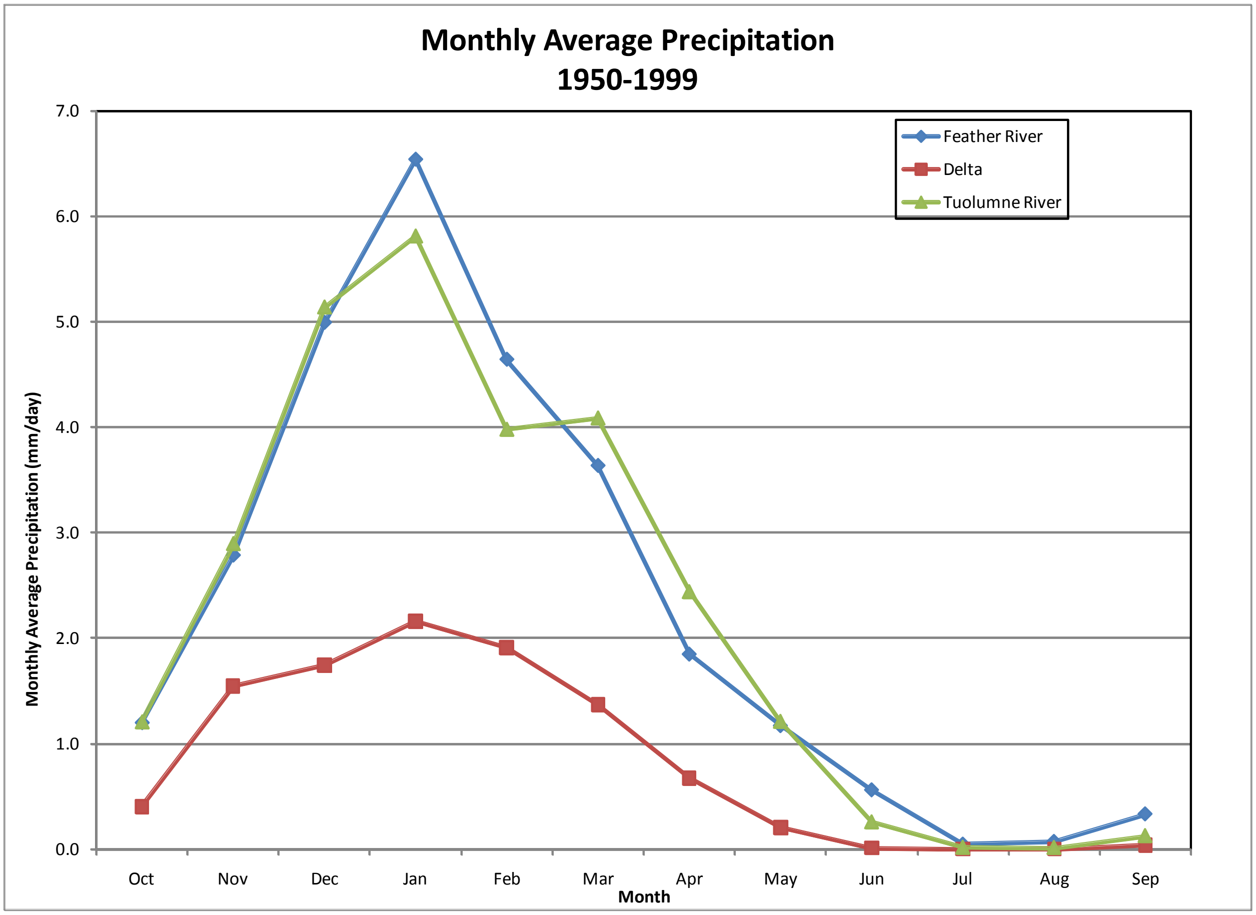


Figure A-5. Monthly Average Precipitation Pattern in the BDCP Study Area (Maurer et al. 2002)

The Delta receives freshwater inputs from the Sacramento River to the north and the San Joaquin River to the south, which collectively drain approximately 40% of the area of California. In contrast to other major river deltas, this delta was formed when sea level rose, forming the present-day estuary, and marshes formed at the landward margin because accumulation of sediment and plant detritus kept pace with submergence (Atwater et al. 1979). Many of the major rivers are fed by melting snow from the Sierra Nevada and Coast Ranges, although many of these have been dammed to provide water for agricultural, industrial, and domestic uses as well as provide flood control. All of these have caused a modified hydrogaph and resulted in less water flowing through the streams, Delta, and San Francisco Bay.

Prehistoric salinity records suggest an annual average inflow to the estuary over the last 2 millennia of about 1,250 cubic meters per second ($m^3 s^{-1}$) (Ingram et al. 1996), similar to the current unimpaired flow of about 1,195 $m^3 s^{-1}$ (mean of estimated values from 1906 through 2002). Exports from the Delta averaged 191 $m^3 s^{-1}$ from 1975 through 2011, or about 16% of unimpaired flow during the period (Kelly pers. comm).

A.2.5.2.2 Geology

Geology refers to the underlying lithography and topography leading to the land forms, sediments, and natural chemical inputs of the study area. California's Central Valley is a trough formed between the Sierra Nevada Mountains and the Coast Range. Its present surface is remarkably flat and consists largely of material eroded from the surrounding mountains and deposited in low alluvial fans. On multiple occasions in the distant past, the valley has been filled with water, creating a large lake that left a veneer of muddy deposits. About 650,000 years ago, rising waters of the most recent lake broke through the Coast Ranges and drained into the Pacific Ocean through the modern San Francisco Bay.

The current San Francisco estuary and the Delta were formed more recently as a result of sea level rise following the last glacial period. Rising sea level has drowned a previous drainage system from the Central Valley. The region assumed its present form only some 6,000 to 10,000 years ago. Geology and topography of the region are complex, owing to alternating periods of subduction and transform movement at the boundary between the North American and Pacific tectonic plates over the past 100 to 200 million years, and alternate periods of high and low sea level in the past 1 million years (Atwater 1979). The south and central portions of the Bay as well as San Pablo Bay were shaped in part by movements of the San Andreas fault to the west and the Hayward fault to the east, which cause the intervening block of crust to be overridden and forced downward, resulting in a broad region of low topography between segments of the Coast Ranges (Atwater 1979). Locations where the Bay penetrates the Coast Ranges, at the Golden Gate and Carquinez Strait, are constricted and deep, with steep bathymetry.

A.2.5.2.3 Marine Conditions

The BDCP Study Area is tidally influenced and dominated by the mixing of marine and fresh water. Tidal- and freshwater-flow affect every aspect of the estuarine ecosystem. Variability in freshwater flow influences the physical, chemical, and biological components of the Delta. For example, in the Plan Area the Low Salinity Zone (LSZ) marks the marine and freshwater mixing zone that can influence distribution of fish species. The LSZ usually is defined by the position of X2. The LSZ is closely and inversely related to outflow with a time lag of about 2 weeks. Tides in the San Francisco estuary are mixed semidiurnal, with a median daily tidal range of 1.8 meters. Additional short-term effects as well as subtidal variations in sea level (i.e., variation with a longer period than the tidal cycle) in the coastal ocean are produced by variation in atmospheric pressure and wind setup along the coast, particularly in the variation in wind conditions that causes upwelling and relaxation (Wang et al. 1997). These variations in sea level have measureable effects on tidal height in the estuary and can be important in exchange between the estuary and the coastal ocean (Walters and Gartner 1985). The spring-neap tidal cycle, resulting from the interference pattern between tidal components of similar period, causes variations in tidal energy and filling and draining of the estuary on a 2-week time scale (Walters and Gartner 1985; Kimmerer 2004).

At any point in the estuary, the water level is a function of tidal forces because of the fluctuation in sea level at the mouth of the estuary and effects internal to the estuary, mainly freshwater flow. In dry years, predicted fortnightly spring-neap cycles fluctuate between large ranges around December and June and smaller ranges in March and September. These cycles result in filling and draining of the estuary at that time scale and are the source of substantial variability in currents. In addition, there is an annual cycle by which tidal elevation overall is highest in February and August. The measured tide roughly follows the predicted tide during dry periods, with additional variability, probably due to month-scale variation in sea level and local wind effects (Walters and Gartner 1985). During wet periods the astronomical signal is swamped by the effect of increased river stage (Kimmerer 2004).

A.2.5.2.4 Biogeography

Biogeography refers to the distribution of species over space and time. In this context it refers to the collection of species and communities in the BDCP Study Area. The Study Area is dominated by introduced, nonnative species that now make up the majority of fish and invertebrates in the Bay-Delta (Cohen and Carlton 1998). Organisms and biological communities vary along geographic gradients of latitude, elevation, isolation, and habitat area. Several factors affect the biogeography of the Plan Area, including anthropogenic modifications that have reduced the connectivity between habitats and the introduction of nonnative species, which have modified the foodweb, species interactions, and habitat use. These factors, among others, have affected the distribution of species in the Plan Area, generally in a negative way (e.g., reduced capacity, productivity, distribution). The anthropogenic changes that have occurred in the Plan Area affect the covered species in different ways, as some species occur only in the Plan Area (e.g., delta smelt) and live out their entire life history within the Plan Area. Other species migrate through the Plan Area and one or more life stages may be in the Plan Area for a relatively short period of time (e.g., Chinook salmon).

A.2.5.2.5 Land Use

Human modification of the Bay-Delta accelerated in the 19th century as a result of agriculture, mining, and urbanization. Human land uses have fundamentally altered the character of the region and become a major overall driver of the ecosystem. The Delta marshes were drained and diked for conversion to farms during and after the gold rush. The Delta is now a mosaic of diked islands surrounded by deep channels, as well as smaller sloughs and shallow lakes. The land surfaces on many of the islands have subsided up to 10 meters below sea level because of compaction, oxidation, and erosion of the peat soils (Jassby and Cloern 2000). Levees on several of these islands have failed, converting the islands to tidal lakes with various degrees of connection to the surrounding channels. This habitat type would not have existed in the presettlement Delta. Most Delta channels are constrained within the levees, and shallow habitats are limited to backwater sloughs and narrow margins of channels and lakes. Some of the channels have been deepened and straightened by dredging either for shipping or for more efficient water transfer (Kimmerer 2004).

Extensive human modifications of the estuary have resulted in the loss of approximately 95% of the estuary's wetlands; introduction of numerous nonnative species; reduction or elimination of stocks of native fish and invertebrates; alteration of bathymetry and introduction of large amounts of sediment through hydraulic mining in the watershed; reduction in sediment supply as a result of damming all major rivers in the watershed; discharge of agricultural and urban waste, including numerous toxic substances; and alteration of the seasonal pattern and quantity of fresh water flowing into the estuary (Kimmerer 2004).

Human land uses have fundamentally altered streamflow and freshwater inputs to the Delta relative to the quantity and pattern under historic conditions. For example, construction of dams to provide hydroelectric, flood control, and irrigation benefits has altered the natural flow regime by storing runoff and releasing it as needed to meet multiple needs. Thus, the pattern of inflow to the Delta has been changed significantly. In addition, diversions both in tributaries and in the Delta remove a significant proportion of total available water.

A.2.5.2.6 Climate Change

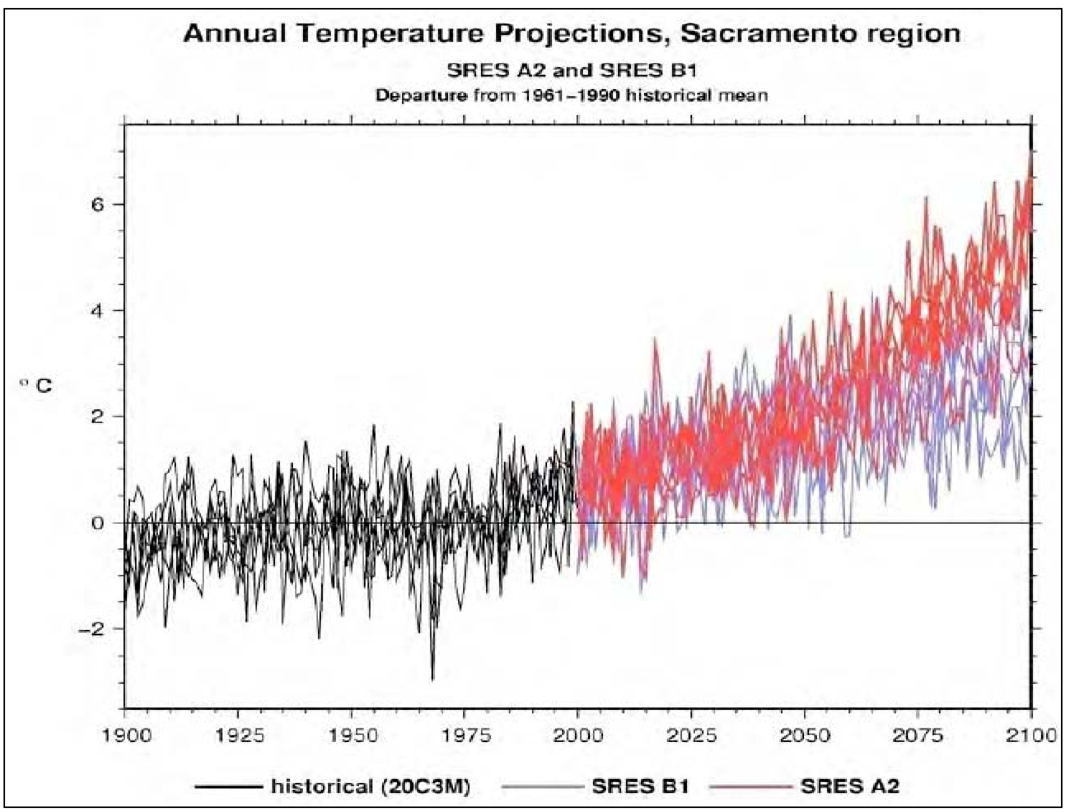
Over the BDCP implementation period, regional climate likely will change in response to changes in climate globally (Pachauri and Reisinger 2007). While the expectations of climate change are robust, predictions of changes must depend on model projections which may differ from what actually occurs. In California, climate change is expected to increase air and water temperature, change precipitation patterns, raise sea level, and change salinity patterns across the Study Area (Hayhoe et al. 2004). Climate change will affect hydrologic conditions and water management (Willis et al. 2011) and likely the success of BDCP actions such as habitat restoration (Battin et al. 2007).

Climate change is effects on temperature, precipitation, and sea level rise are discussed below.

Temperature

Observed climate and hydrologic records indicate that more substantial warming has occurred in the Study Area since the 1970s (Figure A-6). Expectations are that warming will continue to increase across the state, with largest changes in spring and summer and larger changes farther away from the coast. Annual median temperature increases are projected to be approximately 1.1°C and 2.3°C for 2025 and 2060, respectively, with less warming in winter and higher warming in summer. Summer temperatures may increase by 4°C by 2060 (Moser et al. 2009).

The current suite of global climate change models, when simulated under future greenhouse gas emission scenarios, exhibit warming globally and regionally over California. The extent of warming depends on the assumed intensity of future emissions and, as a result, there is some level of uncertainty associated with modeled simulations. Global climate models used by the California Climate Action Team for their 2009 scenarios project a midcentury temperature increase of about 1°C to 3°C (1.8°F to 5.4°F) and end-of-century increase from about 2°C to 5°C (3.6°F to 9°F) (Cayan et al. 2009).



Source: (Cayan et al. 2009).

Figure A-6. Simulated Historic and Future Annual Temperature Projections for the Sacramento Region

Precipitation

Precipitation in California is characterized by extreme variability over seasonal, annual, and decadal time scales. For this reason, projections of future precipitation are more uncertain than those of temperature. While it is difficult to discern strong trends from the full range of climate projections, the California Climate Action Team analysis generally indicated a drying trend in the twenty-first century (Cayan et al. 2009). Changes in precipitation address not only total precipitation but also the form of the precipitation and the mix of rain and snowpack accumulation. In general, snowpack is expected to decrease in California, and more of the precipitation will fall as rain (Moser et al. 2009). Even for hydrologic model simulations with mean precipitation virtually unchanged, there were large impacts on snowpack accumulation, runoff, and soil moisture.

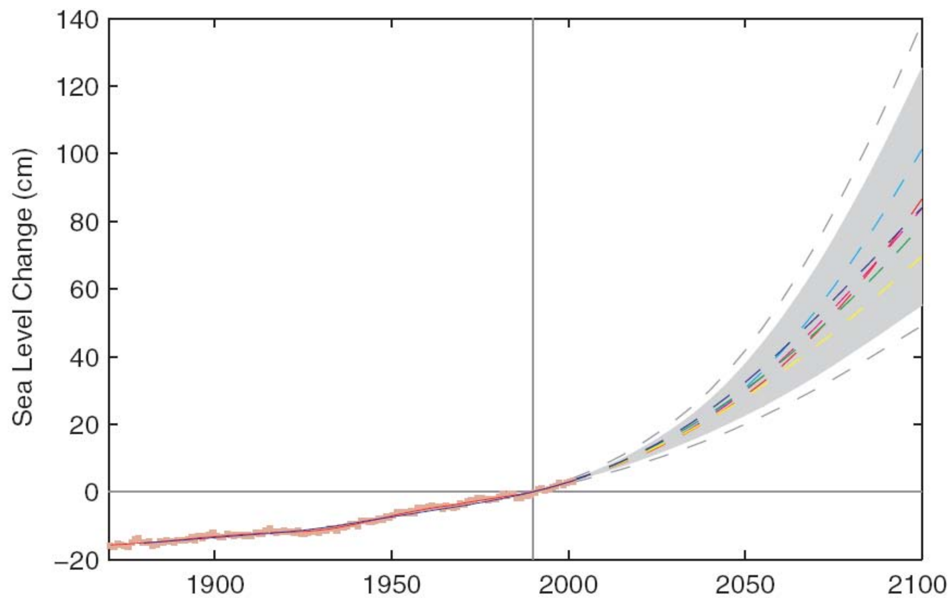
For most of the Central Valley, drying conditions are projected in late spring and summer. Projections demonstrate a bimodal pattern of precipitation changes between the Sacramento Valley and the San Joaquin and Tulare Basins. The hinge-point of wetter versus drier conditions in the winter moves northward with continued warming through time. Areas with increases in annual precipitation are almost exclusively those that experience higher winter precipitation increases over spring decreases.

Sea Level Rise

Global and regional sea levels have been increasing steadily over the past century and are expected to continue to increase throughout this century. Over the past several decades, sea level measured at tide gages along the California coast has risen at a rate of about 17 to 20 centimeters (cm) per century (Cayan et al. 2009).

In addition to overall sea level rise, tidal amplitude is expected to increase as a result of climate change (Jay 2009). Modeling and trend analysis indicate that on average tidal amplitude along the west coast has increased by about 2.2% per century, with San Francisco Bay showing larger increases. Amplitude increases may be greater inland than in coastal areas.

In the future, sea levels are projected to increase globally at a more rapid rate as a result of thermal expansion of water in the oceans due to global warming, changes in the freshwater input to the oceans from melting of glaciers and ice sheets, and changes in water storage on land (Figure A-7). For the scenarios selected for the California Climate Action Team report, sea level rise in California by 2050 is projected to be 30 to 45 cm (12 to 18 inches) higher than 2000 levels (Rahmstorf 2007) suggests end-of-century sea level rise in the range of 50 to 150 cm (20 to 59 inches).



Source: Rahmstorf (2007).

Figure A-7. Past Global Mean Sea Level and Future Mean Sea Level Based on Global Mean Temperature Projections

The BDCP would not directly affect climate change or regional adaptation to climate change. However, several of the core elements of the BDCP, such as Delta marsh habitat, upstream anadromous fish habitat, reservoir and conveyance facility management, and water quality, are likely to be affected by climate change. Figure A-8 highlights some potential changes to these core elements under a future with climate change. As with climate change, there is some level of uncertainty associated with the extent of simulated changes.

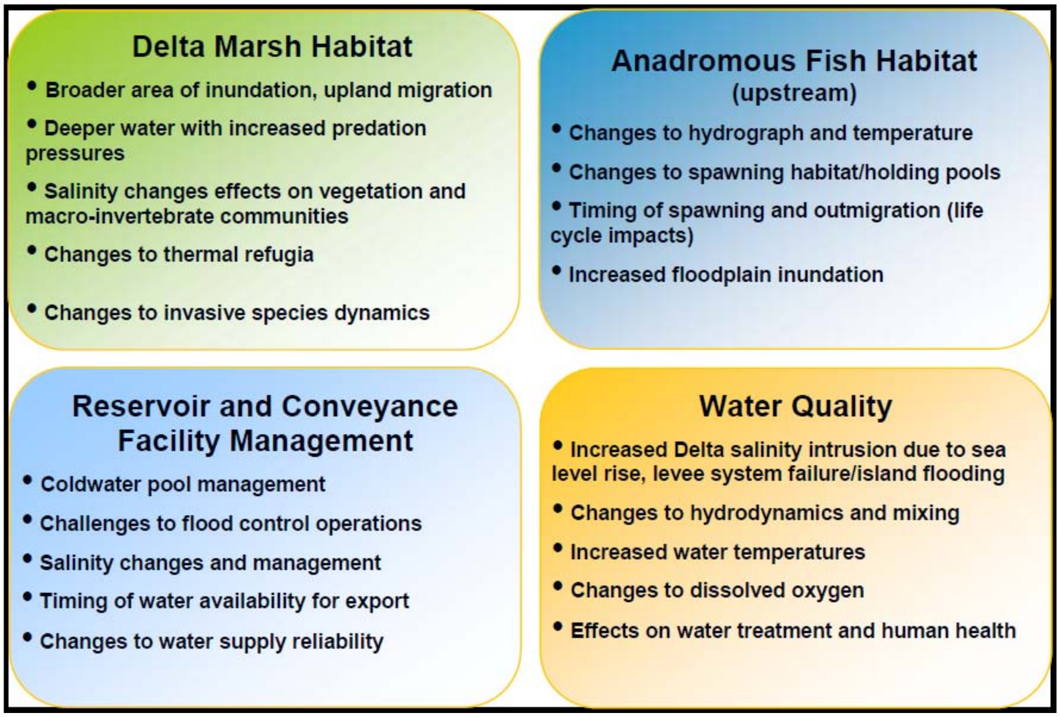


Figure A-8. Interactions of Projected Regional Climate Change and BDCP Conservation Measures

A.2.6 Ecological Principles

The BDCP Science Advisors have proposed a set of ecological principles that emerge from consideration of ecological science and the specifics of the delta. These statements provide the overall assumptions and perspective of the BDCP effects analysis. The principles listed below are based on the *Principles for Conservation Planning in the Delta* (BDCP Science Advisors 2007). The ecological principles will inform the evaluation of the BDCP conservation strategy.

- **Changes in the estuarine ecosystem may be irreversible.** Human land use has become a major driver of the Bay-Delta ecosystem. Human activities have fundamentally altered the physical, biological, and chemical structure of the Delta and introduced numerous new species that now compete with and prey on native species (Baxter et al. 2010). These changes have produced a Delta ecosystem that is different from the historic ecosystem and will remain so even as anthropogenic stressors are modified as a result of the BDCP. BDCP actions take place in the context of natural and cultural elements that differ markedly from predevelopment conditions.
- **Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).** The Delta ecosystem is and will continue to be highly variable and will change in both predictable and unpredictable ways. Recovery of covered species in the Delta will require active and adaptive management that reflects new information, different circumstances, and environmental change.
- **The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.** The effects of

BDCP actions will reflect the environmental context in which they occur, which includes the Central Valley, San Francisco Bay and Pacific Ocean.

- **The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics.** Conditions in the Delta are inherently variable and future conditions are uncertain. Scientific knowledge is limited. Future social and economic factors affecting human land use are uncertain and likely to vary. In short, uncertainty is an inherent feature of the Delta that must be accommodated in an effective management structure.
- **Species that use the Delta have evolved life-history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.** While estuarine species are adapted to highly variable conditions, the fundamental changes to the Delta ecosystem as a result of human activities may be beyond the adaptive potential of native species.
- **Achieving desired ecosystem outcomes will require more than manipulation of a single ecological stressor.** The physical and biological complexities of the Delta ecosystem argue against simplistic single-factor solutions. Restoration of ecosystem health will require more holistic approaches (Baxter et al. 2010).
- **Habitat should be defined from the perspective of a given species.** Habitat is a species-based concept reflecting the physiological and life-history requirements of species. Habitat is not synonymous with vegetation type, land (water) cover type, or land (water) use type. To succeed, species require sufficient diversity, quantity, and quality of habitat to complete their life histories (Williams 2006).
- **Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.** Water quality in the Delta is affected by a variety of discharges from agricultural, industrial, and urban sources that have been linked to ecological changes (e.g.,Thompson et al. 2000; Glibert 2010). The Delta environment is characterized by distinct salinity gradients that vary with managed and natural outflow and tides. Water in the Delta is typically turbid, although dams, submerged aquatic vegetation, and other factors have reduced turbidity. Some or all of these conditions may adversely affect performance of native species.
- **Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants, which, in turn, can affect habitat quality.** The BDCP Study Area is a natural-cultural system with a mix of natural and human-caused features and constraints. Human actions, including the covered activities, may control and alter conditions and could affect species performance.
- **Changes in one part of the Delta may have far-reaching effects in space and time***.* The Delta is a system of interconnected biological and physical processes operating across multiple scales. BDCP covered activities and conservation measures are part of an integrated plan. Actions should not be considered in isolation but rather in the context of the Delta ecosystem.
- **Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred.** The BDCP would significantly alter the Delta environment and CVP/SWP operations. In some cases, BDCP actions address conditions resulting from the past, for example breaching of dikes to expand wetland habitats. However, the sum of action in the BDCP will create a healthier Delta ecosystem that is better able to accommodate future changes in climate and other factors.

- **Adaptive management is essential to successful conservation**. Many of these principles point to the highly variable and unpredictable nature of natural systems and the Delta in particular. Fixed management programs may fail as the system shifts and new stressors emerge. Effective management must be adaptive, accepting uncertainty as an inherent condition. An adaptive approach would require explicit management and scientific designs to implement actions.
- **Conservation measures to benefit one species may have negative effects on other species.** Species are connected through the foodweb and through use of common resources. Efforts to enhance one species or a collection of species may have consequences for other species.

A.2.7 Conceptual Model for the Effects Analysis

A.2.7.1 Drivers of Biological Performance

The premise of this conceptual foundation is that the BDCP will alter the physical and biological environment of the Delta, which in turn will affect biological performance (abundance, persistence, and fitness) of species. The performance of a species in an environment is the result of characteristics of the habitat shaped by natural and anthropogenic factors (Southwood 1977; Peterson 2003).

The ecological structure relevant to the BDCP is summarized in Figure A-9, in which the biological potential of the Delta (species productivity, abundance, and diversity) is depicted as concentric circles. Biological potential is the capability of a system to support species and natural communities. Biological potential is constrained by the external and internal conditions, only some of which are addressed by the BDCP and will be considered in the effects analysis. These constraints define a series of states for biological potential ranging from the intrinsic potential unconstrained by human actions to the current highly constrained system (Figure A-9).

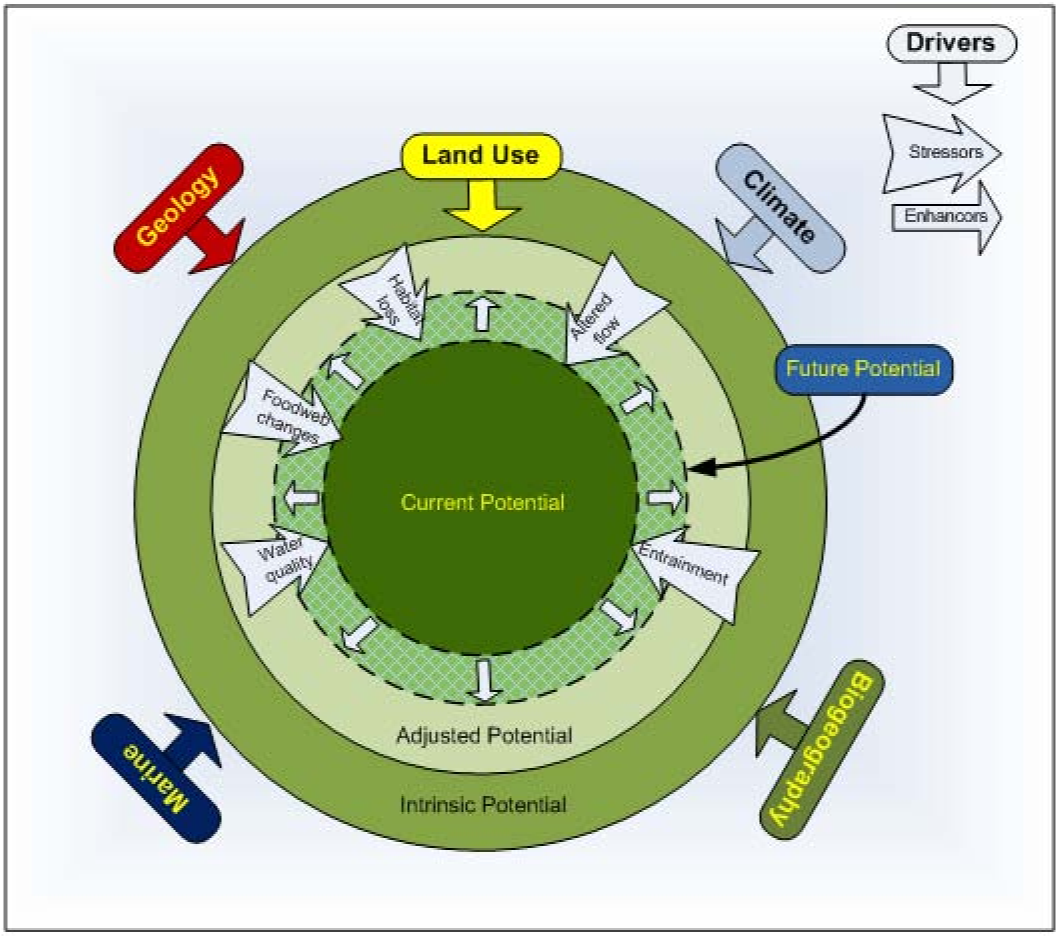


Figure A-9. Constraints on Biological Potential of Species and Natural Communities in the BDCP Plan Area

A.2.7.1.1 Intrinsic Potential

Intrinsic potential of the system (Figure A-9) is defined by the ecological *drivers*. Drivers are large-scale features of the system that determine the possibilities and constraints on the environment in the Study Area. Primary drivers are broad categories of factors such as climate, biogeography, geology, and marine conditions that are stable over long time scales and set the range of possible conditions (Naiman 1998). Secondary drivers are characteristics within these broad categories (Table A-4). For example, climate is a primary driver, and precipitation is a secondary driver affected by climate. Ecological drivers and their impacts on the Delta are discussed in Section A.2.5.2, above.

Flow is a "master variable" (Poff et al. 1997) in aquatic systems in the sense that it is responsible for creation and maintenance of many habitat features affecting biological potential. Characteristics of flow include magnitude, frequency, duration, timing, and rate of change that result in the natural dynamics of the system that structures biodiversity and ecological function of riverine (Stanford et al. 1996) and estuarine (Peterson 2003) systems. The natural flow regime of the system is controlled by the drivers of climate (precipitation and temperature), geology (topography and channel form), and biogeography (vegetation), which control the supply and pathways of water reaching stream channels (Poff et al. 1997).

Table A-4. Primary and Secondary Drivers Setting the Intrinsic Potential of Conditions in the Bay-Delta

Primary Drivers	Secondary Drivers
Climate	Precipitation
	Natural flow
	Temperature
Marine conditions	Tides
	Salinity
Geology	Topography
	Sediment characteristics
Biogeography	Terrestrial vegetation
	Terrestrial invertebrate species
	Terrestrial vertebrate species (birds and mammals)
	Aquatic plants (phytoplankton and vascular)
	Aquatic invertebrate species (zooplankton and mollusks)
	Aquatic vertebrate species (fish)

A.2.7.1.2 Adjusted Potential

The Delta is a system of natural and cultural elements that has been fundamentally altered by human activities (an ecological principle). Over human time scales, development has permanently altered the character of the region such that human land use now acts as a driver on biological potential. However, land use operates within the constraints of the overall drivers in Table A-4. The result is the adjusted potential of the system (Figure A-9). Adjusted potential accounts for the fundamental constraints on biological potential imposed by human land use. For example, the natural flow regime discussed above is constrained within the BDCP Plan Area by dams and flow control structures in the Sacramento River, San Joaquin River, tributaries, and the Delta. These flow control structures are not likely to be removed in their entirety under any conceivable set of circumstances. Therefore, these and other human land use actions assume the character of a driver on system potential.

A.2.7.1.3 Current and Future Potential

The BDCP effects analysis operates within the circles of current and future potential as affected by the BDCP actions. The performance of species in the BDCP Plan Area reflects a host of human activities that reflect short- and long-term social, economic, and biological factors that are termed *stressors* that are the focus of the effects analysis (Figure A-9). Stressors constrain the adjusted potential to create the current potential of the system for covered species and habitats. Stressors differ from the factors behind the human land use driver in that they operate on relatively short time frames and are amenable to alteration through restoration programs such as the BDCP. For example, while the presence of flow control dams and structures is considered a component of the land use driver, management of those structures on a year-to-year or longer basis creates the stressor of flow alteration that is subject to management control including the BDCP.

The BDCP is designed to relax some key stressors on species performance, such as entrainment, water quality, and delta foodwebs, to create a future potential that is enhanced with respect to listed species and described by the biological goals and objectives. Stressors that benefit species performance can be thought of as *enhancers* (Figure A-9). For example, restoration of tidal wetlands (Conservation Measure 4) is an enhancer for delta smelt because it is intended to provide key habitat while improving water quality and contributing to the delta foodweb. The determination of whether an action is a stressor, which decreases habitat suitability, or an enhancer, which increases habitat suitability, reflects species preferences and the definition of habitat quantity and quality for a species. This means that an action that is a stressor for one species could be an enhancer for another.

The effects analysis considers the impacts of BDCP actions on the modifiers acting as stressor or enhancers for covered fish species. Table A-5 lists the stressors considered in the BDCP effects analysis in Chapter 5 and the appropriate appendix where detailed analysis can be found.

Table A-5. Stressors Considered in the BDCP Effects Analysis and Corresponding Appendix

Stressors		**Appendix**
Entrainment	North Delta intakes entrainment	B
	South Delta entrainment	B
	North Bay aqueduct entrainment	B
	Diversions (smaller diversions)	B
Habitat loss		E
Flow	Transport flow	C
	Low salinity zone	C
	Temperature	C
	Turbidity	C
	Dissolved oxygen	C
Passage barriers		C
Food resources		F
Toxins		D
Predation		F
Population effects		G
Disease		F

A.2.7.2 Mechanisms of Biological Performance

A.2.7.2.1 Habitat

As discussed above, a premise of the BDCP effects analysis is the relationship between qualities of the environment and species performance. Fundamental to this is the notion of *species perception*. This is the view of the environment from the perspective of the species and reflects its unique physiological and life history requirements (Mobrand et al. 1997). From the perspective of the species the environment is viewed as *habitat,* which is the suite of physical, chemical, and biological factors determining species abundance and persistence over time (Hayes et al. 1996). As noted in Ecological Principle 7 from the BDCP Science Advisors, "habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type."

The concepts of species perception and the definition of habitat are illustrated in Figure A-10. Species perception acts as a filter on the environment to define the attributes of habitat for the species. The quantity and quality of habitat in turn constrains the species response. Likewise, actions, such as BDCP conservation measures, are viewed as stressors or enhancers of habitat suitability based on species perception. These in turn modify species response as a function of changed habitat.

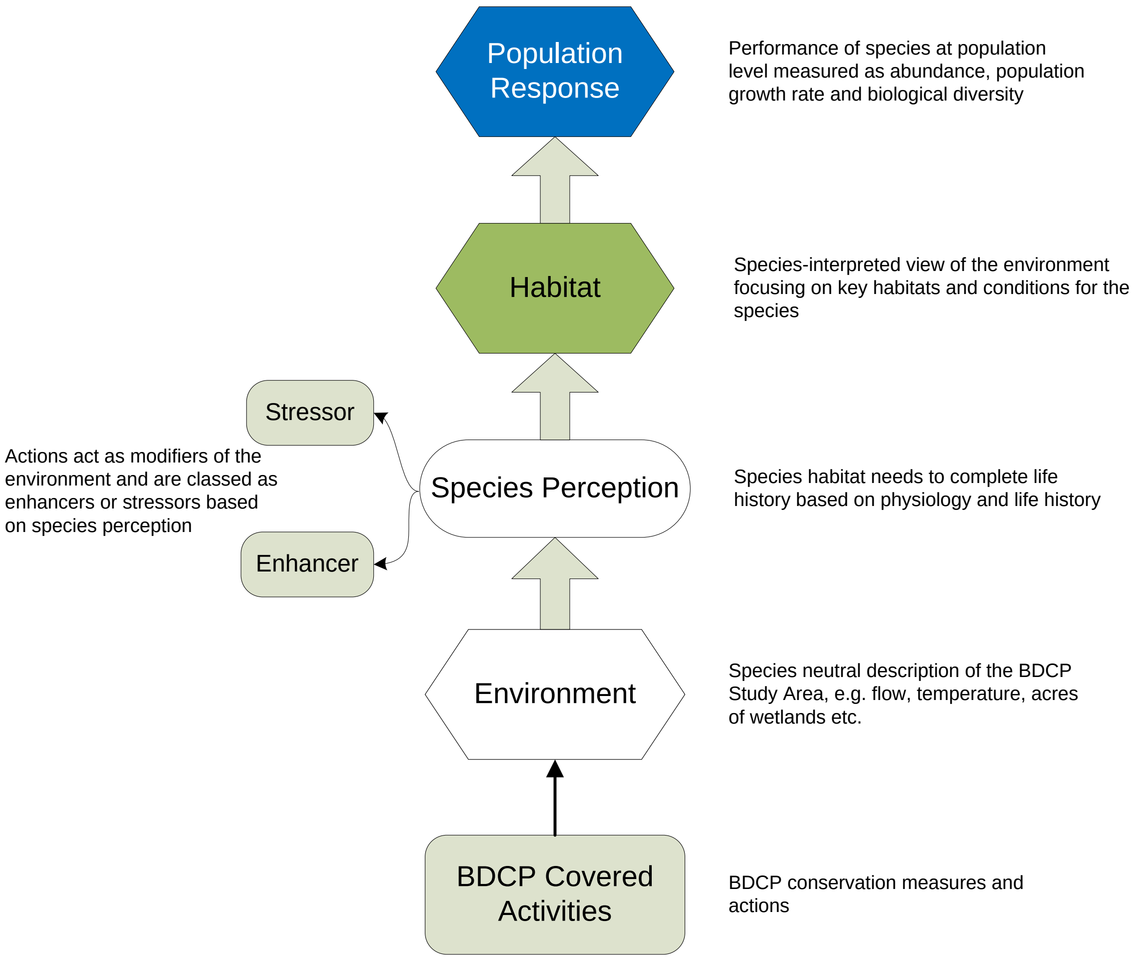


Figure A-10. Species Perception as a Filter on the Environment to Define Habitat for a Species and Regulate Species Response

A.2.7.2.2 Biological Performance

To persist and thrive, a species must experience habitat of sufficient quality, quantity, and diversity across its life history to permit successful reproduction, rearing, and survival to maturity. The result is a level of species performance that defines the biological potential of the environment for that species (Figure A-9).

Habitat characteristics can be measured in multiple metrics of biological performance such as growth, survival, abundance, and population recovery. The concept of viable salmonid population

(VSP) (McElhany et al. 2000) provides a useful framework for defining fish population performance. Because VSP is based on general fisheries population biology, including stock-recruitment (Hilborn and Walters 1992), the general outline of VSP has application for non-salmonid fish species, including delta fish species. Note that there are issues discussed in McElhany et al. (2000) that are specific to recovery of salmon populations that may not be applicable to all species.

VSP defines fish performance along four axes:

- Abundance or population size
- Population growth or productivity
- Diversity
- Spatial distribution of the population

Abundance is simply the number of fish making up a fish population defined by the carrying capacity of the habitat. Populations must be sufficiently abundant to counter the effect of stochastic events (e.g., catastrophes) as well as what are termed *Allee effects*. Allee effects occur when population abundance declines to the point that reproduction and fitness are affected and the population declines regardless of available resources. Allee effects have been posed as a concern for delta smelt because of low abundance (Nobriga and Herbold 2009).

Population growth or productivity is the rate of change in population size over time constrained by overall carrying capacity and density dependence. Density dependence means that survival and population growth are expected to be highest at low population abundance (excepting Allee effects) when competition for resources is least and declines as abundance increases and approaches capacity.

Diversity refers to the variety of morphological, behavioral, and life history traits that can occur within a fish population. Life history diversity represents the range of solutions that allow a population to cope with environmental variation and heterogeneity. Diversity is generally assumed to have a genetic component, although phenotypic plasticity also contributes to diversity within populations (Hutchings 2011).

Spatial distribution of the population refers to its structure across the landscape. To be viable over long time periods, populations need to have multiple centers of productivity to cope with catastrophic events, such as volcanic eruption or earthquakes, which could wipe out the population if it was confined to a single restricted location. Strictly speaking with respect to VSP, this measure refers to the structure of the population across the landscape within an evolutionarily significant unit (ESU) for salmon or distinct population segment (DPS) for steelhead. Although these types of population definitions have not been developed for nonsalmonids, the need for multiple centers of population production holds for others species as well.

Other measures of biological performance are encompassed by these four overall measures. Growth of individuals within a population, for example, reflects productivity and the availability of resources relative to abundance.

The VSP measures can be related to characteristics of habitat (McElhany et al. 2000) and hence to actions, including those in the BDCP. This builds out of the relationship in Figure A-10 to include measures of population performance and habitat (Figure A-11). The following relationships are assumed to occur in Delta fish species:

- Abundance, as affected by carrying capacity, is a function of habitat quantity. Species have unique requirements that define key habitats for each life stage. Hence, habitat quantity refers the amount (e.g., square meters) of specific key habitats for the species and not simply the size of the environment.
- Productivity is affected by habitat quality that is set by values of environmental attributes filtered through the species perception. This includes species requirements for temperature, water quality, nutrients, and so on.
- Diversity is a function of heterogeneity of habitat across the landscape. Habitat heterogeneity reflects the natural dynamics of flow and other habitat forming processes that create a mosaic of habitat of varying quantity and quality spatially and temporally. Within the genetic capabilities of the species, phenotypic, behavioral, and life history diversity develops in response to habitat heterogeneity.
- Spatial structure reflects the distribution of suitable habitat patches across the landscape that can support productive centers for population abundance and productivity (McElhany et al. 2000).

Biological performance and habitat conditions can be measured and monitored using a variety of indicators to chart progress over time (Figure A-11). These indicators can be related to the biological goals and objectives developed for the BDCP. This provides a completed structure to relate BDCP actions to the biological goals and objectives.

Biological performance defined in Figure A-11 is embedded within the structure of biological potential in Figure A-9. Biological performance is ultimately constrained by large-scale drivers and smaller-scale stressors and enhancers of habitat conditions. BDCP conservation measures and action operate within these constraints to achieve biological goals and objectives.

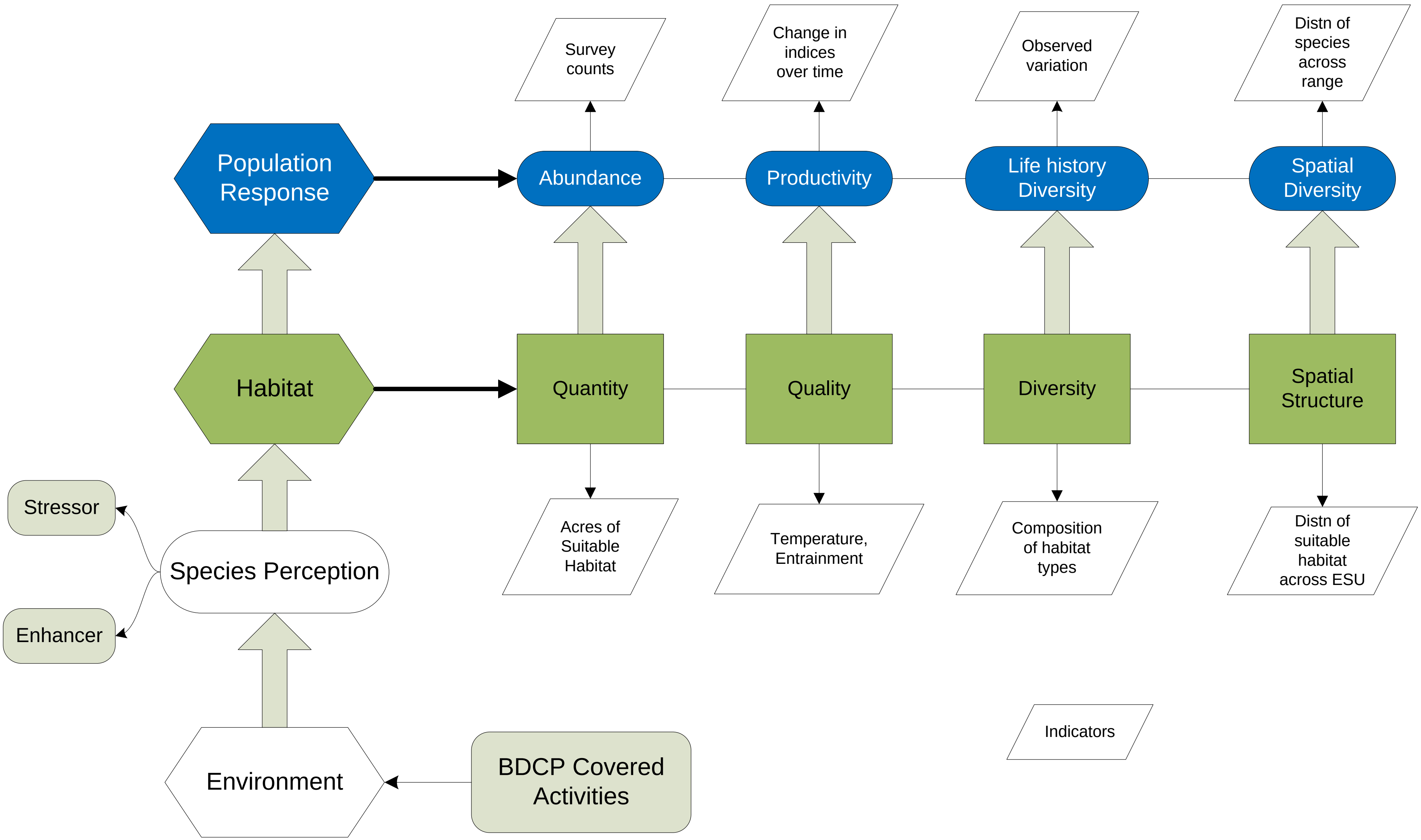


Figure A-11. Relationship between Measures of Habitat and Populations Response

A.2.7.3 Geographic Structure

The BDCP affects conditions and species across a wide array of geographies and environments with varying mixtures of stressors, environments, and species. Assessment of the impacts of individual actions and stressors is enhanced by considering them within a geographic structure that reflects the biogeographical structure of the Delta and its tributaries. Structure and function of ecological systems are often described hierarchically (O'Neill et al. 1986); a hierarchical structure is particularly applicable to estuarine species encompassing a variety of physical and biological features (Peterson 2003). Larger-scale areas can constrain performance of smaller-scale areas. In turn, the performance at any level reflects the performance of smaller-scale features. A hierarchical structure for the BDCP is developed as follows (Table A-6):

- **The BDCP Study Area** (Figure A-12). This is the area where physical changes attributable to the BDCP have the potential to affect covered fish species. Included is the Sacramento River upstream to Keswick Dam, the San Joaquin River upstream to the Stanislaus River, tributaries downstream of SWP and CVP dams (Clear Creek, Feather River, American River, and Stanislaus River), and the BDCP Plan Area (see below).
- **The BDCP Plan Area** (Figure A-12). This is the area in which all covered activities would occur, including all major BDCP conservation measures. The effects analysis for the BDCP will focus on the BDCP Plan Area. The Plan Area includes the statutory Delta (as defined in California Water Code 12220), Suisun Bay, Suisun Marsh, and the Yolo Bypass north of Interstate 80. The Plan Area is likely to be equivalent to the area in which the permits would apply.
- **Geographic regions.** These are clear, large-scale areas that can be distinguished hydraulically, ecologically, and geomorphologically. Regions include terrestrial and aquatic environments. The Study Area is divided into three geographic regions: the Sacramento River watershed, San Joaquin River watershed, and the BDCP Plan Area as described above.
- **Geographic subregions** (Figure A-13). Subregions are broad geographic and hydrologically distinct areas that are relevant to the life history of Delta fish and wildlife species. Subregions include both terrestrial and aquatic resources. Within the BDCP Plan Area, the subregions are based largely on hydrodynamic subregions used by Stoms (2010) that were interpreted from a graphic conceptual model developed by the DRERIP team (J. Burau pers.comm.). Outside the Plan Area, subregions include tributary reaches below dams that prevent fish passage and that may experience indirect effects from BDCP-related activities such as changed release schedules.
- **Restoration Opportunity Areas (ROAs)** (Figure A-14). ROAs encompass those locations considered to be the most appropriate for the restoration of tidal habitats within the Plan Area and within which restoration goals for tidal and associated upland natural communities will be achieved. In many cases, ROAs overlap the conservation zones.

Figure A-12. BDCP Study Area

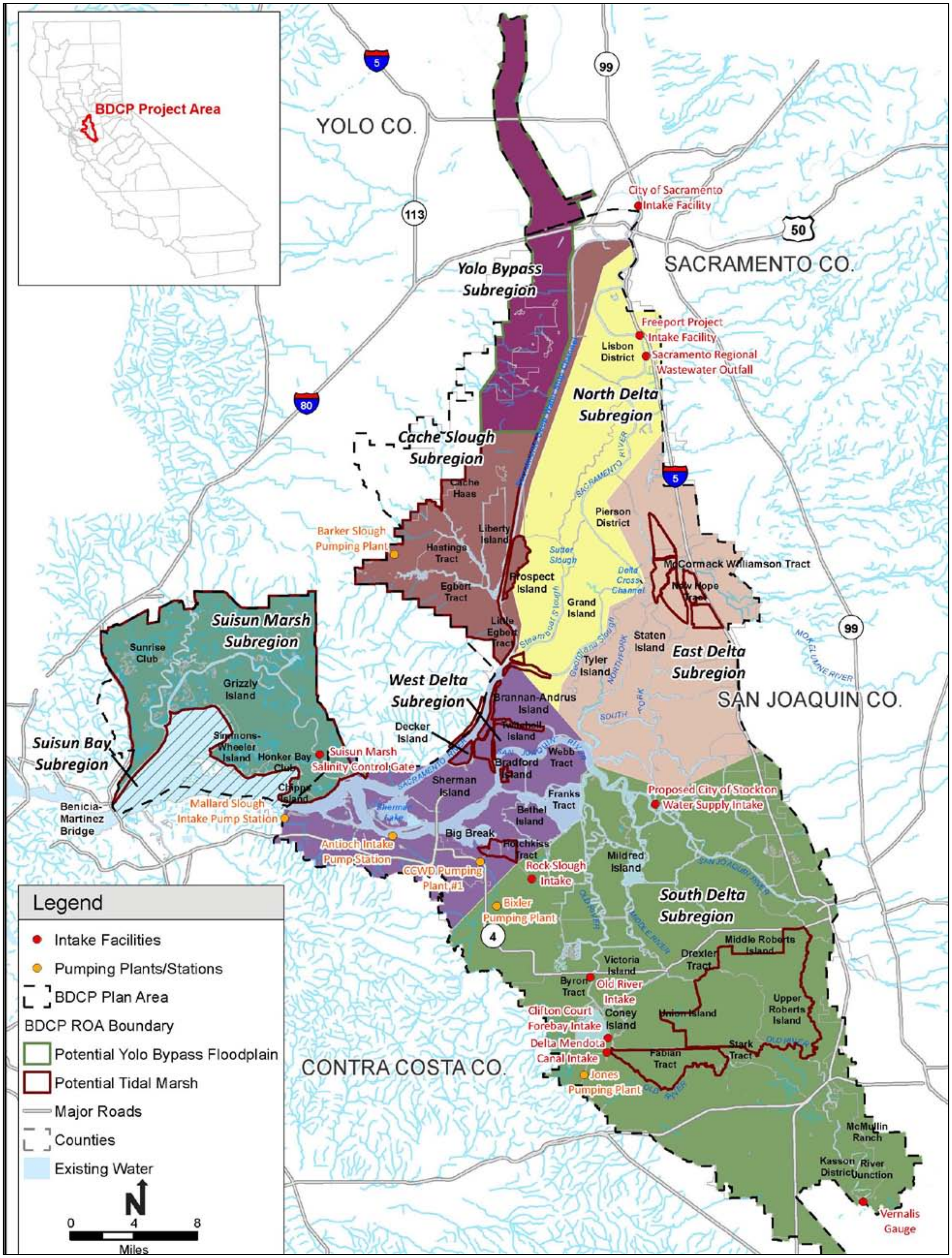
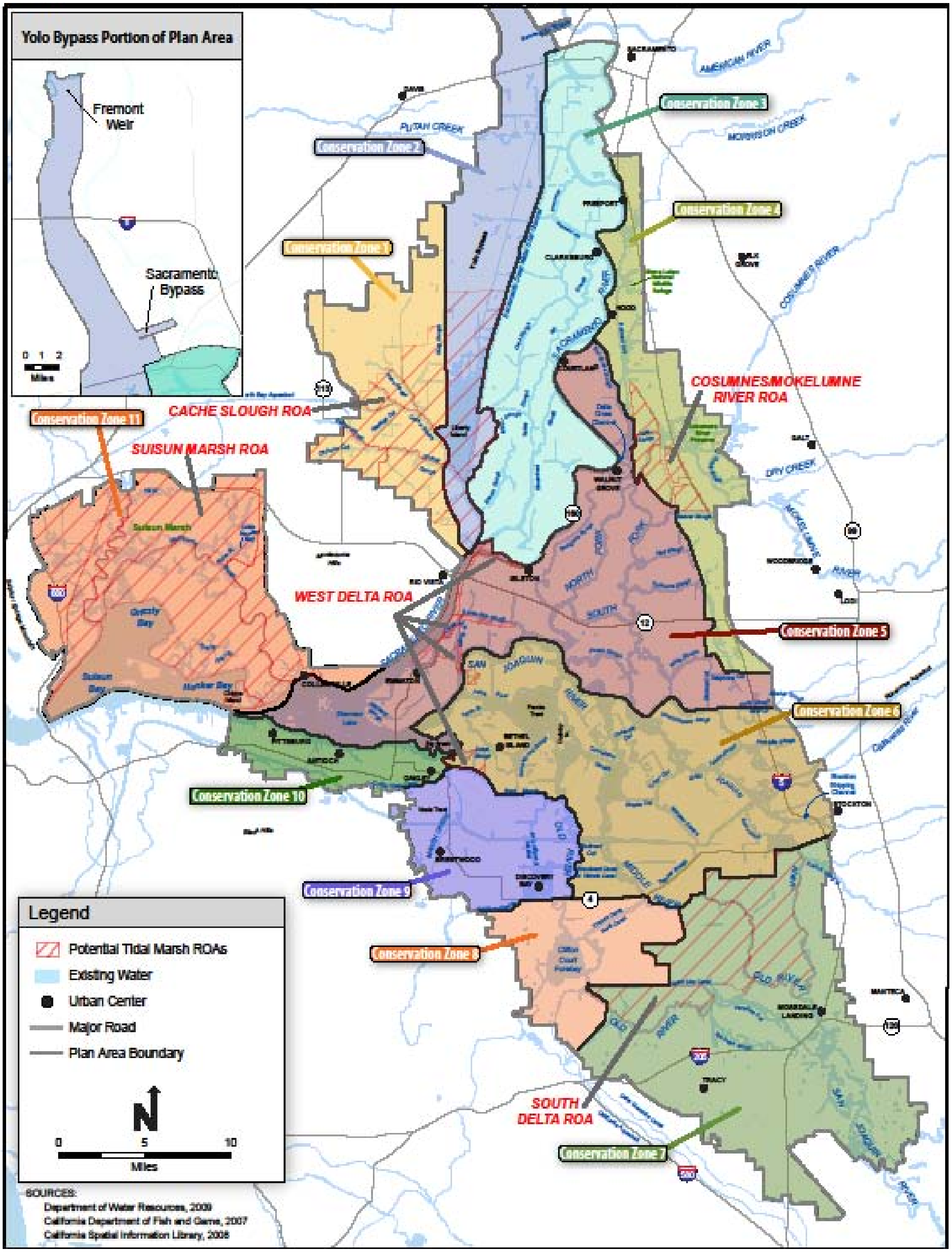


Figure A-13. BDCP Subregions



Conservation zones relate to terrestrial species analysis.

Figure A-14. Restoration Opportunity Areas (ROAs)

Table A-6. Geographic Subregions in the BDCP Study Area

Geographic Region	Subregion	Aquatic Covered Species Present
Delta	South Delta	Delta smelt, Sacramento splittail, salmonids
Delta	North Delta	All
Delta	Cache Slough	All
Delta	Yolo Bypass	Delta smelt, Sacramento splittail, salmonids, sturgeons
Delta	Western Delta	All
Delta	Suisun Marsh	All
Delta	Suisun Bay	All
Sacramento River	American River	Salmonids
Sacramento River	Sacramento 143	Salmonids, sturgeons, lamprey, splittail
Sacramento River	Feather River	Salmonids, sturgeons, lamprey
Sacramento River	Sacramento 194	Salmonids, sturgeons, lamprey
Sacramento River	Sacramento Keswick	Salmonids, sturgeons, lamprey
Sacramento River	Clear Creek	Salmonids, lamprey
San Joaquin River	San Joaquin River to the Stanislaus River	Delta smelt, salmonids, sturgeons, lamprey
San Joaquin River	Stanislaus River	Salmonids, sturgeons

A.2.7.4 Species Models

Species models define a scientific hypothesis regarding how species perceive the environment and are thereby affected by BDCP actions (Figure A-10). They include the spatial and temporal distribution of life stages as well as the distribution of stressors on each life stage. Species models for BDCP effects analysis consist of the following elements:

- Distribution across the BDCP study area
- Life stages
- Life history
- Spatial and temporal distribution of life stages
- Key habitats for life stages
- Stressors

Species that would be affected by the BDCP have complex life histories developed in response to the wide array of environments and ecological challenges of the San Francisco estuary and Central Valley. The life history, habitat requirements, and stressors affecting various species have been described in numerous publications, much of which is captured by the Delta conceptual models (DFG undated). Interagency Ecological Program analysis of the POD also provides useful conceptual models for those covered fish species that are resident to the Delta (Baxter et al. 2010).

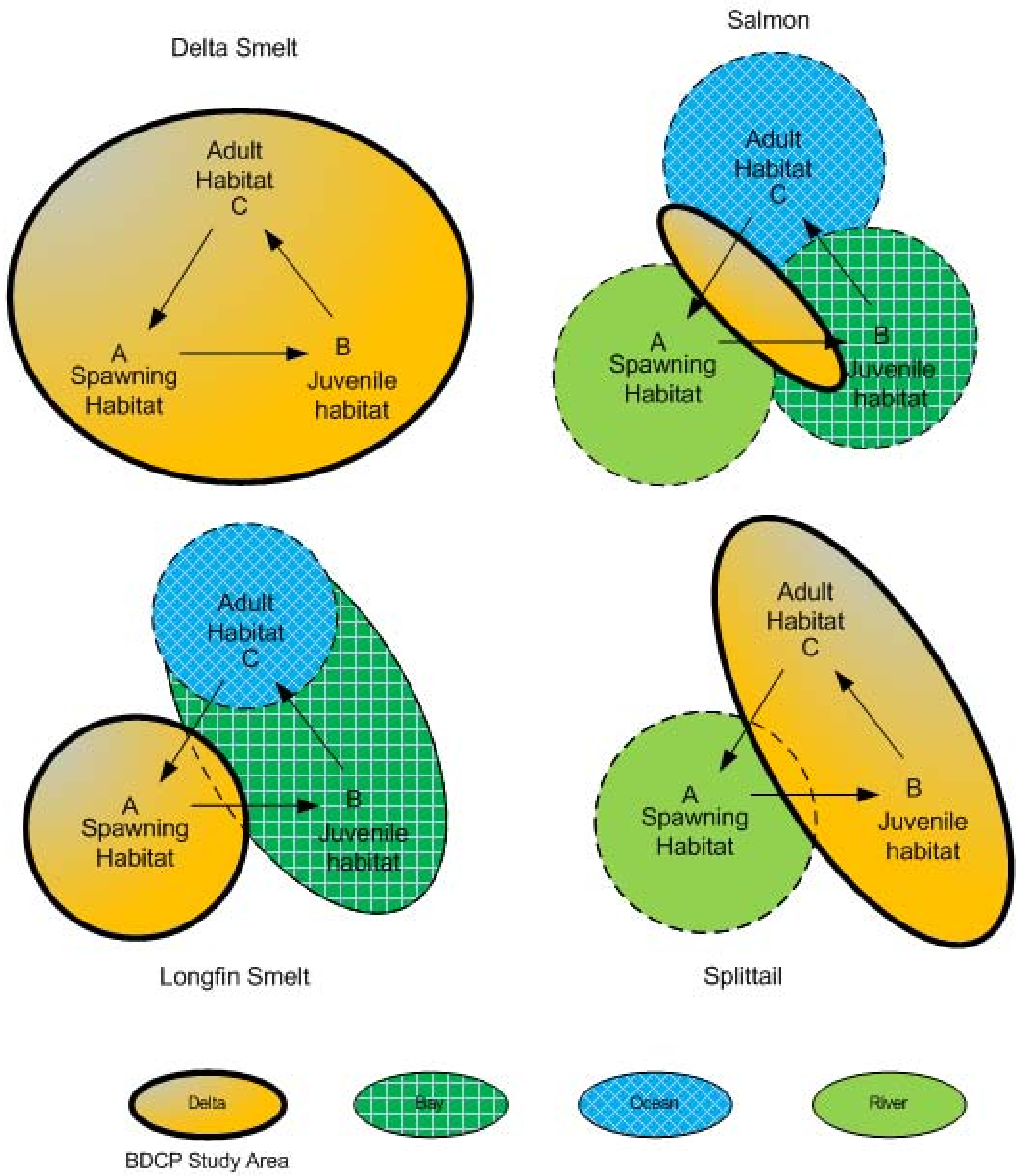
The life histories of covered fish species in the BDCP Plan Area can be broadly classified as anadromous (e.g., Chinook salmon), restricted anadromous[4] (e.g., the majority of delta smelt), and resident (e.g., a minority of delta smelt that reside in the Cache Slough subregion (Baxter et al. 2010). True anadromous behavior like that of salmon involves reproduction and early development in fresh water followed by migration to marine waters where most growth and maturation occur. Restricted anadromous behavior refers here to species that spawn in freshwater areas and migrate to the low-salinity areas of the Delta to mature, and is characteristic of many estuarine species. A resident life history occurs within a single hydrologic environment (fresh water or salt water).

Because of the different types of life histories, fish species will experience the Delta and the effects of the BDCP in unique ways. Figure A-15 shows fish life histories as triangles indicating movement of life stages across different habitat types. The path begins in the spawning habitat where adults produce offspring. The larval fish disperse to the juvenile habitat and eventually move to the adult habitat. The path is completed when the adults migrate back to the spawning habitat to reproduce. The population dynamics of a species are determined by the survival of fish over the migration path, the number of offspring produced by adults in the spawning habitat, and the number of times adults cycle between the adult and spawning habitats during their life cycles (BDCP Science Advisors 2007).

Success of the species is a function of the quality and quantity of habitat available at each point in the life history triangles. In Figure A-15 it is clear that each type of life history (i.e., anadromous, restricted anadromous, or resident) experiences the Delta and the BDCP Plan Area differently. Delta smelt spend their entire life within the Plan Area; hence, the BDCP may have a greater chance of affecting their recovery. Individual salmon, on the other hand, spend less time in the BDCP Plan Area, but juveniles and adults traverse the Delta throughout most of the year. While conditions in the Study Area are important to salmon, their ultimate success is also dependent on conditions across a much wider geographic area.

The complexity of Delta fish species life histories and the diversity of habitats supporting different life stages mean that their abundance and persistence vary over time are due to many factors (Kimmerer 2004). The population dynamics of species and their historic, current, and future abundance are the result of interplay between drivers, environmental processes, and stressors operating across multiple physical and biological scales. This calls for a holistic approach to species recovery that focuses on recovery of the ecosystem and habitats.

[4] Restricted anadromous behavior is also referred to as *semianadromous* (e.g., Bennett 2005).



Note: Arrows indicate migration among habitat types
adopted from (BDCP Science Advisors 2007)

Figure A-15. General Pattern of Use of the Delta by Covered Species over Their Life Cycle

BDCP conservation measures focus on providing benefits for species listed under the ESA and CESA, as well as other special-status species, but realize an ecosystem approach will benefit other native species as well. The plan identifies goals and objectives for numerous sensitive wildlife, plant, and fish species that are addressed by the conservation measures. Fish species addressed in the BDCP effects analysis are listed in Table A-7.

Table A-7. Aquatic Species Covered by the BDCP and Addressed in the Effects Analysis

Common Name	Scientific Name	Life History
Delta smelt	*Hypomesus transpacificus*	Restricted anadromous (some resident)
Longfin smelt	*Spirinchus thaleichthys*	Anadromous
Winter-run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous
Fall- and late fall–run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous
Steelhead	*Oncorhynchus mykiss*	Anadromous
Green sturgeon	*Acipenser medirostris*	Anadromous
White sturgeon	*Acipenser transmontanus*	Anadromous
Sacramento splittail	*Pogonichthys macrolepidotus*	Restricted anadromous
River lamprey	*Lampetra ayresi*	Anadromous
Pacific lamprey	*Entosphenus tridentata*	Anadromous

A.3 Analytical Framework

A.3.1 Purpose and Scope

The analytical framework describes the methodology and structure of the analysis of the effects of the BDCP on the covered aquatic species (effects on terrestrial species will be described in Appendix H). The analysis used in the effects analysis including the subsequent appendices represents the efforts of multiple parties that have contributed and commented on previous analyses. The purpose of the analytical framework is to provide a general scheme and logic for the effects analysis. Major tools and models that are likely to be used in the analysis are discussed; additional tools and detailed methodologies are discussed in each appendix relating to a stressor category.

The analytical framework is based on the conceptual foundation, including the Principles for Conservation Planning in the Delta developed by the BDCP Science Advisors (BDCP Science Advisors 2007). Beyond those in the Conceptual Foundation, the Science Advisors included three principles that inform the effects analysis:

- **There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.** Uncertainty is inherent in the behavior of complex ecological systems. Some of the uncertainty is reducible through research but some is characteristic of ecological systems.
- **Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models.** Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions
- **Data sources, analyses, and models should be documented and transparent so they can be understood and repeated.** All models have strengths and limitations and are appropriate only

for a limited set of applications. The BDCP analysis will use generally recognized and well-documented analytical tools.

A.3.2 Effects Analysis Overview

A.3.2.1 Organization of the Effects Analysis

The effects of BDCP conservation measures and covered activities are summarized in Chapter 5 including the integration (roll-up) of results. That analysis is supported by Appendices B through G, which provide details of the analytical methods, and the results and conclusions of the various analyses.

A.3.2.2 Geographic Structure

Elements of the BDCP effects analysis are organized using the geographic structure described in Section A.2.7.3. Drivers, stressors, and conservation measures act across a range of geographic and biological scales. Regional geology and climate are large-scale drivers whereas local geology and microclimates can drive conditions at smaller scales.

The BDCP effects analysis is organized using the scheme outlined in the conceptual foundation:

- BDCP Study Area (Sacramento River upstream to Keswick Dam, the San Joaquin River upstream to Friant Dam, tributaries downstream of SWP and CVP dams, and the BDCP Plan Area)
- BDCP Plan Area (the legal Delta, Suisun Bay, Suisun Marsh, and Yolo Bypass)
- Geographic Regions (e.g., the Delta, Sacramento River, San Joaquin River)
- Geographic Subregions (e.g., North Delta, South Delta)
- Restoration Opportunity Areas (ROAs)

Much of the analysis is focused at the geographic subregional level while recognizing larger-scale constraints and smaller-scale components.

A.3.2.3 Temporal Structure

The BDCP addresses habitat restoration for covered species and statewide water supply over a 50-year period because that is the term of the proposed permits. The analysis addresses conditions at multiple points within this period, reflecting the implementation schedule for conservation measures. For analytical purposes, time points are established within the BDCP license period at which conservation measures will be evaluated. Conservation measures will be evaluated at these time points to capture the phased implementation of actions. The analysis of flow and entrainment are based on CALSIM II projections. CALSIM II uses a monthly time scale and, for this reason, much of the analysis of flow-related attributes is also at a monthly time scale though relating to the analytical time periods discussed below. Some models such as DSM2 begin with the CALSIM II monthly output to derive finer-scale results for some parameters.

A.3.3 Models

Assessment of the impacts of stressors resulting from the BDCP involves a combination of quantitative and qualitative models. A model is a logical organization of data and observations leading to a conclusion about how a system functions or performs. For purposes of the BDCP effects analysis, *models* include formal quantitative and qualitative models as well as less formal analytical methods such as regression analysis. Quantitative models predict a numeric outcome of an action based on the manipulation of data by mathematical algorithms. The algorithms in a quantitative model reflect a conceptual model of the relationship between attributes, processes, and outcomes. Development of useful quantitative models requires that sufficient theory and data are available to construct algorithms that explicitly describe the relationship between system attributes. Qualitative models, including conceptual models, likewise describe a logical relationship between variables and summarize results of scientific investigations, although the result is not a quantification of biological change. Conceptual models are the first step in constructing quantitative models but they can also stand alone as working hypotheses of the phenomenon.

Models used in the BDCP are listed and described in Table A-8 along with reference to the appendix where the models are applied. The models are categorized in Table A-8 based on their general scope and intent.

Table A-8. Models Used in the BDCP Effects Analysis

Model	Description	Model Type	A	B	C	D	E	F	G	H	I
Conceptual models	Conceptual models organize factors and relationships to explain phenomena. They are a starting point for development of quantitative models and stand on their own as a way to structure discussion and analyses.	Conceptual	X	X	X	X	X	X	X		
DRERIP	The Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models and scientific evaluation process were developed to aid in planning and decision making for potential ecosystem restoration actions in the Delta. The 2009 DRERIP assessment of the BDCP provided qualitative rankings for the effects on covered fish species from the conservation measures proposed at that time.	Conceptual	X	X	X	X	X	X			
CALSIM II	The CALSIM II planning model simulates the operation of the CVP and SWP over a range of hydrologic conditions. CALSIM II produces key outputs that include river flows and diversions, reservoir storage, Delta flows and exports, Delta inflow and outflow, deliveries to project and non-project users, and controls on project operations.	Environmental		X	X	X	X	X	X		
DSM 2	DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta. The DSM2 model has three separate components or modules: HYDRO, QUAL, and PTM.	Environmental		X	X	X		X			
DSM 2 Hydro	DSM2-HYDRO predicts changes in flow rates and depths as a result of the BDCP and climate change. Outputs are used to determine the effects of these hydrodynamic parameters on covered terrestrial and fish species and as inputs to other biological models.	Environmental			X	X					
DSM 2 Qual	The DSM-QUAL module simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs are used to estimate changes in salinity and their effects on covered species as a result of the BDCP and climate change.	Environmental			X			X			

Model	Description	Model Type	A	B	C	D	E	F	G	H	I
DSM 2 PTM	The DSM-PTM module simulates fate and transport of neutrally buoyant particles through space and time. Outputs are used to estimate the effect of hydrodynamic changes on the fate and transport of larval fish and toxics through the Delta, as well as entrainment of larval fish at various locations.	Biological		X	X	X		X			
RMA	The RMA model output is used to evaluate the effects of tidal habitat restoration on flows throughout the Delta and the subsequent effects on covered species, aquatic and terrestrial. It is also used to calibrate CALSIM II and DSM 2.	Environmental						X			
SRWQM	Output from the Sacramento River Water Quality Model (SRWQM) is used as an input to a number of biological models for upstream life stages of salmonids and sturgeon.	Environmental			X	X					
USBR Temp Model	The USBR Temp Model is used to predict the effects of operations on water temperatures in the Feather, Stanislaus, Trinity, and American river basins, which are then used as inputs to the Reclamation Salmon Mortality Model and species-specific habitat evaluations.	Environmental			X	X		X			
MIKE-21	Outputs of MIKE-21 are used to predict the area of inundated habitat in the Yolo Bypass for species such as splittail and Chinook salmon	Environmental			X						
Striped Bass Bioenergetics Model	The bioenergetics model is used to estimate predation rates of striped bass on covered fish species at the proposed North Delta diversion intakes. Results of the model are also used as inputs to the Delta Passage Model and Interactive Object-Oriented Salmon Simulation (IOS) Model.	Biological			X			X			
DPM	The Delta Passage Model (DPM) is used to predict relative reach-specific survival estimates for winter, spring, and fall-run juvenile Chinook salmon passing through the Delta, as well as estimates of salvage in the south Delta export facilities.	Biological		X	X						
IOS	The Interactive Object-Oriented Salmon Simulation (IOS) model is used to evaluate the effects of multiple aspects of the BDCP on survival of winter-run Chinook salmon and population viability.	Population and Life History							X		

Model	Description	Model Type	A	B	C	D	E	F	G	H	I
OBAN	Complementary to IOS, the Oncorhynchus Bayesian Analysis (OBAN) model is used to predict the effects of multiple BDCP actions on winter-run and spring-run Chinook salmon survival and population dynamics and population viability.	Population and Life History			X				X		
SacEFT	The Sacramento River Ecological Flows Tool (SacEFT) is used to predict the effects of flow changes in the Sacramento River on a set of physical (spawning area, juvenile rearing area, redd scour, and redd dewatering) and biological (egg survival, juvenile stranding, and juvenile growth) parameters for all races of Chinook salmon and steelhead. The model also predicts flow-based effects on green sturgeon egg survival.	Population and Life History			X	X					
SALMOD	SALMOD is used to predict the effects of flows in the Sacramento River on habitat quality and quantity and ultimately on juvenile production of all races of Chinook salmon.	Population and Life History			X						
USBR Salmon Mortality Model	The USBR Salmon Mortality Model is used to predict temperature-related proportional losses of eggs and fry for each race of Chinook salmon in the Trinity, Sacramento, Feather, American, and Stanislaus Rivers.	Population and Life History			X						
Fall X2 Model	The Fall X2 Model calculates surface area of water at 2 ppt salinity as related to the position of X2 during the fall (September–December).	Biological			X						
Covered Wildlife and Plant Species Habitat Models	Habitat models for each of the covered wildlife and plant species are based on vegetation/land cover associations that support each species' habitat type modified by parameters such as soil type, elevation, topography, spatial distribution, and proximity to aquatic habitats, as relevant.	Habitat Suitability								X	
Salvage-Density Method	The Salvage-Density Method uses historical salvage and flow data to predict entrainment.	Biological		X							
Old and Middle River Flow Proportional Entrainment Regressions (delta smelt)	The Old and Middle River Flow Proportional Entrainment Regressions use linear regression (based on estimates from Kimmerer [2008] and estimates adjusted based on the rationale provided by Miller [2011]) and CALSIM data to estimate the proportion of delta smelt population that would be entrained.	Biological		X							

Model	Description	Model Type	A	B	C	D	E	F	G	H	I
Salvage Estimation Equation	The salvage estimation equation for delta smelt (Manly 2011) Uses multiple regression to estimate salvage of adult delta smelt as a function of OMR flows, turbidity, and population size.	Biological		X							
Effectiveness of Nonphysical Barriers	The effectiveness of nonphysical barriers assessment discusses results of recent studies at Georgiana Slough and Old River as well as literature studies to determine potential effectiveness of barriers at these and other Delta locations.	Biological		X	X						
Screening Effectiveness Analysis (North Delta Intake)	The screening effectiveness analysis estimates the potential for screening based on different sizes of fish approaching the north Delta intakes,	Biological		X							
Fry-rearing benefit for Yolo Bypass	This model quantifies fry benefits.	Biological			X						
Habitat Suitability Indices	Habitat suitability indices quantify the value of habitat for life stages of a particular covered species. Variables used depend on the species and available data.	Habitat Suitability					X			X	
Maunder-Deriso Delta Smelt Lifecycle Model	The Maunder-Deriso Delta Smelt Lifecycle Model is a state-space multi-stage lifecycle model that evaluates population impacts on delta smelt by allowing density dependence and environmental factors to impact different life stages.	Population and Life History							X		
Kimmerer et al. X2-abundance Regression (longfin smelt)	The Kimmer regression relationships use X2 to estimate annual abundance indices of longfin smelt in fall midwater trawls, bay midwater trawls, and bay otter trawls.	Biological			X						
Glibert Foodweb Regression	The Glibert foodweb regression estimates relative change in abundance of total chlorophyll, diatoms and dinoflagellates, and several copepod and fish species based on changes in individual nutrients and nutrient ratios, the latter having been derived from DSM2-QUAL modeling.										X
Copper Loading	Copper loading analysis uses DSM 2 and the calculated total load of the contaminant within each watershed to estimate the diluted concentration of contaminant in the Plan Area.										X

Model	Description	Model Type	A	B	C	D	E	F	G	H	I
Pyrethroid/EDC Loading	Purethroid/EDC loading uses DSM 2 and the calculated total load of the contaminant within each watershed to estimate the diluted concentration of contaminant in the Plan Area.										X
Selenium Loading	Selenium loading uses DSM 2 and the calculated total load of the contaminant within each watershed to estimate the diluted concentration of contaminant in the Plan Area.										X
Mercury/ Methylmercury Loading	Mercury/methylmercury loading uses DSM 2 and the calculated total load of the contaminant within each watershed to estimate the diluted concentration of contaminant in the Plan Area.										X
Ammonia Loading	Ammonia loading uses DSM 2 and the calculated total load of the contaminant within each watershed to estimate the diluted concentration of contaminant in the Plan Area.										X
	Total Models	**35**	**2**	**10**	**21**	**9**	**4**	**9**	**5**	**2**	**6**

Notes:
Appendix A: Conceptual Foundation and Analytical Framework
Appendix B: Entrainment
Appendix C: Flow, Salinity, Passage, and Turbidity
Appendix D: Toxics
Appendix E: Habitat Restoration
Appendix F: Ecological Impacts
Appendix G: Fish Population
Appendix H: Terrestrial Species
Appendix I: Analyses Not Used
Appendix J: Construction and Maintenance Impacts on Covered Fish

A.3.3.1 Conceptual Models

Conceptual models organize information within a logical structure that provides a plausible explanation for a phenomenon. A conceptual model describes key attributes, linkages, and structure associated with an issue. An important value of conceptual models is that they explicitly lay out assumptions and logic underlying arguments and assessments. Conceptual models have been developed through regional processes that summarize information by groups of regional scientists. DRERIP (DFG undated) has developed conceptual models for key species and processes in the Delta. The Interagency Ecological Program has constructed conceptual models associated with the POD (Baxter et al. 2010). Conceptual models also appear in the appendices to explain issues surrounding stressors.

A.3.3.2 Environmental Models

Environmental models set the stage for the analysis of biological effects by describing key physical and chemical conditions across the Study Area. These conditions include flow, temperature, salinity, and turbidity, which are addressed by models such as CALSIM II and DSM2 (Figure A-16). Because flow is a "master variable" (Poff et al. 1997) in the sense that it creates and maintains many other habitat characteristics, CALSIM II and DSM2 are the basis for many other analyses used in the BDCP effects analysis.

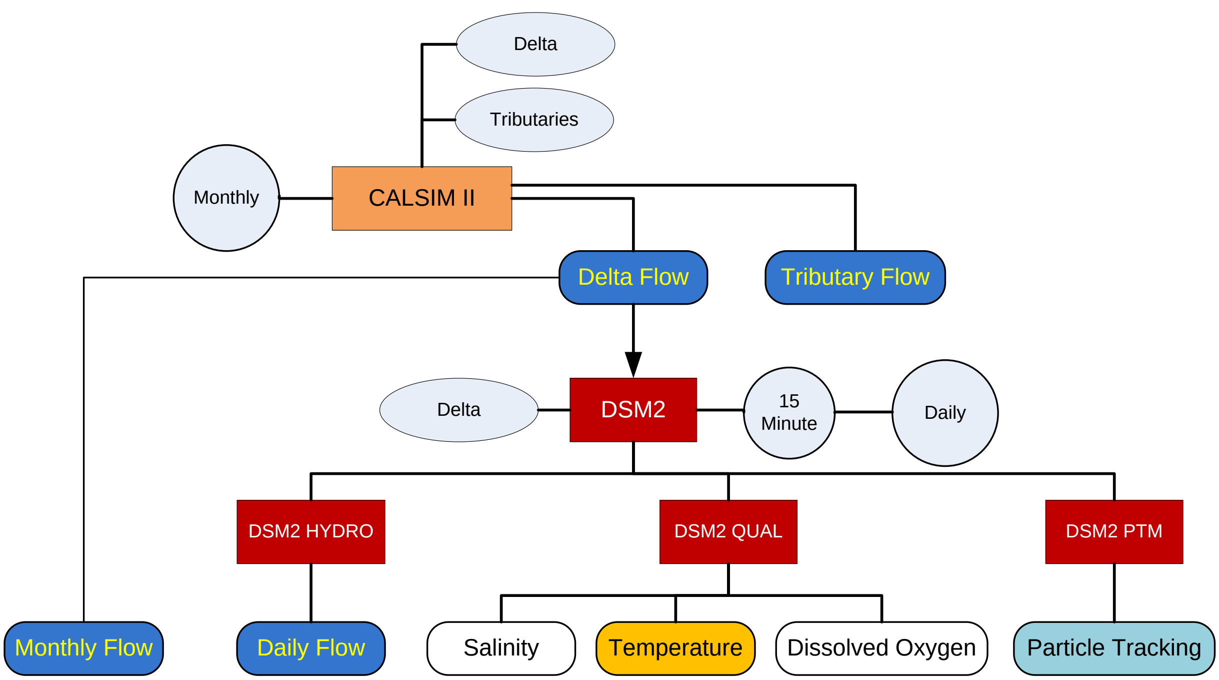
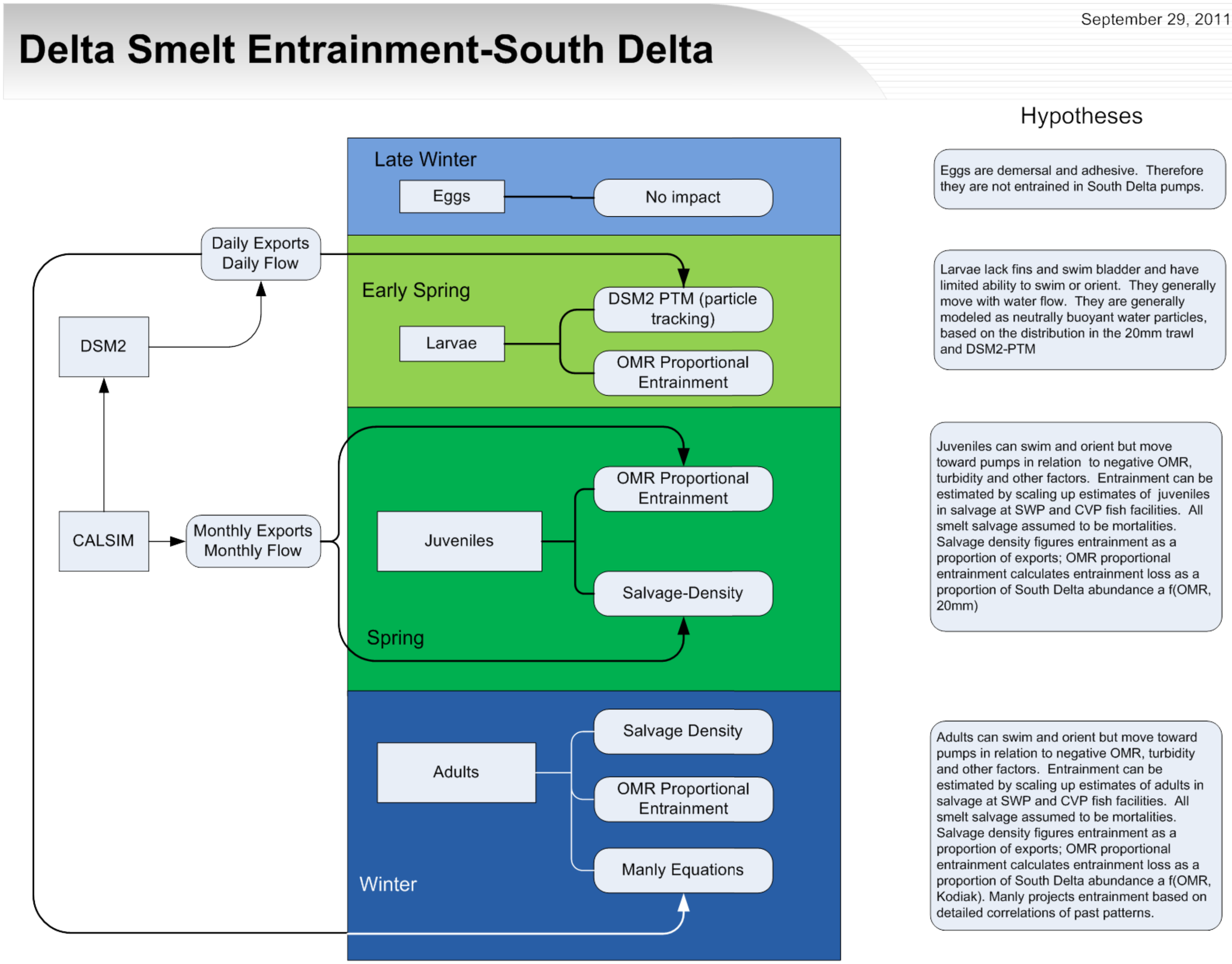


Figure A-16. Relationship between Environmental Models and their Major Outputs

A.3.3.3 Biological Models

Biological models link environmental change, often characterized by the environmental models, to the change in biological performance of life stages or species. Biological performance is typically measured as a change in abundance, survival, or physical impact such as the percentage of a life stage entrained in pumps. Many of the biological models used in the effects analysis are statistical in nature and consist of single or multinomial regressions between physical change, such as flow or exports, and life stage biological performance. Biological models are often linked to environmental models and characterize a biological change expected from the modeled change in physical conditions. Figure A-17, for example, shows the biological models used to assess entrainment impacts on delta smelt and the relationship to CALSIM II and DSM2. This figure also shows how biological models relate to specific life stages and reflect unique hypotheses about stressors and biological performance. Models used to evaluate entrainment (Appendix B) and the effects of flow, temperature, salinity, and turbidity (Appendix C) on biological performance fall into this category.



1
2 **Figure A-17. Relationship between Biological Models Used to Evaluate Entrainment and Environmental Models**

A.3.3.4 Habitat Suitability Models

Habitat suitability models (or habitat suitability index models) evaluate multiple attributes of the environment as habitat for life stages and species. The result is an index of habitat suitability where 0 indicates entirely unsuitable habitat and 1 represents ideal habitat for the life stage and species. Habitat suitability brings together knowledge of life history, key habitats, and environmental requirements to create an index of habitat quality and quantity where a quantitative life cycle-habitat model is not available. Habitat suitability models collect a variety of types of information relating to habitat requirements to create hypotheses of species-habitat relationships rather than statements of proven cause and effect relationships (Schamberger et al. 1982).

Habitat suitability models are commonly used in wildlife assessments and are used in Appendix H to evaluate impacts of the BDCP on terrestrial species. Habitat suitability models are also used to evaluate the value of restored wetland and intertidal environments (Conservation Measures 4 through 7) for covered fish species in Appendix E.

A.3.3.5 Population and Life History Models

Life history models integrate the effects of multiple stressors across multiple life stages to evaluate impacts of actions at population scales. Life history models are conceptually attractive because they offer the prospect of evaluating the effect of multiple stressors on the ultimate survival or abundance of the species (National Research Council 2011). However, life history models are not available for many species. Several life history models for salmonids are listed in Table A-8, reflecting the rich quantitative literature associated with population dynamics of salmonids (Hilborn and Walters 1992). For other covered fish species such as longfin smelt, delta smelt, splittail, and sturgeon, life history models do not exist or are still relatively new. Maunder and Deriso (2011) have developed a life history model for delta smelt that is under review (Appendix G).

A.3.3.6 Integrating Results

The analyses and results from each appendix are summarized in Chapter 5. Where available, quantitative life history models contribute to the roll-up of impacts across stressors and life stages. However, integrative models are limited and not available for many species. As a result, qualitative methods figure prominently in the roll-up of impacts for all species. The goal of the roll-up is to provide overall conclusions within a clear and documented approach. The roll-up technique is developed more fully in Chapter 5 but is described briefly here. Roll-up uses a qualitative scoring system based on the following criteria:

- The importance of the stressor to the current population dynamics of the species.
- The overlap in space and time between life stages and stressors.
- The degree of environmental impairment or biological performance affected by the stressor under baseline conditions.
- The amount of change in the environment or biological performance provided by the BDCP conservation measures and other covered activities.

Table A-9 is an example of a species stressor table that summarizes the first criterion. It is based on the DRERIP conceptual model for delta smelt developed by Nobriga and Herbold (2009). This table will contain scores of the importance of the stressor to the population ranging from 1 to 4. These scores will be based on DRERIP conceptual models and the most recent published research and analysis. Scores across rows and columns are summed and ranked to display relative ranking of life stages (columns) and stressors (rows). The rationale briefly describes the basis for the stressor rankings across life stages.

Table A-10 is an example of a phenology (distribution of species in time and space) table for delta smelt. Each subtable shows the temporal occurrence of the life stage in a geographic subregion; the diameter of the circles represents judgments regarding relative abundance of life stages across months. Color coding of the life stage rows summarizes judgments regarding the relative abundance between geographic areas across the BDCP Study Area. This table depicts phenomena that are highly variable in both time and space; it summarizes judgments regarding distribution and abundance of life stages that can be compared to the temporal and spatial distribution of stressors.

The degree of impairment in biological performance and the change resulting from the BDCP conservation measure as a result of a stressor derives from the analysis in the subsequent appendices. Scores are developed for each species and life stage and then presented in either tabular or graphic form (previous versions of the effects analysis have used a “wheel diagram” format to display similar information which may be used).

1 **Table A-9. Example of a Stressor Table for Delta Smelt**

		Score: 1–4 (most important)					
		Eggs deposited to hatching	Hatch to fully developed fins and air bladder	Actively feeding and growing	Sexually mature and maturing fish headed generally upstream	Rank of summed scores across rows	
Stressors	**Definition of Stressor**	**Eggs**	**Larvae**	**Juveniles**	**Adults**	**Stressor Rank**	**Rationale**
North Delta intakes entrainment	Entrainment and impingement of fish at proposed North Delta intake						
South Delta entrainment	Entrainment at existing South Delta intake						
North Bay aqueduct entrainment	Entrainment at North Bay Aqueduct						
Diversions (smaller diversions)	Entrainment in agricultural and small diversions throughout the Delta						
Habitat loss	Physical loss of habitat due to diking, filling or draining						
Transport flow	Flows that are moving fish through the BDCP regions at any life stage						
LSZ	Low Salinity Zone defined by position of X2						
Temperatur e	Water temperature (°C)						
Turbidity	Water clarity (NTUs)						

		Score: 1–4 (most important)					
		Eggs deposited to hatching	**Hatch to fully developed fins and air bladder**	**Actively feeding and growing**	**Sexually mature and maturing fish headed generally upstream**	**Rank of summed scores across rows**	
Stressors	**Definition of Stressor**	**Eggs**	**Larvae**	**Juveniles**	**Adults**	**Stressor Rank**	**Rationale**
Dissolved oxygen	Dissolved oxygen						
Climate change	Effect of projected changes in climate across multiple parameters						
Passage barriers	Structures that may impede or change migration patterns within the region such as the salinity control gates						
Food resources	Quantity and quality of food resources available to life stages						
Toxins	Chemical constituents of water with negative impacts on survival or behavior						
Predation	Increase in predation beyond normative levels due to species introduction or predator success						
Population effects	Hatcheries and Allee effects						
Disease	Disease						
	Life Stage Rank						

1

1 **Table A-10. Example of a Phenology Table for Delta Smelt (Hypothetical Data)**

Life Stage	July	August	September	October	November	December	January	February	March	April	May	June
Subregion: Yolo Bypass												
Eggs							•	●	⬤	⬤	●	
Larvae							•	●	⬤	⬤	●	•
Juveniles	●	⬤	•								•	•
Adults/Spawners				•	•	•	•	•	●	⬤	●	•
Subregion: Cache Slough												
Eggs							•	●	⬤	⬤	●	•
Larvae							•	•	⬤	⬤	●	
Juveniles	●	●	●							•	•	•
Adults/Spawners	•	•	●	●	●	•	⬤	⬤	⬤	⬤	●	•
Subregion: North Delta												
Eggs								•	●	⬤	●	•
Larvae								•	●	⬤	●	•
Juveniles												
Adults			•	•	•	•	•	•	●	⬤	•	•
Subregion: Western Delta												
Eggs												
Larvae									•	•	•	•
Juveniles	•	●	⬤	⬤	●	•					•	•
Adults/Spawners	•	●	⬤	⬤	●	•	⬤	•	●	⬤	●	•

Life Stage	July	August	September	October	November	December	January	February	March	April	May	June
Subregion: Suisun Bay												
Eggs												
Larvae							•	●	⬤	⬤	●	•
Juveniles	•	●	⬤	⬤	●	•					•	•
Adults/Spawners	•	●	⬤	⬤	●	•	•	⬤	⬤	●	•	•
Subregion: Suisun Marsh												
Eggs								•	●	⬤	●	•
Larvae								•	●	⬤	●	•
Juveniles	●	●	●	●							●	●
Adults/Spawners			•	•	•	•	•	⬤	⬤	●	•	•
Subregion: East Delta												
Eggs								•	●	⬤	●	•
Larvae								•	●	⬤	●	•
Juveniles												
Adults							•	•	•	•	•	•
Subregion: South Delta												
Eggs								•	●	⬤	●	•
Larvae								•	●	⬤	●	•
Juveniles	•	●	⬤	⬤	●	•					•	•
Adults/Spawners	•	●	⬤	⬤	●	•	•	•	●	⬤	●	•

Key:		
Abundant	Rare	Note: The size of the dots portrays the relative abundance of life stages in subregion in the month. The color coding for each life stage within each subregion indicates the overall abundance of the life stage relative to other subregions.
Moderate	Not Present	

2

A.3.3.7 Evaluating Effects from Multiple Methods

Table A-8 shows that multiple models and methods are used to evaluate the effects of stressors and conservation measures. For example, 10 different analytical methods are used to evaluate the physical and biological effects of entrainment (Appendix B) and 22 are used to evaluate the effects of flow (Appendix C). While these methods break down by species and life stage, nonetheless, it is clear that multiple methods and results are used to evaluate effects of stressors and conservation measures. Additionally, data may be used differently in each model and results from each method are not always directly comparable. The number of available analyses and methods available to assess the effects of entrainment and flow reflect the scientific focus on these issues in the Delta and the economic and social impact of restoration actions associated with entrainment and flow.

The integration of multiple lines and types of evidence to determine ecological risk often calls for a *weight-of-evidence* approach (Suter 1993). This approach weighs different sources of evidence, examines convergence of conclusions, and evaluates diverging information to create a structured approach to integrating multiple lines of evidence (Weed 2005). Weight-of-evidence provides a useful approach for reaching conclusions regarding BDCP impacts where multiple analyses and factors are present.

As discussed in Weed (2005), weight-of-evidence methods range from subjective to analytical. Some use a rigorous weighting scheme to evaluate different lines of evidence while others take a more narrative or qualitative approach. A common theme is that judgment plays a large role in evaluating multiple lines of evidence. As Weed points out, weight of evidence, "does not (cannot) determine the outcome; the method requires judgment. Metaphorically, judgment is the intellectual glue, cementing together the evidence and the methods."

For the BDCP effects analysis, a weight-of-evidence approach is applied based on the following factors:

- Reliability of the methods and associated data.
- Direction of conclusions for a particular model in relation conclusions from multiple models.
- Value of the metrics.

Reflecting the principles from the BDCP Science Advisors, the effects analysis is based on reliable, reviewed, and useful methods. Some analyses may not be used because the scientific support is not judged sufficient or that the method does not usefully relate to a BDCP concern (Table A-8). Direction of conclusions addresses the question, "do the available methods all indicate the same general direction of change?" For example, do the available methods all point to a decrease in entrainment under BDCP Conservation Measure 1? If the available methods all indicate the same direction of impact, then a stronger conclusion can be made regarding the type of biological response expected. The final criterion characterizes the range of values for the quantitative metrics provided by the models that will then ultimately be used to judge the magnitude of the effect to individuals and populations.

If the available methods are judged equally reliable but point to fundamentally different conclusions (i.e., a positive and negative effect), then additional judgment is required. The differences are then characterized and highlighted as priority for future research and evaluation. A judgment is made regarding a conclusion for the BDCP based on review of the models, available information, and the weight-of-evidence approach. These factors, which add more or less weight assuming that all other variables are equal, are summarized in Table A-11.

Table A-11. Factors Used to Evaluate Models with Competing Results

Factor	More Weight	Less Weight
Scientific credibility	Peer-reviewed in published literature	Unpublished with limited documentation
Usage	Widely used in the Delta or other systems (utility independently verified)	New and untested model (unverified)
Strength of conclusion	Highly statistically significant result or technically robust	Weak statistical significance or based on limited theory and data
Variability of results	Highly consistent results with different inputs (low uncertainty)	Highly variable results depending on inputs (high uncertainty)

A.3.4 Effects Analysis Analytical Structure

The BDCP effects analysis evaluates the impacts of BDCP covered activities (including conservation measures) on the biological performance of covered species. In most cases, the evaluation of BDCP effects is made by comparing the biological performance of covered species with expected environmental conditions under all BDCP conservation measures at future implementation periods to the baseline environmental conditions.

A.3.4.1 BDCP Analytical Scenarios

Baseline and conservation measure scenarios characterize an assumed set of conditions for evaluation purposes. However, actual conditions in any future year may vary from the assumed conditions in the analytical scenarios. Environmental conditions change in response to variation in precipitation, marine conditions, temperature, and ongoing habitat restoration and other actions designed to benefit covered species. Regulation of flow, exports, and other conditions can be described generally in the scenarios, but in reality, regulators exercise considerable in-season flexibility to meet environmental and management standards. Species abundance varies widely between years in response to factors affecting species across their life histories. For many species (e.g., salmonids or annual plants), key factors governing year-to-year abundance are outside the control of the BDCP.

A.3.4.2 Analysis of Covered Activities

Typically, an effects analysis for an HCP or NCCP evaluates the adverse effects of development projects or other ground-disturbing activities that seek take coverage. These adverse effects are then combined with the beneficial effects of the conservation measures to determine the net effect of all covered activities (conservation measures are also covered activities). The BDCP is unique in that the conservation measures themselves account for the majority of the covered activities and the conservation measures have both beneficial and adverse effects, depending on the covered species. To account for this structure, the effects analysis evaluates the combined effects of all covered activities, including the conservation measures, to determine the net effect of implementing the plan.

The BDCP contains 19 conservation measures that address a spectrum of aquatic and terrestrial conditions across the Study Area and all will be evaluated in the effects analysis (Table A-12). The BDCP include ten conservation measures directed at restoration of 113,000 acres of aquatic and terrestrial habitat, a single conservation measure describing dual conveyance and other flow-related actions, and eight measures dealing with water quality, predator control, and other factors. For a full description of these conservation measures, see Chapter 3, Conservation Strategy. DWR is screening and evaluating a set of alternative facilities and locations for the dual conveyance and alternative strategies for habitat restoration. A subset of these alternatives is evaluated in the EIR/EIS for the BDCP.

Collectively, the covered activities, including 19 conservation measures, comprise the "proposed project" for the BDCP. Some details of the covered activities and conservation measures are still being revised. For this reason, the conservation measures evaluated in the effects analysis are based on those in the November 2010 draft unless otherwise noted. They are referred to as the "preliminary project" and are designated "PP" in the results tables and figures in the appendices.

The measures and actions in the Planned Project are evaluated separately and in combination in the applicable appendices (Table A-12). Results are integrated in Chapter 5, as described in Section A.3.3.6.

Table A-12. BDCP-Covered Activities and Appendices

Covered Activity		Fish Covered Species Effects Evaluated in Appendix	Non-Fish Covered Species Effects Evaluated in Appendix
	Conservation Measures		
Water Flow	1-Water Facilities and Operation	B, C, J	H, J
Habitat and Natural Community	2-Yolo Bypass Fisheries Enhancement	C, J	H, J
	3-Natural Communities Protection	N/A	H
	4-Tidal Habitat Restoration	E, J	H, J
	5-Seasonally Inundated Floodplain Restoration	E, J	H, J
	6-Channel Margin Habitat Enhancement	E, J	H,J
	7-Riparian Habitat Restoration	E, J	H, J
	8-Grassland Communities Restoration	N/A	H
	9-Vernal Pool Complex Restoration	N/A	H
	10-Nontidal Marsh Restoration	E, J	H, J
	11-Natural Communities Enhancement and Management	F	H
Species-Level and Other Stressor	12-Methylmercury Management	D	N/A
	13-Nonnative Aquatic Vegetation Control	F	N/A
	14-Stockton Deepwater Ship Channel Dissolved Oxygen Levels	C	N/A
	15-Predator Control	F	N/A
	16-Non-physical Fish Barriers	B,C	N/A
	17-Hatchery and Genetic Management Plans	F	N/A
	18-Illegal Harvest Reduction	F	N/A
	19-Conservation Hatcheries	F	N/A
	Other Covered Activities		
	Operations and maintenance of existing SWP, CVP, and joint state/federal water conveyance facilities	B, C, D, G	H
	Operations and maintenance of existing Suisun Marsh facilities	B, C, D, G	H
	Monitoring and targeted research	F	H

Table Notes:
Appendix A: Conceptual Foundation and Analytical Framework
Appendix B: Entrainment
Appendix C: Flow, Salinity, Passage, and Salinity
Appendix D: Toxics
Appendix E: Habitat Restoration
Appendix F: Ecological Impacts
Appendix G: Fish Population
Appendix H: Terrestrial Species
Appendix I: Analysis Not Used
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A.3.4.3 Implementation Periods

The BDCP conservation measures will be implemented over a 50-year period. Measures will begin at different points over that period reflecting the implementation schedule in Chapter 6 (Figures 6-1 and 6-2). Over the implementation period, climate across the Study Area is expected to change at local, regional, and larger scales. Therefore, evaluations of BDCP conservation measures are made using conditions expected during four periods within the 50-year period. Analytical comparisons use all or a subset of these periods as appropriate. Evaluation periods for the BDCP effects analysis are as follows:

- **Current.** Current conditions exist prior to implementation of the BDCP.
- **Near-Term (NT) Conditions.** NT conditions are expected under the BDCP in the first 10 years of implementation. During this period, the BDCP is expected to address a substantial portion of the planned aquatic and terrestrial restoration with associated improvements in water quality and food production. Benefits will not be immediate but will accumulate as a result of time required for land acquisition and for maturation of habitat restoration actions. During this period, the dual conveyance will be constructed but no new hydrologic operations will occur. NT climate conditions in reflect physical analysis of the 2015 conditions.
- **Early Long-Term (ELT) Conditions.** ELT conditions BDCP actions from years 10 through 15. During this period, significant changes in the Delta environment will result from the BDCP. Operation of dual conveyance is expected during this period while changes to tidal, floodplain, and terrestrial environments should occur. NLT climate conditions reflect physical analysis of the 2025 conditions.
- **Late Long-Term (LLT) Conditions.** LLT conditions reflect the full implementation and maturation of BDCP actions from years 15 through 50. During this period, all planned habitat restoration should have occurred along with full application of dual conveyance and other measures. LLC climate conditions reflect physical analysis of the 2060 conditions.

A.3.4.4 Environmental Baseline Scenarios

The biological response under the conservation measures is compared to a baseline condition to define the effects of the conservation measures. The baseline condition captures the current or pre-implementation condition of the aspects of the environment relevant to each conservation measure and covered activity. Considerable complexity belies this simple definition of baseline reflecting varying legal standards and future environmental conditions. Legal directives for baseline conditions differ between CEQA, NEPA, and the federal ESA. However, these laws each require a description of existing environmental conditions to inform and develop the environmental baseline. Differences in the CEQA and NEPA baselines for determining impacts are addressed by using two baseline conditions, consistent with the two baselines used for the impact analysis in the EIR/EIS.

The BDCP baseline condition, referred to as the existing biological condition (EBC), reflects the environmental conditions of the Study Area prior to BDCP approval. These include the extent of species habitats, water quality and pollutant inputs, and water temperatures described in Chapter 2, Existing Conditions. The BDCP baseline also reflects the ecological effects of implementing the operating criteria and plan (OCAP) BOs developed by USFWS for delta smelt (2008) and NMFS for salmonids and green sturgeon (2009). These actions were added to the regional water operations structure previously required under Decision 1641 provisions of the State Water Resources Control

Board (State Water Board) (1999), including the Vernalis Adaptive Management Program. The BDCP baseline does not include water operation agreements that are currently being negotiated.

To reflect the differing regulatory directives for baseline, two EBC conditions are included in most analyses (Table A-13). EBC1 reflects the CEQA requirements. In CEQA, the environmental baseline is defined as the physical conditions that exist at the time the Notice of Preparation (NOP) is published. For the BDCP, this baseline condition is defined as when the NOP was revised February 13, 2009, and includes provisions of the 2008 and 2009 OCAP BOs as they have been implemented up to this point. Table A-13 describes the provisions of the 2008 and 2009 BOs that are not assumed in the baseline condition because their implementation requires additional environmental documentation and in some cases, permitting. Component 3, Action 4 of the USFWS Reasonable and Prudent Action (referred to as fall X2) requires that the X2 position be maintained by increasing Delta outflow during wet and above normal water year types, but this provision has not been triggered due to recent dry hydrologic conditions. Because in 2009 implementation of the fall X2 provisions was not a requirement of the BOs (in part, due to ongoing litigation), they are not included in the CEQA baseline (EBC1).

EBC2 captures the requirements of the ESA Section 7 that requires the baseline to include the impacts of all past and present federal, state, and private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects that have undergone Section 7 consultations, and the impacts of state or private actions that are contemporaneous with the consultation in process. Thus, EBC2 assumes that the fall X2 provisions will be implemented. EBC2 also satisfies the NEPA baseline. Under NEPA, the baseline language allows for more flexibility than under CEQA to reflect existing environmental conditions, including the effects of past and ongoing actions that would exist without the proposed action (sometimes referred to as the No Action Alternative conditions) and is typically considered the same as the ESA Section 7 baseline.

Table A-13. Description of Environmental Baseline Conditions for Evaluation of BDCP Alternatives

Baseline Scenario	Regulatory Basis	Description
EBC1	CEQA	2008 USFWS BO and 2009 NMFS BO, but without Fall X2
EBC2	ESA Section 7 and NEPA	2008 USFWS BO and 2009 NMFS BO

In addition to these regulatory considerations for defining base conditions, the analysis considers the effects of climate change expected over the implementation period. Because of this, additional future baseline conditions were defined for ELT and LLT periods. These additional baseline conditions are especially relevant to the analysis of entrainment (Appendix B) and flow (Appendix C). At this time, these future baseline conditions are only defined for the EBC2 scenario and are reflected in the CALSIM II and DSM2 model runs incorporated into the analyses in Appendices B and C.

Table A-14. Actions Identified under USWFS and NMFS BOs that are Excluded from Baseline Conditions (EBC1 and EBC2)

Biological Opinion	Program
US Fish and Wildlife Service	Component 3 (Action 4): Fall X2. X2 position be maintained by increasing Delta outflow during wet and above normal water year types. *EXCLUDED FROM EBC1; INCLUDED IN EBC2.*
US Fish and Wildlife Service	Component 4: Habitat Restoration - Action 6: A program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh shall be implemented. A monitoring program shall be developed to focus on the effectiveness of the restoration program.
National Marine Fisheries Service	Action I.3.5. Measures to Compensate for Adverse Effects of Interim Operations on Spring-Run Reclamation shall provide $500,000 for implementation of spring- run passage improvement projects in the Sacramento River.
National Marine Fisheries Service	Action I.5. Funding for CVPIA Anadromous Fish Screen Program (AFSP) Reclamation shall screen priority diversions as identified in the CVPIA AFSP.
National Marine Fisheries Service	Action I.6.1. Restoration of Floodplain Rearing Habitat In cooperation with Department of Fish and Game (DFG), USFWS, NMFS, and the US Army Corps of Engineers (USACE), Reclamation and DWR shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type.
National Marine Fisheries Service	Action I.7. Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass By December 31, 2011, as part of the plan described in Action I.6.1, Reclamation and/or DWR shall submit a plan to NMFS to provide for high quality, reliable migratory passage for Sacramento Basin adult and juvenile anadromous fishes through the Yolo Bypass. By June 30, 2011, Reclamation and/or DWR shall obtain NMFS concurrence and, to the maximum extent of their authorities, and in cooperation with other agencies and funding sources, begin implementation of the plan, including any physical modifications. By September 30, 2009, Reclamation shall request in writing that the USACE take necessary steps to alter Fremont Weir and/or any other facilities or operations requirements of the Sacramento River Flood Control Project or Yolo Bypass facility in order to provide fish passage and shall offer to enter into a Memorandum of Understanding, interagency agreement, or other similar mechanism, to provide technical assistance and funding for the necessary work.
National Marine Fisheries Service	Action II.3. Structural Improvements Reclamation shall evaluate physical and structural modifications that may improve temperature management capability [Folsom Dam Temperature Control Device, Cold Water Transport through Lake Natoma, El Dorado Irrigation District Temperature Control Device].
National Marine Fisheries Service	Action II.6.1. Preparation of Hatchery Genetic Management Plan (HGMP) for Steelhead Reclamation shall fund DFG to prepare a complete draft HGMP for steelhead production at Nimbus Fish Hatchery, in accordance with current NMFS guidelines, and submit that draft for NMFS review by June 2011. Action II.6.3: Develop and Implement Fall-run Chinook Salmon Hatchery Management Plans for Nimbus and Trinity River Fish Hatcheries By June 2014, develop and begin implementation of Hatchery Management Plans for fall-run production at Nimbus Fish Hatchery and spring-run and fall-run at Trinity River Fish Hatchery. (These actions may have been addressed in recent EIR/EIS).

Biological Opinion	Program
National Marine Fisheries Service	Action IV.4.1 Tracy Fish Collection Facility (TFCF) Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency Reclamation shall undertake the following actions at the TFCF to reduce pre-screen loss and improve screening efficiency: 1) By December 31, 2012, improve the whole facility efficiency for the salvage of Chinook salmon, CV steelhead, and Southern DPS of green sturgeon so that overall survival is greater than 75 percent for each species. a) By December 31, 2011, Reclamation shall complete studies to determine methods for removal of predators in the primary channel, using physical and non-physical removal methods...By December 31, 2012, Reclamation shall implement measures to reduce pre-screen predation in the primary channel to less than ten percent of exposed salmonids. b) By March 31, 2011, Reclamation shall complete studies for the re-design of the secondary channel to enhance the efficiency of screening, fish survival, and reduction of predation within the secondary channel structure and report study findings to NMFS...Reclamation shall initiate the implementation of the study findings by January 31, 2012....
National Marine Fisheries Service	Action IV.4.2 Skinner Fish Collection Facility Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency DWR shall undertake the following actions at the Skinner Fish Collection Facility: ... a) On or before March 31, 2011, improved predator control methods. Full compliance shall be achieved by March 31, 2014.
National Marine Fisheries Service	Action IV.4.3 Tracy Fish Collection Facility and the Skinner Fish Collection Facility Actions to Improve Salvage Monitoring, Reporting and Release Survival Rates Reclamation and DWR shall undertake the following actions at the TFCF and the Skinner Fish Collection Facility, respectively. Actions shall commence by October 1, 2009, unless stated otherwise.... 3) Release Site Studies shall be conducted to develop methods to reduce predation at the “end of the pipe” following release of salvaged fish.... 4) By June 15, 2011, predation reduction methods shall be implemented according to analysis in 3.
National Marine Fisheries Service	NF 4.1. Adult Fish Collection and Handling Facilities Beginning in 2012, Reclamation...shall design, construct, install, operate and maintain new or rebuilt adult fish collection, handling and transport facilities at the sites listed below. The objective is to provide interim facilities to pass fish above project facilities and reservoirs.
National Marine Fisheries Service	NF 4.2. Adult Fish Release Sites above Dams and Juvenile Fish Sites Below Dams Reclamation shall provide for the safe, effective, and timely release of adult fish above dams and juvenile fish below dams. The Fish Passage Plan must identify and release sites. Fish transport and release locations and methods shall follow existing State and Federal protocols. With assistance from the Steering Committee, and in coordination with applicable landowners and stakeholders, Reclamation shall complete construction of all selected sites by March 2012.
National Marine Fisheries Service	NF 4.3. Capture, Trapping, and Relocation of Adults By March 2012, Reclamation shall implement upstream fish passage for adults via “trap and transport” facilities while it conducts studies to develop and assess long-term upstream and downstream volitional fish passage alternatives. At least one fish facility must be in place at terminal upstream passage points for each river that is subject to this measure. Facilities to capture adults currently exist at or below Keswick and Nimbus Dams, though these may need to be upgraded.

Biological Opinion	Program
National Marine Fisheries Service	NF 4.4. Interim Downstream Fish Passage through Reservoirs and Dams Beginning in 2012, following the emergence of the first year class of reintroduced fish, and until permanent downstream passage facilities are constructed or operations are established at Project dams, Reclamation shall carry out interim operational measures to pass downstream migrants...
National Marine Fisheries Service	NF 4.5. Juvenile Fish Collection Prototype Beginning in January, 2010, with input from the CVP/SWP operations Fish Passage Steering Committee, Reclamation shall plan, design, build, and evaluate a prototype head-of-reservoir juvenile collection facility above Shasta Dam. Construction shall be complete by September 2013.
National Marine Fisheries Service	LF 2.1. Long-term Adult and Juvenile Fish Passage Facilities ...Reclamation shall construct long-term fish passage facilities necessary to successfully allow upstream and downstream migration of fish around or through project dams and reservoirs on the Sacramento and American Rivers by 2020, and Stanislaus River depending on results of study provided for in Action NF 4.7.
National Marine Fisheries Service	LF 2.2. Supplementation and Management Plan ...Reclamation shall develop and implement a long-term population supplementation plan for each species and fish passage location identified in V. *Fish Passage Program*, with adult recruitment and collection criteria...The plan shall be developed by 2020.
National Marine Fisheries Service	LF 2.2. Supplementation and Management Plan ...Reclamation shall develop and implement a long-term population supplementation plan for each species and fish passage location identified in V. *Fish Passage Program*, with adult recruitment and collection criteria...The plan shall be developed by 2020.

A.3.4.5 Climate Change

Over the course of the BDCP implementation period, regional climate is expected to change in California in complex and not entirely predictable ways (Hayhoe et al. 2004; Cayan et al. 2009) independently of the BDCP. However, it is likely that expected climate change will affect the biological impacts of the BDCP, and for this reason, projected climate change is incorporated into the preliminary proposal for the implementation periods described in Section A.3.4.2. Appendix XX has a detailed description of the predicted changes in climate in California and the Bay-Delta region.

ELT conditions for the PP scenarios incorporate expected climate change by 2025, while the LLT scenarios incorporate climate change conditions expected in 2060. Climate change is expected to increase temperature and raise sea levels in the BDCP Study Area. Precipitation change is expected to be more variable across the region and is difficult to predict. However, most projections point to an increase in precipitation in the northern Sacramento Basin and a decrease in precipitation in the southern San Joaquin Basin. The general assumptions used for climate change effects on temperature, precipitation, and sea level rise are presented in Table A-15 (see Appendix C for a description of how these assumptions were derived and used). These assumptions are incorporated into the CALSIM II model, and therefore, in entrainment (Appendix B) and flow (Appendix C) analyses that are based on CALSIM II.

Not all environmental effects of climate change can be modeled or incorporated into the effects analysis quantitatively. For example, the modeling assumes no change in tidal amplitude but this may increase as a result of climate change. Climate change effects are also not modeled or taken into account for covered non-fish species because of the uncertainty in specific effects on habitat distribution and quality. However, expected or potential effects of climate change the covered species that could not be modeled will be described qualitatively in the appropriate appendix.

Table A-15. Climate Change Assumptions in the BDCP CALSIM II Analysis

	Change relative to 1971–2000*	
Parameter	**Early Long-term (ELT)-2025**	**Late Long-term (LLT)-2060**
Annual Temperature	+ 0.7-1.4°C	+ 1.6-2.7°C
Flow	Intermediate	Peak flow moved 1-2 months earlier
Sea Level	+ 15 cm (6 inches)	+ 45 cm (18 inches)

* See Appendix C for a description of how these assumptions were derived and incorporated into the CALSIM II model.

A.3.4.6 Water Years

Inflow to the Delta from the Sacramento and San Joaquin Rivers is highly variable, reflecting annual variation in precipitation, regional climate trends, and hydrologic operations. As discussed above, water management changes between years to accommodate a variety of water needs. To reflect the range of flows expected over the BDCP implementation period, the analysis uses flow conditions over the 82-year CALSIM II base period averaged to reflect 5 water year types throughout the Plan Area (on the Sacramento River, San Joaquin River, and their tributaries). These water year types have been established by DWR for hydrologic analysis (DWR 2009b). For those actions that are affected by flow, a range of water year conditions are used to capture the array of impacts across water conditions. The analysis evaluates the change in biological condition resulting from BDCP actions for each of the following water year types:

- Critical (occur in 12 years out of the 82-year base period, or 15% of the time)
- Dry (18 years of 82, or 22%)
- Below Normal (14 years of 82, or 17%)
- Above Normal (12 years of 82, or 15%)
- Wet (26 years of 82, or 32%)

A.3.4.7 Additional Analyses to Support Federal Consultations

As described in Section A.2, Conceptual Foundation, an important purpose of the effects analysis is to support the USFWS and NMFS ESA Section 7 consultation in order to issue the ESA Section 10 permits. Reclamation will also use the effects analysis to consult with USFWS and NMFS for their own actions covered by the BDCP. As part of its responsibilities, NMFS must ensure that their actions are consistent with the Magnuson-Stevens Fishery Management and Conservation Act and the conservation of essential fish habitat.

To support these federal consultations and analyses, the BDCP effects analysis evaluates the effects of BDCP on designated critical habitat and essential fish habitat. Critical habitat has been designated for five covered fish species (Central Valley steelhead, winter-run Chinook salmon, spring-run Chinook salmon, delta smelt, and green sturgeon), three wildlife species (California tiger salamander, vernal pool tadpole shrimp, and vernal pool fairy shrimp), and six covered plants

(Contra Costa goldfields, Antioch Dunes evening primrose, soft bird's-beak, Suisun thistle, and Contra Costa wallflower). (Note: Contra Costa goldfields is likely to be added as a covered species). The assessment of critical habitat describes the effects of the BDCP on the primary constituent elements of each species by life stage, if appropriate, to determine whether adverse modification would occur. Effects on primary constituent elements are quantified where possible using the models and tools described in Table A-1.

The effects analysis also provides a qualitative assessment of the effects of BDCP actions on the endangered southern resident killer whale, which is not a covered species. This species occurs in the Pacific Ocean outside San Francisco Bay and feeds on salmonids that pass through the Plan Area. This assessment supports the internal consultation by NMFS and their consultation with Reclamation.

Federal consultations also require an assessment of the effects of BDCP when combined with cumulative effects of past, present, and reasonably foreseeable future actions. The BDCP effects analysis addresses the cumulative effects of activities not subject to future Section 7 consultations (i.e., actions with no Federal nexus) that could result from individually minor but collectively significant actions that take place over time. The reasonably foreseeable future actions will be developed consistent with the NEPA analysis for the EIR/EIS.

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A.4.2 Personal Communications

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Kelly, Katherine. Chief, Bay-Delta Office. California Department of Water Resources, Sacramento, CA. September 28, 2011—Email to Bill Harrell, Executive Policy and Science Advisor, Delta and Statewide Water Management, California Department of Water Resources, Sacramento, CA.