BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS' REPORT

ON

ADAPTIVE MANAGEMENT

Prepared for
BDCP Steering Committee

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Executive Summary

This report summarizes recommendations from a group of independent scientists (Advisors; Appendix A) convened in December 2008 (Appendix B) concerning incorporation of adaptive management into the Bay Delta Conservation Plan (BDCP). The report includes a general review of pertinent BDCP documents and a recommended framework for incorporating adaptive management into the planning, design, and implementation of the BDCP.

Comments on BDCP Documents

It is clear from documents reviewed by Advisors (Appendix C) that efforts to develop an Adaptive Management Program (AMP) for BDCP are in their early stages. The documents show progress toward defining the elements of an AMP but lack several elements essential to effective adaptive management. The incomplete state of the documents made it difficult to evaluate the plan's scientific foundations, and many statements in the documents suggest a need to more fully assimilate and apply existing knowledge about the Delta to the development of conservation measures and the AMP.

The Advisors offer the following general comments and recommendations:

<u>Existing Knowledge and Peer Review</u> - Far more is known about the Bay-Delta ecosystem than is suggested by the BDCP documents we reviewed. The extensive knowledge base about the Delta should be fully exploited in selecting and designing BDCP actions. The omission of critical knowledge about the functioning of the Bay-Delta ecosystem also indicates the need for more development of the conservation plan itself. **We strongly recommend that technical documents that form the basis of the BDCP be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

<u>Goals and Objectives</u> - We agree that goals and objectives should be placed within a hierarchy of ecosystems, communities, and species. However, most objectives stated in the documents, and the conservation measures meant to address them, apply only to the species level. **We recommend developing explicit community and ecosystem objectives to reflect the hierarchical approach described in BDCP documents.**

<u>Modeling</u> - Models are extremely valuable for formalizing the link between objectives and proposed conservation measures to clarify how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is largely missing from BDCP documents we reviewed. **We recommend more extensive and explicit use of models to formalize knowledge about the system and to select, design, and predict outcomes of conservation measures to be implemented and monitored.**

<u>Feedback</u> – Formal processes for devising actions to maximize learning, and for assimilating new knowledge to provide the feedback that is key to adaptive management, were not discussed in the documents. **We recommend that greater attention be given to the learning value of actions, and to establishing a formal process by which new knowledge is used to alter actions or revise goals or objectives.**

Integration - The documents reviewed by the Advisors did not link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among these clearly related actions. **We recommend the development of models to show clearly how various actions relate and how interactions will be integrated across multiple conservation measures and the entire adaptive management process.**

Guidance for a Robust Adaptive Management Program

Effective adaptive management includes several key steps, some of which are not included in the documents we reviewed. Adaptive management does far more than simply adjust actions as new information becomes available (which is merely common sense). It is a more comprehensive process of deciding how to choose initial actions in the face of uncertainty and systematically learning and evaluating how the manipulated system responds to those activities so that changes can be made as events unfold. Key missing elements of adaptive management in BDCP documents include (1) the formal setting of goals *based on problems to be addressed*, (2) the establishment of objectives (as distinct from goals), and (3) the use of conceptual or simulation models to bring the knowledge base to bear on the problems to be solved and predict outcomes of conservation actions. In addition, (4) monitoring must be more clearly and formally designed to establish criteria to evaluate effectiveness, and (5) monitoring results must be analyzed and assimilated to provide the information necessary for the feedback critical to adaptive management. Most critical are the succeeding steps (6) of capturing and interpreting information from monitoring and other sources to evaluate how the actions are working, what they are accomplishing, and how the knowledge base is changing. These critical steps require substantial investment in time, people, and resources.

We suggest that particular attention be paid to the following:

The Adaptive Management Approach - The form of adaptive management to apply (active vs. passive)[1] to a given conservation measure depends on the scope of the measure and its degree of reversibility. In the design phase, it is important to recognize where an adaptive management strategy resides on the active-to-passive spectrum.

Knowledge Base - The knowledge base comprises the scientific understanding of a system; it should be used to identify likely influences of conservation measures on the ecosystem and the degree of confidence in those influences. It provides the context for establishing goals and objectives, the information base for models, and the foundation for selecting, designing, and monitoring conservation measures.

Assessment and Synthesis - Assessment is critical to making monitoring useful. In the adaptive management framework, monitoring provides a quantitative basis for analysis, synthesis, and evaluation of knowledge to support management decisions.

[1] Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management is not experimental, but is nevertheless approached from a scientific perspective to improve knowledge and adapt strategies during project implementation.

Continual Assimilation of Knowledge and Decision Making - The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from implementation and other sources to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring. This step must be much more fully developed than was evident in the BDCP documents we reviewed. Responsibility for this step should be assigned to a highly skilled agent (person, team, office) having the right mix of policy and technical expertise. This investment is critical to making adaptive management effectively support the BDCP.

1 Introduction

This report presents recommendations from a multidisciplinary group of independent science advisors concerning the use of adaptive management in the development and implementation of the Bay Delta Conservation Plan (BDCP). The advice and recommendations are intended not to question or promote particular plan goals or policies, but to provide guidance for incorporating adaptive management into the BDCP.

The group of nine advisors (Appendix A) was convened by the BDCP Steering Committee at a facilitated workshop held on December 17-19, 2008 (Appendix B). Prior to the workshop, advisors were provided with several draft BDCP documents for review (Appendix C). Comments in this report are based on the documents we reviewed and brief discussions with representatives of the BDCP planning team, who presented overviews of the emerging plan and important unresolved issues during two open sessions at the workshop.

Because the draft documents provided to us were in an early stage of development and did not describe a comprehensive Adaptive Management Program (AMP), we did not evaluate them in detail as a finished plan. Rather, we focused our effort on providing guidance for structuring an AMP for the BDCP that would support effective application of existing and evolving scientific understanding to BDCP decisions both before and during its implementation.

Section 2 articulates eight principles that we suggest be used as a foundation for the BDCP AMP. Section 3 incorporates these fundamental principles into an adaptive management framework tailored specifically to the BDCP and describes key elements of that framework. Appendix D provides two detailed examples of how draft BDCP conservation measures could be revised to better reflect the suggested framework.

2 Principles for Adaptive Management

The following principles for effective adaptive management emerged from our deliberations and are integral to our proposed adaptive management framework (see Section 3):

1. The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g., "active" or experimental adaptive management versus "passive" adaptive management).
2. The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.
3. Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.

4. Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.
5. Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.
6. Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.
7. Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
8. A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.

In the following section we expand on these principles and provide details of the proposed adaptive management framework.

3 Framework for Adaptive Management

Figure 1 presents a framework for incorporating adaptive management into the planning, design, and implementation of the BDCP. The framework is based on previously developed adaptive management frameworks, but has been refined to make key aspects of the process more explicit and to tailor the approach to the needs of the BDCP. The framework is specifically intended to improve the approach described in the draft BDCP documents and to avoid shortcomings of many previous AMPs. **We recommend adopting this refined framework to guide BDCP planning and implementation.**

In the following sections we detail elements of this adaptive management framework, while expanding on the principles presented in Section 2. Appendix D provides two detailed examples of how elements of the proposed BDCP Conservation Measures might correspond to the elements of the diagram and be guided by the proposed framework and principles.

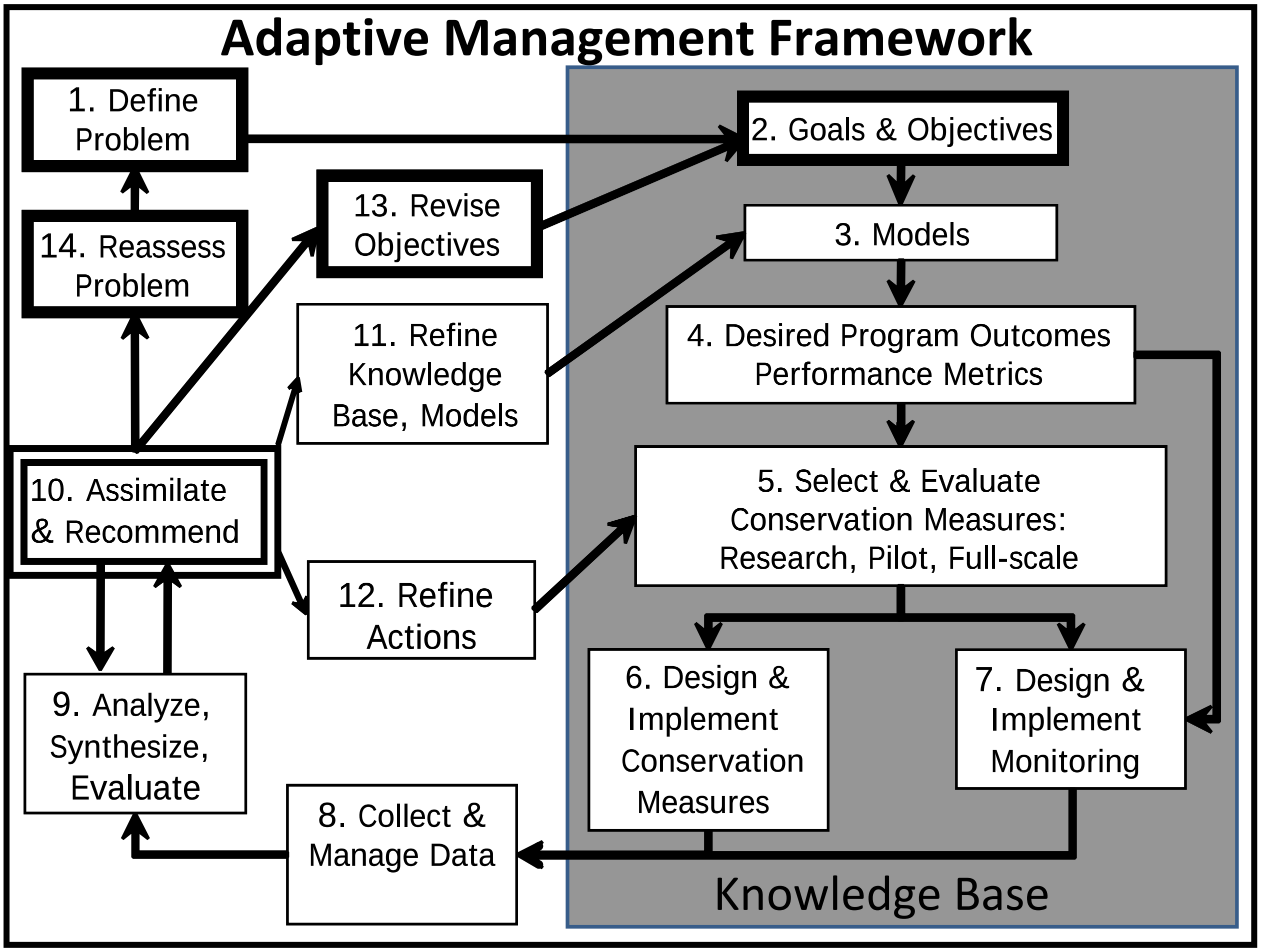

Figure 1. *A recommended AMP framework for BDCP showing the flow of information and responsibilities of different entities.* The large shaded box underlying the right side of the figure represents the knowledge base for defining goals and objectives, designing predictive models, predicting outcomes, identifying performance metrics, and designing and implementing conservation measures and monitoring actions. Boxes framed with thin lines represent tasks performed by technical staff, such as scientists, land and water managers, and other analysts. Boxes framed with bold lines represent tasks performed by senior decision makers (i.e. policy makers and program managers who control program objectives and funding). The box framed with double lines (Box 10) represents a key step that is missing from most AMPs: Assimilate and Recommend. This task requires a body of skillful "polymaths" who understand both the technical and policy implications of the information passed along by technical staff (who analyze, synthesize, and evaluate monitoring and other data; Boxes 8 and 9). The task represented by Box 10 is to assimilate this diverse information, understand its consequences, and formulate recommendations to both the senior decision makers and the technical staff, such as revising plan objectives or conservation measures.

3.1 Form of Adaptive Management (Principle 1)

The literature on adaptive management defines two broad categories: active and passive. Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management refers to actions that are not experimental, but that are nevertheless approached from a scientific perspective in order to improve knowledge and adapt strategies during project implementation.

The form of adaptive management applied to a given conservation measure depends on the scope of the measure and its degree of reversibility. At one extreme, there is only one Delta, ruling out simultaneous replication of actions that broadly affect the system. In addition, some conservation measures, such as major investment in an around-Delta conveyance, are unlikely to be reversed, so temporal replication is also impossible. In such circumstances, monitoring of processes and of system responses to natural and managed events form the basis for learning, as is the case in various non-experimental sciences. At the other extreme, there are many opportunities for experimental manipulation to achieve goals while simultaneously learning. For example, gates on Delta tidal channels could be operated on a schedule intended to produce contrasts with predictable and testable consequences. It is crucial to recognize that passive adaptive management differs from active only in the use of experimental manipulations and the consequently greater power to detect the influence of the manipulations. Otherwise, these two forms of adaptive management proceed according to identical principles and processes, as outlined in Figure 1. Note also that research aimed at particular sources of uncertainty can be part of an adaptive management program (Box 5 in Figure 1).

3.2 Applying the Knowledge Base (Principle 2)

The knowledge base (large gray box in Figure 1) is key to decisions about what conservation measures might be implemented and what responses to monitor. It forms the foundation for all steps from formulation of goals and objectives (Box 2) to the selection, design, and implementation of conservation measures and monitoring (Boxes 6 and 7). The knowledge base comprises the scientific understanding of the system and is used to identify likely influences of conservation measures on the ecosystem. It also includes knowledge of the feasibility, costs, and probable external implications of projects for the broader society and economy of the region. The knowledge base provides the context for establishing goals and objectives, the source of information for models used to project conservation outcomes, and the basis for believing that an action will have a certain outcome. The knowledge base is continually updated as new information becomes available and as adaptive management proceeds.

Far more is known about the Bay-Delta ecosystem than is suggested by BDCP documents we reviewed, which strongly emphasized (1) uncertainties about the system, (2) a central role for hypothesis testing, and (3) the role of monitoring data in reducing uncertainties. We certainly do not discount the importance of these issues, but point out that the extensive knowledge base about the Delta and the planning context should be fully exploited in selecting and designing BDCP actions. Enough is known about the Bay-Delta ecosystem, or can be inferred from studies of other systems, to conclude that:

1. Certain outcomes can be predicted with confidence[2].
2. Most scientific knowledge about the Delta has been derived by approaches other than hypothesis testing (e.g., analysis of monitoring data, modeling, and parameter estimation).
3. Not all pertinent knowledge comes from regular monitoring; knowledge may also stem from short, targeted field campaigns and observations in single natural events that cannot be replicated.
4. Monitoring adds no knowledge without a dedicated process for data management and analysis.

A thorough understanding of the knowledge base is essential for modeling, monitoring, and other actions to be efficiently focused on reducing key uncertainties.

For this plan to incorporate “best available scientific information” requires that the components of the overall knowledge base used for each step in the process be synthesized and referenced. The information in the knowledge base should be used according to a hierarchy that emphasizes peer-reviewed science and other formal evaluations. Published papers should be given the greatest weight (especially highly influential or often-cited, and therefore highly scrutinized and replicated papers), followed by unpublished papers, technical reports, newsletter articles, and presentations or personal communications from experts. Review or summary articles can be used in lieu of extensive lists of publications. Personal communications should be cited with the name and affiliation of the person and the date of the communication. Local knowledge of experts or stakeholders is also an important component of the knowledge base, even if not published, but such knowledge should be recorded explicitly so that it can be reviewed.

Although peer review is the gold standard of scientific publication, it may not always provide assurances as to the quality of the data or the accuracy of statistical analyses, since reviewers rarely have time to replicate reported analyses or examine raw data. Therefore studies used as a basis for significant decisions should be thoroughly checked and analyses replicated if possible.

Data used in analyses must have undergone a quality assurance check. Generally this is done routinely for widely-used data, such as daily flows, salinity, and fish abundance indices. Documents using the knowledge base should promote transparency by explaining clearly what we know and how we know it, with full citations to the sources of information (e.g., papers, data sets, websites, personal communications with affiliation) and ensuring that these are readily available (e.g., posting technical reports on websites).

The incomplete state of the draft BDCP documents we reviewed made evaluation of scientific content of the plan difficult. However, many statements in these documents suggest an incomplete knowledge of the Delta among the project team. For example:

- Literature citations were sometimes inaccurate (e.g., Handout #5 lines 41-45: "highly productive" and similar statements are not true and not stated in the reference).

[2] For example, field studies in the California Bay-Delta and elsewhere indicate that restoring intertidal marsh will increase carbon input to estuarine food webs for well-understood biogeochemical reasons, although monitoring and research would be essential to show the magnitude of this input and its long-term fate.

- Inappropriate citations were used (e.g., the use of Kimmerer 2004 to support a statement about tidal marshes and sea-level rise on page 2-43 of the March 2008 Draft Existing Ecological Conditions Chapter and Covered Species Accounts).
- Often the most recent published findings were not used (e.g., Feyrer et al., 2007).
- Unpublished data and presentations appear to be given equal weight to published findings (e.g., Handout #5 page 28 line 33).
- Several statements fail to reflect the current state of knowledge or provide little substantive foundation, for example, in handout #4 page 14:
  - Lines 41-42: "These zooplankton can reduce phytoplankton to very low concentrations, resulting in a clear water state" is poorly supported by the citations provided. In fact, published work indicates that phytoplankton biomass in the Delta is rarely if ever limited by zooplankton (Kimmerer 2004).
  - Line 35: "Additionally, the statistical analyses used in this paper may be questionable" should be amplified and supported by reference to specific work.

Note that these and several other examples in Appendix D are presented only to illustrate a broad and pervasive problem identified by the Advisors in the documents that were provided. **We recommend that the technical documents that form the basis of the BDCP plan and conservation actions be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

3.3 Problem Statement Leads to Goals and Objectives (Principle 3)

A clear problem statement should link directly to program goals, which in turn are linked to specific objectives. The BDCP documents we reviewed generally failed to distinguish among these elements. The CALFED Ecosystem Restoration Program (ERP) Strategic Plan defines goals and objectives for ecosystem restoration, which BDCP planners might find helpful.

The problem statement specifies the issue or concern that proposed conservation measures are intended to solve or mitigate. If the problem is not stated clearly, the linkages to everything else in the adaptive management framework will be weak or inconsistent, compromising the entire approach.

Goals are broad, general intentions or visions for some aspect of the system. Goals propose broad solutions and encapsulate desired future conditions. For example, a central problem statement for BDCP is that some native fishes are in danger of extinction. One goal therefore is to restore the abundance of those species (ERP Goal 1). However, declines in each species may be linked to broader, systemic problems. Therefore, additional goals call for rehabilitation of natural processes (Goal 2) and habitats (Goal 4), and reductions in the rate of introduction of new species (Goal 5) and in contaminant effects (Goal 6). The last two goals are included regardless of whether a quantitative link can be made to the abundance of a particular species, because it is widely believed that accomplishing these goals is highly likely to favor several species and other societal preferences.

Objectives are specific, often quantitative, statements of outcomes that reflect the goals that the program is expected to achieve. Some objectives can be stated as quantitative targets for species or locations in a hierarchical arrangement (see Figure 4-2 of the CALFED ERP Strategic Plan). However, given uncertainties, it is not yet possible to develop quantitative conservation objectives for many species, communities, or processes, so many objectives must be stated in qualitative form. Nevertheless, as information accumulates, objectives can be refined and made progressively more quantitative. This step need not always await monitoring data, because predictive models applied within the context of the knowledge base can also assist in developing quantitative objectives (Box 3 in Figure 1).

Note that objectives for different species or communities may conflict or require tradeoffs (for example, altering flows to benefit one species may harm another). Such conflicts should not preclude development of objectives for each species or community. Rather, it would be beneficial to explicitly articulate such competing objectives and thereby highlight tradeoffs implicit in planning and management decisions.

We strongly recommend that the problem, goals and objectives, and the linkages among them, be clearly articulated steps in the process. The Advisors agreed with the approach of placing goals and objectives within the hierarchical scaling framework of ecosystems, communities, and species that was included in the draft BDCP Goals and Objectives documents. Careful consideration of program objectives within this context may help identify possible undesirable interactions and minimize conflicts among objectives that might occur if developed independently at the species level. In fact, most examples of objectives in the draft BDCP documents address individual species, with less attention to community and ecosystem level objectives. Thus, they fail to address the array of potential conflicts among objectives. Although the advisors encourage the continued inclusion of these species-specific objectives in the plan, **we recommend development of explicit community and ecosystem objectives to reflect the hierarchical approach described in the BDCP documents.**

3.4 Use of Models (Principle 4)

Models (Box 3) are used to formalize and apply the knowledge base, develop expectations, assess the likelihood of success, and identify tradeoffs. In particular, models should be used to formalize the link between objectives and proposed conservation measures to make clear how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is missing from the BDCP documents we reviewed, except for mention of hydrodynamic and particle tracking models. The use of models would make more explicit the relative potential benefits of different conservation measures and how they may interact (conflicts, tradeoffs, or synergies). Our impression on reviewing the BDCP documents is that this formal analytical step was skipped in jumping directly from objectives to potential conservation measures.

The types of models used in adaptive management should include at least conceptual, statistical, and process models. Conceptual models are used to make clear the expected links between actions and outcomes, the roles of other factors, the degree of confidence in the outcomes, and potential tradeoffs (e.g., among species or alternative conservation measures). The roles of conceptual models are described in Chapter 3 and Appendix B of the ERP Strategic Plan and the uses of conceptual diagrams (as components of conceptual models) are explained at http://ian.umces.edu/pdfs/stc_2008_conceptualdiagrams.pdf. A formalized approach to the development of conceptual models has been developed under the auspices of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and should be used to guide the development of any additional conceptual models needed for the BDCP. Statistical models may allow us to characterize empirically how a system works. However, statistical models may not allow us to predict all system responses, because they apply only within the range of conditions over which data have been collected.

Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond available data), although model calibration and validation of process models are more challenging than for statistical models[3]. Process models should be used increasingly as the knowledge base becomes more diversified and complex. Process models (e.g., population models, particle tracking models) express the mechanisms responsible for the relationships in conceptual models as mathematical equations and can incorporate uncertainty and system variability. Process models are especially useful in analyzing complex actions and developing plans for irreversible changes to the system (e.g., an around-delta conveyance). Given the expense and potential for unforeseen consequences of large-scale permanent changes to the system, process model simulations offer a relatively inexpensive way of anticipating problems and developing operational criteria or other design elements to minimize problems.

Process models also provide a powerful tool for refining reversible actions. For example, BDCP action FLOO1.1 (Yolo Bypass) includes a reference to varying operations to "adaptively manage" floodplain conditions and extensive monitoring to track changes. Such post-hoc monitoring will likely have low power to detect effects given background variability. Enough is known about this system to develop process models to forecast the magnitude of effects of these manipulations and maximize the value of the manipulation and the monitoring. Modeling will allow calculations of the monitoring effort needed to detect effects and comparisons between expectations and observations during the manipulations.

3.5 Desired Program Outcomes and Performance Metrics (Principle 5)

A key component of our proposed adaptive management framework is definition of measurable outcomes and associated performance metrics (Box 4 in Figure 1) that are directly related to the programmatic objectives via models (Box 3 and Section 3.4). These measurable outcomes and performance metrics are critical for several reasons. First, they document desires and expectations about how the system could function in the future following implementation of conservation measures. Second, they are used to track progress toward meeting the objectives. Third, they help define the monitoring essential to the evaluation of any chosen conservation measure. Measurable outcomes can be predicted using models (see Section 3.4). Each outcome should have at least one associated performance metric, a target for successful achievement of

[3] See BDCP Independent Science Advisors Report, November 2007 for a more detailed description of the potential application of statistical and process models to BDCP issues.

that outcome, a monitoring program designed to identify progress toward that target, and decision points for amending actions if acceptable progress is not being made.

3.6 Select and Evaluate Conservation Measures (Principles 2 and 4)

The specific actions to be taken as part of an adaptive management program (i.e., conservation measures) should be selected and evaluated based on a comprehensive and formal application of the knowledge base and models, with full consideration of possible interactions among the actions. At this step in the process (Box 5) critical decisions are made about which conservation measures to implement, as well as whether each measure is to be implemented as a full-scale action, as a pilot study, or as a research program. This decision regarding the nature or level of each action depends on each action's physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong:

- A full-scale action is taken to solve a large-scale problem when (1) the action is considered highly likely to achieve or contribute to one or more key objectives, (2) the benefits are believed to outweigh potential detriments, and (3) there is little additional benefit to performing pilot studies or research before implementing the action.
- A pilot action is taken if there is good reason to think that the action will have an effect, but there are uncertainties that can be resolved only through manipulation of the ecosystem.
- Research is considered a conservation measure if it is directed at resolving specific issues key to implementation of the Plan.

The DRERIP scientific evaluation process initiated by the ERP Science Board includes an approach for evaluating conservation measures using conceptual models. Where available, process models may be more suitable for this task.

It is also important to consider the interactions among various conservation measures. The documents reviewed by the Advisors did not clearly link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among the actions. Yet, many of the actions are clearly linked or represent different aspects of the same manipulation. For example, design of an around-Delta conveyance would perforce include operational requirements on inflows and outflows, cross-channel gate operations, south Delta flows, X2, and other flow-related aspects of the system. Thus, most if not all of the conservation measures would be influenced by, or result from, the new operational criteria. Likewise, changes in outflow (WAOP9) are acknowledged as the principal cause of changes in salinity in Suisun Bay and the western Delta (WAOP10), yet they are presented as if they were separate. It is confusing and inaccurate to present these conservation measures as independent actions. This also results in excessive repetition and impedes comprehension of the documents.

3.7 Prioritization and Sequencing of Conservation Measures (Principle 6)

As part of developing goals, objectives, and outcomes, attention should be given to determining the priority and sequencing of conservation measures. *Priority* indicates the relative importance or urgency of a conservation measure, while *sequencing* indicates the order in which the measures are implemented. It is unlikely that funds and other resources necessary for implementing all conservation measures will be immediately available when the plan is finalized and implementation begins. Even though priority and sequencing may be determined by financial or political considerations, the decision-makers should be provided with an assessment of the consequences of their choices that has been developed using the knowledge base.

Prioritization should involve the allocation of conservation measures to categories (e.g., High, Medium, or Low Priority) rather than ranking all measures relative to one another. This categorization should be based on consensus criteria that consider the scale and breadth of the expected outcomes relative to the objectives. For example, measures contributing to more than one objective should generally receive a higher priority ranking than those contributing to only one. In addition, measures *essential* to achieving an objective should receive a higher priority than measures that may further an objective but are not essential.

Sequencing criteria could include (1) ease of implementation, (2) interdependence of measures, (3) feasibility of near-term implementation, (4) availability of funding, (5) uncertainty of measure implementation and outcomes, and (6) the potential for synergies among measures.

3.8 Design and Implement Conservation Measures and Monitoring (Principles 5 and 6)

Once conservation measures have been evaluated and selected (Box 5) they must be designed, analyzed, implemented, and constructed (Box 6). By "design" we mean to clearly describe the actions to be undertaken, including exactly what will be done, where, on what schedule, how, by whom, with what anticipated results, and with what accompanying monitoring actions. In cases where the measure is being implemented as part of an adaptive management experiment, the design need not adhere to formalisms of strict experimental design. It should focus on achieving the desired conservation outcomes but should also consider how monitoring will be conducted and how data will be managed and analyzed to assess the relative performance of the experimental units. The design should carefully consider the pertinent knowledge base, including results of any relevant research, pilot studies, or full-scale studies performed in the previous step (Box 5).

The monitoring plan for a conservation measure is designed and implemented in parallel with the conservation measure itself (Boxes 6 and 7) to generate data useful in comparing system performance to expected outcomes. The National Research Council (1990) defines three classes or purposes of monitoring: *compliance, model verification,* and *trend*. Building on this concept, the Advisors identified four types of monitoring that seem appropriate within our proposed adaptive management framework:

1. *Compliance* monitoring is built into permit requirements and focuses on whether the conservation measures are being implemented as planned.
2. *Performance* monitoring identifies whether individual conservation measures are achieving their expected outcomes or targets.
3. *Mechanistic* monitoring demonstrates whether the mechanisms thought to link conservation measures to desired outcomes are working as predicted.

4. *System-level* monitoring is used to identify the degree of success of the entire program (i.e., the cumulative effects of numerous conservation measures) relative to ultimate desired outcomes as described in the BDCP documents. This requires a sustained, long-term commitment to monitoring of critical features of the whole system, rather than the response of a single measure in the vicinity of a single locality.

Current monitoring practice is usually limited to compliance and system-level monitoring, with some performance monitoring. However, the outcomes of most conservation measures are likely to be influenced by external factors that are uncontrolled or unobserved. Mechanistic monitoring is therefore essential to understand whether changes at the system level are a result of one or more conservation measures or are due to external factors beyond the control of BDCP. Thus, mechanistic monitoring is crucial to adaptive management because it allows effects of the conservation measures, acting through the proposed mechanisms, to be distinguished from other effects.

Table 3X[4] lists a series of hypotheses associated with each conservation measure and monitoring target. Framing the monitoring targets as hypotheses makes clear the links to mechanistic monitoring. In order to be useful, however, scientific hypotheses should be stated in ways that allow them to be tested. For example, the first hypothesis in the table, "Increase production of organic carbon in support of food production within the Delta" is not stated as a hypothesis, and contains two concepts that should be separate if they are to be tested. This could be restated as: (1) The production of labile organic carbon will increase during the additional periods of flooding; and (2) The production of zooplankton (i.e., food for fish) in the estuarine foodweb will increase during periods of flooding. Note that some hypotheses lend themselves to formal tests, whereas others are more suited to parameter estimates (e.g., in the above example, the quantitative increases in carbon production and zooplankton production). Also note that hypotheses may not apply to all monitoring targets, particularly compliance and system-level monitoring.

Much of the trend monitoring and some of the other types of monitoring for aquatic species are already being conducted by the Interagency Ecological Program (IEP) and other agencies. BDCP should capitalize on these ongoing efforts to the fullest extent possible. However, these other monitoring programs may be altered or discontinued by the controlling agency; therefore, BDCP should coordinate with those agencies to ensure continuity of monitoring required specifically for evaluating the performance of the BDCP.

3.9 Collect, Manage, Analyze, Synthesize, and Evaluate Data (Principle 7)

Assessment is crucial to making monitoring useful. Much of the current monitoring in the Bay-Delta produces data that are under-analyzed and therefore under-used. The purpose of monitoring in the adaptive management framework is to provide a quantitative basis for analysis, synthesis, and evaluation. These activities are essential steps in the feedback to management decisions that are hallmarks of adaptive management.

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[4] This was a draft summary table titled “Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses” provided to advisors in December 2008.

Monitoring data must be made readily available online as soon as quality-control analyses have been completed. This has not always been the case with Bay-Delta monitoring programs, but it is essential for ease of access and transparency. Data management is also critical to allow analyses, synthesis, and evaluation. Data management must include the metadata required to identify how the data were collected, the methods used, any calculations employed, time and date, and site locations and characteristics. Effective data management is designed before data collection begins and is integral in the budgeting of successful monitoring frameworks.

Figure 1 highlights the expectation that the consequences of any conservation measure will be monitored and assessed to improve understanding of whether and how the measure is having the desired effects. No data should be collected under BDCP without a specific plan for analysis and synthesis by a particular person or group, with an adequate budget expressly allocated for data analysis and synthesis. This budget should be at least 10% of the cost of the monitoring, based on the Advisors' collective experience. The synthesis should provide answers to the questions implicit in the design of performance metrics: how have things changed, have they changed in expected ways, and what might have caused deviations from the expected trajectory? Note that expectations, generated by conceptual or simulation models, are essential to this effort. Although expectations often will not be met, they provide a basis for evaluating the data and trends. The results of these analyses should be published in technical, peer-reviewed reports to ensure both a degree of external review and easy access.

3.10 Translating Information into Action (Principles 7 & 8)

The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from the implementation of conservation and monitoring actions (Boxes 3 through 9) to the governance actions of sustaining, refining, or replacing program goals and objectives or judging an action to be complete and successful (bold boxes in Figure 1). However, adaptive management plans rarely define the process and the responsibility for assimilating this information into the governance of the conservation plan. In the absence of this step, the adaptive management plan cannot really be adaptive. Information from technical reports is often captured and transmitted to decision-makers in irregularly scheduled exercises, such as ad hoc white papers and through conferences to brief managers or policy-makers. Such processes are inefficient and ineffective as a means of informing decision-makers, and lack the transparency needed in adaptive management.

To assimilate information and formulate recommendations (Box 10) requires both policy and technical expertise. This step is fundamental to the successful integration of accumulating knowledge and information into plan policies, such as revising goals and objectives, refining analytical models, or allocating funding. This step also is a key responsibility that is generally lacking from AMPs, a flaw that undermines successful implementation of adaptive management. The link between the technical step of "Analyze, Synthesize, Evaluate" and the decision-making step of "Assimilate and Recommend" requires regular interaction and exchange of information between technical staff and decision makers.

Box 10 in Figure 1 therefore highlights the need for some highly skilled agent (person, team, office) to be assigned the responsibility for continually assimilating scientific information generated by investigations *both within and external to the adaptive management program* and transforming it into knowledge of the kind required for management actions. Boxes 11 through 14 indicate that such actions may include (1) refining a particular conservation measure, (2) refining the knowledge base and models of system behavior that are extracted from the knowledge base, (3) revising objectives of an entire conservation measure, and (4) reassessing whether the original target problem is solved, transformed, or still a problem. This last action may also be affected by external events such as changing societal preferences, newly recognized environmental threats, or other changed or unforeseen circumstances.

The actions of the agent represented by Box 10 need to be carried out continually but on a range of time scales. For example, individual components of the knowledge base might be refined gradually and annually, whereas particular conservation measures might be refined only after a few years of project implementation. The entire problem might be re-assessed or re-visited once in a decade. The key principle, however, is that *the process of transferring and transforming the results of technical analyses into knowledge to support decisions cannot be taken for granted in the hope that it will occur in the absence of a body specifically charged with making it happen*. This function requires remarkably skillful people, who are truly inter-disciplinary ("polymaths"). Whatever their training, these individuals (or team of individuals) need to be comfortable with a wide range of technical information, as well as understand the functioning of government, law, economics, and the management of large projects.

Although this component of the adaptive management process is not well-developed in the field of environmental and resource management, examples of it are widespread in other, well-capitalized areas of human affairs. For example, the medical and biotechnology industries support highly trained personnel to monitor the myriad scientific results relevant to that field and to convey that information into forms that support the goal of the industry to deliver products and make a profit. This is the foundation of evidence-based medicine (Elstein 2004). Military Departments support links to the scientific community (e.g., Army Research Office, Office of Naval Research, Strategic Environmental Research and Development Program) to assimilate their useful results and recommend support for relevant studies. In government, the Congressional Budget Office, Government Accountability Office, and the Office of Science and Technology Policy all employ people who can assimilate disparate technical information into forms required for government decision-making.

Investment in some entity with the specific role of assimilating knowledge from the technical studies and making recommendation for changes is an essential component of large, complex environmental management projects. **We strongly recommend that BDCP put considerable thought and investment into institutionalizing an entity that is specifically tasked with assimilating knowledge and recommending adaptive changes to goals, objectives, models, conservation measures, and monitoring, as illustrated in Box 10 of Figure 1.** We consider this investment critical to the success of BDCP and to making adaptive management an integral part of the plan.

4 Literature Cited

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Appendix A – Advisor Biographies

Cliff Dahm, Ph.D., Lead Scientist, CALFED Science Program, Sacramento, and Professor, Department of Biology, University of New Mexico. Dr. Dahm is an ecosystem ecologist with expertise in restoration ecology, biogeochemistry, microbial ecology, hydrology, climatology and aquatic ecology. He is presently on loan to the US Geological Survey to serve as lead scientist for the CALFED Science Program from the University of New Mexico (UNM), where he is a professor in the Department of Biology. He emphasizes interdisciplinary approaches required for understanding aquatic ecosystems. He has served as interim director for the Sevilleta Long-Term Ecological Research (LTER) Program at the Sevilleta National Wildlife Refuge in central New Mexico, director for the Freshwater Sciences Interdisciplinary Doctoral Program at UNM and is currently a member of the Science Steering Group for the Global Water Budget Program of the U.S. Global Change Research Program. He has served as a program director for the Division of Environmental Biology of the National Science Foundation and was awarded the NSF's Director's Award for Program Management Excellence. He has worked on adaptive management protocols in Florida and Queensland, Australia. Dr. Dahm received a B.S. in Chemistry from Boise State University, an M.A. in Chemical Oceanography from Oregon State University, and a Ph.D. in aquatic ecology and oceanography from Oregon State University.

Tom Dunne, Ph.D., Professor of Environmental Science & Management and of Earth Sciences, University of California Santa Barbara. Dr. Dunne conducts field and theoretical research in fluvial geomorphology and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis. He has worked on hydrology and geomorphology in many parts of the world, including New England, Northern Canada, Kenya, the Pacific Northwest, and the Andean and lowland parts of the Amazon River Basin. His current work concentrates on sediment transport and river channel evolution in gravel-bed rivers of the Sacramento and San Joaquin basins, including the relationship between physical and biological processes in a restored reach of the Merced River. He has served on many National Research Council Committees, the CALFED Ecosystem Restoration Program, the CALFED Independent Science Board, as well as the Adaptive Management Forum of the US Fish and Wildlife Service. Dr. Dunne received his Ph.D. in Geography from The Johns Hopkins University.

Wim Kimmerer, Ph.D., Research Professor of Biology, Romberg Tiburon Center for Environmental Studies, San Francisco State University. Dr. Kimmerer's research focuses on the San Francisco Estuary, emphasizing effects of human activities on the estuarine ecosystem. Research topics include zooplankton ecology, effects of introduced species and variable freshwater flow, population dynamics of fish such as salmon, striped bass, and the threatened delta smelt, simulation modeling of populations, and analysis of the extensive monitoring database from the estuary. Dr. Kimmerer is chair of the Interagency Ecological Program's Estuarine Ecology Team, and has assisted the IEP with long-range planning and design of monitoring programs. He was a member of the CALFED Ecosystem Restoration Program Core Team, developing a strategic plan for the program, and the Ecosystem Restoration Program Science Board, providing guidance on the application of adaptive management in the program. He is also serving as a science advisor to the CALFED Science Program, and has participated on numerous review panels on key issues in the Delta. Dr. Kimmerer received his Ph.D. in biological oceanography from the University of Hawaii.

Denise Reed, Ph.D., Professor, Department of Earth and Environmental Sciences, and Interim Director, Pontchartrain Institute for Environmental Sciences, University of New Orleans. Dr. Reed's research interests include coastal marsh response to sea-level rise, the contributions of fine sediments and organic material to marsh soil development, and how these are affected by human alterations to marsh hydrology. She has worked on coastal issues on the Atlantic, Pacific, and Gulf coasts of the US, as well as other parts of the world, and has published the results in numerous papers and reports. She is involved in restoration planning both in Louisiana and in California, and in scientifically evaluating the results of restoration projects. Dr. Reed has served on numerous boards and panels concerning the effects of human alterations on coastal environments and the role of science in guiding ecosystem restoration, including the Chief of Engineers Environmental Advisory Board, a number of National Research Council Committees, and the Ecosystems Sciences and Management Working Group of the NOAA Science Advisory Board. She received her B.A. and Ph.D. from the University of Cambridge in England and has worked in coastal Louisiana for over 20 years.

Elizabeth Soderstrom, PhD., Senior Director of Conservation for American Rivers. Previously, Dr. Soderstrom was the Senior Director for Sierra and International Rivers at the Natural Heritage Institute, during which time; she managed the Sharing Water Project on the Okavango River in Southern Africa, launched the Mountain Meadows Initiative, and applied adaptive management principles to river restoration as a Switzer Leadership Fellow. She also assisted both the CALFED Science Program and the Sierra Nevada Conservancy in developing and using performance measures. Dr. Soderstrom has also served as an International Engineering and Diplomacy Fellow with the American Association for the Advancement of Science at USAID's Center for the Environment in Washington, DC, and at USAID's Regional Center for Southern Africa based in Gaborone, Botswana. In these positions, she implemented the International Coral Reef Initiative, was an advisor and representative to the Ramsar Convention on Wetlands of International Importance, and the Convention on Biodiversity, and researched and designed a role for United States assistance in the management of international rivers in southern Africa. Dr. Soderstrom received a B.A. in English Literature, and a B.S. and M.S. in Biological Sciences from Stanford University, and a Ph.D. from the University of California, Berkeley.

Wayne Spencer, Ph.D., Senior Conservation Biologist, Conservation Biology Institute, San Diego. Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses on rare and endangered mammal species, including the endangered Stephens' kangaroo rat, Pacific pocket mouse, and Pacific fisher. He has also worked extensively on approaches to designing landscape-level reserve systems and maintaining ecological connectivity. He is a Research Associate with the San Diego Natural History Museum and a science advisor to numerous conservation NGOs. He received his B.S. in Biology and Wildlife Management at the University of Wisconsin, Stevens Point, his M.S. in

Wildland Resource Science at UC Berkeley, and his Ph.D. in Ecology and Evolutionary Biology at the University of Arizona.

Inge Werner, Ph.D., Associate Adjunct Professor and Director of the Aquatic Toxicology Laboratory, University of California at Davis, School of Veterinary Medicine. Dr. Werner's research focuses on the molecular, biochemical and physiological responses of fish and aquatic invertebrates to anthropogenic environmental stressors, and interpreting these in an ecological context. Her work includes aquatic monitoring programs to assess pollutant impacts in California's Sacramento-San Joaquin watershed and delta, studies on the impact and efficacy of alternative pest control methods in orchard and field agriculture, and the effects of elevated temperature, pesticides and heavy metals on aquatic organisms. She has worked on various zooplankton, amphipod and clam species, as well as native fishes including Chinook salmon, steelhead trout, delta smelt, and green sturgeon. Dr. Werner has an M.S. in Limnology from the University of Freiburg, Germany, and a Ph.D. in Zoology with specialization in aquatic toxicology from the University of Mainz, Germany.

Susan Ustin, Ph.D., Professor of Environmental Resource Science, Department of Land, Air, and Water Resources, University of California Davis. Dr. Ustin is an ecosystem ecologist with 25 years experience in environmental applications of remote sensing. Her current research involves working at a variety of scales from leaf level radiative transfer modeling to quantify landscape biogeochemistry to global mapping of wildfire occurrence. She has extensive experience in developing methods of analysis for hyperspectral imaging data, focusing on detection of environmental stresses and degradation. She has worked on many projects in the San Francisco estuary and delta, starting with her dissertation research and most recently mapping invasive aquatic plants in the delta region. She received a B.S. and M.S. in Biological Sciences from California State University Hayward and a Ph.D. in Botany from the University of California Davis in 1983 in the area of plant physiological ecology with work on physiological responses to salinity and drought stress in wetland plant species in the California Delta.

John Wiens, Ph.D., Chief Conservation Science Officer, PRBO Conservation Science, Petaluma. John Wiens grew up in Oklahoma as an avid birdwatcher. Following degrees from the University of Oklahoma and the University of Wisconsin-Madison (M.S., Ph.D.), he joined the faculty of Oregon State University and, subsequently, the University of New Mexico and Colorado State University, where he was a Professor of Ecology and University Distinguished Professor. His work has emphasized landscape ecology and the ecology of birds, leading to over 200 scientific papers and 7 books. John left academia in 2002 to join The Nature Conservancy as Lead Scientist, with the challenge of putting years of classroom teaching and research into conservation practice in the real world. In 2008, he joined PRBO Conservation Science as Chief Conservation Science Officer. His aim is to build on the long-standing work of PRBO on bird populations to address conservation in a rapidly changing world – "conservation futures." Climate change is affecting species distributions, economic globalization is altering land uses, and demands for the goods and services provided by nature are changing how people relate to nature. John is working with PRBO staff and partners to develop guidance for assessing the impacts of these changes and how management practices can help natural systems adapt.

Appendix B – Workshop Agenda

DECEMBER 17-19, 2008

<u>Wednesday - December 17, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **12:00 – 1:30**
   (Advisors Only)
   - *Advisors meet to review charge*

2. **<u>OPEN SESSION</u> – Embassy Suites Sacramento – Steamboat Rm.** **2:00 – 4:00**
   (Steering Committee and Public welcome)
   - *Introduce advisors*
   - *Background presentations by SAIC and others*
   - *Steering Committee representatives interact with advisors*

3. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **4:00 – 5:00**
   (Advisors Only)
   - *Organize Review*
   - *Homework assignments*

<u>Thursday - December 18, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm.** **8:00 – 12:00**
   (Advisors Only)
   - *Discuss program strengths and weaknesses*
   - *Discuss successful elements from other programs*
   - *Craft initial recommendations*

   Lunch **12:00 – 1:30**

2. **<u>OPEN SESSION</u> – Resources Building – Rm. 1131** **2:00 – 3:30**
   (Steering Committee and Public welcome)
   - *Present initial findings and recommendations*
   - *Discuss findings with Steering Committee representatives*

3. **<u>CLOSED SESSION</u> – Resources Building – Rm. 1131** **3:30 – 5:00**
   (Advisors Only)
   - *Refine recommendations*
   - *Work on findings memorandum.*

<u>Friday - December 19, 2008</u>

<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm. **8:00 – 12:00**
(Advisors Only)
- *Finalize language for findings memorandum*

Adjourn **12:00**

Appendix C – Documents Reviewed By Advisors

Adaptive Management Section, Chapter 3, Conservation Strategy; Draft. December 2, 2008. BDCP Steering Committee Meeting, Handout #6, December 5, 2008.

An Overview of the Conservation Strategy for the Bay Delta Conservation Plan. December 12, 2008.

Annotated BDCP HCP/NCCP Document Outline. Bay Delta Conservation Plan Steering Committee Meeting, Handout #6, November 21, 2008.

Bay Delta Conservation Plan Independent Science Advisors Report, Independent Science Advisors (Reed et al.), November 16, 2007.

Bay Delta Conservation Plan Independent Science Advisors Report Concerning Non-Aquatic Resources. Independent Science Advisors (Spencer et al.), November 2008.

BDCP HCP/NCCP Biological Goals and Objectives; Working Draft. BDCP Goals and Objectives Working Group, Technical Meeting. December 11, 2008.

Biological Goals and Objectives: Hierarchical Relationships. Goals and Objectives Working Group meeting. November 21, 2008.

Chapter 2 Existing Ecological Conditions. Science Applications International Corporation, March 7, 2008.

Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans. USGS, 2004.

Draft Water Operations Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, October 31, 2008.

Examples Demonstrating Relationships Among Goals and Objectives, Viability Attributes, Monitoring, and Adaptive Management For Selected Species. Bay Delta Conservation Plan Steering Committee Meeting, Handout #11, November 21, 2008.

Guidance for the NCCP Independent Science Advisory Process, California Department of Fish and Game, August 2002.

Monitoring and Adaptive Management Sections for Selected Conservation Measures; Draft. Science Applications International Corporation, December 12, 2008.

Section 3.3 Approach to Conservation: Overview of Key Conservation Measures and their Integration; *Working Draft.* Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, November 21, 2008.

Table 1. Proposed Conservation Measures Contributing to Improving Viable Salmonid Population (VSP) Parameters for the Sacramento River Winter-Run ESU. Science Applications International Corporation, December 5, 2008.

Table 3.X. Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses. Science Applications International Corporation, December 5, 2008.

Third Draft Habitat Restoration Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #3, October 31, 2008.

Third Draft Other Stressors Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #4, October 31, 2008.

Appendix D.

Examples of Recommended Adaptive Management Framework Applied to Two Proposed Conservation Measures

The Advisors selected two examples of BDCP proposed conservation measures to illustrate how our proposed Adaptive Management Framework would apply to them and to developing additional conservation measures. These examples illustrate the need for goals and objectives to be articulated clearly and that the existing knowledge base must be integrated into models (conceptual or otherwise) to identify expected outcomes. This will connect goals and objectives, expected outcomes, performance metrics, and monitoring in a logical manner. We also point out inaccuracies or gaps in how these examples are presented in the draft BDCP documents. We recommend that these examples be used to improve the development, analysis, and presentation of conservation measures for the BDCP.

Other Stressors Example

Conservation measure TOC01 is to "Reduce the Load of Ammonia in Effluent Discharged from the Sacramento Regional County Sanitation District into the Sacramento River…If Warranted Based on Research." [5]

Knowledge Base

The knowledge base is currently provided in the form of a rationale in draft BDCP documents. Although information from a few key scientific publications is cited, the rationale does not provide a satisfactory summary of the knowledge base with respect to ammonia/ammonium and effects on different trophic levels of the Delta, as well as secondary effects due to trophic interactions. The information provided is also not well substantiated. Ammonia and ammonium are some of the best-characterized contaminants in this system, and information on concentrations producing toxic effects for fish and other species is relatively abundant. The BDCP documents should explain in a more specific manner why ammonia and ammonium are of concern in the Lower Sacramento River. Examples of available information that should be included are data on total ammonia/ammonium concentrations collected by Sacramento Regional County Sanitation District (SRCSD), California Department of Water Resources, and the Interagency Ecological Program toxicity information reviewed in US EPA (1999), as well as many scientific papers in the peer-reviewed literature. Results from Teh et al. (2008) are misquoted, as no conclusive evidence was found to support the statement that ammonium caused the observed reduction in survival of prey species (copepods) for delta smelt and longfin smelt.

[5] This goal is inaccurately worded, and this inaccuracy is perpetuated throughout BDCP documents. The terms ammonia and ammonium refer to two chemical species that are in equilibrium in water (un-ionized ammonia and ionized ammonium). Chemical tests usually measure both ammonia and ammonium (NH3, NH4+), while the toxicity is primarily, but not completely, attributable to the un-ionized form. Ammonia concentration is not directly measured but can be calculated if temperature and pH are known.

Goals and Objectives

This conservation measure is essentially a research and monitoring program, but no clear goals or objectives are provided, and the title of the conservation measure is inconsistent with the performance measure or measures of success, which are focused on adverse effects on fish (see below). For example, a clear goal statement would be:

Minimize or eliminate direct and indirect toxic effects of ammonia and ammonium from Sacramento Regional County Sanitation District (SRCSD) effluent on covered species.

Objective statements could then be:

1. Reduce the load of ammonia and ammonium in SRCSD effluent to levels which will not cause adverse indirect or direct effects to covered species in the Lower Sacramento River.
2. Reduce the load of ammonia and ammonium in SRCSD effluent to ….mg/L (quantitative threshold).
3. Reduce the load of ammonia and ammonium in SRCSD effluent to minimize or eliminate risk of indirect and direct ammonia/ammonium toxicity to covered species in the Lower Sacramento River.

This would lead directly to specifications of performance metrics and potential research goals, such as monitoring total ammonia/ammonium concentrations as well as pH and water temperature downstream of the outfall in areas where fish habitat and elevated concentrations coincide (Objective 2; relatively easy), reducing ammonia/ammonium to “safe” concentrations of ammonia/ammonium for covered fish species and their prey (Objectives 1 and 3) and identifying performance metrics for monitoring adverse effects on Delta species at different trophic levels (more difficult).

This conservation measure is stated as contingent upon ongoing or planned research. The BDCP documents should explain specifically what the goals of this research are, and what outcomes will warrant the implementation of the full-scale conservation measure.

Tradeoffs are not explicitly addressed, but should be. For example, it is possible that a reduction in nutrient input due to an increased level of treatment could affect primary productivity or phytoplankton community composition downstream of the treatment plant. It is important to discuss different levels of wastewater treatment (nitrification or coupled nitrification and denitrification to achieve removal as nitrogen gas) and their expected outcomes. This should be discussed in the context of studies by Dugdale et al. (e.g., 2007; ammonium inhibition of diatom growth), Jassby et al. (2002; 2008; nutrient loading and dynamics), and Lehman et al. (2005, 2008; *Microcystis aeruginosa*), as well as related publications and ongoing studies referred to in the “Rationale.”

Models

Models should capture and formalize the knowledge base. A conceptual model could provide the framework for the conservation measure and inform selection of performance metrics, but sufficient data already exist to create a more quantitative model. For example, information on the oxidation of ammonia and ammonium in municipal wastewater treatment effluent after upgrading to tertiary treatment (nitrification only) is readily available from the Stockton Wastewater Treatment Plant, which recently switched from secondary to tertiary treatment. Information on total ammonia/ammonium concentrations in the Lower Sacramento River is also available (DWR, SRCSD, Interagency Ecological Program (IEP) Pelagic Organism Decline (POD)). There also is a relatively large body of information on the acute and chronic toxic effects of ammonia and ammonium on fish and some aquatic invertebrates, and US EPA water quality criteria exist (US EPA, 1999).

Desired Program Outcomes and Performance Metrics

Contingent upon the goals and objectives, it is important to clearly state the desired outcomes of the conservation measure: While it is relatively easy to define desired outcomes and performance metrics if the goal is to "reduce the load of effluent-related ammonia and ammonium…," it is more difficult to define these if the goal is to "reduce adverse direct or indirect effects on covered fish species." The latter requires information on acute, chronic, and sublethal effects of ammonia and ammonium on covered fish species and their prey under current conditions and conditions projected under reduced loading. It also requires seasonal assessment of ammonia and ammonium loads under variable pH and temperature and the hydrodynamic transport and fate of the ammonia and ammonium downstream in the Sacramento River and within the Delta.

Select and Evaluate Conservation Measures

The choice about whether to implement a conservation measure as a full-scale action, as a pilot study, or as a research program depends on its physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong (see Section 3.6). A full-scale action is taken to solve a problem when the action is considered highly likely to achieve or contribute to one or more key objectives, and there is little additional benefit to performing pilot studies or research before implementing the full-scale action. Clearly, this is not the case here. At present, the actual conservation measure TOC01 provided in the BDCP document consists of a research program to "evaluate the need and, if demonstrated to be necessary to protect covered fish species, reduce the levels of SRCSD effluent-derived ammonia and ammonium entering the Delta." The "need" is defined by the goal "to protect covered fish species." The full-scale action would be to improve the SRCSD wastewater treatment process to reduce ammonia and ammonium in the effluent. To realize this measure, the plan calls for monitoring total ammonia/ammonium concentrations in the river, and for performing studies to provide conclusive evidence of whether or not the discharge of ammonia and ammonium in effluent from the SRCSD Wastewater Treatment Plant has substantial adverse direct or indirect effects on covered fish species.

It would facilitate evaluation and future adaptive management decisions if the development of this conservation measure was described in detail, provided clear information on goals and objectives, specified research objectives, and detailed why presently available data are insufficient to implement a full-scale action.

Design and Implement Conservation Measures

As stated above and in Section 3.6, the actions to be undertaken under this conservation measure should be described in greater detail. What are the specific research goals and hypotheses, and what is monitoring expected to show? How is risk to covered species defined? Provide details of the design to be used in determining what levels of ammonium and ammonia have adverse direct or indirect effects on covered fish species, and how often these levels are exceeded. Specific information gaps that lead to uncertainties should be addressed clearly. What actions will be taken to reduce uncertainties? Text in Lines 16-18 of the draft plan describes neither uncertainties nor risks. Identify alternative strategies if identified partner entities choose not to collaborate on the conservation measure.

Collect, Manage, Synthesize, and Evaluate Data

Performance metrics should provide useful information to evaluate the success of the conservation measure and should be directly related to the objectives. For example, data collection and management planning should address the questions of how and where will monitoring be conducted, what sorts of inputs may be required to model the system, and how will results be analyzed? As an important example, monitoring of total ammonia/ammonium should involve simultaneous pH and temperature measurements so levels of un-ionized ammonia can be calculated. The spatial and temporal scope of data collection also needs to be considered as impacts to foodwebs and covered species are evaluated. A well designed data collection and management plan will facilitate effective synthesis and evaluation of the resulting data as the BDCP is implemented.

Remaining Components of the Adaptive Management Framework

The full-scale action to reduce the ammonia/ammonium load in the Lower Sacramento River by improving treatment technology at SRCSD would be costly and largely irreversible. This conservation measure makes the full-scale action contingent upon the significant risk of direct or indirect toxic effects on covered fish species due to effluent-derived ammonia/ammonium. Establishing the "need" for the full-scale action, or refining the conservation measure to achieve this goal, requires in-depth scientific knowledge of ecotoxicological principles and risk assessment strategies. Highly skilled individuals are needed to successfully include results provided by research in adaptive management decisions.

Riparian Restoration Example

The stated conservation measure is to "restore between XX and XX acres of riparian forest and scrub communities as a component of restored floodplain, freshwater intertidal marsh, and channel margin habitats."[6]

Knowledge Base

The benefits to covered species of restoring riparian forest and scrub are presumably supported by previous science and applied management, but little of this background knowledge is apparent in the plan documentation. Only two citations are provided to support elements of the rationale for the conservation measure.

While it is not necessary to provide complete documentation of all of the knowledge that underlies development of the plan, the knowledge base should be developed sufficiently to provide a clear and transparent foundation and justification for the proposed plan.

Goals and Objectives

Goal NACO1 is to "Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian communities to provide habitat and ecosystem functions to increase the natural production (reproduction, growth, and survival), abundance, and distribution of covered species."

This goal is too broad and includes implicit assumptions that may not be warranted. The first part is about plant communities, the second about unspecified habitat, the third about functions of unspecified parts of the ecosystem, and the fourth is about population processes of unspecified species. Moreover, this goal includes five habitat types and production, abundance, and distribution characteristics for each habitat type. This makes it impossible to define clear metrics for each of these important Delta habitats. This goal should be broken into parts that logically hang together. Again, the ERP Strategic Plan provides guidance on this. More carefully stated, this might read as four goals, each having a discussion of why these goals have been selected:

1. Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian plant communities.
2. Protect or restore functional habitat types.
3. Restore and enhance ecosystem functions such as….
4. Increase the natural production, abundance, and distribution of covered species.

Objective NACO1.5 is to "Restore at least XX acres of riparian forest and scrub within the Delta to provide habitat and ecological functions in support of covered species."

This is a clearly stated and measurable objective, although it is not clear what variables or processes qualify as "ecological functions." The objective should lead to specific outcomes that

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[6] The documents we reviewed did not supply acreages, but explained these would be determined in the future.

can be evaluated to determine whether the goal (as expressed in this objective) is being achieved. What does "support" mean operationally?

Models

There is no indication in the documentation we received that modeling of any sort has been used to assemble and synthesize the knowledge base about the dynamics and controlling factors of riparian forest and scrub communities and their linkages to various habitats in the Delta. Such models might be used, for example, to determine *how* restoration of riparian forest and scrub will actually provide habitat and "ecological functions" to covered species. Is XX acres a sufficient amount of forest or scrub to provide habitat to which covered species (species differ in the amount of habitat needed to support functioning populations)? One might use existing information on breeding birds in riparian habitats, for example, to model how restoration at different levels might affect reproduction, growth, or survival of different species. Spatial optimization models might be employed to assess the consequences of different spatial arrangements of riparian forest and scrub restoration within different areas of the Delta, and to explore tradeoffs among different approaches to riparian restoration. At a minimum, the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models could be used to be more explicit about the relationships between the covered species and riparian forest and scrub.

Desired Program Outcomes and Performance Metrics

Expected outcomes are scattered through the description of Riparian Habitat Restoration conservation measures. For example:

- "At floodplain restoration sites that function hydrologically as flood bypasses (e.g., the Yolo Bypass), riparian vegetation is expected to establish along margins of existing and created drains and channels and other locations with suitable hydrology."
- "Levees constructed and maintained by other entities that incorporate "green" levee components would also increase the extent of riparian habitat … by allowing for the establishment and growth of riparian vegetation on levee surfaces."
- "Restoring riparian forest and riparian scrub habitats is expected to … increase the extent of valley elderberry longhorn beetle habitat and nesting habitat for Swainson's hawk and yellow-breasted chat; … increase … instream cover … through contributions of instream woody material; … increase production and export of terrestrial invertebrates into the aquatic ecosystem; and … increase cover for rearing juvenile salmonids and Sacramento splittail."

In general, these outcomes are framed in ways that enable conservation measures to be developed and measurements designed to assess progress in meeting the goal and objectives. Thinking about outcomes could be broadened to include other benefits, such as the potential role of riparian vegetation in flood abatement, water retention or in carbon sequestration. In general, outcomes could be more broadly considered in the context of ecosystem services.

Metrics to measure progress toward realizing these outcomes are not provided; this section is still in preparation.

Select and Evaluate Conservation Measures

Presumably the evaluation and selection among several potential conservation measures has already occurred, although this measure is sufficiently broad that it likely includes several alternatives. It would facilitate adaptive management if the conservation measures were developed in greater detail, to indicate how restoration is to be accomplished, where restoration will be targeted, what factors will be considered in determining whether, when, where, and how to undertake restoration, and the like. For example, the approach embraces a "build it and they will come" philosophy – e.g., "riparian habitat would be allowed to naturally establish in floodplain habitat areas that are restored…"[7] A more proactive approach to ensuring that the desired type of riparian habitat becomes established may be more effective. This additional level of detail will be needed before this measure can be evaluated using the DRERIP tools.[8]

The possibilities of conducting preliminary research or pilot studies to evaluate whether the conservation measures are likely to produce the expected outcomes in a cost-effective and timely manner are not considered; this may be an outcome of the recent scientific evaluation using the DRERIP tools. Pilot projects can be invaluable tools for generating public support for restoration actions and for the design of larger-scale projects (e.g., Toth et al. 1998).

Design and Implement Conservation Measures

Details of the design(s) to be used in restoring riparian habitat are not provided; it may not be the intent of this plan to include such details, but they will be needed in order to design effective monitoring programs.

Design and Implement Monitoring

The BDCP documents indicated that monitoring will be conducted to assess the use of restored habitats by covered species, factors that govern the establishment and growth of native riparian vegetation, the need to control non-native invasive species, and the ability of restored habitat to provide unspecified "desired ecosystem and covered species benefits."

Monitoring must be adequate to determine whether the expected and desired outcomes are being met. This requires a monitoring plan be developed that describes what will be monitored, at what spatial and temporal intervals, by what methods, and how the data will be used to assess performance.

Remaining Components of the Adaptive Management Framework

The report mentions using adaptive management to (1) improve the design and management of restored areas to provide for the successful establishment, growth, and benefits of restored riparian habitats, and (2) evaluate the need for control of non-native invasive species or the use of riparian plantings to improve success. These are appropriate adaptive management responses.

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[7] Although the report acknowledges that this approach could allow the establishment of non-native invasive species, it does not fully address the implications of this issue.

[8] The BDCP independent science advisory report concerning non-aquatic resources (November 2008) also noted that simply restoring semi-natural hydrological regimes in floodplains won't restore natural riparian conditions, that restoration is a process rather than a one-time action, and that there is a useful knowledge base for guiding restoration actions that should be fully integrated into restoration planning, implementation, and monitoring.

The application of adaptive management to riparian habitat restoration, however, would be enhanced by considering the potential management responses to various outcomes *as part of the conservation plan*. The use of models to explore likely scenarios would help managers anticipate and plan for adaptive management actions as the effects of the conservation measures undertaken become evident through focused monitoring.

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