ADAPTIVE MANAGEMENT IN THE SACRAMENTO-SAN JOAQUIN DELTA:

HOW IS IT USED AND HOW CAN IT BE IMPROVED?

A Report from the
Delta Independent Science Board

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Executive Summary

The Delta Reform Act of 2009 designates adaptive management as a tool for making water supplies more reliable and ecosystems healthier. Adaptive management is widely regarded as an effective, structured approach to environmental management and decision-making in the face of uncertainty. The approach provides a way of building science and experience into management practices under changing conditions. Adaptive management is most useful when considerable uncertainty exists about the outcomes of management actions, but actions must be taken nonetheless—a common predicament in the Delta. However, although it is often talked about, adaptive management as a comprehensive, science-based management process has rarely been used in the Delta.

The Delta Independent Science Board (Delta ISB) recently reviewed how adaptive management is perceived and used in the Delta and considered how it might be applied more efficiently and effectively. We used a questionnaire to survey practitioners, followed up with interviews, and reviewed relevant scientific and management literature. In this report, we summarize our findings, identify several impediments to applying adaptive management in the Delta, and offer recommendations that may provide a path to making adaptive management an integral part of management of the Delta and its resources.

Impediments to adaptive management in the Delta

The familiar wheel of adaptive management cycles from planning, through doing, to evaluating and responding. At the planning stage, agencies and managers generally support the use of conceptual models, but some question the value of more complex (and expensive) quantitative models. Difficulties more commonly arise when monitoring and analysis are involved, and the wheel often grinds to a halt when the findings must be interpreted and communicated to those who make decisions and the decision-makers must determine whether a change is required.

Our assessment highlights several factors that impede the use of adaptive management in the Delta:

- Aversion to taking risks. Because adaptive management addresses uncertainty and unknowns, there is a significant chance that goals and objectives may not be achieved. An aversion to explicitly address such risks complicates decision-making and may contribute to a reluctance to engage in adaptive management.

- Slowness of the process. Adaptive management can be ponderously slow, failing to keep up with the rapid pace of events and the urgency of management decisions.
- Regulatory requirements and delays. Management of a system as complex as the Delta, involving multiple local, state, and federal agencies in decisions, is suffused with an array of regulations and permit requirements, further impeding the flexibility needed to manage the Delta's complex and dynamic water and ecological systems.
- Perceptions about monitoring. The costs of monitoring are sometimes perceived to be greater than the benefits achieved with adaptive management.
- Communication gap between science and policy. If scientific findings from well-designed monitoring and careful data analysis are not translated into clear and understandable language, managers and decision-makers will be unlikely or unable to use the information to respond adaptively.
- Insufficient and undependable funding. Where they are not accorded a high priority, adaptive management and monitoring activities are likely to languish when funds are tight. Moreover, available funds often come in pulses, making it difficult to sustain the monitoring, data analysis, and evaluation that are essential to doing adaptive management.
- Accelerating pace of environmental change. Rapid environmental changes in the Delta, such as the appearance of invasive species (e.g., the overbite clam) or extreme climate events (e.g., the current drought) may outpace the capacity of management to respond. Such changes can occur too rapidly for the effectiveness of the actions to be scientifically assessed for management decisions.

These factors can impede the use of adaptive management, but they are not excuses for not doing it. The following recommendations may help to move adaptive management from a topic of conversation to a common and useful aspect of management programs and actions for the Delta.

Recommendations

1. **Create a Delta Adaptive Management Team.** To foster the mutual trust, respect, and interactions among scientists, managers, stakeholders, decision-makers, and agencies needed for coordinated adaptive management, we propose creation of a team of full-time individuals skilled in all phases of the adaptive-management process. Among its actions, this team will provide leadership and coordination in aligning adaptive management with management needs; consider how future conditions should be incorporated into adaptive management; identify potential synergies among agencies; advise the

Delta Stewardship Council and other regulators on compliance issues; encourage a greater emphasis on entire ecosystems and functioning landscapes; and assemble, synthesize, and communicate information and guidance about adaptive management.

2. **Support adaptive management with funding that is dependable yet flexible.** Adaptive management cannot be done in fits and starts—it requires sustained and dedicated funding for all phases of the process. Investment in adaptive management can reduce the likelihood of undertaking inappropriate management actions or making expensive mistakes and can help take advantage of opportunities, such as learning from water years that are unusually wet or dry.

3. **Monitor.** Monitoring the right things, at the right times, and in the right places, is essential. Without monitoring, little is learned and success (or failure) cannot be evaluated. Designing monitoring protocols to fit management actions and the timing of important ecosystem processes will make the value of adaptive management more readily apparent.

4. **Capitalize on unplanned experiments.** Adaptive management relies on careful planning and implementation of management actions, but unplanned "experiments" (e.g., extreme droughts, large floods, levee breaks, construction of salinity barriers, cold-water releases from dams) unavoidably occur. The adaptive-management process can enhance learning from such events. To make adaptive management anticipatory rather than reactive, modeling of potential future conditions should be incorporated into the process, and the process should be flexible.

5. **Use selected restoration sites to test adaptive-management and monitoring protocols.** The habitat restoration envisioned in California EcoRestore is an extraordinary opportunity to select locations that can act as practical laboratories for applying adaptive management. Careful design that applies adaptive management to the objectives of restoring habitat can improve the success and timing of restoration activities and help to develop solutions that can be applied elsewhere in the Delta.

6. **Integrate science and regulations to enhance flexibility.** Rigid regulations and permitting rules inhibit the nimble flexibility required to change directions quickly when it becomes apparent that management actions are not performing

as planned. Regulations should be interpreted or revised to allow sufficient flexibility to implement adaptive management.

7. **Recognize where adaptive management is not appropriate.** Adaptive management should be the default position for management actions in the Delta. In some situations, however, the approach may be inappropriate or need to be streamlined to require fewer resources and move more quickly. Such decisions should be made thoughtfully after careful consideration of the alternatives.

8. **If the impediments to conducting adaptive management are insurmountable, revisit or revise the mandates.** The use of adaptive management is often legally mandated, whether it is appropriate for the situation or not. Neglecting adaptive management may therefore provide a basis for challenging the legal validity of a plan or project or for finding it inconsistent with the Delta Plan. In arenas where adaptive management yields few benefits or is simply too difficult to implement, however, the mandates for using adaptive management should be reconsidered.

Table of Contents

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I. The Context

The Sacramento-San Joaquin Delta ecosystem is one of the most studied estuaries in the world. It is also highly variable in time and space, which creates considerable uncertainty about the outcomes of current and proposed management practices. Management of the Delta must be flexible and adaptive. Science is central to this effort.

The Sacramento-San Joaquin Delta Reform Act of 2009 (SBX7 1) directed the Delta Stewardship Council to develop a Delta Plan to serve as the blueprint for achieving the coequal goals of (1) providing a more reliable water supply for California and (2) protecting, restoring, and enhancing the Delta ecosystem. The Act stipulated that the Plan "include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions" (Water Code section 85308(f)). The Delta Plan further stated, "Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management" (Delta Plan G P1; 23 CCR section 5002(4)). In establishing the Delta Independent Science Board (hereafter, Delta ISB or "we"), the Act further required that the Delta ISB "provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews…" (Water Code section 85280(a)(3)).

This report summarizes a Delta ISB review of how adaptive management is being conducted in the Delta. We also offer our perspectives and recommendations on how we believe adaptive management can be incorporated into programs more effectively. Adaptive management in the Delta was reviewed in 2009 by the Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management[1]. The findings and recommendations of that report remain pertinent.

We emphasize at the outset that many agency staff, practitioners, and decision-makers in the Delta recognize the importance of adaptive management and appreciate the value of basing management practices and decisions on a solid foundation of science, data, and knowledge. Many individuals and programs would like to manage adaptively,

[1] Available at http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Independent_Science_Advisors_Report_on_Adaptive_Management_-_Final_2-1-09.sflb.ashx.

yet find it difficult to do so. Accordingly, in this report we consider how adaptive management is perceived and used in the Delta and how its application might be made more efficient and effective. Our focus is on the process of adaptive management itself, rather than on the specifics of the science that supports adaptive management.

To provide the context for this review, we begin with a brief background on adaptive management: what it is, when it may be most useful, and what factors have limited its applications. Additional background on adaptive management may be found in the references and suggested readings listed in Appendix A.

What is adaptive management?

Simply stated, adaptive management is a structured approach to environmental management and decision-making in the face of uncertainty. It involves taking risks, assuming that plans may not always turn out as intended, having a backup plan, and continuing to evaluate progress toward goals. It provides a pathway for undertaking actions when knowledge about a system is incomplete and then modifying the approach as knowledge is gained and uncertainty is reduced. Adaptive management makes learning more efficient and improves management practices.

The Delta Reform Act offers a more detailed definition: "a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project[2] to achieve specified objectives" (Water Code section 85052).

Adaptive management is the antithesis of continuing to implement previously planned management actions even when it becomes apparent that they aren't having the desired effects and something else should be done. Adaptive management fosters flexibility in management actions, but it does so through an explicit process. It entails having clearly stated goals, identifying alternative management practices or objectives, framing hypotheses about ecological causes and effects, systematically monitoring outcomes, learning from the outcomes, sharing information with key players and decision-makers, and being flexible enough to adjust management practices and decisions in light of what is learned. It involves planning ahead for surprises, doing the monitoring and analyses to see them coming, and having a Plan B (and then Plans C, D, …) ready

[2] There is some ambiguity about the term "project," which may refer formally to a defined activity, usually with designated funding and a defined start and end date, or more informally to a general area of ongoing activities. We use "project" in the former sense and "management action" or "action" for the latter.

and waiting. Computer models often are used in adaptive-management programs to integrate available knowledge and, as learning occurs, to provide synthesis and a means of developing and exploring promising management actions before they are attempted as field experiments or pilot projects.

Adaptive management is most powerful in reducing uncertainty when management actions are thought of as experiments. By using a structured design that includes appropriate controls (or references), monitoring, and replication, the factors that produced the observed outcomes can be disentangled from a welter of potentially confounding factors. As a result, one can have a good idea of *why* a management action did or did not work as expected. For example, restoration of the Tijuana Estuary in southern California involved partitioning the area into a series of modules that could be subjected to different, replicated experimental treatments (e.g., planting of different combinations of marsh plants). The results could then be used to adjust subsequent restoration efforts (Zedler and Callaway 2003). The South Bay Salt Pond Restoration Project described in Box 1 provides another example.

In most cases, however, there is only one action that can be undertaken at one place and time and there can be no replication, so the best one can do is to monitor the previous and subsequent states of the system. Adaptive management may still be used in such situations if the basic requirements noted above—setting goals, monitoring, learning, and flexible decision-making—are met.

Adaptive management is not something new or mysterious. It has been used in a variety of fields. Our emphasis in this report is on the use of adaptive management in resource management, but the literature is replete with examples from medicine, engineering, and financial management, to name but a few.

When is adaptive management most useful?

The Delta Reform Act requires that adaptive management should be used in science-based management of the Delta and its resources. Conducting comprehensive adaptive management, however, can be demanding, expensive, time-consuming, and politically sensitive. Adaptive management should not be undertaken if there is no opportunity to apply what is learned, if there is little uncertainty about what actions to take or their outcomes, or if there is little agreement among parties about goals and objectives (Williams and Brown 2012).

Adaptive management is most likely to be useful and effective when:

1. There is considerable uncertainty, making it difficult to predict with confidence the outcomes of management actions, but when actions must nonetheless be taken (i.e., waiting for better knowledge is not an option);
2. The system is complex and nonlinear, which means that many direct and indirect pathways can affect outcomes and identifying cause(s) and effect(s) is difficult;
3. The system is changing rapidly, which means that the conditions when the desired outcomes are expected may differ from those when the management actions are first applied;
4. There is the potential to learn (and reduce uncertainty) by observing and recording what happens in response to management actions;
5. There are technical and institutional means to incorporate what is learned into revised management practices and a commitment to sustain adaptive management; and
6. The management actions and their effects on the system are not irrevocable and management is flexible.

Most of these criteria for adopting an adaptive-management approach are frequently met in the management of ecological systems, although the fifth point may require greater institutional flexibility and openness to change than is often the case. The last point is more problematic—if an action results in a permanent or long-term alteration of the system (e.g., construction or removal of a dam, installation of a large pumping station, filling a wetland, or extinction of a species), the "adaptive" part of adaptive management may no longer be possible, although some elements of the approach may still be useful.

What factors limit the use of adaptive management?

Despite the incorporation of adaptive management into the guidelines for many governmental agencies and the hundreds of papers and books written on the subject, actual examples of effective adaptive management are distressingly rare. For example, of the 1,336 published papers dealing with adaptive management reviewed by Westgate et al. (2013), fewer than 5% explicitly claimed to do adaptive management, and of these only a few actually met the criteria for adaptive management. Nonetheless, several management or restoration actions show that, with sufficient funding and continuing communication and collaboration, adaptive management is possible in large, complex ecosystems.

Ecological restoration in San Diego Bay provides a model of many of the elements of effective adaptive management (Zedler and Callaway 2003). The restoration was prompted by the need to mitigate damages from highway and flood-channel

construction and to provide habitat for endangered species. The work entailed close collaboration of scientists with state and federal agencies. Frequent meetings ensured that information was shared among all parties. Restoration actions, standards, and eventually the design of the mitigation program itself were adjusted based on the results of ecosystem monitoring.

In other cases, the goals are long-term and there has not been sufficient time for the effectiveness of the adaptive-management process to be determined. The Delta Plan used restoration of the Kissimmee River in Florida as an example of adaptive management. Although this project involved planning, design, monitoring, and evaluation, it was (understandably) not structured as an experiment and has yet to incorporate what has been learned into adaptive decision-making. Restoration of the Everglades is also often cited as an example of adaptive management of a complex ecosystem. Doremus et al. (2011) and LoSchiavo et al. (2013) provide summaries of what has been learned so far; because there are close parallels between restoration efforts in the Everglades and adaptive-management challenges in the Delta, we include a synopsis from Doremus et al. (2011) as Appendix B.

Another example illustrates both the potential and the failure of planning for adaptive management. In 1993 The Trillium Corporation purchased some 272,000 hectares of forested land in Tierra del Fuego, Chile (Lindenmayer and Franklin, 2002, provide details on the early history of the project). The intent was to integrate sustainable production of valuable forest products on a grand scale with conservation and ecotourism. After extensive design and planning (and navigating several legal and bureaucratic challenges), the Rio Condor project was implemented in 1999. The design incorporated extensive monitoring and scientific research to support a rigorous adaptive-management process that included experimental testing of both forest-management and conservation-practice hypotheses, with periodic evaluation by outside experts. What could go wrong?

The answer, as is so often the case, is funding. Trillium had underestimated costs and overestimated returns, and defaulted on the loans to purchase the lands in 2002. So much for the adaptive-management plan! Fortunately, Goldman Sachs stepped in to acquire the defaulted loans, donating the area to the Wildlife Conservation Society in 2004. Renamed Karukinka Natural Park, it now serves multiple conservation functions, including assessing carbon benefits, protecting populations of guanaco (*Lama guanicoe*) and several endangered species, and promoting ecotourism.[3]

[3] See http://www.wcs.org/saving-wild-places/latin-america-and-the-caribbean/karukinka-landscape-chile.aspx

Why are there so few examples of successful adaptive management? As in the Rio Condor example, the funding needed to support the phases of adaptive management is often not secure (even when a large corporation is involved). But there are numerous other barriers (see page C-4 in the Delta Plan):

1. Understanding complex systems requires multiple disciplines that are typically housed in different agencies and have different responsibilities, different priorities, and different approaches; transcending these boundaries is difficult;
2. Uncertainty about the response of complex systems to multiple factors can lead to a hesitancy to move forward on adaptive management once a management decision is made;
3. Mechanisms and approaches for designing and implementing large-scale ecosystem experiments are not well-developed;
4. Support for adaptive management and its goals may shift with the political winds, creating administrative uncertainty that inhibits implementation;
5. Managers are often risk-adverse, reluctant to take actions that might not work as planned and could be regarded as "failures";
6. Key stakeholders have not been involved in the planning and design of a management action, do not understand the underlying rationale, and consequently do not buy in to the process;
7. Regulations (e.g., restrictions under the Endangered Species Act) are often perceived as limiting experiments or data gathering (although such activities may be undertaken if they are included in the authorized actions; i.e., are planned in advance);
8. The need to obtain multiple permits from multiple entities to conduct complex adaptive management causes delays, during which time the system changes, requiring adjustment of plans or goals, which may then require additional permitting;
9. Human resources (i.e., expertise, time) needed to plan, implement, monitor, or evaluate the actions and outcomes are not available;
10. Communication among all parties, especially among scientists, managers, decision-makers, and stakeholders, is not accorded a high priority.

In Box 1 we consider how these factors have come into play in the adaptive management of the South Bay Salt Pond Restoration Project in San Francisco Bay. Generally, however, these barriers impede the implementation of adaptive management. Unless they can be resolved, adaptive management will continue to be a fine-sounding aspiration that is rarely realized. We will return to consider the major impediments to implementing adaptive management in the Delta in Section VI.

Box 1. Adaptive Management in the South Bay Salt Ponds Restoration Project

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II. The Structure of this Report

The Review Process

Our assessment of adaptive management in the Delta is based on the results of a questionnaire (Appendix C) distributed to several agencies, in-person interviews with individuals directly involved in managing the Delta and its resources, and a review of pertinent scientific and management literature. Respondents to the questionnaire and individuals interviewed are listed in Appendix D. They provided thoughtful, detailed, and candid responses to our questions, and we much appreciate their willingness to help us understand how and why adaptive management seems to be such a hard thing to do in the Delta. We used this approach because so little is documented about how adaptive management is actually done in the Delta; we felt that evaluating impressions and perceptions of adaptive management by the professionals doing management in the Delta may reveal needs and solutions to adaptive-management implementation and challenges.

The Sections

We begin by describing how the adaptive-management process is perceived by the people we interviewed. We then delve into a more detailed treatment of how adaptive management is or is not implemented in the Delta, organized by the nine steps of the process described in the Delta Plan. We follow this with comments on factors that appear to constrain or impede the application of adaptive management in the Delta. We then take a broader view of adaptive management—how can the process be streamlined; how can it be made more responsive to rapid changes in the physical, ecological, and social environments, especially when systems encounter thresholds and undergo state transitions; and what does "best available science" really means in the context of adaptive management? We conclude with recommendations for what we think is needed to make adaptive management more achievable and effective in the Delta.

The raw materials for this report are the responses, comments, and insights provided by the individuals and groups we consulted. Throughout this report we indicate direct, verbatim quotes from questionnaire respondents or interviewees (without naming names) in *italics*.

III. General Responses

To get a sense of how respondents to the questionnaire viewed adaptive management, we initially presented a series of statements to be rated on a scale of 1 (strongly disagree) to 5 (strongly agree). These statements were modified from a nationwide survey of adaptive management reported by Benson and Stone (2013). The results are tabulated in Appendix E and are summarized here.

Respondents generally agreed that adaptive management requires a high degree of collaboration, that conceptual models should include human (i.e., sociopolitical) as well as ecological factors, and that it is important to communicate the results to stakeholders. However, there was not as much agreement about whether baseline information about the Delta is usually gathered or conceptual models are usually built before action is undertaken, the degree to which results from monitoring and assessment are used in decision-making, and whether adaptive management leads to changes in management and actions. There was even greater variation in responses to other questionnaire statements—some agreed, others disagreed about whether their agency did or did not use adaptive management; whether the agency's management was flexible enough to do adaptive management; whether laws and regulations did or did not restrict management options; and whether laws and regulations could be changed to make adaptive management more successful.

The strongest, most uniform response we received, however, was *disagreement* with the statement that "Monitoring is adequately funded to support adaptive management." This concern will emerge often in this report; we consider it further in Section VI.

IV. Perceptions of Adaptive Management: How is it Useful?

If adaptive management is not perceived to be useful, then it will not become a common practice, even in situations that cry out for an adaptive-management approach. Several individuals questioned whether adaptive management really yields any benefits beyond those of normal, non-adaptive management. For example, one respondent wondered whether "*the results of adaptive management are worth the effort*" and another asked, "*Does the cost and effort to implement adaptive management take resources away from implementing the actual project?*"

Most of the people we surveyed, however, saw value in at least some elements of the process, if not in the entire process itself. They recognized the potential for adaptive management to promote discussion among parties with opposing views, clarifying the

problem to be solved, and articulating the decisions that need to be made. For example, adaptive management can help to identify areas and sources of uncertainty and target where additional research or knowledge is needed. In this way, the process emphasizes the importance of an "*upfront investment in knowledge*" to increase the likelihood that the actions will yield the desired results and prompt discussion of how this knowledge can inform decisions. By developing hypotheses of how and why a system might respond to management actions, the process can help to determine "*What does one do at a fork in the road?*" The conceptual framework or model developed as part of the adaptive-management process can focus thinking about an action and its possible outcomes. Moreover, this approach can help to determine reasons why things might not have worked as planned and provide the basis for looking for a mechanistic understanding of the issues of concern.

Adaptive management can also provide insights into causes of ecological changes and system linkages beyond the object(s) of management interest, such as whether there is a need to examine other stressors and connectivity pathways. In practical terms, it can be used to determine which disciplines or agencies need to be involved to address a problem or engage in collaborative work on a project. Consequently, it can help to avoid mistakes that might result from a failure to consider a full range of system dynamics and mechanisms. Finally, some respondents felt that adaptive management can facilitate communication by transmitting scientific knowledge about a system and its performance to managers and policy makers.

These and other responses demonstrate broad recognition among Delta scientists and managers that adaptive management can aid in identifying knowledge gaps and sources of uncertainty; using knowledge about the Delta to consider alternative courses of action; fostering clarity and transparency in developing management plans and making decisions; understanding and anticipating how a system may respond to management actions; identifying both direct and indirect consequences of those actions; engaging multiple parties in discussions and planning; and fostering communication among scientists, managers, and decision-makers.

At a conceptual level, then, most people whom we interviewed have a general understanding of what adaptive management is and how it can benefit management. The real questions are whether this understanding translates into actually *doing* adaptive management and, if not, what factors impede the implementation of adaptive management?

V. Implementation of Adaptive Management: How is it Being Done?

One questionnaire respondent stated that "*We include actions to conduct studies and monitoring to resolve uncertainties and to verify assumptions made in establishing standards, limits, or performance measures, and also consider opportunities to revisit and revise decisions, pathways, and milestones based on new information or unforeseen circumstances*." If this process were widespread in the Delta, this report would be unnecessary. But such statements tend to obscure the reality: adaptive management in the Delta is frequently talked about, is often claimed to be used, but is rarely implemented as a rigorous, science-based process.

Results from a survey conducted by the Delta Science Program illustrate this point. In 2011, when the implications of the Delta Reform Act were just beginning to become apparent, the Program surveyed state and federal agencies and several non-governmental organizations to determine whether they were including adaptive management in their programs.[4] Of the 46 programs that were surveyed, 7 had no response to whether they used adaptive management, 10 indicated that they did not use it, 8 said they planned to use it sometime in the future, and 21 claimed to use it in some form. The latter responses, however, included such things as managing program administration to respond to change, using data to make decisions, reviewing programs for performance, or adjusting programs on the basis of experience. In other words, almost anything that might lead to change in a program was regarded as adaptive management.

It is apparent from the 2011 report and our recent surveys and interviews that an understanding of what "adaptive management" is varies substantially and is very much in the eye of the beholder. Different agencies and programs often perceive adaptive management in multiple ways and modify their definition and approach to suit their purposes. One interviewee observed that "*there is no agreement about what adaptive management is, but everyone thinks they are doing it.*" Although it may be appropriate to tune the process to focus on the specific needs and responsibilities of program or agency, the divergence of approaches and interpretations can impede the communication and collaboration that is needed to achieve adaptive management of the Delta.

To clarify and standardize how adaptive management should be structured, the Delta Plan describes a cyclic, nine-step process (Fig. 1). Many versions of the adaptive-management cycle exist in the literature, embodying anywhere from three to more than a dozen steps, some depicting a circular sequence and others a web of interacting processes. However, all are founded on science and all involve the same basic activities:

[4] The report is available at http://www.deltacouncil.ca.gov/sites/default/files/documents/files/D-ISB_on_the_DSP_January_2012_v2.pdf

Plan (identify the problem and design the management approach(es)); *Do* (implement the management action(s) and monitor the results); and *Evaluate and respond* (analyze and synthesize the results, communicate the findings to appropriate parties, and make any necessary adjustments).

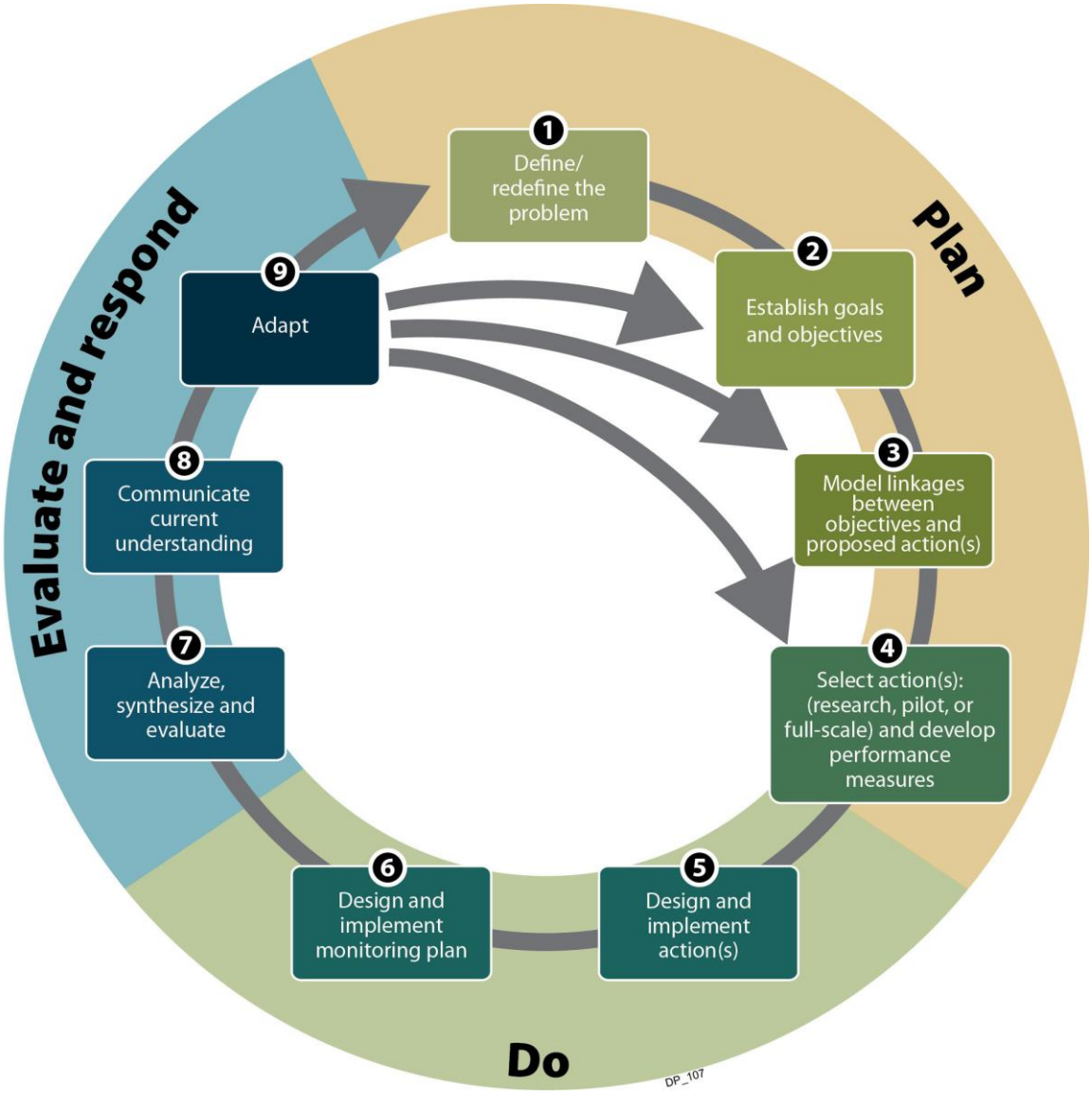

Figure 1. The nine-step framework for adaptive management depicted in the Delta Plan. Boxes represent steps in the process, and the circular arrow represents the general sequence of steps. The additional arrows indicate possible next steps to address the problem or revise the selected action based on what has been learned.

To assess perceptions about the nine-step approach, we asked questionnaire respondents and interviewees to comment on how the nine steps are expressed in practice; the discussions and implications for management in the Delta are summarized for each step below.

1. ***Define/redefine the problem***

Although managers and scientists usually have an idea of the problem to be addressed through their planning and actions, disagreements and uncertainties may develop if the problem is not clearly articulated. Everyone involved needs to agree about what the problem is and see it in the same way. Defining the problem is the starting point for effective management.

Everyone we interviewed considered their work to begin with a clear understanding of the problem. Clear definition of the problem can indicate at the outset the array of collaborators needed to address the problem and establish the baseline conditions for management against which progress (or at least change) can be measured. Often, however, the problem is defined by entities other than those designing and doing the management. As one respondent observed, "*We are typically told what the 'problem' is by other agencies. Our job is to figure out how to fix the problem.*" In at least some cases, the problem statement is accompanied by an identification of key uncertainties, which helps define knowledge gaps that need to be filled. Appropriately, the problems are defined by perceived management, political, or societal needs rather than science needs. The role of science, after all, is to help address the specified problem in a rigorous way—"*the science should be relevant to the problem*."

Overall, our impression is that the various agencies and programs do a good job, individually, of framing the problem (even if it is not "their" problem), in many cases setting the stage for the subsequent steps in the adaptive-management process. Sometimes there is clear coordination and collaboration among agencies or entities to address a common problem, although this is not nearly as prevalent as it should be.

2. ***Establish goals and objectives***

Clear goals and objectives are essential to adaptive management; as Yogi Berra once observed, "If you don't know where you are going, you'll end up someplace else." With clear goals and objectives, reliance on subjective feelings that "things just aren't right" or "this isn't working" can be avoided.

Most problems are considered in terms of outcomes; managers "*look first at the outcomes and then ask what is needed to ensure getting there*." The desired outcomes, in turn, dictate what performance measures will be used to determine the "success" of a program (and thus the need to adaptively manage). When the goals and objectives are set by administrative or regulatory criteria (e.g., meeting water-quality standards or permit specifications), as is often the case, the targets or outcomes of actions are clearly specified but the mechanistic understanding of causes (*why* did the actions produce the observed outcomes) needed to conduct adaptive management may remain elusive. Some programs and agencies are able to identify ecologically sensitive performance measures (e.g., juvenile fish migration survival rates, spawning density, dissolved oxygen), but obtaining detailed information on such measures is often difficult. As one respondent commented, "*Performance measures have generally been established in federal ESA biological opinions or State water rights decisions and are often too broad, too difficult, and too costly to measure.*"

This statement indicates the challenge faced by scientists, managers, and decision-makers in the Delta. It is important to frame clear goals and objectives that are (in keeping with the State's coequal goals) relevant to managing both water availability and the integrity of Delta ecosystems. However, if progress toward meeting those goals and objectives cannot be assessed because the outcomes are difficult to measure (e.g., juvenile fish survival) or the indicators are not directly related to the goals (e.g., salinity at some locations), it will be difficult to determine whether it is appropriate to stay the course of action or adaptively change practices.

Overall, all of the programs and agencies we interviewed have a clear sense of their goals and objectives even though many struggle with meeting objectives that are not their own and are under constraints that limit their ability to measure progress toward meeting those objectives.

3. ***Model linkages between objectives and proposed action(s)***

Conceptual and quantitative models are key components of this step. Through this process, cause-effect pathways are established. Models help to define the mechanisms underlying causal pathways that often determine whether a management decision meets expectations or does not. Typical responses were: "*We use conceptual models to guide our understanding of the complex nature of ecological systems and to help identify data gaps*" and "*We ultimately decide which models to use based on the state of the science, availability of appropriate models and modeling expertise, cost/benefit of modeling versus not modeling an action, and project budget.*" There is also a general recognition of the need to develop quantitative modeling expertise and tools to implement adaptive

management and balance long-term benefits against short-term costs. Even when quantitative models are used, however, there is often little follow-up and no adjustment of models based on new information. Developing quantitative models that capture the complexity of Delta systems requires data (and data management) and modeling or quantitative staff who are well-versed in systems thinking, but such staff are difficult to attract and retain and "*are often pulled off to address immediate needs*."

While most respondents use conceptual models and recognize at least the desirability of complex, quantitative, systems models, others question the value of modeling in addressing problems in the Delta. There is a perception that even conceptual modeling may not be needed to conduct adaptive management, particularly when the ecological or physical processes are well known; "*we need to ask what a model can tell us that we don't already know that will add value to management.*" As one respondent put it, "*we model to exhaustion, modeling begets more modeling.*" Another noted that "*having models is great, but not at the expense of delaying action*."

Thus, while many individuals and entities working in the Delta embrace (albeit sometimes reluctantly) the role of modeling and its value in organizing thinking, identifying critical uncertainties, and communicating options to decision-makers, others prefer to base their actions instead on experience, expert opinion, or intuition. Although sophisticated, quantitative modeling is not necessary in all situations, we believe that conducting adaptive management in a complex, multivariate system must at a minimum entail the development of a comprehensive conceptual model, organized in relation to the overall problem being addressed, the goals and objectives, the uncertainties involved, and the desired or anticipated outcomes. For example, in developing guidance for ecosystem restoration for the Army Corp of Engineers, Fischenich et al. (2012) suggested that conceptual models for adaptive management should (1) identify causes of degradation (i.e., the problem); (2) indicate how the causal factors influence key system components; (3) indicate how management can reduce stresses or restore the system (i.e., meet the objectives); (4) incorporate hypotheses to be tested; and (5) indicate what needs to be monitored, why, and over what time frame.

As complexity, the need for quantitative predictability, and/or the risk of unintended consequences of actions increase, more sophisticated models may be needed. Because such models are demanding of expertise, time, and money, they should be developed in a collaborative framework. The collaborative development of CALSIM by the US Bureau of Reclamation and the California Department of Water Resources is a good example. In May 2015 the Delta Science Program and UC Davis Center for Watershed Sciences organized a workshop on "Integrated Modeling for Adaptive

Management of Estuarine Systems."[5] Models may therefore play an additional role of fostering inter-agency collaboration, which in turn may reveal insights or knowledge gaps apparent to one agency but not to others.

Overall, we found that there is broad acceptance of the value of conceptual models but differences in perceptions of quantitative modeling, and these models are often not adjusted as new information becomes available.

4. ***Select action(s): (research, pilot, or full-scale) and develop performance measures***

Adaptive management often identifies alternative actions that might be undertaken to address a problem. Models may help to select among these, but uncertainty may remain about which actions will produce the desired outcomes. When the actions are expensive, difficult to change, or have the potential to produce unwanted side effects, additional research or a small-scale pilot study may be appropriate before undertaking full action. One respondent indicated, "*if outcomes are fairly uncertain and time sensitivity is not an issue, then a small scale implementation (pilot) study is generally conducted before a larger scale project is undertaken*." This generally involves consultations among multiple agencies and stakeholders. Some programs use decision support tools (e.g., Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Action Evaluation Procedure and Decision Support Tool[6]) to help determine what actions may be most appropriate in a particular situation. Others view conducting a pilot study before full-scale action as an alternative to implementing adaptive management after the action is taken—an approach that could be described as "plan, do a pilot study, and then forge ahead and don't look back."

Understandably, people in agencies with management responsibilities in the Delta feel "*the curse of the immediate*," the push to take action without the luxury of first getting more information to increase the likelihood of long-term success. Despite this, some programs are committed to conducting pilot studies (and perhaps even more research) when the situation warrants and they can justify (and fund) it. In practice, "*the lack of funding and staff resources for science is the primary limiting factor for targeted research and pilot studies*."

Clearly, information and knowledge can be obtained in many ways, and additional research involving an experiment or hypothesis test isn't always necessary for

[5] See http://deltacouncil.ca.gov/enewsletter/stories/july-2015/may-integrated-modeling-workshop-brought-together-international

[6] http://www.dfg.ca.gov/erp/scientific_evaluation.asp

adaptive management. One interviewee noted that "*management decisions are typically made in response to regulatory requirements and to short-term crisis situations, so they are often made without considering targeted research or adaptive management*." There is a perception that "*there is a tradeoff between implementing actions and conducting the science to evaluate the actions,*" Research may be necessary in some situations involving critical knowledge gaps or uncertainties, but several respondents questioned whether the adaptive-management framework is simply another way for scientists to justify doing more research. Thus, "*there should be a very clear division between adaptive management and scientific research*," or, more bluntly, adaptive management "*will make projects more costly, complicated, and promote further implementation delays. In the end, less gets done, [we] go to more meetings, the resources continue to suffer, while the scientists wait for irrefutable answers*." Another respondent cautioned, "*Adaptive management should focus on finding out if the broad project objectives are being met, not with discovering answers to detailed scientific questions*."

There is disagreement about whether adaptive management should routinely involve new scientific research, or whether it should be based on existing knowledge, with research needs identified as knowledge gaps become apparent in the process of implementing adaptive management. There is no single answer. We believe that the level of science and research required should be scaled to what needs to be understood to inform subsequent management actions, to the costs (in terms of time, money, and staff) of the research, and to the likelihood that the research will significantly reduce uncertainties and enhance knowledge. A good conceptual model can help to define whether additional research is needed and where it should best be directed.

Overall, then, there appears to be considerable angst about including additional scientific research under the banner of adaptive management, even though everyone seems to agree that science is central to the process and an important way to fill knowledge gaps and reduce uncertainties.

5. ***Design and implement action(s)***

The first stage of the "Do" phase of the adaptive-management process is designing actions and monitoring. All of the programs we considered included the design of management actions, often in considerable detail, although not always in the sequence outlined by the previous stages of the adaptive-management process. Differences in goals and objectives among projects can lead to divergences in design, especially in monitoring. If an action is designed to address regulatory needs, for example, the monitoring protocols are generally not designed to answer scientific questions. It is compliance monitoring rather than performance or scientific monitoring. Consequently,

although the monitoring design may tell one whether management actions have complied with regulations or permit requirements, "*this monitoring data is typically useless to answer any questions.*" Even when the emphasis is on monitoring ecosystem performance, the focus tends to be on outcome measurements rather than mechanistic understanding of why actions succeeded or failed.

To be most effective, the planning and design of actions should be developed in tandem with the plan and design of monitoring—management plans and monitoring design are inseparable. This is especially important when the adaptive management process is structured as an experiment or designed to test hypotheses. Linking monitoring with the design of management actions will also help to ensure that the monitoring is targeted, informative, and cost-effective rather than broad-based and unfocused. Monitoring should be focused on what the objectives are and should be proportional to the magnitude of the action. Unfortunately, monitoring details "*are often worked out as the project proceeds and funding becomes available*." Not surprisingly, the design of monitoring protocols generally receives less attention than the design of the management actions to be taken. This can lead to ineffective monitoring or monitoring the wrong things. Developing and adopting standardized monitoring protocols that are action specific could significantly improve the quality of data collected and facilitate synthesis. Above all, monitoring must be designed to enhance knowledge—if one hasn't learned anything, then how can one make adaptive changes?

Overall, we conclude that relating monitoring to management actions remains a major impediment to the implementation of adaptive management in the Delta.

6. ***Design and implement monitoring plan***

Almost all programs and agencies implement actions more or less as they were designed, within the framework of the goals and objectives. Once initiated, most management sticks to the original design unless it is overwhelmingly obvious that something is amiss—the system is not responding as expected, the environment has changed in ways that were not anticipated, or external forces such as funding or administrative support have changed.

Monitoring and data management are another matter. As Lindenmayer and Franklin (2002) observed, "monitoring is necessary to generate the empirical data that are the definitive measure of the degree to which a management program is achieving its objectives." Some respondents and interviewees reported that their data are assembled in one or another data bank or data-management system that is available to others, although this was more often than not a work in progress. In other situations, however, "*database*

linkages outside individual projects are generally not worked out very well or at all." The management of Delta data is a topic of active consideration by the Delta Science Program ("Enhancing the Vision for Managing California's Environmental Information"[7]).

Overall, programs often seem to find it difficult to maintain ongoing monitoring while implementing actions, much less after the actions are thought to have been completed. We comment further on monitoring in Section VI.

7. Analyze, synthesize, and evaluate

Several respondents indicated that the analysis of the results of an action is often done "*within a year or two*" of project completion or occasionally during implementation of the actions if conditions warrant. Where the actions are undertaken in a regulatory setting or have permitting conditions attached, however, there may be built-in checkpoints or triggers for assessing status. For example, "*when adaptive management triggers are met, we respond accordingly, with varying degrees of effort, detail, and adequacy*." In other words, mid-project assessments are generally done to comply with reporting timelines and permit requirements rather than to assess whether the system is responding to management as hoped. Other respondents or interviewees said that "*the most common project evaluation is a qualitative assessment of whether a project has been implemented as designed*" or "*on the ground observations and assessment of habitat conditions and consideration of changes in environmental conditions are continually analyzed, but likely not well documented.*"

There seems to be a general pattern related to analysis, synthesis, and evaluation. If management actions are related to a multi-agency effort (the Interagency Ecological Program was frequently mentioned), then prompt, ongoing, and thorough analyses may be conducted, as for the POD, MAST, or Fall Low-Salinity studies. More often, the burden (and it is often perceived in this way) of analysis and synthesis falls within a program or agency, and it may be delayed or not done at all unless there are specific requirements and appropriately trained staff to do so. It is important to emphasize that this is *not* the result of a disregard for the importance of analysis and synthesis or a lack of intent to do so; rather, it reflects the incessant, multiple demands that are made on programs, staff, and agencies that are understaffed or lack the expertise to conduct basic data analyses. The difficulty is exacerbated when monitoring is inadequate or piecemeal, not targeted on the most appropriate response variables, or the data are not managed in a way that facilitates appropriate analysis.

[7] See http:// http://deltacouncil.ca.gov/docs/enhancing-vision-managing-california-s-environmental-information.

In short, this phase is where the adaptive-management process, when it is actually undertaken, most often begins to break down. The failure to conduct the necessary analysis, synthesis, and evaluation of the results of management actions, particularly while the actions are underway (and thus potentially amenable to adaptive adjustment), is a major barrier to achieving adaptive management. To some degree, this situation is created by the imperative to move ahead on other actions once one project is completed. This, in turn, reflects the perception that a project is "completed" when the action is done; as a result, analysis, synthesis, and evaluation are regarded as an add-on to be done as time and resources permit. Although it is clear that some (perhaps many) programs and agencies *want* to do the analysis, synthesis, and evaluation needed to gauge the effectiveness of their actions (and thus follow through with adaptive management), even the best intentions may be overwhelmed by the immediacy of management challenges in the Delta. Ecosystem-level, performance-based analysis and synthesis is especially important for creating an integrated system of actions over time, rather than planning opportunistic actions that tend to occur today without regard for future plans or changes.

Without timely analysis, synthesis, and communication, little is learned, at least in a way that can be incorporated into science-based management. This problem relates back to monitoring issues and the lack of secure funding, which we discuss later in this report.

*8. **Communicate current understanding***

If the scientific findings and knowledge gained in the previous steps of the adaptive-management process are not translated into clear and understandable language, managers and decision-makers will be unlikely or unable to use the information to respond adaptively.

Everyone we surveyed recognized the importance of communicating the results of their actions to decision-makers, other agencies, stakeholders, and the public. In some cases there is frequent communication among managers and agency staff about habitat and management conditions for a specific project. Scientific findings are generally reported in conferences and briefings, some of which are directed toward the public. Translation of the science, however, "*is often not done until managers/decision-makers identify a specific question(s) they need answered*" and often the communication is to upper-level administrators about budgets rather than assessing what has or hasn't worked or coupling the communications with informative and up-to-date performance measures. One respondent noted "*the information that drives management decisions seems to be more based in local politics and whose land is being sought after for what purposes or with specific conflicts between parties that could result in lawsuits*" and another felt that

"*there has not seemed to be an interest in what science-based actions might be assisting in the recovery of specific animal populations as marker of progress to species recovery as it related to water/flood/land management decisions*."

Tailoring communication to facilitate adaptive management isn't easy. Managers and decision-makers have many responsibilities, so the challenges are to distill the results of all the previous phases of the adaptive management process and to determine how much information, of what sort, is needed to inform decisions. Lengthy reports or scientific papers are ineffective or are too often and too easily ignored. The Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management (2009) recognized the need for individuals skilled in communication *and* science to translate scientific findings for managers and decision-makers, a finding that we endorse.

Overall, while effective and broad communication is viewed as essential for adaptive management and for overall management of resources in the Delta, there is an unfilled need for an organizational structure that accommodates science writers or translators who can prepare informative briefings as important results become available. Moreover, communication must be multi-way, with decision-makers, stakeholders, and all participants in adaptive management informing as well as being informed by others. Without broad communication of the appropriate information, the next step in the adaptive-management cycle may not occur and the process will not continue.

*9. **Adapt***

In a broad sense, all of the previous steps in the adaptive-management process are about learning. The challenge is to put that learning into practice. As Hilborn (1992) noted, "if you cannot respond to what you have learned, you really have not learned at all." And responding involves making decisions.

In our interviews with agency representatives, the questions of who makes the decisions and how they do it came up repeatedly. In some programs, the process is adaptive but informal. If the results are desirable, then the actions continue and the techniques are applied elsewhere; if not desirable, the practices are assessed and changes may occur. Evaluating what outcome is or is not desirable should be related to the initial goals and objectives, although who deems what is a desirable outcome at the end of a project may not be the same person as the one who initially framed the goals and objectives, which may have been done years earlier. Moreover, as conditions change, what looks undesirable now may look more desirable as time passes (or vice versa). One respondent mentioned that "*we need tools to assist programs to conduct that critical but usually missing link in the cycle: adapt and then re-evaluate and change program goals*

and objectives." In some instances, determining whether change is necessary may be based on the use of models to inform decision-making, although this may be slow because data needed to run the models are insufficient. In this case, best professional judgment, stakeholder input, or external peer review may be an appropriate substitute. The trickiest part of the adaptive-management process may be determining when the mismatch between the results of management actions and the original goals and expectations of a project is great enough to warrant changing the actions, models used, goals and objectives, or even restating the initial problem (Fig. 1).

These two aspects of the "adapt" phase of adaptive management—who makes the decisions about whether to continue or to change management actions, and how much departure from expected outcomes should trigger a change in practices—do not always receive sufficient attention. The first is usually determined by who's in charge, which is usually tied to the administrative or organizational structure for conducting a project. The second depends on whether the mismatch between desired and realized outcomes has exceeded a threshold of acceptability, which is determined by such things as the cost and feasibility of making a change, the suitability of alternatives, the priorities of stakeholders and interest groups, and a multitude of other factors. Both the decision-making and the determination of trigger points are situation-specific. Nonetheless, it is important to know something about both issues as one goes through the steps in the adaptive-management cycle, because this will affect how plans are formulated, what data are gathered, and how the findings are translated into useful information. Misidentifying who makes decisions or being either premature or tardy in responding to triggers can easily derail the adaptive-management process.

Overall, it is our impression that decisions about whether to continue or change management approaches and actions are often based on some level of monitoring and analysis, combined with experience and professional judgment, current management needs, and the political (and funding) climate. The process varies tremendously among and within agencies, however, and it is often an informal rather than a systematic process. There is a tendency to regard any process that might result in change as adaptive management, which may be why so many think they are doing it.

VI. Why is Adaptive Management Not Done More Often in the Delta?: Constraints and Impediments

In Section I we listed factors highlighted in Appendix C of the Delta Plan that generally impede applications of adaptive management. Several of these apply with particular force to management in the Delta and were mentioned frequently by questionnaire respondents and interviewees. Making adaptive management a common

practice in the Delta requires that these impediments be lessened or removed, so we comment on them here.

Aversion to taking risks

Adaptive management addresses uncertainty and unknowns. Dealing with uncertainty entails risk. Risk carries with it a probability of failing to achieve goals and objectives. Failure is an anathema to a results-driven and political culture, which any management agency must be. How can a manager or decision-maker risk spending money on a project with uncertain results, especially when the stakes are high? How would she or he explain it to their managers, or to politicians, or to the public? Perhaps these constraints and anxieties have encouraged managers to believe that it is better to err on the side of caution and be conservative in modifying actions.

While this characterization does not describe the approach of many programs, managers, and agencies working in the Delta, it may not be too far off the mark for others. As one respondent observed, "*Agencies and agency staff are risk adverse. They would rather not act, if there is a possibility that they may make the wrong decision, and having it attributed to them*." To implement adaptive management, however, managers must not be penalized for trying approaches that later turn out to be ineffective or even to fail.

The tendency of managers, decision-makers, policy specialists, and engineers to be risk-adverse or to strive to maximize certainty in what they do contrasts with the culture of science, in which uncertainty and risk are the *sine qua non.* To a scientist, doing an experiment or conducting a study in which the results were certain and there were no risks of surprises would be unexciting and pointless. This difference in perspectives may contribute to communication difficulties between scientists and managers.

The curse of the immediate

Conducting comprehensive adaptive management will often be ponderously slow. Once the problem, goals, and objectives have been defined (which itself can be slow and contentious if multiple parties and interests are involved), doing the planning, modeling, designing, and permitting can easily take years before all is set to implement an action. Litigation can add further delays, and risk-aversion by managers or decision-makers can create additional excuses for delaying action. It is little wonder that carrying the adaptive-management process to full term is rare.

Even if steps can be taken to reduce some of these delays, the orderly, sequential process of adaptive management is susceptible to being repeatedly sidetracked in the environmentally, politically, and socially dynamic setting of the Delta. Crises arise often, derailing attempts at long-range planning or continued monitoring. Staff assigned to data analysis, modeling, or monitoring may be shifted to address more immediate concerns, so knowledge to inform adaptive management may be obtained sporadically, in fits and starts. As one respondent put it, "*the need to make decisions outpaces information flow*." Put simply, the pace of adaptive management does not match the pace of events and management decisions in the Delta. Faced with this temporal mismatch, it may often be tempting to move ahead with an action while assuring that adaptive management will be implemented later if it turns out to be needed. While some actions may need to be taken quickly (the construction of a salinity barrier under extreme drought conditions comes to mind), this need not preclude the careful thought and planning that underlie the first phases of adaptive management (see Section VII).

Regulations impede flexibility

Management of a system as complex as the Delta, with multiple local, state, and federal agencies involved in decisions about water and the environment, is suffused with an array of regulations and permit requirements. These regulations and requirements reflect a desire and need to establish order, certainty, and stability; they set standards and limits and prescribe the legal and operational domain within which management must operate. In contrast, the targets of management—smelt or salmon, water quality, incoming flows, demands on water exports, salinity intrusion, and the like—are anything but orderly, certain, and stable. The targets are assumed to be stationary, but in fact they are constantly moving. The flexibility needed to deal with changing conditions or to implement the "adaptive" part of adaptive management may be precluded by regulations. Listing of species under the Endangered Species Act, for example, places restrictions on experiments or pilot studies that might improve management and leads to a focus on single species rather than the larger ecosystem. Once permits have been issued for management actions it is difficult to change directions in mid-project, even if new knowledge indicates that change is needed. The need to modify permits or obtain new ones may bring a project to a halt, particularly if it prompts litigation.

Monitoring is difficult to maintain

Science is the lynchpin of adaptive management and should be the foundation of monitoring. Without monitoring the right things, at the right times, at the right places, there is little way to know whether management actions are on track, whether they are moving toward the desired goal or toward an alternative outcome. As Lindenmayer and

Franklin (2002) noted, "it is impossible to systematically assess whether management goals are being achieved without adequate monitoring, which in turn, ensures that the effectiveness of policies, legal obligations, and social commitments… can be assessed." In short, without proper monitoring there is no way to manage adaptively.

Monitoring needs to be done before and during a project, not delayed until after the project is completed or when it is too late to make changes. Because the outcomes of actions are frequently not immediately apparent, however, monitoring also may need to be continued for some time after project completion to gauge the effectiveness of the management actions. All of this emphasizes the importance of a continuing, long-term commitment to monitoring if adaptive management is to deliver on its potential.

However, developing the needed long-term vision and commitment in the crisis-driven setting of the Delta is challenging. As one respondent noted, "*Unless there are legal or regulatory mandates to do monitoring, it is often the first thing to go when money gets tight.*" Others suggested "*monitoring is typically [of] discrete elements for a short duration to meet regulatory requirements*" and "*not designed to answer science questions*." More generally, "*Adaptive management science efforts are not funded. They get added to a project and other resources and staff are depleted to meet the new requirements*."

There is also a perception that the level of monitoring required by adaptive management is excessive and may not add value commensurate with its costs. Such monitoring "*takes away from other resource management obligations and needs*." For example, "*Monitoring for a 300-acre restoration project far exceeds the costs of doing the restoration, so one can't blend implementation with monitoring or the project becomes too expensive.*" This may be particularly true if the monitoring must generate sufficient statistical power to detect responses to management actions in the complex and variable environment of the Delta. The success of the Interagency Ecological Program in catalyzing continuing, long-term monitoring of aquatic resources in the Delta shows that it can be done, although it requires dedicated and stable funding.

Adequate long-term funding is unreliable

Without exception, the individuals and agencies we canvassed identified the lack of reliable, long-term funding as the greatest single impediment to adaptive management and monitoring in the Delta. Thus, "*little to no money is available or designated for developing and implementing monitoring to determine outcomes.*" Or, "… *funding occurs for those programs mandated by law*"; otherwise, "*details of adaptive management and monitoring are often worked out as the project proceeds and the funding becomes*

available." Or, "*There is insufficient funding to conduct the science and collaboration necessary for evaluating actions and developing a response.*" Or, "*Funding for monitoring of habitat enhancement after construction is not typically a priority or directive of fund sources*."

The difficulty of funding adaptive management indicates that it is often not as high a priority as it should be. Even if funding is available to support the adaptive management that programs or agencies want to do, however, the funds often come in ebbs and flows that render the process inefficient or ineffective. "*Support comes in pulses that put a premium on showing progress, rather than deliberate, long-term projects.*" Bond funding, such as that from Proposition 1, may provide money to do things, but not to follow up and determine the outcomes. General Fund allocations to conduct adaptive management and monitoring are difficult to obtain and there is a perception among some that these activities are thinly disguised ways to fund scientific research that does not address real problems.

Thus, adaptive management is often viewed as an unfunded mandate. We believe that people and programs generally want to, and try to, practice adaptive management, but without dedicated and reliable funding they are reluctant to do so at the expense of existing projects and programs. But adaptive management is not something that can be done now and then, in fits and starts or as an add-on when resources are available. It must be built on an intent to follow through; it requires an underlying commitment to long-term stewardship of the Delta and its resources. Adaptive management should be a high priority. It should be the default practice, the "Plan A" for most projects and management actions.

VII. Standing Back and Looking Forward: Broadening the Perspective on Adaptive Management

So far, our review has focused on the details of the adaptive-management process and how it is used and perceived by those working in the Delta, relying heavily on their own words. Now we take a broader view, offering some thoughts prompted by those comments and responses. We hope that these thoughts will provide some guidance for making adaptive management more user-friendly, and thus more widely used in dealing with resource issues in the Delta.

Adaptive management may not always be appropriate

We just stated that adaptive management should be the default approach to management actions in the Delta. It is also mandated by the Delta Reform Act and the

Delta Plan. But adaptive management is not appropriate for every situation. Adaptive management should not be forced upon a project that is unsuited for it, either because the actions do not warrant it or the institutional or stakeholder support is lacking. In the *Department of Interior Applications Guide for Adaptive Management*, Williams and Brown (2012) suggest that adaptive management is appropriate to situations in which both uncertainty and controllability are high, when the approach may reduce uncertainty by controlling (i.e., adapting) the actions that are taken. Rist et al. (2013) indicate that the key determinants of adaptive management are its appropriateness, feasibility, and likelihood of success, and they provide a useful decision tree for evaluating whether and when a situation might meet these criteria.

Perhaps the most important factor influencing the decision to use adaptive management is funding. It may make little sense to initiate an elaborate and expensive adaptive-management process if the money isn't there to do it properly. However, for high-priority management actions in which the stakes, costs, and economic impacts are high, rigorous adaptive management may be essential. Here the value in investing in upfront knowledge acquisition to increase the likelihood that the actions will yield the desired results may justify the expense, especially if once an action is started it cannot easily be changed. Such situations call for comprehensive adaptive management, and the nine-step process shown in Figure 1 provides clear guidance.

In many situations, however, the nine-step process might better be regarded as aspirational rather than prescriptive. Can the adaptive-management process be streamlined to require fewer resources and to move more quickly, and in doing so have less potential to disrupt a program? Steps 1 (defining the problem), 2 (establishing goals), 4 (selecting action(s)), and 5 (designing and implementing actions) are the core components of any management activity, whether adaptive or not. It is important that they be done thoughtfully, with an eye toward flexibility. Step 3 (modeling) is often considered a barrier, but this depends on the kind and level of modeling required. It should not take much time or effort to assemble enough of what is known about a system to develop a reasonable conceptual model, which can quickly reveal unrecognized linkages and critical knowledge gaps and can suggest alternative actions. The impediments to such modeling are more institutional than they are intrinsic to the modeling process.

Likewise, step 6 (monitoring) needn't involve assessing all components of a system using rigorous and demanding procedures. A good conceptual model may help to identify reliable indicators of system responses to management actions, and planning ahead to think about the circumstances that might lead to a change in management could help to determine where, when, and with what level of detail the targets should be

monitored. Finally, steps 7 through 9 (analyze, communicate, and adapt) can be adjusted to the complexity and quantitative level of the information gathered and what changes, if any, are suggested and may need to be justified. The "synthesize and evaluate" part of step 7, especially, requires careful, focused thought and discussion among project participants (including stakeholders).

The bottom line is that there are ways to manage adaptively, whether or not one does comprehensive adaptive management following the steps of Figure 1. The key is to understand the value and advantages of the process and to be looking ahead rather than reacting or, worse, avoiding the risk of an approach that might not work or clinging to an approach that isn't working. Conducting adaptive management requires patience, persistence, and commitment (Williams and Johnson 1995), but it also benefits from thoughtful assessment of how much of the process is just right for the circumstances and objectives.

Conditions change

Looking ahead is important not just so one can gauge the effectiveness of an action and make changes before it is too late, but also because the Delta, like the rest of California and most of the world, is undergoing rapid change. All coastal areas will be affected by sea-level rise, and models of future climate change predict higher temperatures and different rainfall and snowfall patterns, with changed hydrological flows in the Delta. New, non-native species will arrive. Regulatory requirements and the economic values of land and water also will continue to change. Consequently, even the most thoughtfully planned and carefully designed management actions may no longer be appropriate by the time they are completed (or even by the time they are implemented, if planning, permitting, and the like take as long as they sometimes do). If the system changes rapidly and unpredictably, an action may not produce the desired outcomes or it may be difficult to determine whether a change in the system is due to the action itself or to changes in other factors. Although some people question whether the rapidity of these environmental changes precludes the effective use of adaptive management, others suggest that it is the best approach to dealing with these rapid changes because they require flexibility, which is an essential element of decision-making in a rapidly changing world.

Adaptive management also provides a way of anticipating changes through modeling and monitoring. Some plans for tidal wetland restoration, for example, are incorporating projections of sea-level rise, hydrology, and sedimentation to target actions at appropriate tidal elevations for future conditions (see Box 1). It may be useful to develop "anticipatory adaptive management," in which the management actions are

designed with reference to future conditions, when the actions will be completed and the outcomes are expected, rather than to the conditions existing at the time the actions are planned or initially implemented. Vleig and Zandvoort (2013) describe such an approach to adaptive management in the Rhine-Meuse Delta of the Netherlands and compare it with the approach outlined for the Sacramento-San Joaquin Delta in the Delta Plan.

Another consequence of environmental change impinges on how or whether adaptive management is implemented. If change is great enough or rapid enough, it may overwhelm any inherent resilience of a system and push it over a threshold or tipping point. Once a threshold is passed, the system may be so altered that it functions differently, rendering it difficult or impossible to return to its former condition even with intense management. In such cases, the dynamics of the system may have been fundamentally altered, changing cause-effect relationships. Consequently, the previous understanding of the system, on which management relies, may no longer apply—the rules of the game have changed. The problem with thresholds, of course, is that you generally don't know they are there until you've passed them, when it may be too late to do much about it. In a complex ecosystem that has undergone massive alteration, such as the Delta, some thresholds have already have been passed; the Pelagic Organism Decline (POD) may be an example. We found little evidence that much thought has been given to the complications that might be posed by thresholds. The possibility of thresholds heightens the need to incorporate flexibility and adaptability into planning and management.

The bottom line is that future changes should always be considered in planning management actions, even though (as Yogi Berra also said), "It's tough to make predictions, especially about the future." Nonetheless, future changes will determine the effectiveness of management whether or not the approach is adaptive, whether or not there are legal or regulatory requirements to consider the future, and whether or not the approach is explicitly anticipatory.

"Best available science" may not always be best

The use of "best available science" is a common requirement for management actions in an uncertain environment. It is explicitly mandated in the Delta Reform Act and is discussed at some length in the Delta Plan. Best available science "requires scientists to use the best information and data to assist management and policy decisions" (Delta Plan, page C-1). In essence, it is the gold standard for applied science.

We do not intend to challenge the importance of using current and well-tested scientific knowledge to support management or the desirability of aspiring to the criteria

established for best available science (Delta Plan, Table C-1). It may be worthwhile, however, to reflect on whether it is always the most appropriate or productive goal for science-based management in the Delta. We have several concerns.

First, what is really intended is that the best available *knowledge* be brought to bear on an issue or used to support a proposed action. Knowledge comes in many forms, of which science is only one. The learning that is the aim of adaptive management involves increasing the quality and quantity of knowledge, not just adding more science to the mix. Admittedly, "best available knowledge" doesn't have the same cachet as "best available science," but it may more accurately capture what is really being sought.

Second, the emphasis on "best" and the criteria used to define it appropriately sets a high bar. It may be set so high, in fact, that actions may sometimes be delayed while the search goes on for better data, better analyses, or additional scientific publications, all in the interests of meeting the goal of "best." There are already excuses available for delaying actions (especially controversial ones); aiming for "best" should not be one of them.

Third, what might be "best available science" (or knowledge) under some circumstances may not be matched by the available technology. There is often an unstated assumption that the technological or engineering means to implement the science are available and feasible, that the application of science is not constrained by technology. This may not always be the case.

Fourth, adaptive management involves a succession of steps that build on what is good enough to take action—further reduction in uncertainty is not needed to move ahead. In fact, it is often necessary to initiate a management action when the available knowledge is just "good enough," rather than being the "best available." The same criteria used to identify "best available" science might also be used, in a somewhat more relaxed form, to define what is "good enough" science. Essentially, thinking of the science as "good enough" allows a manager or decision-maker flexibility in considering the additional costs, risks, uncertainties, effort, and potential benefits of attaining "best available." There is a legitimate concern that using a "good enough" standard may weaken the role of science in informing management and policy or open the door to all sorts of pseudo-science or advocacy entering the fray and influencing decisions. Realistically, however, even the most stringent definition of "best available science" is still susceptible to the inclusion of suspect or subjective science.

All of this may be quibbling about words. Words matter, however. "Best available science" implies (correctly or not) that scientific certainty is as good as currently

possible. Science that is just "good enough" doesn't sound nearly so rigorous. Nonetheless, striving for the best may not always be the most prudent approach.

VIII. Overall Findings

We found that most practitioners and managers in the Delta have a general understanding of what adaptive management is and what it entails. "Adaptive management," however, is perceived in multiple ways and is often regarded as any process that might lead to changes in actions. Yet we find little evidence that the actual process is being fully implemented. Instead, adaptive management, the research needed to fill knowledge gaps and reduce uncertainty, and the essential monitoring needed to successfully implement it are often regarded as add-ons, obligations that divert attention from needed projects.

Despite the successful application of adaptive management in a variety of fields, ranging from engineering to medicine, there are several reasons for the struggle to implement it fully in the Delta. It's easy to blame a lack of funding, and funding to undertake the adaptive-management process (including the necessary monitoring) is indeed sporadic and inadequate. But increased funding, by itself, would not ensure that adaptive management would be fully implemented. To do so will require a change in the culture of management in the Delta. Managers and decision-makers must become more willing to take risks, weighing the risks against benefits by using conceptual or quantitative modeling or informed judgment. Agencies must become more actively engaged in collaborations with one another and be willing to share staff and resources as the challenges require. Adaptive management must be recognized as a high priority, an integral part of management plans and actions.

The cost savings from sharing staff skilled in data management, analysis, and modeling may be particularly great. Perhaps most importantly, adaptive management requires greater flexibility—flexibility in decision-making, in regulations and permitting, and in planning for future changes.

These changes will not be easy or achieved quickly. However, we believe that implementation of the following recommendations will help move adaptive management toward a more effective and integrated approach to managing the Delta, its water, and its ecosystems.

IX. Recommendations

Science, management, and policy in the Delta are in a state of flux, brought on by the proposal to build new water-conveyance facilities; the heightened imperilment of several species at risk of extinction; the entry of new, non-native species into the Delta; changes in hydrology and sea-level rise due to climate change; the specter of increased salinity intrusion into the Delta; and increasing conflicts over who gets the water—all exacerbated by the ongoing drought. This cauldron of change provides an unusual window of opportunity—and an imperative—to develop a more thoughtful and effective approach to achieving the coequal goals highlighted in the 2009 Delta Reform Act for the future of the Delta. The Delta Plan and Delta Science Plan provide frameworks for capitalizing on this opportunity, and the theme of "One Delta, One Science" offers a way to bring coherence to the science currently fragmented among agencies and disciplines. This fragmentation thwarts effective adaptive management. A more holistic and integrated approach to science-based management in the Delta is needed.

Despite legislated mandates to use adaptive management, this is unlikely to happen spontaneously. We offer the following recommendations; if implemented, they can move adaptive management beyond being an abstract label to something that is a common and valued element of management programs and actions in the Delta.

1. **Create a Delta Adaptive Management Team (AMT).** This is not a new recommendation; similar suggestions have been made in the past. In the context of the CALFED program, for example, Zedler and Callaway (2003) proposed developing an adaptive management team that "meets annually, identifies priority research needs, prioritizes sites where adaptive restoration might take place, reviews research results, and recommends future actions." Subsequently, the Delta Science Plan developed by the Delta Science Program in 2013 recommended (1) the creation of several "adaptive management liaison" positions to provide advice to their counterparts engaged in adaptive management in agencies and organizations; and (2) convening an annual "adaptive management forum" to share lessons learned and provide training in adaptive management. Currently, two interrelated programs operate under court orders to develop a science and adaptive-management program to inform the implementation and development of Biological Opinions related to listed smelt and salmon. The Collaborative Science and Adaptive Management Program (CSAMP) is a policy group composed of agency directors, regional directors, and general managers. The Collaborative Adaptive Management Team (CAMT), which includes senior scientists and high-level managers, is embedded within CSAMP. The recirculated draft RDEIR/SDEIS for California WaterFix that replaces BDCP proposes formation of a Collaborative Science and Adaptive Management Program that would absorb the functions of CSAMP and CAMT, focusing primarily on the

design and operation of water-conveyance facilities, associated water-quality and ecosystem-protection requirements, and mitigation measures such as habitat restoration.

We envision something greater. The AMT should be composed of individuals who are knowledgeable and skilled in all phases of adaptive management. These individuals may be drawn from agencies, non-governmental organizations, universities, or other sources, but all will be dedicated, full-time members of the Team who operate independently of state or federal agencies. The Team will work closely with those who plan, implement, or oversee management actions in the Delta. Strong leadership will be required to foster the mutual trust and respect among scientists, managers, stakeholders, decision-makers, and agencies that are needed to design and conduct coordinated adaptive management and navigate the tangled web of Delta interests.

The AMT will provide guidance, expertise, and support to enhance the application of adaptive management in the Delta and integrate agencies' efforts. More specifically, the AMT will:

- Provide leadership in aligning adaptive management with the needs and context of management actions. There is no "one-size-fits-all" approach for applying adaptive management to an action. Some large-scale, complex actions may require comprehensive adaptive management; for smaller, site-specific actions a streamlined adaptive process may be most useful; and some projects may be unsuited to adaptive management at all. The scope and level of adaptive management should be aligned to improve outcomes and reduce or accommodate critical uncertainties. The adaptive-management plan for a management action should explain why adaptive management is needed (or not), likely benefits, and which steps of the adaptive-management process will be undertaken, abbreviated, or omitted. By articulating the pros and cons of alternative-management scenarios, the AMT may help programs and agencies decide on the best course of action.

- Consider how expected changes in future conditions should be incorporated into adaptive management plans and actions. The Delta is a dynamic place. Climate change and sea-level rise will make it more so. Adaptive-management plans need to be designed to consider likely impacts of future changes on the outcomes of management actions and should include contingency plans and resources if changes are likely to be great.

- Support agencies in using adaptive governance and identify potential synergies among agencies. Adaptive management requires flexibility. Managers must be willing to take reasonable risks on actions that may not work out as planned; to reassign staff to needs that arise during adaptive-management implementation or in response to unplanned experiments; and to share resources and staff expertise with other agencies or programs in response to shared needs. The AMT will work with programs and agencies to develop collaborations and realize economies of scale.

- Advise the Delta Stewardship Council and other regulators on compliance issues. The Council is responsible for evaluating whether covered actions are consistent with the Delta Plan, which includes the application of adaptive management. The AMT can evaluate whether the adaptive-management plan for an action is appropriate to the scope and context of the action.

- Encourage a greater emphasis on whole ecosystems and functioning landscapes. Most management actions in the Delta address the ecology of single species or deal with the management or restoration of specific sites. Such actions will be more effective and more amenable to adaptive management if they take into account the broader landscape and ecosystem contexts. The AMT will develop case studies and facilitate research to document these benefits.

- Assemble, synthesize, and communicate information about adaptive management. Adaptive management is being undertaken in many places in the world to address diverse problems. The AMT will act as a conduit to convey the findings and experiences of these efforts to managers and practitioners in the Delta. The adaptive-management process and its components—science, modeling, monitoring, analysis—must themselves be adaptive.

The devil, of course, is in the details, such things as staffing, funding, authority, and relation to existing programs (e.g., CAMT, the Delta Science Program). These remain to be resolved (see Section X).

2. **Support adaptive management with funding that is dependable yet flexible.** Adaptive management in the Delta will not become a reality unless the paucity and unpredictability of funding to support critical stages of the process are remedied. Radical approaches to funding adaptive management are needed. The

past and present piecemeal approaches will not provide the long-term support needed to reach the "adapt" part of the process, without which there is only a business-as-usual management approach. We suggest that budgets should include a line-item allocation at a fixed proportion (10-20%) to support Delta adaptive management above and beyond monitoring. The dollars could be the foundation of a general Delta Adaptive-Management (Trust?) Fund to assist high-priority management actions or programs and support the activities of the Adaptive Management Team. The funds should not be transferred from other existing activities into a bin labeled "Adaptive Management" (i.e., robbing Peter to pay Paul) but should be newly dedicated funds.

Adaptive management can be economical. Coordinating planning and actions among projects, programs, and agencies should realize net cost savings. The monitoring that is so essential to adaptive management can be expensive, yet these costs may be reduced by identifying appropriate monitoring proxies, cost-effective protocols, and optimal monitoring locations and timing at the outset. Flexibility is needed to take advantage of opportunities, such as learning from water years that are unusually wet or dry.

3. **Monitor**. Monitoring the right things, at the right times, and in the right places, is essential. Without it, there is no way to know whether management actions are moving toward the desired goal or toward a different, less desirable, outcome. Designing monitoring protocols to fit the magnitude of management actions and the timing of important ecosystem processes would make the value of adaptive management more readily apparent. Developing an institutionalized regional approach to monitoring could also help to coordinate actions among projects and facilitate the collection, analysis, and synthesis of data that are compatible across projects.

4. **Capitalize on unplanned experiments.** Large, ecosystem-level experiments are expensive, difficult to design and replicate, and require burdensome permitting. But unplanned experiments (e.g., extreme droughts, large floods, levee breaks, construction of salinity barriers, cold-water releases from dams) do happen. These provide opportunities to learn and to implement adaptive management. Capitalizing on these opportunities requires being prepared—having contingency plans, monitoring protocols, and modeling capability in place and identifying funds and staff that can be shifted to respond.

5. **Use selected restoration sites to test adaptive-management and monitoring protocols.** The habitat restoration envisioned in California EcoRestore presents an extraordinary opportunity to select locations that can act as learning laboratories for applying adaptive management. Careful design that applies adaptive management to the objectives of restoring habitat can help to develop solutions that can be applied elsewhere in the Delta.

6. **Integrate science and regulations to enhance flexibility.** Rigid regulations and permitting rules inhibit the nimble flexibility required to change directions quickly as it becomes apparent that the outcomes of management actions are not performing as planned. Opportunities are lost. Regulations should be interpreted or revised to allow sufficient flexibility to implement adaptive management.

7. **Recognize where adaptive management is not appropriate.** Adaptive management should be the default position for management actions in the Delta. In some situations, however, the approach may be inappropriate or need to be streamlined to require fewer resources and move more quickly. Such decisions should be made thoughtfully after careful consideration of the alternatives.

8. **If the impediments to conducting adaptive management are insurmountable, revisit or revise the mandates.** The use of adaptive management is often legally mandated, whether it is appropriate for the situation or not. Neglecting adaptive management may therefore provide a basis for challenging the legal validity of a plan or project or for finding it inconsistent with the Delta Plan. In arenas where adaptive management yields few benefits or is simply too difficult to implement, however, the mandates for using adaptive management should be reconsidered and revised. It is counterproductive to impose a requirement on agencies and managers that they cannot meet, even with the best of intentions. In this case, other means should be examined to achieve the original legislative intent of adaptive management.

X. What Next?

It will not be easy to implement these recommendations. In our view, however, it is essential to do so if adaptive management is to become an integral part of management of the Delta and its resources. Making this happen will require leadership in science and policy from programs and agencies. However, the work of the Delta ISB on fostering wider and more nimble application of adaptive management to Delta management should not end with this report. We envision continuing Delta ISB involvement in several follow-up activities:

1. Work with the Delta Stewardship Council and others to create the Adaptive Management Team, as proposed in recommendation 1. Several issues must be resolved: the skills, interests, perspectives, and affiliations of the Team members must be defined; the authority of the AMT must be determined; funding sources must be identified; and relationships to existing programs must be worked out. The Delta ISB will engage in comprehensive, detailed, and inclusive discussions to address these and other issues.

2. Meet with individuals and respondents who provided the raw material for our review to discuss our findings, how to address the impediments, and how best to progress from words and plans to adaptive actions.

3. Present and discuss these findings and recommendations with multiple audiences (e.g., State of the Estuary Conference, a perspective paper in *San Francisco Estuary and Watershed Science*).

4. In partnership with the Delta Science Program, the Delta Conservancy, CAMT, the Public Policy Institute of California, and others, organize and host an Adaptive Management Forum, including local and invited experts and multi-perspective panels to discuss and evaluate what is needed to do adaptive management in a system as complex as the Delta.

5. Work with the Delta Science Program and the Delta Adaptive Management Team to track progress on the implementation of adaptive management and the recommendations in this report.

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Appendix B. Adaptive Management in the Everglades. From Doremus et al. (2011).

The Everglades: Without Clear Goals, Adaptive Management Goes Nowhere

The Comprehensive Everglades Restoration Plan (CERP) illustrates one instance where adaptive management has failed primarily because it was mandated by Congress in an inappropriate context. The CERP was adopted in 2002 in an effort to restore the ecological functioning of the Florida Everglades.[2] Congress intended "to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection."[3] The $8 billion cost of the restoration plan was to be shared equally by the federal government, through the Army Corps of Engineers, and the non-federal sponsor, the South Florida Water Management District (SFWMD).

Heavy emphasis has been placed on satisfying stakeholders' economic interests rather than the environmental mandates, and this imbalance places a chokehold on experimentation, learning, and adaptation. In response to stakeholders' demands, the CERP devotes a great deal of attention to the use of ever more heroic engineering techniques to expand water supplies and ensure flood control for South Florida's exploding population. Meanwhile, it gives low priority to the improvement of necessary sheet water flows—the primary ecological hallmark of the Everglades. As a result, the CERP remains in a planning mode, rather than an adaptive implementation mode. In a 2007 review, the Government Accountability Office observed that no CERP projects had been completed and that the only progress that had been made involved a few, select CERP-related pilot projects designed to understand nutrient removal in abandoned agricultural fields.[4]

Why has such a well-funded attempt at adaptive management faltered? One factor is the articulated goal of the CERP, which strives to have it all: ecosystem restoration as well as uninterrupted water supply and flood protection. As in other cases where private economic stakes are high, regulated entities and other stakeholders want certainty and stability. If scientists cannot predict outcomes with a great degree of certainty, experimentation in many instances, if not most, simply will not take place. As a result, the Everglades plan is stuck on modeling and data collection rather than learning through active experimentation and resolving uncertainties in favor of ecological resilience.

A second factor is the basic congressional directive for all Corps' decision-making, which gives the agency discretion to proceed with a project whenever benefits "to whomsoever they accrue" exceed costs.[5] These grants of broad discretion free the Corps to establish priorities based on politics instead of principled reasoning and evidence. As a result, the American public has been saddled with hundreds of questionable dams, levees, and other structures justified only by dubious cost-benefit analyses. In a study of Mississippi River management in 2004, the National Research Council issued a sweeping indictment of the misguided methodology used by the Corps to justify replacing locks and dams on the upper river.[6] The CERP appears to suffer from similar flaws.

Appendix C. The Adaptive-Management Questionnaire

DELTA INDEPENDENT SCIENCE BOARD

REVIEW OF ADAPTIVE MANAGEMENT IN THE DELTA

The Delta Reform Act of 2009 charges the Delta Independent Science Board (DISB) with providing "oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs "such that" all Delta scientific research, monitoring, and assessment programs are reviewed at least once every four years" (§85280 (a)(3)). Rather than reviewing individual programs one-by-one, we are conducting reviews based on broad thematic areas. This questionnaire is the first stage of our review of how adaptive management is being thought about, planned, and implemented in the Delta and how science can best support those efforts.

We intend that our review go beyond oversight to be constructive and helpful. To probe more deeply into the responses to this questionnaire, we will follow up with in-person interviews with some respondents. After preparing a report on our findings, we will engage in further discussions to help selected programs advance their adaptive management planning and actions and adjust the focus of future reviews.

Designing and implementing adaptive management isn't easy, and it is done much less often than it is talked about. By thinking about the following questions and then providing brief responses, you'll help us suggest whether, when and how adaptive management should be used, how it can be improved, and how science can best aid this process. The questionnaire is in three parts. **Please provide links to or copies of documents that you think would help us better understand how you are thinking about, planning, and/or implementing adaptive management.**

It would be most helpful if you could return the completed questionnaire to **Martina Koller (martina.koller@deltacouncil.ca.gov)** or **Lauren Hastings (lauren.hastings@deltacouncil.ca.gov)** by **November 20**.

I. A QUICK SURVEY

We'd like to develop a quantitative understanding of how adaptive management is used in Delta programs (after all, we're scientists). **Please assign a value from 1 (strongly disagree) to (5 strongly agree) to each of the following statements regarding your agency, division, or program ("entity") and current or planned programs.** (You'll have the opportunity to say more in the sections that follow.)

I'm responding for (name of entity) _____. The entity is an agency, division, program, or other (specify) [**check one**]

1. My entity uses adaptive management as an organizing framework for its activities.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

2. In my entity's experience, adaptive management efforts often require collaborations among multiple agencies and stakeholders.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

3. My entity's broad management plans (e.g., resource management plans) include the flexibility necessary to engage in adaptive management.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

4. Laws and other administrative and regulatory requirements often constrain our entity's efforts to engage in adaptive management.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

If so, can you list any specific legal requirements that you believe hamper or facilitate adaptive management?

5. Changes could be made in existing legal requirements to make adaptive management more successful.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

If so, can you suggest specific changes to existing legal requirements that would facilitate adaptive management?

6. We usually build a conceptual model of the management action before implementing the action.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

7. Conceptual models should include both human and ecological systems.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

8. We gather baseline information and/or data about the relevant system(s) before management actions are implemented.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

9. Monitoring is adequately funded to support adaptive management.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

10. Monitoring and assessment results are integrated into adaptive management decision-making.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

11. It is important to communicate the results of adaptive management experiments to stakeholders.

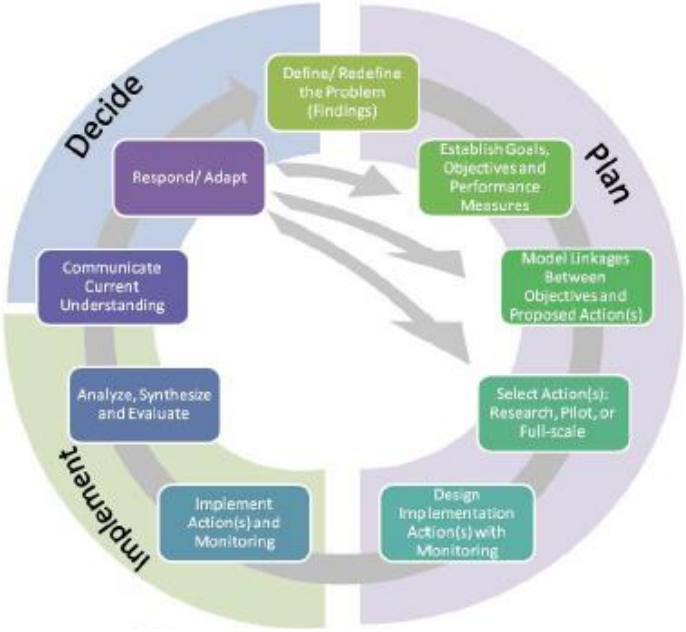
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

12. In my entity's experience, when adaptive management experiments tell us something new, management actions are changed to reflect what is learned.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

II. THE ADAPTIVE MANAGEMENT PROCESS

In the Delta Plan and the Delta Science Plan, adaptive management is visualized as a nine-step process. The figure illustrates how these steps are linked in sequence, and provides a useful framework for describing how you are thinking about, planning, or implementing adaptive management.



The following sections relate to each step of this adaptive management process. **Please briefly describe (a few sentences or short paragraph will suffice) how or whether each step is conducted or being planned in your program(s), along with any comments you'd like to share with us.** *The questions for each are there to help you think about the step; please feel free to address those questions or respond in any other way that suits you.*

Step 1: Define the problem. Adaptive management depends on a clear understanding of the problem to be addressed through some combination of science, management, and policy. Click here to enter text.

Step 2: Establish goals, objectives, and performance measures. Goals and objectives provide specific guides or targets for adaptive management, and performance measures indicate whether actions are working well. How are performance measures identified and

employed? What are some common performance measures for your projects? Click here to enter text.

Step 3: Model linkages between objectives and proposed action(s). Developing models helps define the structure and relationships of the system being managed. Models may be conceptual, analytical, simulation (of varying complexities), and involve probabilistic risks or scenarios. How are you using models, of which type(s)? How do you decide what kind of modeling is needed or justified, or how detailed it should be? Click here to enter text.

Step 4: Select actions: Research, pilot, or full-scale: Depending on the situation, the state of existing knowledge of the system, the uncertainties and risks of undertaking a planned action, its costs, and other factors, additional research (literature, modeling, field observations or experiments) may be needed before implementation, or it may be useful to conduct a pilot study. What is done in your program, and how are decisions made about what to do? What steps are taken to assemble and make accessible a knowledge base for the project or problem? How is targeted research incorporated into adaptive management? Click here to enter text.

Step 5: Design implementation action(s) with monitoring: Are details of adaptive management and monitoring in place *before* a project is started. Click here to enter text.

Step 6: Implement action(s) and monitoring. Monitoring generates lots of data. How are data managed? Are data bases linked with other data bases outside the project? Click here to enter text.

Step 7: Analyze, synthesize, and evaluate. When is analysis done after or during implementation? What kinds of project evaluation are common? Click here to enter text.

Step 8: Communicate current understanding. Communication of analysis results and synthesis of scientific data usually requires translation into readily understandable messages for managers and decision-makers. When is this done, how, and by whom? Click here to enter text.

Step 9: Respond/Adapt: How are decisions made about whether to change goals and objectives, revise or conduct more modeling, or conduct additional research or take different actions to achieve the objectives? Click here to enter text.

III. SOME SPECIFIC QUESTIONS

Here are a few additional questions that we'd like you to think about and tell us what you think, especially the last question.

1. How should one decide when adaptive management is needed or appropriate and when it is not? What criteria should be used to make this decision? Click here to enter text.

2. How have linkages among projects or actions and their effects been considered in your planning (or how should they be considered)? Click here to enter text.

3. What mechanisms exist for bringing scientists, managers, and stakeholders together throughout the adaptive management process? Click here to enter text.

4. What is the role of independent peer review, and in what phases of the process is it best applied?
   Click here to enter text.

5. How are your adaptive management science efforts funded (or how should they be funded)? What staff support is needed, with what sorts of expertise? Click here to enter text.

6. What legal, regulatory, or administrative barriers to doing effective adaptive management have (or will) you encountered? Click here to enter text.

7. Given the uncertainties that prompt adaptive management, there is a real likelihood of being wrong or mistaken. How do you deal with that possibility?
   Click here to enter text.

8. How are you incorporating anticipated future conditions (e.g., climate change, sea-level rise, land-use change) into adaptive management? Click here to enter text.

9. Do you have suggestions for making adaptive management work more effectively?
   Click here to enter text.

10. What question(s) should we have asked but didn't (your answer would be helpful)?
    Click here to enter text.

Appendix D. Agencies and Individuals Consulted for this Report

Agencies responding to the questionnaire

- California Department of Fish and Wildlife – Ecosystem Restoration Program
- California Department of Water Resources – FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO)
- Central Valley Regional Water Quality Control Board
- San Francisco Bay Regional Water Quality Control Board
- Suisun Resource Conservation District
- U.S. Bureau of Reclamation, Bay-Delta Office

Individuals interviewed personally

- Dan Castleberry, U.S. Fish & Wildlife Service
- Joshua Collins, San Francisco Estuary Institute
- Val Conner, Collaborative Adaptive Management Team
- Steve Culberson, U.S. Fish & Wildlife Service
- Ted Frink, California Department of Water Resources – FESSRO
- Les Grober, California State Water Resources Control Board
- Bruce Herbold, Environmental Protection Agency (retired)
- Campbell Ingram, Delta Conservancy
- Gail Newton, California Department of Water Resources – FESSRO
- Kim Webb, U.S. Fish & Wildlife Service
- Carl Wilcox, California Department of Fish and Wildlife
- Leo Winternitz, Collaborative Adaptive Management Team

Appendix E. Responses to Questionnaire Statements about Adaptive Management (1 = strongly disagree, 5 = strongly agree)

The statements:

1. My entity uses adaptive management as an organizing framework for its activities.
2. In my entity's experience, adaptive management efforts often require collaborations among multiple agencies and stakeholders.
3. My entity's broad management plans (e.g., resource management plans) include the flexibility necessary to engage in adaptive management.
4. Laws and other administrative and regulatory requirements often constrain our entity's efforts to engage in adaptive management.
5. Changes could be made in existing legal requirements to make adaptive management more successful.
6. We usually build a conceptual model of the management action before implementing the action.
7. Conceptual models should include both human and ecological systems.
8. We gather baseline information and/or data about the relevant system(s) before management actions are implemented.
9. Monitoring is adequately funded to support adaptive management.
10. Monitoring and assessment results are integrated into adaptive management decision-making.
11. It is important to communicate the results of adaptive management experiments to stakeholders.
12. In my entity's experience, when adaptive management experiments tell us something new, management actions are changed to reflect what is learned.

The responses:

	Respondent							
Question	Agency A	Agency B	Agency C	Agency D	Agency E	Agency F	Mean	Range
1	4	5	4	2	3	2	3.3	2 to 5
2	5	4	4	5	4	5	4.5	4 to 5
3	4	5	4	2	3	4	3.6	2 to 5
4	3	2	4	5	4	4	3.6	2 to 5
5	2	3	3	5	2	3	3	2 to 5
6	3	4	4	2	4	2	3.2	2 to 4
7	5	5	4	5	5	5	4.8	4 to 5
8	5	4	4	3	3	4	3.8	3 to 5
9	2	2	2	3	2	1	2	1 to 3
10	3	4	3	3	3	3	3.2	3 to 4
11	5	5	4	5	5	5	4.8	4 to 5
12	3	4	3	4	3	4	3.5	3 to 4