APPLICATION OF "BEST AVAILABLE SCIENCE" IN ECOSYSTEM RESTORATION: LESSONS LEARNED FROM LARGE-SCALE RESTORATION EFFORTS IN THE U.S.

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PRODUCT OF THE
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EXECUTIVE SUMMARY

The Puget Sound Nearshore Ecosystem Restoration Program (PSNERP) proposes to restore degraded shoreline ecosystems of Puget Sound. In the process of providing scientific direction for PSNERP, the Nearshore Science Team (NST) sought to more clearly define the role and position of scientific input into large restoration programs such as PSNERP. As part of the planning phase of this program, the NST conducted a "lessons learned" exercise to characterize the role of science in five other large-scale programs around the country. These programs including the Chesapeake Bay Program, the Comprehensive Everglades Restoration Plan, the California Bay-Delta Authority, the Glen Canyon Adaptive Management Program, and the Louisiana Coastal Areas Ecosystem Restoration Program. The NST's goal was to better understand how science is incorporated into program management and organizational structure, such that the "best available science" is realized. This document summarizes lessons learned by the NST about maximizing the best available science in conceptualizing, designing and implementing large-scale restoration.

The NST found that maintaining the independence of science from policy pressures in order to assure legitimacy and quality facilitated the incorporation of best available science into restoration actions. The NST found that the strongest assurance for scientific credibility was rigorous peer review, both internal and external to the organizational structural. "Vertical integration" was an effective tool to coordinate science with other sectors of the program. Several programs had successful strategies for educating stakeholders about science issues with publications and web sites. Although they all acknowledged the need for rigorous adaptive management, one program in particular demonstrated that adaptive management is a powerful tool that can only be effectively used if all involved understand it; this suggests that education and information dissemination are important and often neglected aspects of adaptive management. The NST found that these programs often struggled with fundamental cultural differences between science and policy and, at times, had difficulty estimating scientific resource requirements for true ecosystem management and restoration. In spite of difficulties encountered by these programs, the NST was encouraged by the numerous innovative approaches being employed to meet the challenges inherent in large-scale restoration.

These observations hopefully will guide the utilization of science in PSNERP's Feasibility Study Phase and throughout the General Investigation Study. The NST intends this document to stimulate interest in improving the role of science in ecosystem restoration and provide present and future restoration practitioners with practical advice gained from predecessor programs.

INTRODUCTION

The use of the best available scientific information is required under U.S. law in many environmental decisions. In most instances, statutes requiring the use of best available science (BAS)[1] have left the term undefined. Therefore, interpretations of BAS have been developed in state, regional, and federal courtrooms to guide scientists, policy makers, and natural resource managers in deciding what is and is not good science. Best available science "include[s] biological, ecological, economic and social data"[2] and the generation of BAS generally involves peer review, scientific methodologies, logical conclusions and reasonable inferences, quantitative analysis, appropriate context, and thorough references[3]. Even less well defined is the most appropriate way to use best available science in difficult policy and management decisions, such as those involved in ecosystem restoration.

The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) is a cost share agreement between federal partners and the State of Washington to identify urgent ecosystem problems in the Puget Sound basin, evaluate potential solutions and restore and preserve critical ecosystem features of degraded shorelines of Puget Sound.[4] This process-based, ecosystem restoration project was launched in 2001 and is in its planning phase.[5] Scientists within PSNERP were aware of the many approaches to using science in large-scale restoration programs across the country. At its inception, PSNERP formed a Nearshore Science Team (NST) to provide technical products and scientific guidance for the project. In order to better understand the role of scientists and science in formulating a comprehensive restoration strategy, we sought the opportunity to critically examine science in several more mature ecosystem restoration programs beyond the Pacific Northwest region. The purpose of this document is to convey some of the essential lessons learned by the NST to other members of PSNERP and to the broader community of restoration practitioners.

OPPORTUNITY ADDRESSED

There are numerous publications concerning the science of restoration ecology (i.e. Jordan *et al.* 1987, Zedler 2001) and on the incorporation of science into environmental policy (i.e. Lee 1993, Healey and Hennessey 1994, National Academy of Sciences 1995, Huxham and Sumner 2000, National Academy of Sciences 2000, Leschine *et al.* 2003). However, published literature concerning the use of science in restoration policy is lacking. One exception, although outdated, is the NRC report, *Restoration of Aquatic Ecosystems* (1992). Although updating and filling this information gap is beyond the scope of this paper, it is our intent to bring attention to the need for improved

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[1] Best Available Science is required by the National Environmental Policy Act, Section 102, Subsection B, Marine Mammal Protection Act, Section 108, Endangered Species Act, Section 7(a)(2), and Magnuson-Stevens Fisheries Management and Conservation Act, Section 301(1)(2).
[2] Code of Federal Regulations § 602.12(b)(1).
[3] Washington State Legislature, Growth Management Act – Procedural Criteria for Adopting Comprehensive Plans and Development Regulations, Part Nine: Best Available Science (365-195-900 thru 365-195-925). See also (Bisbal 2002).
[4] PNSERP website: http://www.pugetsoundnearshore.org/whatwedo.htm
[5] PSNERP website: http://www.pugetsoundnearshore.org. For more information contact Bernie Hargrave (Bernard.L.Hargrave.Jr@nws02.usace.army.mil) or Tim Smith (smithtrs@dfw.wa.gov)

understanding of the incorporation of best available science into restoration programs, such as PSNERP.

HYPOTHESIS AND PURPOSE

The NST's fundamental hypothesis is that a restoration program that efficiently and effectively uses science as a foundation for making decisions will be, in the long run, more successful in making progress towards meeting restoration goals. Here we use efficiency to describe those cases where science is free to examine all technical approaches to restoration in the absence of non-scientific constraints. We define effectiveness as a situation where science, operating within the confines and structure of the discipline, contributed to a decision making process leading to the accomplishment of restoration goals. We hypothesize that the organizational structure of the program that develops to address large-scale restoration will dictate the efficacy of science in the near-term. Therefore, our aim is to examine the organizational structure, and specifically the placement of science within that structure, in five case studies. Judging the "success" of these restoration programs is not appropriate at this time because all are ongoing and each has its own methods for determining success. Instead, by dissecting the organizational structure we will compare elements of programs that influence the efficiency and efficacy of science. The purpose of this document is both to inform and guide the restoration strategy in the Puget Sound and to inform ongoing and future restoration efforts elsewhere, ultimately improving the practical application of restoration science.

SELECTION CRITERIA AND CLARIFICATION OF TERMS

We considered case studies that were large-scale and to some extent process-based and ecosystem focused. "Large-scale" refers to the target area impacted by restoration actions. Generally, and in the case of all programs examined here, large-scale programs have a very large and complicated organizational structure that has developed out of the need to address large spatial areas, long time scales, multiple jurisdictions, and robust financial resources. More importantly, we focused on large-scale programs because we believe that many of the environmental degradation challenges cannot be resolved with small-scale actions alone, but will instead require large-scale, landscape approaches. This expanded scope requires a strategic approach to management and the coordination of interdisciplinary science.

Many early restoration efforts resembled what we would now consider to be site-specific mitigation, with emphasis on restoration of ecosystem structure rather than ecosystem process. Based on the ecological understanding that structure and function follow process, it is increasingly expected that the aim of restoration efforts should be to restore processes (i.e., sediment transport, erosion) rather than to restore structure (i.e., a beach or wetland). Therefore, we selected programs that, to some degree, specifically approached their goal from the perspective of restoring ecosystem processes. Our five case studies are by no means an exhaustive list of all process-based restoration programs in the U.S.

Our final criterion in the selection of cases for study was that restoration programs have the general intent to restore the ecosystem as opposed to restoring specific elements of the ecosystem, such as target species or bird nesting habitat. While full restoration of ecosystem processes, structure and function may be yet beyond our scientific capabilities, we selected programs based on their intent rather than their success at restoring the ecosystem. The five programs studied are the Chesapeake Bay Program (CBP), Comprehensive Everglades Restoration Program (CERP), California Bay-Delta Program (CALFED), Glen Canyon Dam Adaptive Management Program (GCDAMP), and Louisiana Coastal Areas Ecosystem Restoration Program (LCA).

METHODS

Insights into the role of science in large-scale restoration efforts were acquired by the NST over two years and were generated from four major sources: (1) site visits, personal interviews, (2) peer-reviewed literature, (3) websites, and (4) unpublished documents. The data gathered were used to populate two matrices, described below. Members of the NST traveled to Louisiana and the Chesapeake Bay to meet with LCA and CPB program staff and tour project sites and also invited representatives from CERP, CALFED, and GCDMRP to Seattle. The NST sought a comprehensive understanding of each program by interviewing scientists, policy or decision makers, and applicable non-governmental organizations.

Semi-structured interviews were conducted using a list of question organized by topic similar to the method described by Kvale (1996). The topics and the respective sub-questions were designed to provide information about the role of science and elicit the strength and weaknesses of the approaches taken by each program. The topics that were addressed included:

- Project organizational structure and activities
- Restoration planning and guidance
- Assessment of the causal mechanisms
- Data management
- External factors (such as socioeconomics and policy)
- Integrating science into restoration planning and assessment
- Monitoring and adaptive management
- Peer review

In order to organize and evaluate the data collected from the interviews, publications, and websites, two matrices were designed to compare elements of the programs. The Program Background Matrix contains basic program information (Appendix B) while the Program Comparison Matrix summarizes the answers to relevant questions organized by topic (Appendix C). The Program Comparison Matrix is based on the interview questions presented in Appendix A. Where answers were not provided or where clarification was needed, individuals within programs were contacted to verify information.

The lessons discussed in this paper were developed by comparing and contrasting program features summarized in the matrices and relating these to lessons explicitly stated by program representatives or those lessons gained by the NST over the course of this study. Thus, the lessons presented arise from 1) the experience of program representatives, 2) characteristics and strategies for incorporating BAS that the NST deemed noteworthy, and 3) the best professional judgment of the NST.

Program Backgrounds

This section provides a brief description of each program that highlights organization and structure specifically relating to the role of science. The five programs represent a diverse collection of environmental, historical and social issues, organizational structures, and management approaches. Each program has approached its respective challenges differently and has integrated science into the organizational structure in unique ways. The programs are ordered from oldest to youngest based on the observation that the role of science may evolve as these programs mature and as new programs learn from the mistakes made by predecessors.

The following paragraphs are not intended to be a complete overview of each program. We have presented the minimum amount of background necessary to frame our discussion of lessons learned regarding the role of science.[6]

Chesapeake Bay Program

Project Formation and Purpose

Formed in 1983, the Chesapeake Bay Program is based on an agreement between Maryland, Pennsylvania, Virginia, and the District of Columbia to restore and protect the Chesapeake Bay and its tidal tributaries. The initial focus of this restoration was water quality, driven by increasing eutrophication (Batiuk *et al.* 2003). The watershed for the Bay encompasses an area of over 166,000 km^2 extending into six states.

In its early years, the program focused on reducing nutrients in the Bay. A notable goal of the program was to reduce nutrients in the bay by 40% by the year 2000. While substantial progress toward this goal has been made, subsequent analysis has identified a need for even greater reductions to effect meaningful restoration of the system. In subsequent years, this focus expanded to include reduction of excess sediments and toxics, as well as restoration of important habitat areas and populations of target organisms, such as oysters and finfish. The program monitors the health of the bay through numerous ecosystem indicators.

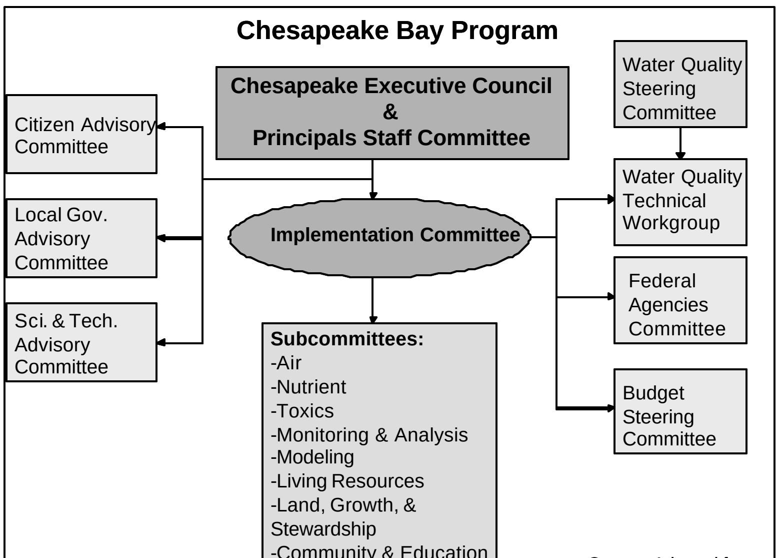
Organizational Structure and Science

The program is funded and staffed by the U.S. Environmental Protection Agency (EPA) and the partner states. Direction is provided by an Executive Council composed of the governors of the three states, the mayor of the District, the EPA administrator, and the chair of the Chesapeake Bay Commission (a body of state legislators). The Executive Council is served by a Principal Staff committee composed of the secretaries of natural resources for the three states and senior staff for other Executive Council members. Routine operations of the Program are overseen by an Implementation Committee, composed primarily of senior state and federal agency personnel and the chairs of the many Bay Program committees. Numerous program committees address issues ranging

[6] A lesson learned by the authors is that these programs are constantly evolving and this it is difficult to put down on paper an accurate and up-to-date description that is not immediately outdated.

from living resources to local government interests. There is an emphasis on stakeholder involvement and public outreach on all committees.

A year after the Chesapeake Bay program was established, a Science and Technical Advisory Committee (STAC) was formed to enhance scientific communication and outreach throughout the Chesapeake Bay watershed and beyond. The STAC provides scientific and technical advice to the program in various ways, including (1) technical reports and position papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical conferences and workshops, and (5) service by STAC members on CB Program subcommittees and workgroups. The STAC also serves as a liaison between the scientific/engineering community and the CB Program. Through professional and academic contacts and organizational networks of its members, the STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Bay watershed. The Chesapeake Research Consortium, Inc. provides staff and logistic support.



Source: Adapted from Soileau, 2002

The STAC reports to the Implementation Committee quarterly and to the Executive Council annually. The 38 member committee is composed of 11 scientists (appointed by governors and the mayor), six federal agency scientists, and 21 scientists selected by their peers to represent a mix of disciplinary expertise. STAC members are not compensated for their service, although travel expenses are reimbursed. Turnover and the input of fresh perspectives was a recognized problem that has been addressed by establishing term limits. STAC operates with a limited budget that supports the staff, meetings, workshops and reviews. STAC does not fund or undertake research. The committee makes research needs assessments and recommendations, but these are passed to other committees within the Bay Program for further action. Program committees, subcommittees, and workgroups each solicit funding to accomplish tasks. Although these groups report back to the Implementation Committee, inter-committee communication/coordination is not always optimal and, in the face of limited program funding, committees compete with each other for resources (Batiuk et al. 2003).

COMPREHENSIVE EVERGLADES RESTORATION PLAN

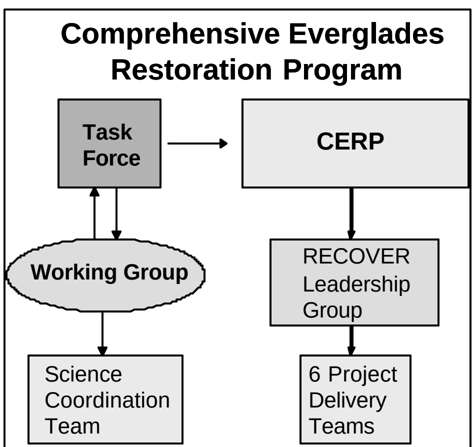
Project Formation and Purpose

The Comprehensive Everglades Restoration Plan (CERP) is led by the U.S. Army Corps of Engineers (USACE) and the South Florida Water Management District as equal federal and state partners. CERP evolved in response to the realization that water flow from central Florida through the Everglades had decreased dramatically due to extensive engineering and diversion projects and that nutrient concentrations of water reaching the Everglades had increased. As a result, the heath of the Everglades ecosystem was found to be in broad decline. The program covers an area of 47,000 km^2 and aims to restore, preserve, and protect an Everglades ecosystem in S. Florida that is self-sustaining and ecologically rich while mitigating risk of flood and meeting water supply needs to the area through the year 2050.

The Water Resources Development Acts of 1992 and 1996 gave the USACE authority to reevaluate the Central and Southern Florida Project. The reconnaissance phase of the Restudy was initiated in June 1993 and the feasibility phase of the Restudy was completed in 1999 with the submission of the Comprehensive Everglades Restoration Plan to Congress. Supported by the passage of the Water Resources Development Act of 2000, the CERP has the goal to "deliver the right amount of water, of the right quality, to the right places, and at the right time." This four part goal is addressed in the plan with numerous discrete projects, rather than one overarching project, many of which are pilot or experimental projects. These projects are not solicited by requests for proposals, but directed by the program and assigned to appropriate experts (an example of a "top-down" approach). Funding for the project comes primarily from the USACE budget, *ad valorum* taxes from the South Florida Water Management District, and the State of Florida budget. Addition funding is provided by other agencies such as the Department of the Interior.

Organizational Structure and Science

While CERP is at the center of the restoration efforts in Florida, CERP coordinates extensively with other on-going restoration efforts in the state. The RECOVER Team (REstoration, COordination, and VERification) was established in 1999 at the completion of the USACE's Restudy to coordinate science in the program and throughout the implementation of individual projects. RECOVER is a scientific and technical group specifically charged with establishing scientific indicators, assessing progress of the plan, and ensuring an overarching perspective of program actions.[7] RECOVER is led by two program managers, one from the USACE and one from the South Florida Water Management District. RECOVER leadership is composed of 12 agency representatives. Six Project Delivery Teams serve as the working groups for science and are coordinated by RECOVER. These multidiciplinary teams are populated by RECOVER leaders and other interested parties.



Source: Adapted from Soileau, 2002 and Applebaum, 2003

[7] Comprehensive Everglades Restoration Program website: http://www.evergladesplan.org/pm/recover/recover.cfm

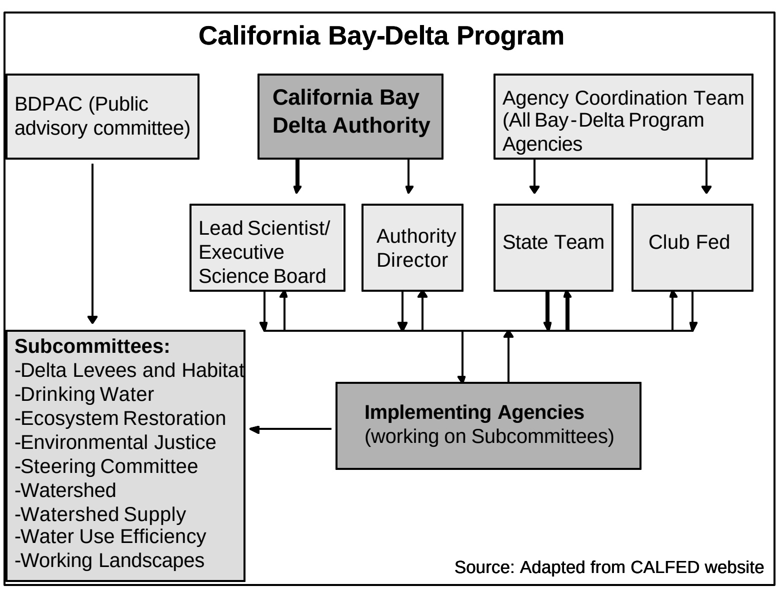
The South Florida Ecosystem Task Force (the Task Force) was established by the South Florida Water Management District in 1993. The Task Force is composed of 13 members, 7 federal and 6 non-federal agency representatives, and meets several times per year. The Task Force coordinates policies and strategies and, although not actually part of CERP, provides advice and guidance to CERP. The Working Group is subordinate to the Task Force and composed of 33 members from state agencies. The Working Group meets monthly to carry out tasks and provide reports to the Task Force. Under the Working Group the Science coordination team was established to develop a science coordination plan. The Science Coordination Team was disbanded after the completion of the Restudy, but may be reinitiated directly under the Task Force (Applebaum 2003).

The Committee for the Restoration of the Greater Everglades Ecosystem (CROGEE), which was established by the National Academy of Sciences, provides independent scientific review to CERP. The Task Force approves CROGEE's work plan and CROGEE provides completed reports to the Task Force.

CALIFORNIA BAY-DELTA AUTHORITY

Project Formation and Purpose

CALFED, now called the California Bay-Delta Authority[8], was established to coordinate efforts to address numerous interrelated water management, ecosystem restoration, drinking water quality, and levy reliability issues in California's Sacramento-San Joaquin Delta. The Program was formally launched in 1994 with the signing of a "Framework Agreement" by federal and state environmental and natural resource agencies. This agreement evolved into a long-term program, CALFED, which is being cooperatively implemented by more than 23 state and federal agencies to manage the quality and quantity of water allocation to urban, agricultural, and ecosystem needs in the bay-delta region, an area of 3,000 km^2. The program addresses four interrelated objectives – water supply reliability, water quality, ecosystem restoration, and levy system integrity – which are further divided into eleven components. The program addresses these goals by formulating water quality standards and coordinating the State Water Project and Central Valley Project operations with regulatory requirements the Authority



[8] As of August 2002, the California Bay-Delta Program, commonly called CALFED, was renamed the California Bay-Delta Authority. As a convention we will use CALFED when referring to this program.

hopes to ensure long-term solutions to problems in the Bay-Delta estuary.[9]

Governance of this program is carried out by both individual state and federal agencies with legislative authority to conduct activities. Overall coordination is the responsibility of the California Bay Delta Authority, a state agency specifically created in 2002 to fill the oversight role in the program.[10] The program shares the staff of partner agencies and has its own staff dedicated to supporting the accomplishment of program mandates (Luoma and Taylor 2002).

The main program funding source is state and federal appropriations, while auxiliary or new program requirements can be met with bonds or special state and federal appropriations. The program has completed Phase I (assessment) and II (selection of alternatives) and is now entering Phase III, the implementation of preferred alternatives and construction. Thus far, several early action ecosystem restoration projects have been completed. These projects are generally selected on a competitive basis in response to a request for proposals (Luoma and Taylor 2002).

Organizational Structure and Science

Science and technical expertise is integrated throughout all areas of the CALFED program; however, the Science Program housed within the California Bay-Delta Authority is the nexus of authoritative scientific and technical information[11]. The Science Program focuses on disseminating information, developing common language, acting as publication support within CALFED, and providing advice and support for the integration of science throughout the rest of the program (Taylor 2003). The Science Program staff is composed of experts that are employed by their agency and compensated for CALFED time (Luoma and Taylor 2002).

Within the Science Program, the Executive Science Board is a standing committee of recognized experts that directly advises the Authority. A core element of the Science Program is a system of advisory boards and peer-review panels that are overseen by the Independent Science Board. Standing Boards are composed of experts appointed by the Lead Scientist that combine interdisciplinary expertise to provide advice and review. Technical Panels and *ad hoc* working groups are assembled to address specific technical and scientific issues (CALFED 2003b). In general these science groups do not address policy questions, but strictly provide technical advice to the Authority for application to policy decisions (Luoma and Taylor 2002).

GLEN CANYON DAM ADAPTIVE MANAGEMENT PROGRAM

Project Formation and Purpose

The Glen Canyon Dam Adaptive Management Program (GCDAMP) is coordinated by the Department of the Interior's Grand Canyon Monitoring and Research Center (GCMRC). GCMRC's mission is "to provide credible, objective scientific information to the Glen Canyon Dam Adaptive Management Program on the effects of operating Glen

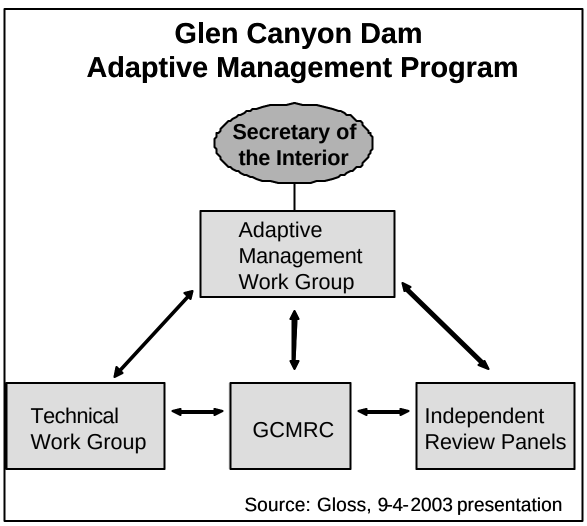
[9] (CALFED 2000); CALFED website: http://calwater.ca.gov
[10] CALFED website: http://calwater.ca.gov
[11] CALFED website: http://science.calwater.ca.gov/index.shtml

Canyon Dam on the downstream resources of the Colorado River ecosystem."[12] Over time it was found that dam operations had several negative downstream affects including alteration of the structure and integrity of downstream beaches resulting in loss of spawning and rearing habitat for endangered fish species. In response, the Glen Canyon Dam Adaptive Monitoring Program, the GCMRC aims to evaluate the impacts of dam operations on the Colorado River Ecosystem by carrying out a long-term monitoring and research program using an ecosystem-based approach.[13] The GCMRC has carried out the scientific investigations called for in the GCDAMP since the establishment of the research institution in 1996.

We selected this program as a case study because of its noteworthy employment of adaptive management, that is, the incorporation of scientific experiments into natural resource management.

Organizational Structure and Science

The Adaptive Management Work Group (AMWG) of the GCDAMP directs the monitoring program for the lower Colorado River from Lake Powell to the western most boundary of the Grand Canyon National Park. The scientific results generated by the activities of the AMWG are used by the GCMRC to improve ecosystem management in Lake Powell, the lower Glen Canyon, and in the Grand Canyon.



The AMWG is a federal advisory committee comprised of federal, state, tribal, and other stakeholder representatives. The AMWG meets semiannually to review the Glen Canyon Dam management and operations; it makes recommendations to the Secretary of the Interior on dam management and advises and directs the GCMRC (GCMRC 1999). Several Independent Review Panels operate within the GCDAMP to increase scientific credibility of GCMRC science.

LOUISIANA COASTAL AREA ECOSYSTEM RESTORATION PROGRAM

Project Formation and Purpose

The coast of Louisiana loses coastal wetlands at a rate of approximately 60 km^2 per year – a combined result of the interruption of natural deltaic sedimentation processes due to diking and channelization of the Mississippi River and the natural subsidence of the delta.[14] In 1990, as a response to national wetland degradation and to the alarming rate of land loss in Louisiana, Congress enacted the Coastal Wetlands, Planning, Protection and

[12] Glen Canyon Monitoring and Research Center website: http://www.gcmrc.gov
[13] Ibid
[14] Louisiana Coastal Area Ecosystem Restoration Program website: http://www.coast2050.gov/lca.htm

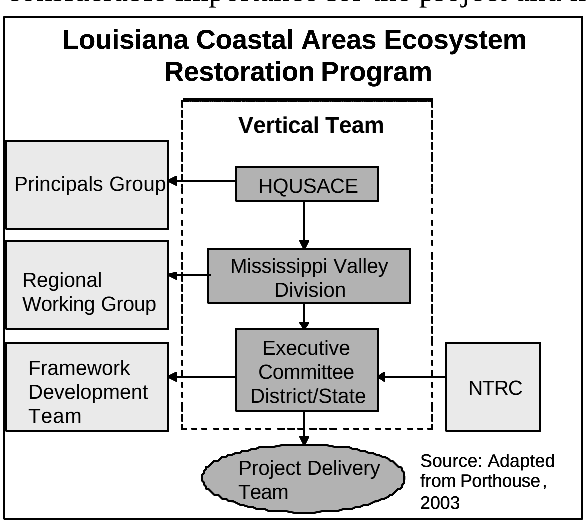
Restoration Act (CWPPRA, also known as the Breaux Act). CWPPRA funds wetlands enhancement projects and has contributed substantially to the planning for large-scale restoration of Louisiana's disappearing coast, making this program the largest, in area, of the case studies.

In recognition that the CWPPRA effort alone could not address the scale of the Louisiana's coastal degradation problem, a new state and federal plan was adopted in 1998. The report entitled Coast 2050: Toward a Sustainable Coastal Louisiana (Coast 2050)[15] divides Louisiana's coastal area into four (sub-province) regions and aims to restore or reconstruct the natural coast-building processes in Louisiana at a more regional scale. Eighty-eight restoration strategies for the four regions are presented in this document, which was developed by state, federal, and local participants, including stakeholder and public interest groups.

In May of 1999, the U.S. Army Corps of Engineers (USACE) headquarters commissioned a feasibility study under the Louisiana Coastal Area Authority of 1967. The cost of the study is shared by the New Orleans District of the USACE and the State Department of Natural Resources (DNR). This feasibility study, projected to last 2 years, is based on the strategies identified in the Coast 2050 plan and is called the Louisiana Coastal Areas Comprehensive Coastwide Ecosystem Restoration Study (LCA). The aim is to determine a comprehensive action plan for the four sub-provinces based on the ideas presented in the 88 restoration strategies identified in Coast 2050. The study area includes all of coastal Louisiana stretching from Mississippi to Texas.[16]

Organizational Structure and Science

The LCA Feasibility Study is directed by an Executive Committee lead by a secretary from DNR and a commander from the USACE. A Project Delivery Team oversees production of reports and the dissemination of information within the project. The Project Delivery Team also facilitates involvement from the broader scientific community. This outside, non-agency contribution of scientific information has been of considerable importance for the project and has addressed tasks, such as synthesizing the state of the science and developing complex ecological modeling techniques.



Several teams advise the Executive Committee and the Project Delivery Team. The National Technical Review Committee (NTRC) provides independent peer-review and valuable outside perspective to the Executive Committee. The NTRC is comprised of 10 scientists from around the country representing expertise in the natural sciences, economics, engineering, and planning (Porthouse 2003). The Vertical Integration Team, comprised of local and

[15] Ibid.
[16] (LCA 2002) and http://www.lacoast.gov/cwppra/org/techcom.htm#description

federal representatives, is charged with expediting scientific reviews and issue resolution (Porthouse 2003). The Vertical Integration Team's vital function is to provide a mechanism by which science and policy issues are communicated to all levels of the program.

Several other groups provide advice and help to identify and resolve conflict. A Principals Group coordinates agency input into the program and the Regional Working Group facilitates the transfer of information between local participants and the Principals Group. A Framework Development Team is comprised of local representatives of federal and state agencies, academia, and Non Governmental Organizations (NGOs) (Porthouse 2003).

RESULTS

We found that these five programs represented a range of approaches to address the fundamental challenges of integrating science into policy and decision making. Each program has evolved in very different natural and political environments. We make no attempt to judge overall program performance, or "success"[17], only to learn from the various scientific strategies undertaken in each program. In this section we will address some specific lessons learned program by program. Refer to the Program Comparison Matrix (Appendix C) for details.

CHESAPEAKE BAY PROGRAM

The Chesapeake Bay Program (CBP) demonstrated the importance of a lead scientist to negotiate compromises between science, politics, and stakeholders. In this program, the intentions of individuals and program goals were important, but the final accomplishments of the program have been largely a result of the personalities of the individuals at the table.

The Chesapeake Bay Program demonstrated the benefit of cultivating involvement with outside academic scientists. This horizontal integration requires dedicated effort to maintain, but is facilitated by collaboration with research consortia, such as the Chesapeake Research Consortium, Inc. We also found it important to ensure turnover among program managers and science committee members. In the Chesapeake Bay Program, science fellows, often PhD students on a two year contract to work with the science program, help bring fresh perspective into the program and keep high-level and innovative science going. In the CBP, science fellows also provide staff support to work committees so that committee members do not become overwhelmed with managerial and administrative details.

This program also provided several lessons regarding public buy-in and participation. In the late 1990s when the CBP found itself working on very important issues in the Bay that the public did not relate to, program leaders shifted the focus from eutrophication to include more charismatic problems, such as decreasing oyster and finfish populations.

[17] Joy Zedler (2001) argues against the use of "success" in discussions of meeting restoration endpoints because of the implied possibility for failure if success is not attained within the program confines. She suggests "progress" replace "success" in most cases because this term allows success to take on multiple forms. We agree and also favor the term "performance" to describe elements of restoration programs.

This program also demonstrated that problems should be phrased to engage the public and decision makers. For example, "recover oyster populations" is likely to draw more and broader support than "improved sediment dynamics." This shift in the CBP has engaged the public in scientific issues, therefore increasing saliency of the scientific program (see Discussion section), and has helped focus the program on the entire ecosystem. An additional lesson that was highlighted by the CBP is that these large, ambitious programs often fail to plan appropriately for the expense and time required to manage resources at an ecosystem scale. The Chesapeake Bay Program substantially underestimated the effort required to transition from a regulatory water quality program to ecosystem management.

The public is extensively involved in the Chesapeake Bay Program and we noted two successful strategies for gaining this participation. Chesapeake Bay Foundation, a non-profit organization, provides tremendous help with public outreach. Forming alliances with local NGOs helps to spread resources and offer more people and groups the opportunity to become involved and feel ownership for the program's progress. Also, the Chesapeake Bay Program puts substantial effort in regularly communicating scientific results to the public via weekly and quarterly publications (The Bay Journal and the Chesapeake Futures Report). This has helped obtain public support and educate stakeholders.

COMPREHENSIVE EVERGLADES RESTORATION PLAN

CERP was established to address the water distribution crisis in South and Central Florida. Because the "crisis" was widely accepted politically and publicly, CERP was able to generate political and financial support. CERP has been well served by such a clearly defined and urgent problem. In the late 1980s, program members conducted a unique brainstorming session to develop program goals and objectives, which served to inform and define the U.S. Army Corps of Engineers (USACE) reconnaissance and feasibility study and ultimately the CERP.

In this program, the organizational structure was fixed and the range of restoration options already pre-determined before science began to play a role. This situation constrained innovative science and limited the power of science to influence decisions. Also, this program has often been frustrated by tensions between state and federal agency partners. This may be a result of the USACE's tendency to rely on engineering solutions to solve environmental problems or the highly political nature of the problem. At times, this conflict has hindered progress and consumed resources. This program also demonstrated the importance of a charismatic leader in gaining broad support for the program and negotiating compromises between individuals and groups involved in the project.

CERP has successfully established a spectrum of performance measures/indicators. They did this by winnowing a list of 1,000 potential indicators to approximately 50 that will be tracked; less than 10 were used for planning purposes in reporting to high-level decision makers. Although the exercise resulted in a list of indicators, the approach taken may not have been the most efficient or effective. CERP also has an adaptive monitoring assessment team that *assesses* early actions, or "demonstration" projects. The system-wide monitoring and assessment plan that is scheduled to be released at the end of 2003

(Applebaum 2003) may resolve the lack of attention and resource paid to monitoring in this program.

California Bay-Delta Program

The simplified objective of any program should be to determine that the appropriate restoration and management actions are proposed and that they will work. CALFED has done well to ensure that projects are proposed and accepted that answer pertinent questions about estuarine function and structure, are of high scientific quality, and have high probability for exceptional experimental performance.

CALFED is a strongly "bottom-up" restoration program. The CALFED Program posts requests for proposals widely and selects projects on a competitive basis. This strategy guarantees high quality science through a competitive process, whereas the "top-down," or directed, approach employed by most other programs in this study may diminish scientific creativity and quality. Because "bottom-up" restoration actions tend to be more opportunistic and potentially disjointed, CALFED has instituted a separate, directed science program to strategically address specific science and monitoring needs. Although CALFED has a monitoring plan, they are still struggling to determine what to monitor and have instituted a dedicated action program to scientifically resolve monitoring metrics that comprehensively assess the contribution of CALFED restoration.

CALFED has demonstrated that peer-review is the most effective way to ensure the use of best available science. Their extensive internal and independent peer-review system has shown that the best combination of experts for a peer-review panel includes individuals who are local and involved in the program, local and uninvolved, and non-local and uninvolved. These individuals should be recognized as much for their objectivity as for their expertise.

Additionally, CALFED has managed to infuse science throughout the program, partly aided by several "integration teams." Vertical integration, as discussed in the methods section under the LCA program description, is best accomplished with purposeful help from planners or facilitators, as scientists themselves often do not excel at integrating their work with policy.

Conceptual models have played an important role in communicating basic ecosystem understanding to CALFED program participants and as a scientific aid in making program decisions. Also, funding packages or portfolios, used by CALFED, are an innovative and creative approach to ensuring long-term funding and to integrating science throughout the process. It remains to be seen how funding portfolios will play out in the long-term.

Glen Canyon Dam Adaptive Management Program

The most valuable lesson that this program provided was regarding the use of adaptive management in a restoration and experimental ecosystem management context. Adaptive management in this program requires a high level of participation and commitment from resource managers and scientists. It also requires constant feedback between resource users and scientists, so feedback mechanisms must be in place to support it. Scientific experiments, the foundation of adaptive management, are often difficult to generate support for, as demonstrated by the fact that there has only been one experimental flooding event (flood pulse) at the Glen Canyon Dam. In comparison, it is generally easier to generate support for monitoring programs.

The practice of adaptive management is often misunderstood and in order for this tool to be properly used, it must be explained to all involved. The Glen Canyon Program demonstrated the importance of educating users and stakeholders about adaptive management.

LOUISIANA COASTAL AREAS ECOSYSTEM RESTORATION PROGRAM

The integration of science into the LCA program has been slow, possibly because science was not explicitly involved in the formation of the program. This disadvantaged position does not facilitate optimal use of science and the program is still struggling to bring science into the decision making process. Also, political pressures and powerful stakeholders, such as oyster growers, control and dictate the range of possible solutions, thus limiting and confining science's influence and threatening the legitimacy of science within the program.

This program demonstrated several long and short-term problems that arose from not having science infused throughout the program; however, LCA's Vertical Integration Team represents a good example for a strategy to coordinate restoration efforts and link science and policy.

Although the LCA program has successfully addressed the symptoms of the problems facing the Louisiana coast (land loss and eutrophication of the Mississippi River), it has struggled to address the underlying problems themselves (dam construction and operation in the Missouri/Arkansas river basins, agricultural chemical use in the Mississippi River watershed, and coastal land use practices). Because the root problem includes resources use practices in the entire Mississippi-Ohio-Missouri River Basin, this program has been forced to balance the tendency to focus on smaller, localized problem symptoms with a long-term approach aimed at the underlying problems. This was demonstrated by the transition from the restoration activities accomplished under the Breaux Act, the majority of which were small in scale and uncoordinated, to the watershed-scale LCA program which aims for a strategic approach to restoration planning activities.

Similar to CERP, this program has been frustrated from tensions and misunderstandings between state and federal agency partners. Also, like most programs, the LCA has struggled to incorporate monitoring into their program. They have, however, recently established a long-overdue monitoring scheme for some Breaux Act actions.

The National Technical Review Committee provides essential outside review of the overall program. This team of external, but informed panel of experts meets at least twice a year and serves as an excellent template for a strategy to ensure appropriate program actions and focus.

DISCUSSION

In this section we organize lessons learned by general topic and explicit subject headings. Lessons presented in the Results section are discussed in the context of current knowledge and available literature. Three similarly structured documents provided especially helpful comparisons of restoration programs, *Putting it Back Together: Making Ecosystem Restoration Work*, published by Save the Bay (Koehler and Blair 2001), *Investigative Review: Institutional Arrangements*, published by USACE's Engineering Research and Design Center (Soileau 2002), and *Lessons from Large Watershed Programs*, published by the National Academy of Public Administration (Adler *et al.* 2000). Although these documents do not focus specifically on the role of science, they contributed to our comparative understanding these programs.

BEST AVAILABLE SCIENCE AND RESTORATION POLICY

The published literature is rich with insights into the often troubled relationship between science and policy.[18] Throughout our interactions with the five projects, we were reminded of several basic principles of an effective working relationship between science and policy that further suggest fundamental strategies for optimizing the role of science in the decision making processes.

In order to avoid the misuse, and ensure the best use of science, fundamental limitations of the scientific discipline should be understood by all. Science is a process of inquiry grounded in hypothesis testing and observation. Scientists aim to produce objective, value-free information from data gathered from the natural world.[19] Thus, scientists are comfortable collecting information that can be used to understand the potential consequences of actions; however, scientists generally begin to feel uncomfortable when asked to advise decision-makers regarding what *should* be done given the scientific information presented. Scientists who abandon objectivity for advocacy run the risk of loosing credibility in the eyes of other scientists and the public (Boesch and Macke 2000). Therefore, scientists should not be asked what *should* be done, but rather to define the possible range of actions and evaluate the consequences of those actions. Decision makers should then consider other factors, such as social, economic, and legal issues in addition to scientific input (Boesch 1999, Huxham and Sumner 2000).[20]

In order for science, and problems addressed by scientists, to effectively influence decision-making, the science must be judged to be relevant. According to Clark *et al.* (2002), three attributes that influence the effectiveness of science are:

- *Saliency* – whether science is perceived as addressing policy-relevant questions
- *Credibility* – whether science meets standards of scientific rigor, technical adequacy, and truthfulness
- *Legitimacy* – whether science is perceived as fair and politically unbiased

Generally, attaining these three attributes requires making difficult compromises. Although, deficiencies in one attribute may be offset by strengths in another, some threshold level of all three attributes is required for science to contribute to policy decisions (Clark *et al.* 2002).

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[18] For early articles see (Dunn 1980, Webber 1983).

[19] For discussions of whether or not science is truly value-free see (Huxham and Sumner 2000) p. 52-55.

[20] Sabatier rejects the notion of neutral scientists in his promotion of the concept of an "advocacy coalition framework" (Sabatier 1988, 2000). See also Hass for a related discussion on "epistemic communities" (Hass 1990).

In this study, all programs demonstrated that peer-review is the best way to ensure credibility and the development and use of best available science. These programs used the term peer-review to describe activities that ranged from rigorous and anonymous review of products by outside technical experts to review of the overall restoration program by respected scientists from outside the program region. The optimal combination for review of products and proposals is that of objective experts who are local-involved, local-uninvolved, and uninvolved and non-local. Saliency and legitimacy were enhanced in these programs when high-level external review was employed.[21] These programmatic reviews provided critical outside advice to guide the focus and structure of the program.

Although peer-review is clearly the best way to ensure credible science, there are a range of opinions about what is encompassed in 'best available science.' The dissenting view proposed that "science" is not a monolith; not a thing, but just one way to frame issues in a very narrow context. One interviewee suggested that the term "scholarship" is perhaps better because it includes dimensions that are important to humans, such as the humanities, history, and the social sciences. Many people we talked to agreed that the divide between natural and social sciences should be narrowed, but few had demonstrated practical techniques.

PROBLEM STATEMENTS AND PROGRAM GOALS

All programs demonstrated that clearly articulated problems and goals are essential to ensure federal and state agency coordination. Also, the problem statement almost always emerges from a widely accepted "crisis" which means that the public has to be involved in defining the problem. Public buy-in at the problem-definition stage of the project is tied to many aspects of the potential for progress towards meeting restoration goals. Articulated problems should be phrased for the public; i.e. "recover populations of key species" rather than "improved sediment dynamics."

The overall goal of large-scale restoration programs should be to determine that the right actions are proposed and that they will work. This should include a well-developed approach to addressing problems.

FIX THE PROBLEM NOT THE SYMPTOMS

All programs should be mindful of looking deeper than the surface of the problem if a long-term solution is to be achieved. We were warned to be aware of surrogates; water flow requirements and intact salt marsh habitats are all indicators that show overall ecosystem change and degradation. These surrogates are both individually valuable targets and important stepping stones to the paramount goal of recovering the integrity of ecosystems, but it should be remembered that surrogates are not the endpoint.

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[21] External programmatic review can lend credibility to national programs subjected to intense external scrutiny. LCA has benefited from a National Academy of Engineering review (scheduled to be released in April, 2004) and also has established its own institutionalized panel, the NTRC. In 1999 the GCMRC's adaptive management plan was reviewed by the NRC (National Research Council 1999). CERP was recently reviewed by the General Accounting Office (2003) and is in the process of establishing a NRC review panel (Applebaum 2003). CALFED's Independent Science Board provides review and advice and works with the NRC when outside review is necessary (CALFED 2003a).

CULTURAL DIFFERENCES BETWEEN SCIENCE AND POLICY

Clear communication *between* scientists and *among* users of scientific information, or horizontal and vertical integration (see following section), is a challenge for those at the policy/science interface (Douglas 2000). This arises from the cultural differences between scientists and policy makers. The need for translation between science and policy is often quite real as the disciplines have differing world views, peer-pressures, reward systems, and specialized speech and jargon. A well documented source of misunderstanding is the different interpretations of uncertainty. Scientists are trained to work with uncertainty and confidence intervals or probability statements to describe levels of uncertainty. To policy makers uncertainty often translates to risk, which in the political arena is to be avoided at all costs (Lee 1993, Boesch and Macke 2000, Bierbaum 2002). The divide separating interpretations of uncertainty is large; "where science thrives on the unknown, politics is often paralyzed by it" (Gore 1992).

A complaint of science often heard from policy makers is that scientists often fail to generate information in the short timeframe of most policy decisions (Boesch and Macke 2000, Douglas 2000, Bierbaum 2002). Science should not be asked to generate quick results from long-term studies, however, scientists could package preliminary results for delivery to policy makers. Conversely, future policy decisions can be based on a long-term strategy where planning decisions are coordinated with the expected delivery of key scientific results.

Science should phrase results in a way that is useful to decision-makers. For example, it is helpful for decision makers to know "*x*% of a particular ecological feature must be unencumbered for it to be functional (± error bars)." This way information is packaged in such as way that decision makers can weigh scientific input against other factors that contribute to decisions, such as social values and economics.

We found that often too much is expected of science and that sometimes scientists oversell what science can accomplish. Science can help reduce uncertainty by disproving experimental hypotheses. Science does not naturally provide clear policy solutions. Even among the volumes of published literature explaining the distinct cultures of science and policy, there is still a need to translate between scientists and policy makers.

PROGRAM ORGANIZATIONAL STRUCTURE

For several programs, a strong lead scientist has been vital for negotiating compromises between science, politics, and stakeholders. These charismatic leaders should convey the consequences of actions on spatial and temporal scales and stay focused. The establishment of leadership should be done early rather than later. Intentions and goals are important, but the final accomplishments of the program will likely be a result of the personalities in leadership roles.

Another lesson was of the importance of building into the program a mechanism to incorporate new people and fresh perspective. If the program will operate for more than five years, it is essential to have turnover in leadership and membership. Research fellows or short-term apprentices are a unique way to incorporate fresh perspective.

Several programs mentioned the importance of a common geographic center for science and planning activities. Having a co-located team makes for better interactions if program participants share space and resources. Also, teams and work committees should be provided with staff support for optimal operation, so that experts are not swamped with administrative details.

Maximizing Use of Science

To address the high uncertainty in large-scale restoration, science should clearly have a role in any large-scale restoration project. However, there is not one correct model for that role. The programs examined all involved science, but the best strategies incorporated science into the process early, often from the beginning or before the formal creation of the program. If the program structure is fixed before science begins to play a role, the alternatives that science can evaluate are often predetermined and already limited and all the stakeholders do not necessarily see a thorough scientific assessment of all technically viable alternatives. In this situation, science is not operating optimally and may be frustrated by the organizational constraints of the program.

In general, we observed that a bottom-up approach to soliciting restoration projects and proposals guaranteed high quality science through a competitive process, whereas top-down approaches can diminish the creativity and quality of the science. However, a bottom-up approach that allowed science to "bubble up" from the broader scientific community tended to result in an *ad hoc*, disjointed approach to opportunistic, small-scale restoration while a top-down approach resulted in strategic, coordinated science. Thus, we found the best approach for incorporating science into the program was by using a directed approach with a built-in mechanism to incorporate unsolicited proposals. CALFED demonstrated this combination of bottom-up and top-down approaches by using RFPs to solicit proposals from the scientific community while still maintaining the vision of strategic, long-term science.

In these programs, science tended to be most effective when there was a formal pathway for transporting or translating scientific information to decision makers and when science itself was insulated from the planning process; thus, scientists were not put in a position to advocate for decisions and risk loosing credibility or be influenced by political pressures and risk compromising legitimacy, but were still able to inform decisions with unbiased scientific information. Most programs, however, lack an efficient and established method for getting scientific information to policy makers. We found that most programs are still driven by policy makers without adequate feedback from scientists.

Vertical and Horizontal Coordination and Integration

Most programs stressed that science is most effective when it is involved in the program formation process and infused throughout every level of the program. If science is not well integrated into the program it can be detrimental to the long-term progress of the program because fundamental science issues may be overlooked. This infusion requires a concerted integration effort. We found that integration is often limited by not having dedicated staff because integration is placed on the shoulders of part time staff as *extra* work. Full-time research fellows have helped the Chesapeake Bay Program staff the integration effort. In two programs, vertical integration teams have been essential in coordinating restoration players within the program and linking policy and science. Also, CALFED's portfolio funding approach helped to integrate science throughout the process.

Horizontal integration includes coordinating with appropriate academic groups and consulting firms. This effort also deserves assigned responsibility because it can be extremely valuable to tap into outside sources of information and expertise. Programs were most successful at horizontal integration when there was an existing research consortium in the area with which to collaborate.

Lack of coordination between state and federal partners sometimes resulted in tensions that frustrated progress. We also noted that conflicting science issues, if not resolved, can disrupt the coordination of the program. Sometimes this resolution requires trained facilitators and outside planners.

CONCEPTUAL AND NUMERICAL MODELS

Conceptual Models are helpful tools for communicating scientific understanding to program participants, stakeholders, and the public. These models also allow us to clearly explain the working hypotheses behind ongoing restoration projects and determine appropriate performance measures. Often there is conflicting scientific evidence for environmental degradation. When the resulting competition between so-called objective experts is seen as politically motivated, it compromises scientific credibility and hampers acceptance of the needed contribution of science and technology to ecosystem restoration. We found the approach of drawing on a diverse community of scientists/technicians to develop conceptual and numerical working models to test all restoration strategies to be one of the better approaches to resolving conflicts and for passing a scientific "consensus" on to restoration managers and decision makers. In addition, the requirement in bottom-up programs such as CALFED whereby proponents for funding were required to provide a conceptual model of the project and expected outcomes greatly improved the quality of proposals and resulting projects.

ADAPTIVE MANAGEMENT

The integration of monitoring, adaptive management, and continual assessment of actions is necessary for successful implementation and continued scientific learning in long-term restoration programs. Adaptive management is a very powerful, yet poorly understood, natural resource management tool that purposefully includes learning from scientific experiments. It can be an extremely powerful tool, but adaptive management must be understood by those who use, support, fund, and challenge it. Therefore, education is a very important part of adaptive management.

PERFORMANCE MEASURES

We found indication that performance measures can be more politically than scientifically useful. It is important to be able to gauge progress in response to restoration actions, but the danger is in forgetting to look past the selected indicators. Selection of appropriate indicators of system health or program performance is extremely difficult; we found several scientists who were reluctant to judge ecosystem health with such narrow, static measures. Few programs have actually established performance measures.

MONITORING AND ASSESSMENT

Overwhelmingly, we heard from scientists that if it is not possible to monitor the results of project actions, the worth of the project should be seriously questioned. It was suggested by several NST members that no less than twenty-percent of the money spent on restoration actions be devoted to monitoring and assessment. Scientists and policy-makers have spent far too much money already on actions with unknown effects. Monitoring is the only way to understand short and long term effects of restoration action and more often than not it is the first thing to be cut from the budget.

PUBLIC INVOLVEMENT AND SUPPORT

Regular and extensive communication of scientific results is one of the most important ways to obtain stakeholder/public investment in the program. In order to optimally use the best available science in restoration decision making, it must be perceived by stakeholders and the public as credible, legitimate, and salient. In these large-scale restoration programs, public support is vital because it is ultimately linked to the long-term sustainability of the program in terms of public buy-in and cooperation and funding appropriated to restoration action. All programs were in agreement that there needs to be an established method of pubic outreach that is an assigned responsibility of some person or group. Public involvement can, however, be aided by the outreach capabilities of involved local NGOs.

There was some disagreement over the quantity and form of public involvement. Most people indicated that there can never be too much, while others cautioned that too often the public's prejudices or uninformed gut feelings are allowed to define project direction and restoration actions. This view held that it is the responsibility of governmental agencies or resource managers to create an educated populace and to help the public understand the consequences of actions on spatial/temporal scales. This role is, of course, dependent on managers and agency representatives who are themselves scientifically informed.

All programs agreed that it is essential to build credibility and trust in the program and, ultimately, its science. The best techniques for cultivating credibility and trust are with tools including peer-review and outreach, user-driven milestones, and articulated shared "statements of truth".[22] It is also essential to acknowledge the difficulty of explaining uncertainty and to demonstrate a convincing and accurate problem statement.

CONCLUSIONS

Science has an essential role in large-scale ecosystem restoration. The high degree of uncertainty inherent in the scientific and technical requirements of ecosystem-scale restoration demands that actions are based on the best scientific understanding available. Through ongoing ecosystem restoration efforts such as we describe in this document, this role is becoming more defined and the strategies for incorporating science are gradually improving. We were encouraged by the number of large-scale restoration programs available for our analysis. In general, these programs are making impressive progress

[22] For a discussion on "shared statements" of truth relative to PSNERP, see the introduction of the Guiding Ecological Principles document.

towards the difficult task of ecosystem restoration on a landscape scale. The diverse natural and political environments that shaped these programs and their resulting organizational structures provided a variety of strategies for optimal use of science. In essence, they provided us with experimental treatments to test the diverse approaches of incorporating science into their programs. They also documented, albeit in hindsight, an array of pitfalls to be avoided. As more large-scale restoration efforts emerge in the future, we trust that the lessons learned in these earlier programs will be reflected as heightened incorporation of the best available science and proportional decrease in restoration uncertainty.

GENERAL CONCLUSIONS

1. Clear and well-defined program goals must be translated into scientific and technical objectives
   - the process of placing broad program goals into a scientific and technical context frames the initial scope, feasibility, and uncertainty associated with available approaches to restoration
   - It is essential to ensure science is a participant in goal setting and problem definition and can contribute to the technical success of the program from the beginning
   - Goals must be phrased to engage the public and decision makers

2. Maintain the independence of science while balancing maximum communication and coordination across all program sectors
   - Science should inform policy, and vice versa, but neither should regulate the role of the other; scientists and policy makers could each become a student of the other's culture
   - Incorporate and populate the scientific sector early, preferably at the same time that policy, management, outreach and the other sectors are developed
   - Science should be allowed to focus on the technical and scientific goals, and those efforts not diluted by infusion of other demands from the program for scientific analysis and advice not directly related to their mission.
   - Inter-program communication, or "vertical integration" is essential, where science is explicitly represented in other management, policy, outreach, and other program sectors

3. Both "bottom-up" and "top-down" scientific direction needs to be integrated into a large-scale ecosystem restoration program
   - Large-scale ecosystem restoration cannot be strategic if left to bottom- ("bubble") up science alone; distribution of restoration alternatives across the landscape must be scaled to restore ecosystem processes that is difficult, if not impossible, with *ad hoc* deployment of opportunistic, small-scale restoration
   - Similarly, scientific creativity must not be stifled by an overly authoritative science structure; programs should incorporate mechanisms and support for unsolicited proposals that allow the program to grow and evolve "outside the box" as well as draw in qualified outside expertise
   - In exemplary programs, illustrated to some degree by CALFED, some level of "top-down" scientific guidance provides a template within which "bottom-up" science can flourish and contribute

4. Establish several layers of independent scientific review

- Establish a peer-review system of local-involved, local-uninvolved, and external-uninvolved objective experts to critique solicited and unsolicited program initiatives and products
- Form an outside panel for broad programmatic review/advise, potentially modeled after the LCA's NTRC, that can provide critical guidance and credibility at the national/international level of expertise; this should serve as the program's reality check (or, as some would say, provide the "red-face test")

5. Allow science to systematically analyze the initial range of all possible restoration strategies and promote scientific assessment of emerging alternatives
   - After science has outlined the possibilities, these alternatives can be examined in detail by all stakeholders, through politics, economics and social and legal factors for an equitable and sustainable solution

6. Because large-scale restoration must ultimately develop spatially explicit models of fundamental ecosystem processes and structure, require the use of conceptual models and promote more advance modeling
   - Conceptual models are essential to broad understanding at all levels of science, policy and stakeholder involvement
   - All restoration strategies should be based on a basic conceptual model, whether narrative or diagrammatic
   - Predicting ecosystem responses and quantifying the level of uncertainty associated with restoration alternatives is best served by multiple levels of numerical modeling in order to capture underlying ecosystem processes and "forcing factors"

7. Invest in a rigorous, science-based definition and application of adaptive management
   - Science is implicit in adaptive management, not an afterthought of a token policy concept; adaptive management is explicit experimentation and large, ecosystem-scale restoration is by definition experimental
   - Commit to intensive monitoring and evaluation of initial, "demonstration" restoration projects; increased scientific understanding should be the goal, rather then simply to "move dirt."

8. Seek strong scientific leadership, and avoid suppressing it
   - The strongest programs, such as CALFED, have strong scientific leadership, where a "lead scientist" who is broadly respected provides guidance for the science role in the program
   - Such a lead scientist should not be a spokesperson for management, but a communicator to management and the other sectors; they can provide much of the important vertical integration (see #2)

9. Synthesize and disseminate scientific information in a timely and stakeholder comprehensible manner
   - Synthesize available information and organize into transmittable knowledge
   - Begin putting out regular publications for the communication of scientific results to the general public
   - Involve program scientists in outreach activities

10. Encourage independent scientific collaboration and input

- Fund a research fellows program, that supports ("post-doc") scientists early in their careers to work within the program, particularly to incorporate a fresh perspective and to link academic institutions to agencies and other technically-involved stakeholders, such as NGOs
- Solicit input and presentations by scientific experts, professionals, and restoration practitioners from outside the program
- Encourage collaboration with non-expert, local working groups
- Promote incorporation of social science into science teams or workgroups

OBSERVATIONS

Several observations that were made during the 'lessons learned' exercise deserve specific mention, but not always because they were highlighted by these restoration programs; several were most notable for their absence in all of the programs. The four observations briefly discussed below either frustrate present restoration efforts – in the case of the first two – or limit the full potential of optimal use of best available science in large-scale restoration efforts – the second two. Among our case studies we did not find resolution to these issues; however, we discuss them here because they constitute, nonetheless, lessons learned by the NST.

Realistic Estimate of Required Resources and Time Frame

We found that programs are, not surprisingly, planning poorly for the numerous expensive and time-consuming unknowns characteristic of ecosystem management. Politics and special interest groups still dictate the focus of most programs, which results in a distraction from program goals. With hind sight, many of the political distractions could have been avoided with pro-active assessment of the political climate and receptiveness of the public. Generally speaking, natural scientists are not good at judging the receptiveness of the public to their restoration suggestions, so perhaps this important initial task should be assigned to trained professionals. The method of presentation could mean the difference between a successful, publicly supported program and a program that the public, or select stakeholders, sabotage.

Funding

Scientists in several programs were frustrated by the constraints of the fiscal year budget cycle. Programs that were particularly linked to the U.S. federal budget, such as those under the USACE authority, typically described their efforts as scrimping during most of the year's limited funding only to spend feverishly at the end of the year. In addition to being an obviously inefficient use of resources, this spending pattern is especially contrary to the long-term and steady funding needs of most restoration ecology studies. Alternatively, funding packages or portfolios, such as those used by CALFED, are an innovative, creative, and more efficient approach to ensuring the long-term funding that allows scientific and restoration efforts to proceed optimally.

Data Management

Despite the NST's lengthy consideration of a comprehensive data management system and standard policy for coordination of PSNERP scientific and planning information, we found that none of the programs we surveyed highlighted data management as a prominent organizational or funding priority. There was no good example of an effective approach to data management, although all programs were generally aware of its importance. While considerable investment in data management will not guarantee good science *per se*, a valid argument claims that a strategic approach to data management is fundamental to the application of scientific results and should be formulated at the onset of the program. Good data management also provides the means to translate and widely disseminate data within and outside the program.

Social Sciences

Although several programs mentioned the importance of incorporating all scientific disciplines – social as well as natural sciences – into restoration efforts, none of the programs actually involved social scientists as a part of their institutional framework. The incorporation of a broader, more inclusive meaning of science into our definition of 'best available science' is a challenging yet worthy objective of future large-scale, ecosystem restoration efforts where humans make up an increasing and inexorable part of the landscape.

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APPENDIX A: INTERVIEW QUESTIONS

PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION

INTERVIEW QUESTIONS:

LESSONS LEARNED IN LARGE-SCALE RESTORATION

GENERAL QUESTIONS FOR RESTORATION PROJECT PLANNERS AND SCIENTISTS:

A. Project organizational structure and activities

1. **What is the purpose of your program? What are the problems (actual or perceived) that are the focus of the program? What are the goals? Are there project milestones? How are decisions made?**

2. **What is the organizational structure of your program? Is there a Steering Committee or a NST analog? How were members at all levels selected?**

3. **What SPECIFC actions have been taken as part of this program? How was it decided to take these actions? Who proposed them? Are they part of a large plan? How were they funded? Are the projects being monitored? Who is doing this monitoring?**

4. Does your program review or comment on specific permit types of actions?

5. How does your program connect to the public? How much local "control" or input is there? What are the other players in the game in the area and how do they have input?

6. How has the program evolved/changed over time? How would you characterize today vs. the program's start-up?

7. Did they have suites of early action projects that have been "no regrets"

B. Restoration planning and guidance

1. **Are you doing process-based restoration (vs. structure -based)? How do you define "project" site in a process-based restoration scheme? Examples?**

2. **Is there a set of guiding ecological or science principles? How do you decide between opportunistic projects vs. strategic ecosystem restoration?**

3. **Is there a plan available that provides guidance? How was the plan developed? Is the plan intended to just guide your specific program or is a larger scale plan?**

4. **Did you develop a conceptual model or models to guide the program?**

5. Did you have strategy at first? Were there bad assumptions?

6. How does your program distinguish among the disparate components of science to determine what may provide useful guidance and what may not.

C. How is the system "broken?" Assessment of the causal mechanisms?

1. **What are the major scientific uncertainties (i.e., major information needs) in the program? How were those identified? What is being done about them?**

2. **How do you balance between theoretical long-range strategic science and short-term needs?**

3. **How do you narrow down lists of problems to the primary issue(s) your program will address?**

D. Data management

1. **How does your program handle and manage data? Do they collect and maintain their own? Is there a central data base/location that all have access to?**

E. External factors

1. **What inputs does socio-economics have in the decision making process?**

2. **What are major impediments (of all types) to attaining goals and objectives (science based, policy based, financial impediments)?**

F. Integrating science into restoration planning and assessment

1. **What inputs does "science" have in the decision making process? Is there policy or political control of science? If science was not used in selected parts of the Program, which parts and why not?**

2. **How much of your project's scientific studies could be considered "basic" science, as opposed to direct application to the project, e.g., for a better, broader understanding of ecosystem processes?**

3. **What were the specific recommendations from the science team that helped in guiding restoration? How were recommendations used? If recommendations weren't used, why not?**

4. **How was science used in the development of the restoration plan?**

5. **How do you "translate" science to managers/decision makers?**

6. **How would you recommend integrating science into large projects such as Puget Sound Nearshore Ecosystem Study?**

7. How to "update" 20-year old (thinking) scientists?

8. How to balance high-level science oversight (program review) vs. on the ground needs for design/review?

9. Is there modeling? In particular, are there scenario (e.g., effects of future actions) types of models that are used to help decision making?

10. How to involve larger local scientific community? Has this increased or decreased the incentive of the academic scientists involved to participate in similar investigations in the future?

11. How to turn science into political support "tell a story"?

12. How were science:policy/politics conflicts resolved, if they were?

13. How did you handle multi-disciplinary work?

G. Monitoring and adaptive management

1. **Is adaptive management, in the true sense of using restoration as an experiment that can be modified adaptively in response to scientific/technical assessment, applied in the in your program? If so, how? Is there an adaptive management plan? How was it developed?**

2. **How are you learning from early projects? Do you have the ability, mechanism and inclination to change the program from early actions?**

3. How essential is a comprehensive managing program (upfront studies vs. actions vs. monitoring, monitoring each site)?

4. How are performance measures developed and evaluated? Do you use objective metrics such as IBI, etc.?

H. Peer review

1. **What has been the role of "outside" peer reviews? What types and how many of these types of reviews are there?**

2. How does high-level (e.g., NAS/NRC) peer-review happen?

APPENDIX B: PROGRAM BACKGROUND MATRIX

Appendix B. Program Background Matrix

	Chesapeake Bay Program (CB)	Comprehensive Everglades Restoration Project (CERP)	California Bay-Delta Project (CALFED)	Glen Canyon Adaptive Management Program (GCAMP)	Louisiana Coastal Areas Program (LCA)	Puget Sound Nearshore Ecosystem Restoration Project (PSNERP)
Purpose	To manage the Chesapeake Bay as an integrated ecosystem and to restore and protect it.	CERP to restore, protect, and preserve the water resources of Central and Southern Florida	To improve by collaboration and cooperation water supplies in California and the health of the San Francisco Bay-Sacramento/San Joaquin River Delta Watershed.	To measure the effects of the Glen Canyon Dam (GCD) operations on the Colorado River (CR) from GCD to Lake Mead.	To restore and/or mimic the natural processes that built and maintained coastal Louisiana.	To identify significant ecosystem problems in Washington State's Puget Sound Basin, evaluate potential solutions and restore and preserve critical nearshore habitat.
Mission	To evaluate progress in the Chesapeake Bay restoration effort; to monitor environmental condition and environmental response to restoration efforts; to provide information needed to establish restoration goals; to inform and involve the public in achieving the restoration goals; to make detailed information and reference data for these indicators available on request.	To promote a sustainable South Florida by restoring the ecosystem, enhancing water supplies, and maintaining flood protection	Develop and implement long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta	To provide credible, objective scientific information to the GCD Adaptive Management Program on the effects of operating GCD on the downstream resources of the CR ecosystem, utilizing an ecosystem science approach.	Restore and protect disappearing coastal wetlands	Still being developed.
Problem Statement (clearly stated, widely-accepted "crisis"?)	Nutrients, habitat loss, toxic chemicals, overfishing, and sediments. Very clear and compelling and recognized as a "crisis."	Water shortages for urban and agriculture and a destroyed Everglades. Problem is clear and a widely accepted "crisis."	Decreased health of the Bay. Problem statement is clear, but could be clearer. Widely accepted as a problem by a well-informed public.	The GCD has impacted the biological, cultural, and physical resources of the CR. Problem is clear and compelling, but not considered a "crisis."	Coastal land loss due to sediment diversions and coastal land use practices. Clear and compelling "crisis."	The problem is a combination of many problems emerging from several places. The problem statement is still being refined.
Goals and Objectives	1. Restore, enhance and protect living resources, their habitats and ecological relationships to sustain all fisheries and provide for a balanced ecosystem. 2. Preserve, protect and restore those habitats and natural areas that are vital to the survival and diversity of the living resources of the Bay/tributaries. 3. Achieve and maintain the water quality necessary to support the aquatic living resources and to protect human health. 4. Develop, promote and achieve sound land use practices which protect and restore resources and water quality and maintain reduced pollutant loadings. 5. Promote individual stewardship and assist individuals, organizations, businesses, local governments and schools to undertake initiatives to achieve the goals and commitments of this agreement.	The overarching objective of the Plan is the restoration, preservation, and protection of the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection. The goals are to enhance ecological values and enhance economic values and social well being. These goals will be accomplished by delivering the right amount of water, of the right quality, to the right places, and at the right time.	Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species; reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system; reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees. Objectives are to improve water quality, ecosystem quality, water supply, decrease vulnerability of Delta functions.	The goals of the GCMRC are to develop monitoring and research programs and related scientific activities that evaluate short and long term impacts of the GCD on the biological, cultural, and physical resources of the CR Ecosystem. The goal is also to provide leadership to accomplish a free flowing CR.	Objectives are to identify and explore long-range, large-scale ecosystem restoration strategies to restore and protect coastal Louisiana and to sustain coastal ecosystems that support and protect the environment, economy, and culture of southern Louisiana, and that contribute greatly to the economy and well-being of the nation.	Preliminary goals are to 1. Rehabilitate ecosystem natural processes, 2. Protect and/or restore functional habitat types in Puget Sound, 3. Prevent future listings and achieve recovery of at-risk native species, 4. Prevent the establishment of additional non-native species, 5. Improve and/or maintain water and sediment quality conditions, 6. Increase the understanding of the natural processes and functions of the Puget Sound.
Year of Program Formation	1983	1992	1994	1996	1999	2001
Formation Process	Citizen motivated	Federal/state motivated	Federal/state and citizen motivated	Grassroots motivated	Federal/state motivated	Federal/state motivated
Evolution Since Formation	Evolved from water quality/eutrophication focus to fisheries and habitat.	Unknown	Authority added in 2002	Very little	LCA Breaux Act ? Process Based Restoration	Unknown
Geographic Scope	The CB watershed is over 166,000 square km	the target area in Southern FL is 47,000 square km	The Bay-Delta area is 3,000 square km	From the forebay of Lake Powell to the western boundary of Grand Canyon National Park (293 river miles or 473 km).	The entire Louisiana coast from MS to TX	4,000 km of shoreline X width of nearshore
URL	http://www.chesapeakebay.net	http://www.evergladesplan.org/	http://calwater.ca.gov/	http://www.gcmrc.gov/	http://www.coast2050.gov/lca.htm	http://www.pugetsoundnearshore.org

APPENDIX C: PROGRAM COMPARISON MATRIX

Appendix C. Program Comparison Matrix

		Chesapeake Bay Program (CB)	Comprehensive Everglades Restoration Project (CERP)	California Bay-Delta Project (CALFED)	Glen Canyon Adaptive Management Program (GCAMP)	Louisiana Coastal Areas Program (LCA)
Science within the Organizational Structure	**Is there a science team?**	Concentrated on STAC, but also occurs on subcommittees	The RECOVER team is the organizational center of science, but science also occurs and is represented on all project delivery team.	Science is integrated throughout the program but the ERP's Science Board provides the most direct scientific guidance to restoration.	Adaptive Management Work Group	Dispersed throughout the project, but the only group of scientists is organized solely under the modeling role and other specific tasks. The NTRC reviews and advises.
	If there is a science team, when was it formed? If science is dispersed throughout the project, is there a 'scientific headquarters'?	Formed in 1994, rather late in the process. STAC is the scientific 'headquarters.'	RECOVER is the "headquarters". It was formed in 1999. Science is also dispersed on all project delivery teams.	The ERP Science Board emerged very early. The Science Program is lead by the Executive Science Board, a panel of experts nominated by the Science Program lead and approved by the Authority, but came later.	Science makes up the majority of the program. The AMWG is a focus of scientific activity.	Science was not embraced until later in the program and is playing catch-up. The NTRC also came into the process late, after many of the science decisions were already formulated.
	Science team/committee member selection process	Appointed and recommended	The leadership team of RECOVER is appointed by represented agencies. The membership of the other 6 teams is ad hoc (whoever is interested).	Recommended	Governmental agency representation	Science team make up came out of Robert Twiley's work.
	Is science solicited using more of a "top-down" or a "bottom-up" approach?	bottom-up	top-down	Bottom-up RFP approach (still lacking feedback and guidance from science)	Top-down	Top-down programmatic approach (2050 proposes a top-down approach, but previous projects under CWPPRA were more bottom-up)
	Who makes program decisions? See organizational charts in Appendix 1.	Executive	The Project Managers who represent the Corps of Engineers and S. FL Water Management District	The Authority which is advised directly by the Executive Science Board.	Unknown	Made at the Vertical Integration Team or Executive Committee level
	Organizational evolution/change over time regarding science	Increasing role of academic and other non-agency scientists in program.	The Science Coordination Team was involved during the Restudy, but has since been disbanded.	Although Science Program came late, it has refined the mechanisms for science in the program.	program has grown to include more disciplines than just science	Post-feasibility report, an explicit Science Plan directs the evolution of the science as applied to restoration.
	Issues/problems encountered	Changing program structure and purpose was more difficult than anticipated.	This program was fixed before science was brought in, thus science was confined to work within the already fixed range of alternatives. Creativity was limited and any other option besides "replumbing" was not an option.	Contracting (between state and federal agencies over terms, data rights, and conflicts of interest) and fiscal issues (1). Some of the science issues are extremely challenging.	It's been very (politically) difficult to run a second experimental flood.	Strong political pressure for inclusion of some restoration actions and methods that are not strongly supported by science. For example, a lawsuit by oyster growers against the State, for damages due to restoration action, in one region severely reduced technical options considered in that region, despite scientific evidence supporting those restoration options.
	How is science integrated into the rest of the program, if it is?	No directed integration; very bottom-up in this respect?	Science is not always well integrated although the attempt is made by having science represented on all project delivery teams.	Science provides input to all levels of the organizational structure.	Predominantly a science-based program, so strong vertical and horizontal integration.	LCA's vertical integration team was an innovative approach to coordinating restoration players. However, in general science has not been well integrated.
	Is science from outside the program integrated with science within the program (i.e. is there collaboration with a research consortium)?	Yes, this is aided by interactions with the Chesapeake Research Consortium, Inc.	No, CERP is isolated from academic and outside science. Outside science is only incorporated through agency contact and through some relations between local universities and the S. FL Water Mgmt Dist.	Yes, they have established a research consortium. In addition, the CALFED Science Conference is a very effective mechanism to involve the broader scientific community.	To some degree; USGS promotes collaboration.	No outside scientific involvement at this stage. A consortium is handling much of the technical science (e.g., hydrodynamic modeling) but this is fundamental program component. Thus far, there are few formal mechanism for input from outside the program.
	Is science independent from policy?	Yes	Mostly. There is a concerted effort to separate the two.	Yes; science is asking and raising difficult questions.	Yes, if you consider removal of the dam not an option.	No
	Does the science have supportive staff?	Somewhat. Science fellows also play this role.	The only staff is that provided by the scientist's agency	Yes; they provide it through contactors.	Unknown	Only as part of scientific tasks. The NTRC is provided no staff.
	Is there a way to involve fresh scientific perspectives?	Yes, science, or research fellows.	No formal way. There is plenty of turnover and fresh perspective does not need to be solicited.	This is an articulated future goal for the next few years (1, p4).	No	Not at moment, but proposed Science Plan provides for that.
Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Diagnosis of problem and causal mechanisms	**Was there a obvious and agreed-upon problem?**	Yes, the health of the bay was the problem, but the cause was more difficult to understand.	Yes, the loss of the Everglades and water shortages/problems.	Yes, water quantity and quality issues as well as ecosystem degradation/habitat loss.	The dam was obvious, but it wasn't an agreed-upon problem save for the ecosystem.	Yes, it was universally agreed that land loss was the problem with several causal factors behind it.
	How were information gaps/needs in the program identified?	Public opinion is influential	By a large "brain dump" in the '80s. This became the Corps project.	Through issue-focused workshops supported by both the ERP and Science Program; explicit products have been produced by these workshops.	Unknown	Identified by scientists
	How do you identify issue (s) to address from list of problems?	Science and technical experts mostly identifies issues	From CERP's science plan and from risks and uncertainty identified from projects. Some science needs also come from outside of CERP.	CALFED did an especially good job identifying numerous actions to address problems that could work, but is only now in the process of setting priorities. A conceptual model in each ERP proposal also facilitates that process.	Science identifies issues	Management integration of combination of scientific advise and stakeholder input, but that has evolved from thinking about the problems at the local scale to the system scale.

Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
The Role of Science in Restoration Planning and Action	**Was there a large base of existing scientific knowledge?**	yes	Yes	Yes	Not as much	Yes
	What inputs does "science" have in the decision making process?	Input is transmitted through reports	Science contributes primarily via products delivered to program management.	Executive Science Board advises the Authority	Formulation of experiments for adaptive management (water releases) and interpretation for water regulation.	The advice of the science and technical experts is seldom heard by the public or even the PMs
	When did science begin playing a role in decision-making?	Late	From the beginning	The Executive Science Board formed late (in 2000), but there was always science infused in the program.	From beginning.	Still fighting to bring science into the program.
	What is the source of science used?	Mostly academic and agency. Some independent (i.e. consulting firms)	Most science is agency science, either existing or generated from within CERP.	Peer-reviewed agency science and published peer-reviewed literature. The science agenda is determined partly by management and stakeholder questions and partly by scientific charge of the program's goals and objectives (1).	Predominantly science agency (USGS) and academic	The Corps brought specifically selected scientists to review the product, raising credibility issues. Late in the development of restoration options, the State brought in academic scientists to provide critical input.
	Is there political of how science is used?	Not too much.	Some, because decisions are made about funding…	No	Yes, the power companies are powerful.	Politics does influence how science is used.
	Is the science mostly directed or is there some discovery?	Directed with some room for discovery. Also the many academic institutions and research consortiums contribute to discovery-derived knowledge.	Directed.	Discovery based. Most is basic ecosystem science is directly applicable to the project but not directed or requested by the project	Directed with some room for discovery because the main organization is the GCMRC under DOI. So even their "directed" research is fairly "discovery"	Directed. PMs identified scientific needs and capable researchers to answer specific questions because of speed and efficiency.
	Are models or scenarios used to make decisions?	Yes, extensive use of models	Yes, at least somewhat (namely the Natural System Model)	Yes, extensively	Yes	To inform decisions only.
	Is there involvement from the larger scientific community?	Yes, substantial.	Somewhat	Some, but there should be more.	Unknown	No; limited.
	How did you handle multi-disciplinary work?	Unknown if there is a specific strategy	The project delivery teams are all multidisciplinary. The challenge is more in working with multiple agencies. Sometimes facilitators are brought in to solve relationship issues.	Standing Boards are appointed for integrated work. Technical Panels address individual issues (1, 13). Explicit encouragement, though proposal funding and directed action review.	Participating science composition	As needed through directed program tasks.
	How were science:policy/politics conflicts resolved, if they were?	Public and stakeholder involvement	Program may have adapted to the problems	Purposefully with workshops, facilitators and integration teams. Also with lots of updates, milestones, and products (all programs).	Unknown	Not resolved

Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Restoration Planning and Guidance	**Are there "Guiding Ecological Principles" or "Science Principles"?**	Unknown	Unknown	Yes, not widely known	Unknown	There are restoration principles, but Science Plans provides explicit principles for conducting science.
	Is there a restoration plan to provide guidance? Did science contribute to its formation?	Yes, and scientists were active in its formation.	Yes, but it was largely formed by the time science was brought to the table.	Yes, within the "Ecosystem Restoration Program"	Unknown	Yes, through the 2050 plan.
	Is there a comprehensive project or merely one specific action?	Comprehensive planned actions	A strategic portfolio of discrete actions	Lots of separate actions that are influenced by policy as well as science	Smaller actions support one large action (experimental flooding)	A set of actions organized around the program purpose
	Is there a Conceptual Model?	Yes	yes, as well as other models that use hydrology as a performance measure	There are lots of conceptual models; all proposals must include a CM and each element of the program has its own CM. CALFED demonstrated well the importance of a CM	Unknown	Yes, as well as other models. CM was often in narrative form and sometimes not clearly stated.
	If so, is it used as a decision-making tool?	Yes		Yes, contributing to restoration design and assessment.	Unknown	Yes, in terms of identifying consequences of identifying restoration actions.
	Was there a strategic plan at the onset? Is there a strategic approach to addressing science issues?	Unknown	yes, because top-down	Yes, there is a 1997 document that lays out a strategic plan for ERP.	Unknown	Yes, because top-down. 2050 constitutes a strategic restoration plan, but there wasn't not a strategic science plan and science has not been well integrated until the proposed Science Plan.
	How does your program distinguish among the disparate components of science to determine what may provide useful guidance and what may not?	Unknown	Unknown	The CMs help fit the science into the overall program, and demands rigorous scientific review.	Unknown	Science is very internalized.
	How do you balance between theoretical long-range strategic science and short-term needs?	There is support for long-range planning	Little room to meet more than immediate needs	All studies have to be renewed for funding every 3 years; however, CALFED embraces theoretical studies as much as possible by employing a bottom-up approach to soliciting proposals. They use adaptive management to balance long and short term science.	Short-term needs are not so pressing as to eliminate long-term planning	Short-term needs are extremely pressing but require some long-term planning, which they have yet to really address (although Science Plan does attempt to do that).
	Was there an analysis of historic condition?	Yes, this has been a major focus of effort	The historical analysis was made up of anecdotal information which was combined with present science knowledge to produce simulations of historical conditions.	Yes, lots of information to make up the historic analysis.	Limited	Yes
	How do you address the difference between fixing the problem and not the symptoms?	Yes, more so.	Somewhat, although urban and agricultural water use is not being decreased.	Somewhat, although most actions seem to be concentrated on physical/structural rather than population growth and control.	No because the dam will not be removed in the near future.	Not really, but fixing the problem involves the entire mid-west. However, there are explicit process-based solutions at the coastal scale.
	How does the program deal with data management?	No strategic plan	No strategic plan	Discussing applying a web-based system to CALFED. Managed by supporting the Delta Science Consortium and by encouraging data coordination and analysis (1).	Developing a plan	No strategic plan, except that the proposed Science Plan has an explicit informatics strategy.

Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Actions and Activities	**Were there early action ("low-hanging fruit") projects? Successful or not?**	Yes. Helpful	Yes, four pilot projects that have yet to be constructed. These are mostly to test technologies.	High profile projects, with extensive stakeholder involvement and organization, are "signature projects" that have been useful in testing restoration success, but they're still trying to figure out next steps for those areas.	Not really	CWPPRA constituted these projects.
	In what stage is the program?	Well along with actions and project and long-term direction	In the final planning stages before implementation	ERP in implementation.	Have conducted one AM experiment and still learning and planning for the next	Finished reconnaissance study and preparing to submit feasibility report to congress
	Is there explicit selection criteria for restoration actions? Are they strategic, long-term?	Unknown	The selection criteria are largely political	Proposals are awarded funding on competitive basis and must fit into the focus of CALFED. Projects are reviewed by the technical review board and the geographic review board	Unknown	As yet no process beyond cost-effectiveness.
	Are actions monitored (and by whom)?	Yes. Monitoring is organized by subcommittees and carried out by agencies, academics, or by citizen groups	Very little.	Performance measures are the main way to not only monitor but assess progress; just now requiring project to do monitoring. New IRWM program has yet to develop protocols.	Yes. Monitoring is organized by the GCMRC and contracted out or assigned to other groups	CWPPRA has well developed monitoring program, which LCA will likely build on.
	How does your program ensure the best actions are being taken?	Unknown	Unknown	Ensure "good" proposals by not being afraid to say "no" and by holding workshops to teach people how to write a good proposal.	Unknown	No process at present.
	How are actions funded?	Many funding sources, federal budgets	direct federal/state	Many proposals are selected by a highly competitive RFP, however some program areas, such as conveyance projects, have not yet been subject to rigorous competition.	federal program budget	As part of program implementation strategy, based on feasibility report.
Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Monitoring and Adaptive Management	**Do you practice adaptive management? How?**	Working towards AM, but practicing adaptive learning	Yes, there is an adaptive monitoring assessment team that assesses progress and monitors.	Adaptive management is a fundamental tenant of the ERP.	Yes. This is the foundation of the program	No, working on adaptive learning, but Science Plan lays out principles.
	Is there an adaptive management plan and how was it developed?	Unknown	The adaptive management plan is still being developed. The process is coordinated by the RECOVER team.	The plan will be developed using workshops, CMs, integrating peer-reviewed AM project proposals, and panels of experts.	Yes, developed by scientists	In proposed Science Plan.
	Is there a mechanism to incorporate lessons learned from early action projects? Do you use it?	Yes	Yes, the pilot projects address areas of uncertainty and each has mechanisms to learn from the experience.	ERP has made some attempt at a "look back" exercise.	Yes, through AM.	Conducted under CWPPRA; LCA would conduct it through Science Plan.
	Is there monitoring? Has it been difficult to justify? Does it play a large role?	Yes, water quality monitoring started very early, but it has only recently expanded to be widely useful. It remains somewhat challenging to justify.	There has been heavy financial investment in monitoring from early on. Early action monitoring projects are called "demonstration projects."	There is limited monitoring of specific projects. They're still struggling with a token commitment to monitoring and poor follow through (from visit notes).	Yes, monitoring is a substantial part of the program and it has been challenging to justify, but it started when the dam was built so that helped.	Monitoring of Breaux Act efforts is well established, albeit at minimal levels.
	Do you have performance measures?	Yes, mostly in form of ecosystem indicators. "40% reduction of nutrients" was a note-worthy measure.	Yes, from early on. Developed 1,000 indicators and narrowed down to under 50.	Yes, prototypes have been developed and PMs will follow.	Unknown	Not explicitly, and may have actually been de-emphasized; LCA would develop performance measures through Science Plan.
	How were performance measures developed and how used in evaluation?	Unknown	Developed by making a long list and winnowing it down. This method may not have been the most efficient or correct approach.	Prototype PMs developed by Science Program consultant using Science Program's template for guidance of PM selection. As more is learned, real PMs will be substituted for prototypes (1).	Unknown	None at this time.
Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Peer Review	**Do you employ "outside" peer reviews?**	Yes	CROGEE provides independent scientific review. Currently working to establish an outside National Academy of Sciences review panel that will likely replace CROGEE. (website).	All proposals and products are peer reviewed. The Independent Science Board is the main peer-review panel, but other technical panels and standing boards also provide review (8/14/03 meeting, item #8).	Unknown	There is Nat'l Tech Review Committee is the outside review board, and there is a NRC review on-going.
	Is there some other established way to access expert advice?	Yes, collaboration with research consortiums	Currently putting a peer-review program together to review RECOVER products.	There has been some problems securing external peer review and access to advice from outside experts. But, they invest considerable resources in peer review. This is due to a lack of an established system (1).	Unknown	Working panels have independent scientists. Also, the NTRC
	How does high-level (e.g., NAS/NRC) peer-review happen?	Unknown	Infrequent review (e.g. OMB study)	It doesn't happen within the program; too fine of scale. In the next couple years they're planning a National Academy Comparative Review (1p18).	Unknown	Little review of Breaux Act proposals. There is a NRC on-going, and will review the Nat'l Tech. Review report.

Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
Public involvement	**In what ways is the public involved?**	Lots of public involvement	Little public involvement.	Lots of public involvement with public bonds, outreach, and a high level of existing public interest	Unknown	There have been many public meetings under 2050, and similar stakeholder meetings under LCA.
	Is there science outreach to the public?	Yes with regular reports and publications	Not specifically from science, but CERP has an outreach program and public meetings are held to deliver scientific information to the public.	Yes, involvement on working groups CALFED has recently introduced an on-line science journal, and all documents, including proposals, on the web.	Unknown	No science outreach.
	Is the public informed? Supportive?	Informed and supportive, yes.	Informed yes, and largely supportive although there is stakeholder conflict.	Informed fairly well, and fairly supportive although there is stakeholder conflict; but they have supported funding propositions.	Informed fairly well, and supportive from all but the power companies who are no longer very critical.	Informed of the problem, but not of the solution. There is tremendous stakeholder conflict especially from the oyster growers, but general public is supportive as shown by state-wide passage of constitutional amendments for funding.
	How do you structure/control public involvement?	Unknown	Unknown	Through FACA	Unknown	LCA has actually been avoiding FACA.
	Do you employ facilitators in public sessions?	Rich sort of fills this role	Unknown	To some degree.	Unknown	Have tried to.
Prog. Comp. Matrix, cont'd.		CB	CERP	CALFED	GC	LCA
External factors	**Impact of socio-economics on decisions?**	Unknown	large impact	Socio-economics are a factor in decision making. On the Science Board, other disciplines are also represented other than just technical science. Explicitly included in Environmental Water Account.	medium impact	There is a cost effectiveness analysis, but no multi-criteria decision making.
	What are the primary impediments to attaining goals?	Unknown	Unknown	Magnitude of challenge, and water resource constraints.	Unknown	Potential resource conflicts, and the scale of the problem and likely solutions.

1. California Bay-Delta Program: Science Program Multi-Year Program Plan (Years 4-7). August 2003

GLOSSARY OF TERMS

Adaptive management – scientific experiments applied to natural resource management. It prescribes adapting management based on the results of rigorous scientific experimentation that is build into the management plan.

Conceptual Model – a model, either numerical or diagrammatic, that summarizes and describes a simplified version of, in the cases examined here, the natural environment.

Directed vs. discovery science – directed science is what we've referred to as "top-down," or science that is called for as part of a science plan. Discovery science, or "bottom-up" science is not orchestrated by an overarching plan, but "bubbles" up from the broader scientific community.

Ecosystem – system which includes all the organisms of an area and the environment in which they live (Collin 1988). A biological community together with the physical and chemical environment with which it interacts (National Research Council 1992).

Ecosystem Function – any performance attribute or rate function at some level of biological organization (e.g., energy flow, detritus processing, nutrient spiraling) (National Research Council 1992).

Indicator – a substance which shows that another substance is present; species which has particular requirements and whose presence in an area shows that these requirements are present also. An indicator species is sensitive to changes in the environment and can warn that environmental changes are taking place (Collin 1988).

Landscape Scale/Large-scale – this is a gauge to measure the magnitude of the project relative to its surroundings. Large-scale projects usually overlap governmental jurisdictions thus requiring collaboration from a broad range of participants. Large-scale is also a measurement relative to other restoration projects in the region. For example, CERP is large-scale and the Kissimmee River project, dwarfed by CERP, is smaller scale.

Mitigation – actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystem (National Research Council 1992).

Performance Measures – metrics or indicators, see above, that are related to an ecosystem process or function and which are measurable in a natural ecosystem that can be used to judge the performance of restoration actions. Programmatic performance measures could measures of public support, access to funding, etc.

Processes-based restoration – restoration (see below) or processes that shape an ecosystem, such as sediment transport or erosion, rather than the restoration of features of ecosystems, such as tidal marshes or species populations.

Restoration – returning an ecosystem to a close approximation of its pre-disturbance state in terms of structure and function (National Research Council 1992).