USFWS Anadromous Fish Restoration Program
CALFED Bay-Delta Program

FINAL REPORT

ADAPTIVE MANAGEMENT FORUM FOR LARGE-SCALE CHANNEL AND RIVERINE HABITAT RESTORATION PROJECTS

Prepared by the

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and

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1. EXECUTIVE SUMMARY

The U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (AFRP) and CALFED Bay-Delta Program, Ecosystem Restoration Program (CALFED), jointly are funding ambitious tributary restoration projects on the Tuolumne and Merced Rivers and Clear Creek to improve conditions for native species, especially Chinook salmon. To ensure maximum benefits from the many millions of dollars that they spend on ecological restoration in the Sacramento and San Joaquin river watersheds, the AFRP and CALFED have required that adaptive management be an integral component of the restoration projects they help fund. The Adaptive Management Forum (Forum) was initiated to review current restoration project designs and offer recommendations on how to make adaptive management a more comprehensive and active component of the projects at the reach, tributary and basin scale.

The Forum was created in 2001 to assist these agencies and the individual tributary restoration teams with the incorporation of adaptive management, as defined in the Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration, into the design, implementation and monitoring of restoration. The Forum has reviewed and made recommendations concerning each tributary restoration project individually. In this, its final report, the Forum considers institutional and technical obstacles to implementation of its previous recommendations and adaptive management in general, prospects for integration among restoration projects on the three tributaries, and the effectiveness of the Forum process in facilitating adaptive management. The report and its recommendations are directed at the river restoration teams, the Forum planning team, and the AFRP and CALFED program managers and policy-makers.

Institutional Constraints

Four main institutional, non-technical constraints (regulatory environment, funding, human resources, and communication) discourage the implementation of adaptive management in the way envisioned by the AFRP and CALFED.

Regulatory Environment

Permitting requirements for such issues as threatened and endangered species, water quality (turbidity and mercury), flows and flow regimes, and floodway management and conveyance do not allow the design flexibility and speed of response required for effective adaptive management. These habitat restoration projects are clearly different from other regulated activities and some form of regulatory exemption or special status needs to be negotiated for the projects so that they can pursue innovative and creative approaches to adaptive management.

Funding

There were four categories of funding constraints.

1. Funding for the individual projects comes from various sources with somewhat different objectives. Satisfying the differing goals of funding sources can impose significant constraints on the projects and may compromise long-term success (as in the unwillingness of some sources to fund baseline studies or monitoring).
2. Design, construction and monitoring of projects can extend across many funding cycles, and funding is provided as a single package when the project is approved. This may not be the most efficient way to proceed as project managers have little flexibility to modify budgets to address cost increases or design problems. An alternative approach might be to approve a project in principle in its entirety but only to fund the design in a first phase of funding. Once the design is complete, the AFRP and CALFED will be in a much better position to determine the best approach and costs of the construction phase. The design phase should also clarify the necessary structure and duration of the monitoring program but monitoring might also be considered a separate fundable program. A related issue related to funding cycles is that, under the annualized budget cycles of the funding agencies, substantial funds are sometimes provided at the end of a fiscal year and must be spent in a short period. As a result, construction may have to begin before important preliminary modeling, baseline studies, or design work is completed. Finding a way for projects to bank funds between funding cycles would prevent such conflicts and would provide greater flexibility and certainty to ensure project success.
3. There were difficulties in securing funding for monitoring. Some funding sources simply would not fund monitoring. In other instances, project proponents perceived that high monitoring costs might jeopardize funding for their project. Monitoring presents perhaps the most difficult match to normal funding cycles and budgets. Monitoring can appear open-ended in terms of both the amount of information to be gathered and the time frame over which information should be gathered and this may be a concern to funding agencies. Provided that monitoring is well connected to the assumptions of the restoration design, and the time frame is tied to clear and quantitative milestones, this concern should seldom arise. However, the budgeting problem for monitoring is further complicated because certain kinds of measurements may only need to be made intermittently but at those times may involve intense and costly data gathering (such as during a flood).
4. Finally, concern was expressed that critical comments by the Forum might jeopardize future project funding. This was particularly a concern, it was suggested, if restoration teams did not adopt all of the Panel's recommendations. The Panel emphasizes that its comments are advisory only and projects should not be jeopardized if they reject comments for good reason.

Human Resources

Another constraint to implementation of adaptive management was staffing, which also can be categorized into four issues.

1. Scientifically based monitoring requires specialized staffs that, for understandable reasons, were not recruited in the initial phases of these projects. In addition, everyone currently involved with project monitoring already has many other duties that distract from effective monitoring. There is a definite need to provide staff and resources to develop robust monitoring programs for each of the projects.
2. None of the individual projects has the staff properly trained to design experiments in the context of the overall tributary effort. A significant opportunity for learning about effective tributary restoration will be lost if the restoration teams and supporting agencies are unable to take advantage of the potential for experimentation within these projects.
3. Neither funding nor staff has been budgeted to explore and take advantage of the opportunities for analysis and experimentation among projects within a tributary and among the tributary efforts.
4. Finally, monitoring of these individual projects and tributary efforts will generate significant quantities of data. If these are to be of value to the community of professionals interested in river restoration, properly trained staff must be committed to the storage, analysis, synthesis and dissemination of the data.

Communication

A fourth constraint involved communication among projects within a tributary and also among the three tributary scale efforts. For some projects there did not appear to be one person who was responsible for the project as a whole. For all projects, there appeared to have been inadequate involvement of those responsible for the conceptual design in the actual construction. These issues were raised in the individual tributary reports. Communication among projects concerning issues of design, implementation and monitoring also appear to have been minimal. This is in part a staff and resources problem but also reflects a lack of appreciation of the learning opportunities offered by the projects.

Technical Issues

Seven general technical issues were common to all tributary efforts.

Conceptual Models

There was some continuing confusion about the nature and use of conceptual models. There is no single "right" way to express a conceptual model. The most effective way to represent a concept depends on the purpose of the model and the audience. A simple pictorial model may be best for a non-technical audience but may be less useful as a basis for decisions about project implementation or as the foundation of an adaptive management program. For final decisions about specific design features, conceptual models may have to be replaced by mathematical or numerical simulation models. Both conceptual and simulation models can be assembled from the best technical judgments of experts, as was done by the consulting firm ESSA in preparing their decision support model for Lower Clear Creek. Since the model embodies the qualitative and quantitative technical beliefs of key decision makers it provides a powerful tool for exploring in an objective way how their decisions are likely to propagate through the ecosystem. Regardless of their form, models at smaller geographic scales need to be functional components of models at larger scales. That is to say models at smaller scale should be nested within models at larger scale.

Implementation of Adaptive Management

A second technical issue involved the structure of the restoration projects. None of the restoration projects evaluated by the Forum have been designed and implemented using adaptive management to the degree desired by the AFRP and CALFED. The projects most closely resemble passive adaptive management but lack appropriate specification of responses to manipulation and monitoring as required by adaptive management. Clear Creek is best developed of the three because its monitoring programs are more complete. Even in Lower Clear Creek, however, critical expected consequences of the restoration model have not been clearly specified nor has monitoring been designed to measure these consequences. The first priority should be to make the projects good passive adaptive management projects by specifying, in quantitative terms where possible, the expected responses of the modified channels and incorporating proper monitoring protocols. At present, expected behavior of the systems is specified primarily in qualitative terms and monitoring is not well designed to address the main features of the projects. In addition to passive adaptive management, the projects provide many opportunities for active experimentation. By incorporating active experimentation into the projects, the restoration teams can learn substantially more about system response to the application of restoration strategies than would be possible with passive adaptive management. In doing so, the teams can also begin to address uncertainties. As experiments, the projects will also attract more attention and interest from the academic community.

As with conceptual models, there continues to be confusion about what constitutes adaptive management. Forum participants frequently referred to ad hoc adjustments to channel design or evolving channel structure as "adaptive management". It is important to distinguish between tweaking channel morphology to maintain certain configurations and adaptive experimentation. Indeed, treating the channel restoration as an experiment means recognizing the need to allow the channel to evolve for some time before taking "corrective" action, even if it appears to be changing in undesirable ways at some locations. The restoration teams need to build a broad concept of temporal patterns of change and a reach wide appreciation of channel morphology into their assessment of performance as opposed to an immediate and site-specific concept.

As platforms for adaptive management, the restoration projects offer so many possibilities for experimentation that choosing which experiments to conduct is problematic. Experiments that may effect management decisions are to be preferred, and it is always better to do a few experiments well than a lot poorly.

Monitoring

Another technical constraint involved the design and implementation of monitoring plans. Due largely to institutional constraints, monitoring plans to evaluate the effectiveness of the three tributary efforts generally have not been adequately designed and implemented. Despite good faith efforts by the restoration teams, the lack of staffing, financial resources, and training hinders the kind of monitoring needed for projects of this scale and complexity. Additionally, the projects lack the resources to conduct the ongoing, timely analysis required to practice adaptive management. The lack of resources contributed to the inability of the restoration teams to design monitoring programs that met data collection requirements, the need to conduct of monitoring across spatial scales, and the integration of monitoring from project level to the tributary. There is a need to link project-level restoration activities with tributary-scale monitoring to enable success at the project level to translate into measurable improvements at the scale of the whole river.

Fluvial Dynamics

The fourth area of technical concern related to the use of a fluvial model as a template in project design and the balance between simplicity and functionality. The channel restoration projects on the three tributaries are built around the concept of a single thread meandering channel configuration. Several restoration locations push this model to the limits of its applicability and the uncertainty of channel behavior has not been thoroughly thought through. A more thorough analysis of hydraulic and sediment response of the channel coupled with some experiments might help to clarify channel response over the long term. The model also involves starting with a simple channel design and letting it evolve its own complexity over time. Simplicity of design reduces initial construction costs but may not always evolve toward optimal complexity. An experimental approach might help clarify how complexity develops and what channel configurations at the construction phase will evolve toward the most desired end states.

Project Design

Technical issues related to project design also impacted the work of the restoration teams. In addition to project design issues discussed in the individual Forum reports, including defining of project objectives, prioritization of projects, and need for sediment transport models, two design issues emerged: concern that other paradigms for conceptual designs were not considered and finding a balance between simple, inexpensive designs and costly, complex designs.

Fish

Another area of technical concern related to fish populations, including the value of the tributaries as nursery habitat for Chinook salmon, food as a limiting factor, and habitat use by non-salmonid fishes. The value and importance of the tributaries as nursery habitat is unknown although a variable number and proportion of fry use them as nurseries. Resolving this issue has important implications for restoration of Chinook salmon. Associated with the value of the tributaries as nursery habitat is the availability of food for Chinook salmon fry. The invertebrate community of the channels has not been systematically evaluated as a primary food supply for Chinook salmon. Finally, although native non-salmonid fishes are a target of restoration, virtually nothing is known about their distribution or habitat use in the tributaries. All these unknowns contribute to uncertainty in the long-term success of the individual restoration projects and tributary efforts.

Revegetation of Floodplains

The final area of technical concerns involved revegetation of floodplains, the effect of revegetation on channel migration, and the shape and colonization of the floodplains by native and non-native herbs. Revegetation of the floodplains of the rivers is important to the restoration of ecological function in the river corridor. However, revegetation also has the capacity to prevent erosion and channel migration, especially if several years of low flows allow vegetation on the riverbank to become well established. Although it is not possible to predict channel bank erosion and deposition with certainty, planting density is likely to affect these processes and should be scaled in relation to expected volumes of sediment to be transported and desired channel functionality. If riparian vegetation stabilizes bank materials too effectively, scarification or vegetation removal may be employed to encourage erosion.

To date, projects have not experienced too rapid an invasion of non-native herb species. The dry and well-drained nature of floodplain soils may give the advantage to native species. However, experiments to determine the best ways of encouraging native species to establish while discouraging non-native species would provide useful information for other restoration sites.

The geomorphic restoration projects on three tributaries are all based on the same model of ideal channel configuration. However, there are sufficient differences among the projects and the project sites to make inter-project comparison a valuable source of information. Outside the Forum, there was little organized exchange of information among the projects, and staff and resources were not budgeted to consider opportunities for comparison among the projects. Indeed, both within and among projects there was a need for a properly constituted investigative team to take advantage of the many opportunities for descriptive and manipulative experimentation.

The Forum itself was an experiment in communication and evaluation within and among projects. In general, the Forum achieved its primary goals as established by the AFRP and CALFED. Scientists of high caliber were attracted to the restoration projects and were enthusiastic about serving on the panel. Restoration teams had the opportunity to debate their projects with technical experts and to exchange information among projects in ways that would not otherwise have occurred.

2. BACKGROUND

Over the past several years, the U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (AFRP) and the California Bay-Delta Program. Ecosystem Restoration Program (CALFED), have jointly contributed millions of dollars to the design and implementation of large-scale river channel and floodplain habitat restoration efforts in the Sacramento and San Joaquin River basins in California. Knowing that the field of river restoration is still largely exploratory and that it is important to learn as much as possible from every restoration project, the AFRP and CALFED have sought to increase the information gained from the projects by incorporating adaptive management into project planning, design, implementation, and monitoring (USFWS 2001; CALFED 2000, 2001).

Adaptive management is an iterative process resource managers can use to incorporate the problem-solving power of the scientific method into ongoing management actions (Walters 1986). The AFRP and CALFED anticipate the following benefits from incorporating an adaptive management approach:

- Success and failure in the restoration projects will be ascribed to specific causes, thereby reducing uncertainty in future projects;
- The models and methods used in river restoration will be able to be updated on the basis of sound, scientifically credible information, and subsequent projects can then be redesigned to be more effective;
- An objective process for incorporating new knowledge (from carefully designed and monitored projects and experiments) into future project design and implementation will emerge; and
- The credibility of multi-million dollar river restoration efforts will increase as will support from project stakeholders and the public.

The Adaptive Management Forum for Large-Scale Channel and Riverine Habitat Restoration Projects was initiated in the spring of 2001 to provide advice to the AFRP, CALFED and the tributary restoration teams on ways to strengthen adaptive management in the context of river restoration projects already in various stages of implementation.

The objectives of the Forum were to:

- Review conceptual models and habitat restoration plans;
- Evaluate the integration of multiple restoration projects;
- Generate recommendations on project design, implementation, and monitoring within an adaptive management framework at the tributary scale; and

- Compare similar river channel and floodplain restoration projects in different watersheds and provide comments and recommendations on ways to address key technical uncertainties associated with similar types of large-scale riverine habitat restoration efforts.

2.1 STRUCTURE AND PROCESS OF THE FORUM

The Forum provided a structured way for river restoration teams and staff from the AFRP and CALFED to work with a panel of independent scientists and technical experts that reviewed the restoration projects and provided recommendations on conceptual modeling, restoration planning, and project design, implementation, and monitoring. The Adaptive Management Forum Scientific and Technical Panel (Panel), which was drawn from academia and the private sector, consisted of experts in adaptive management, fish biology, fluvial geomorphology, aquatic invertebrates, aquatic ecology, riparian vegetation ecology, and civil and hydraulic engineering. The Panel included two members of the CALFED ERP Independent Science Board to provide a link to the CALFED Ecosystem Restoration Program.

The three tributaries addressed by the Forum were the Tuolumne and Merced rivers (tributaries to the San Joaquin River), and Lower Clear Creek in Shasta County (tributary to the Sacramento River). They were chosen because these rivers are focal areas where significant investment in restoration had been committed by both programs and where channel and floodplain restoration projects were already in varying stages of implementation.

The format and structure of the Forum was developed by the Forum Planning Group, which included representatives from the AFRP, CALFED Ecosystem Restoration Program, the CALFED Science Program, and the University of California, Information Center for the Environment (ICE). Initial representation on the Forum Planning Group included a CALFED or AFRP staff member with an established working relationship with the local restoration team for each of the tributaries to be evaluated. They served a dual role of planning the Forum to address the programmatic goals of CALFED and AFRP and of closely coordinating with the local restoration teams to assist their preparations for their respective Forum session. Unfortunately, staffing changes resulted in a loss of the Clear Creek liaison mid-way through the process. This loss was significant as the liaisons served a critical role in communicating expectations and process between the panel members and the river restoration groups. The ICE was retained to recruit the scientific and technical review panelists, handle local logistics for the forum, distribute advance materials, facilitate the process, and compile and edit reports.

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CALFED Ecosystem Restoration Program. The Forum Planning Group formulated a set of questions for the Panel to consider as a way to focus the Panel on the issues of key importance to the programs (Appendix I). The Panel reviewed the questions in advance with the Forum Planning Group to clarify the desired outcomes of the Forum process. The Panel used the questions as guidance, but their reports also reflect issues and concepts that were identified during each Forum session. Prior to each session, Panel members were provided with relevant background material to prepare for the Forum, including tributary restoration plans, project descriptions and interim reports.

The Forum began in March 2001 with a one-day workshop on conceptual modeling for all the restoration teams. At this workshop, the benefits and uses of conceptual models in adaptive management were presented, examples of conceptual models were discussed and evaluated, and a sample conceptual model for river channel restoration was envisioned.

During the next year, three, multi-day Forum sessions were held, one for each tributary. Each session had about 40-50 attendees. Active participants at each session included members of the Panel, the local restoration team members, the project consultants, and the AFRP, CALFED, and ICE project staff. In addition, each Forum session had about 15-20 observers. The first day of each session was spent touring the rivers and visiting project sites. The second day consisted of presentations by and facilitated discussions among the participants, with an intent to discuss topics introduced in the field, detailed information, such as monitoring results, and questions developed as a result of review of advance materials distributed to Panel members. The Panel members met privately on the third day to discuss the tributary restoration effort and projects, to develop preliminary recommendations, and to outline the session report for the Forum. To protect the independence of the Panel, the report was constructed in the session and not reviewed by the restoration teams.

The Panel wrote short reports on each Forum session that summarized their comments and recommendations on ways to incorporate adaptive management into the projects (Adaptive Management Forum Scientific and Technical Panel, 2001; 2002; 2003). In this final report, the Panel synthesizes their recommendations from the individual tributary reports and makes recommendations to address key issues and technical uncertainties associated with these types of habitat restoration projects. Before the preparation of the final report, an additional meeting was held for the Panel, restoration teams, and the AFRP and CALFED program staff. The goals of this final meeting were to:

- Provide an opportunity for the Panel and restoration teams to discuss the Adaptive Management Forum reports and current status of the projects one more time before the Panel wrote the final report; and
- Get feedback from the Panel and restoration teams about improving the structure and process of the Forum for the future.

3. INTRODUCTION

The three tributary-scale river restoration efforts examined by the Forum comprise an ambitious and novel approach to the physical and biological restoration of the lowland gravel-bedded rivers of California. On all three tributaries, the fundamental assumptions guiding channel and floodplain restoration project designs are that it is possible to create a set of geomorphic processes and fluvial (channel and floodplain) landforms, rescaled in size to the modern, regulated flow regime, and that doing this will restore enough natural ecosystem functioning to increase natural production and survival of key species of plants and animals, principally fall-run Chinook salmon. Remarkable progress has been made on all three tributaries, and there are many reasons to believe that their continued refinement and implementation will improve the way these tributaries function.

On all three tributary efforts, the large-scale restoration goals have evolved over time. In the last decade of the last century, declining populations of Pacific salmon and steelhead resulted in state and Federal legislation that identified the goal of doubling natural production of these fish populations (California Fish and Game Code Sec. 6900 et.seq. 1988; Public Law 102-575, Title 34, Sec. 3406, 1992). Early restoration actions to achieve this goal, such as adding gravel to a single spawning riffle, were generally small in scale and solely focused on salmonids. By the mid-1990's the draft restoration plan for the AFRP, a component of CVPIA, expanded this perspective and identified that restoring natural channel processes and riparian habitat values is essential to achieving this goal (U.S. Fish and Wildlife Service. 2001). Later CALFED's Ecosystem Restoration Program Plan broadened the goals to consider fishery restoration in an ecosystem context, based on scientific adaptive management (CALFED Bay Delta Program. 2000).

To compete for substantial AFRP and CALFED funding, the goal of these restoration projects was broadened from restoring the Chinook salmon runs to re-establishing fluvial geomorphic functions (under regulated flow and sediment conditions) and improving aquatic and terrestrial habitats and ecological conditions to benefit native fish, wildlife, and plants (McBain & Trush 2000; Stillwater Sciences 2002; McBain & Trush et al. 2000). Each of the three tributary restoration efforts has developed a tributary specific, habitat restoration plan to document these broader restoration goals and to establish the strategic, scientific and social framework for restoration projects on the Tuolumne River (McBain & Trush 2000), the Merced River (Stillwater Sciences 2002) and Clear Creek (McBain & Trush et al. 2000).

Each tributary restoration effort consists of several reach-scale projects, but envisions linking the projects into a chain of rehabilitated habitats as future funding, collaborations, and time will allow. While there are important differences in the approaches and context on the three tributaries, all are driven by a strong and rich coordinating conceptual model that is based on fluvial geomorphology. The design principles for each of the restoration projects are to:

- Create space for the river channel to migrate across the floodplain (usually by creating or reconstructing a floodplain, often between dikes);
- Rescale a single-thread channel to accommodate a two-to-three year flood (approximately bankfull);
- Adjust the texture of gravel on the bed so that it will favor Chinook salmon spawning and be mobile at flows near bankfull;
- Create at least a small amount of pool and off-channel habitat for juvenile anadromous fish rearing and other aquatic species; and
- Re-vegetate the floodplain with native woody species and create enough micro-topography on it to provide a diversity of drainage and soil moisture conditions for a variety of preferred aquatic and terrestrial species.

It is intended that after construction the channel-floodplain system will rapidly evolve toward a dynamic state of natural functioning that will require little-to-no engineering intervention to sustain it as productive habitat.

The Forum reports for the Tuolumne and Merced rivers and Lower Clear Creek focused on ways to improve and evaluate project success and identified opportunities to incorporate both passive and active adaptive management practices into the already-existing restoration designs (Adaptive Management Forum Scientific and Technical Panel, 2001; 2002; 2003). Prior to development of the final Forum report, restoration teams had an opportunity to clarify information from previous reports and to update the Panel on current projects being implemented on the tributaries and what the teams considered to be "adaptive management" changes that have been made to project designs and implementation in response to the Panel's recommendations.

This final Forum report does not emphasize the individual restoration projects but makes more general recommendations applicable to all three tributaries. The report is 'future-oriented' and suggests enhancements and improvements in the projects as well as encourages the broadening of funding and relaxing of institutional constraints by the funding and regulatory agencies.

The three main audiences for this report are:

- The river restoration teams (including current and future project proponents, consultants, and technical advisors);
- The Forum planning team (project staff from the AFRP and CALFED);
- The AFRP and CALFED program managers and policy-makers.

Some of the recommendations in this report are specifically directed toward one audience, but most of the recommendations will be of interest and useful to all three. Other groups that could find the recommendations in this report useful include:

- Technical staff from the AFRP, CALFED, and restoration project staff working on other Central Valley rivers and streams;

- Regional research and restoration bodies such as the Interagency Ecological Program (IEP);
- Stakeholder groups;
- Consultants who are contemplating involvement in future restoration projects;
- Scientists and other technical experts who may become engaged in future restoration evaluation in the region and beyond.

The three tributary efforts evaluated by the Forum represent an extraordinary commitment of financial and human resources to river restoration, and hold the promise of great benefits, both directly in improving habitat and salmon production, and indirectly by generating new information that can be transferred to other rivers in the region.

4. INSTITUTIONAL CONSTRAINTS

The Panel identified four main non-technical constraints that prevent the projects from implementing adaptive management in the way envisioned by the AFRP and CALFED:

- Regulatory Environment
- Funding
- Human Resources
- Communication

4.1 REGULATORY ENVIRONMENT

There are daunting regulatory constraints on the implementation of adaptive management. Permitting constraints related to threatened and endangered species, water quality (turbidity and mercury), flows and flow regimes, and floodway management and conveyance do not allow the design flexibility and speed of response required for effective adaptive management. Rigid application of regulation, or even the expectation that there will be no flexibility on the part of a regulatory agency, discourages project designers from considering the potential for novel approaches and from analyzing in a quantitative way whether relaxing regulations in particular cases carries significant risks. Examples of regulatory concerns that came up during the Forum are establishment of elderberry in constructed floodplains, the issue of mercury in dredger tailings, and the issue of spilling of water from reservoirs to satisfy flood management and conveyance regulations which impacts conduct of experiments in the channel.

AFRP, CALFED, and other regulatory agencies are aware of these constraints, but the need to negotiate regulatory exemptions or modifications for these kinds of projects should be of the highest priority for program managers. The nature and intent of these habitat restoration projects and tributary efforts are clearly different than other regulated activities and there should be enough regulatory flexibility to accommodate innovative and creative approaches to adaptive management in a manner that is consistent with the need to protect public safety and infrastructure. For example, the ability to experiment with a variety of re-vegetation strategies, rather than having species and planting densities dictated by regulatory protocols, is critical to developing new and effective site-specific restoration techniques. The cases of elderberry shrubs and longhorn beetle are relevant examples. It should also be possible to find ways of introducing organic loading and large, woody debris (LWD) into the streams without jeopardizing the safety of downstream bridges, apparently one of the primary objections of the California Reclamation Board to artificial introduction of LWD.

Recommendations

4.1.1 Restoration projects should be allowed regulatory exemptions or modifications that explicitly recognize their unique nature and intent and the need for such projects to use novel and innovative approaches to ecosystem restoration.

4.2 FUNDING

Funding of these restoration projects, particularly over the long term, is an important issue. Furthermore, funding for these projects comes from various sources with different objectives. For example, the AFRP and CALFED are two major funding sources with somewhat different objectives. The AFRP is watershed-based and is concerned with anadromous fish restoration. The CALFED Ecosystem Restoration Program has a regional focus and is concerned with restoring ecosystem function as part of a larger, balanced water management program. The Four Pumps Agreement is another important source of funding but is focused on habitat restoration for salmon as mitigation for Delta pumping facilities. Satisfying these differing goals can impose significant constraints on the individual projects and tributary efforts and may compromise long-term success (as in the unwillingness of some sources to fund baseline studies or monitoring).

Concerns about funding that were raised during the Forum fell into three areas:

- The mismatch between funding cycles and amounts and the time frame for design, implementation and testing of the restoration projects;
- The perceived difficulty in funding monitoring that was sufficient to evaluate restoration projects; and
- The perception that critical comments, or even supportive but skeptical inquiries or uncritical evaluations, by the Panel could jeopardize future funding for projects.

<u>Funding Cycles and Amounts</u>

Large-scale, ecosystem-based restoration projects have a long time horizon and the funding cycles of traditional funding sources do not match the project cycles well. The Panel understands that funding is provided for design, construction and monitoring as a single package. Although this imposes discipline on projects in terms of overall budget it may not be the most efficient way to proceed in terms of restoration. An alternative might be to approve a project in principle in its entirety but only to fund the design in a first phase of funding. The process of actually designing a project is likely to reveal aspects of construction that may not have been anticipated in the original conceptual design, and this will allow the project manager and the AFRP and CALFED the flexibility to determine the best approach and costs of the construction phase. The design phase should also clarify the necessary structure and duration of any baseline and post-construction monitoring program to ensure the restoration functions as intended and to maximize learning opportunities from the project. Monitoring might also be considered a separate fundable program of indeterminate length to be renewed annually until certain evaluation criteria are met. This tripartite approach might result in delays between design and construction or between construction and monitoring, but these could be minimized if approval of the project in principle has already been obtained.

Agencies operate on annualized budgets and most discretionary projects are of relatively short duration, usually no more than three or four years. Funding is not assured from year to year and this injects great uncertainty into these restoration projects that have a time horizon of 30 years or longer. Although individual components or phases of the projects can have shorter time frames (design and implementation of individual restoration projects, for example), the overall success of these projects needs to be judged over decades. Restoration teams are rightly concerned that project funding may be withdrawn because agencies become preoccupied by new priorities. Confirmation that long-term habitat restoration projects and tributary efforts have priority within the limits of funding agency budgets would be helpful.

Levels of funding are also sometimes poorly matched to actual costs for these projects. Shortage of funds is the universal complaint of project managers but, in the case of these long-term restoration projects, problems with funding amount are tied into the way project funding is decided. As the design, construction and evaluation budgets are set at the time a project is approved there is limited flexibility for project managers to modify budgets should greater costs or unexpected economies show up during detailed design or when cost overruns plague the construction phase. Unexpected economies are usually not a problem for the project itself but presumably the funding agencies would like to be able to recoup these savings to use on other projects. Unexpectedly higher costs can lead to protracted contract renegotiation and put the project in jeopardy. These problems can be exacerbated by the long time frame to implement some projects during which construction and monitoring costs are likely to change in ways that may not be predictable.

Finally, given the annualized budgets of the funding agencies, substantial funds are sometimes provided on short notice and must be spent in a short period. As a result, construction may have to begin before some important preliminary modeling, baseline studies, or design work is completed. The finalization of design and construction of the floodway restoration project on Lower Clear Creek, for example, had to begin before modeling of sediment transport could be completed because to delay would have meant losing a substantial portion of the funding.

Funding for Monitoring

Another major funding issue is funding for monitoring. The Panel was told that some funding sources simply would not fund monitoring. If that is the case, these agencies should reconsider their priorities. If these agencies are prepared to fund appropriate monitoring, they need to communicate this to project proponents. Even when funds came from sources that were prepared to fund monitoring, project proponents perceived that high monitoring costs might jeopardize funding for their project. The Panel is concerned that proponents and some funding sources still need to be convinced of the importance of a well-designed monitoring program.

Monitoring presents a difficult match to normal funding cycles and budgets. For most of the individual projects evaluated by the Forum, any funding for monitoring was relatively short term (about three years). Although nothing precludes project proponents from applying for additional funds to continue monitoring, the Panel was concerned that the restoration teams did not demonstrate great enthusiasm for such requests, and the projects might fail to secure monitoring funding over the long time periods necessary to evaluate the effectiveness of the individual projects and tributary scale efforts. Monitoring can appear open-ended in terms of both the amount of information to be gathered and this may be a concern for funding agencies. This concern could be addressed by ensuring that monitoring is well connected to the assumptions of the restoration design. Even so, defining what constitutes a sufficient set of information for evaluating project performance is not easy, and there is unlikely to be a general answer for all projects.

The budgeting problem for monitoring is further complicated because certain kinds of measurements only need to be made intermittently. Of particular concern was the need to adjust monitoring efforts to take advantage of hydrological or biological events that are important to the functioning of the projects. For example, overbank flows are essential to channel shaping, fish habitat structuring and floodplain regeneration. Such flows are infrequent by nature and their occurrence difficult to predict. It is quite possible that such an event would not occur during the funding cycle for one of these projects. Yet, if the geomorphological response of the channel is to be evaluated, it is critical that a broad suite of measurements be made prior to, immediately before, during, and for some months after such a flow event; and if possible with emphasis on different parts of the system at different times during the monitoring period. Thus, the routine annual measurements of a monitoring program may be relatively inexpensive and constant but, from time to time, more costly investment in measurements needs to be made. As a consequence, monitoring costs may vary dramatically and unpredictably from year to year. In addition, the funding for such monitoring needs to be immediately available to undertake such unpredictable periods of intensive investigation. Such flexibility is generally not compatible with traditional agency budget cycles and funding procedures. The time required to award a contract, for example, makes it particularly difficult to mobilize resources to study and understand unpredictable events such as high discharge, a thermal shock, or a biological surprise like an unexpected invasion of non-native species.

Finally, it is usually impossible to predict with certainty how long monitoring will have to be conducted to ensure thorough evaluation of a project. Establishing clear and quantitative milestones for project success will help and a Bayesian[1] updating of progress will give objectivity to any decision about when a milestone has been reached. Nevertheless, the time frame for monitoring, at least in its initial stages, will be highly uncertain.

Effect of the Forum Recommendations on Funding.

Some restoration team members expressed concern that even mildly critical comments of the projects, or even skeptical inquiries, resulting from the Forum might jeopardize future project funding. This was particularly a concern, it was felt, if restoration teams did not adopt all of the Panel's recommendations, even if they were not practical in the context of the project. The intent of the Forum was not to dictate to the restoration teams or funding agencies, but to offer suggestions for improvements to projects, or simply ideas to explore. The restoration teams have an obligation to take the comments of the Panel into account, because the Panel was tasked to conduct a review by the two main funding agencies of these tributary projects, but they should not feel bound to follow all recommendations. Nor should funding agencies take the Forum reports as the final word on restoration in these tributaries. By the very nature of these limited-duration reviews, the Panel's interaction with the restoration teams was brief and their knowledge of the projects and local conditions incomplete. The Panel's broad overview of the restoration projects is not a substitute for the detailed local knowledge of members of the restoration teams.

Recommendations

The following recommendations regarding funding are directed primarily at senior program managers and funding agencies. The Panel is well aware of the constraints on decision makers concerning funding cycles, budgetary oversight, and contracting. However, perhaps creative ways can be found to address some of the serious funding issues faced by these long-term habitat restoration projects.

4.2.1 Restoration teams and funding agencies could evaluate the extent to which the differing objectives of funding sources may have compromised optimal restoration designs.

4.2.2 Find a way to assure project proponents of priority for continued funding within the constraints of uncertain future budgets.

4.2.3 Funding agencies could collaborate and agree to fund whole projects in principle, but divide funding into modeling, project design, implementation, and monitoring/evaluation phases.

[1] Bayes' theorem is a formal way of adjusting the probability of a particular outcome or consequence of some action as new information is gathered (Walters 1986).

4.2.4 Consider funding projects on an hourly basis so that modifications to contracts involve only adjustments of hours not reassessments of design.

4.2.5 Explore ways to assure restoration teams that funding will be available for monitoring so that lack of funding sources is not an excuse for poor monitoring and evaluation.

4.2.6 Explore practical ways to avoid the "use it or lose it" problem with funding.

4.2.7 Look for opportunities to create more flexible approaches to funding monitoring so that financial resources will be available to the projects when and where needed.

4.2.8 Find ways to build flexibility into the contracting process to address the short-term, unpredictable needs of these restoration projects.

4.2.9 The Panel emphasizes that funding agencies should not withhold funding from a project because the restoration team has not responded to every comment or has not adopted every recommendation made in the Forum reports.

4.3 HUMAN RESOURCES

A major concern that emerged from the Forum is that the individual projects and tributary efforts are not currently staffed to design, implement, and analyze the results of monitoring programs of the scope needed to evaluate habitat restoration projects of this scale and complexity. In addition, none of the projects have the necessary staff to carry out projects of this scope using an active adaptive management, i.e. experimental, approach. Nor is there staff available to archive, assimilate, and transfer the information that is being accumulated at great public expense. The restoration teams have a legitimate interest in being able to observe whether their channel and floodplain restoration projects are effective. In addition, the restoration teams, their consultants, and many other restoration professionals in California and the rest of the nation need access to the data, information, and experience being generated by these and other similar projects being funded by the AFRP and CALFED. It is clear that additional human resources are needed to implement the ambitious, forward-looking approach of ecosystem-based adaptive management adopted and expected by the AFRP and CALFED.

Four main issues related to project staffing surfaced during the Forum:

- The need for additional, specialized staff to design, carry out, and analyze the results of monitoring programs to evaluate the overall effectiveness of the restoration projects;

- A need to infuse these and future projects with a more investigative culture than currently exists or is conceived of by the project proponents, restoration teams, or their funding agencies;
- The opportunity to implement and highlight comparative studies within and across the projects and tributary efforts; and
- The need to collect, analyze and share data and information that can be used in these and other river restoration projects.

Monitoring Overall Project Effectiveness

The design, measurement, and analytical phases of a monitoring program require specialized training that, for understandable reasons, has simply not been recruited for in the early phases of these projects. It is unrealistic to expect a project design and implementation team to take on responsibility for long-term monitoring and analysis of a restoration program of the scale and complexity of these projects at the individual or tributary level. Restoration team members involved with project performance monitoring already had many other duties, which are likely to become intense just at the critical times (floods, sediment transport events, salmon migrations and spawning, critical periods of high salmon mortality, project reporting deadlines, etc.) when intensive, perhaps round-the-clock monitoring measurements need to be made. There is a definite need to recruit staff and add resources to the restoration teams or some other body that monitors projects so that robust monitoring programs can be developed and implemented.

Infusing Projects with an Investigative Culture

If the AFRP and CALFED wish to use projects that are currently funded as sources of information to improve the efficiency and effectiveness of future restoration projects, these and future projects need to be infused with a more investigative culture than is currently the case. This distinction is not trivial. As currently designed and implemented, the projects evaluated by the Forum are unlikely to yield much knowledge that can be transferred to other reaches or rivers. All three tributary efforts evaluated by the Forum were limited in their outlook, both in terms of the scope of the projects and in communication and coordination with similar restoration projects. When the Panel pointed out opportunities for coordinated data collection or comparative studies across the projects to yield information of the very kinds needed by the restoration teams, the suggestions were acknowledged but resisted. This is understandable for on-the-ground projects that are watershed-based, developed locally, and that have traditionally used a trial-and-error approach to project design and implementation. However, the resistance wastes opportunities for learning new ways of restoring rivers and for assessing overall program progress. Furthermore, information transfer among projects requires staff time and budget that was not included in the funded project designs.

Recommendations

If an ecosystem-based adaptive management approach is to be implemented, additional staff, including some with new skills, will have to be recruited to the restoration teams or to some other body that can designate and implement experiments and monitor the effectiveness of the restoration projects and tributary efforts. These new staff can also be tasked with the analysis, synthesis and communication of these data to the project teams and other prospective users. Monitoring of long-term project effectiveness and the implementation of comparative studies needs to be given a higher status, adequately supported, and made more effective. The Panel recommends that this issue be addressed directly and urgently because it will affect the degree to which investments already made in projects sponsored by the AFRP and CALFED can be leveraged into useful knowledge for future projects and to other tributary efforts. It is inefficient to keep reinventing fragile wheels.

The following recommendations regarding human resources concern all the entities involved with these restoration projects and the Forum. The Panel acknowledges that funding resources are tight at this time; however, it hopes that creative ways can be found to address some of the staffing issues that are keeping individual and large-scale projects from generating the knowledge that the AFRP and CALFED envision.

4.3.1 Recruit specialized staff to design, implement, and analyze the results of monitoring programs to evaluate the overall effectiveness of the restoration projects.

4.3.2 Infuse these and future projects with a more investigative culture than currently exists so as to facilitate the incorporation of active experimentation into the projects and tributary efforts.

4.4 COMMUNICATION

Some Panel members perceived that within and among projects there were significant gaps in communication that endanger their success. At the individual project level, good communication is essential so that everyone involved in the design phase can work together to provide a complete, effective project. And there are numerous benefits to improved communication and data sharing among the projects; most notably that the projects could generate new information that would be transferred to other rivers in the region.

Within-Project Communication

Good communication is essential for minimizing the potential for mistakes. It forces all persons involved in the design phase of a project to collaborate to provide as complete a project as possible. Two major elements of good communication seem to be essential in these efforts: 1) a single person who is ultimately responsible for the project, and 2) a design team made up of biologists, fluvial geomorphologists, engineers, and construction managers.

In private practice, designers who place their seal on bid documents are responsible for the project. The threat of litigation ensures good communication and contracting procedures to clearly define responsibilities. In the projects reviewed by the Panel, it was evident when there was an absence of a single individual who was in obvious control of the entire project. While a team approach may be necessary, it may be difficult to determine who will be held responsible if a project fails to perform as expected, or gravels used as backfill test positive for mercury, or a re-vegetation project fails to mature and new channels are formed in an overbank event. If one designer has ultimate responsibility, that person will have to evaluate whether a project, as designed, is appropriate to achieve the goals that have been set forth and how to distribute and minimize the risk of project failure. If failures occur on the Special Run Pool projects (Tuolumne River), the Dredger Tailings Reach (Merced River), or the Lower Clear Creek Floodway Rehabilitation projects, who will pay to reconstruct the projects, the AFRP and CALFED? While this may seem like an academic question, it deserves to be thought about because the lack of a clear structure of responsibility and implementation hierarchy will make it difficult to determine who is in primary charge of the design teams and how communication is achieved.

In addition, it is important for design teams to be representative of the breadth of expertise needed and include biologists and fluvial geomorphologists, engineers, and construction managers. The scientists (biologists and geomorphologists) tend to emphasize the complexity of natural systems and recognize the difficulty inherent in understanding the linkage between the physical and biological attributes of a system. This understanding is important, but as a result, the scientists tend towards advocating a complex conceptual design. Design engineers, whether they have a clear appreciation for the complexity of the natural system or not, tend to focus on developing plans and specifications that can be constructed in an efficient and cost effective manner. They tend toward simplification because complex project designs are more costly and can be fraught with problems during construction. The contractors also may or may not have a clear appreciation for the complexity of the natural system; they are concerned mainly with minimizing project cost, producing the constructed project required by the bid documents, and reducing the potential for construction error. As a result, they tend even further toward project simplification.

If conceptual design, project design, and project construction are done in isolation by separate individuals or groups, then the original conceptual design can become diluted and simplified to the point where friction develops because the project being built is completely different than the project originally envisioned. The design team can then collectively determine how to present to a contractor teams in a clear and concise manner the conceptual designs of the project proponents and restoration. An earlier issue recognized by the Panel in reviewing these projects was a lack of continuity of influence from concept to engineering design to construction. It is equally important for the engineers and construction experts to be involved in the early stages to make sure it is practical to build the concept that is being designed. Foolproof designs are rarely attainable, but if communication channels are open and clearly demarcated early in the project, problems will generally be minimized.

Project-to-Project Communication Among Tributary Efforts

The three tributary efforts reviewed by the Panel represent an extraordinary commitment of financial and human resources to river restoration, and hold the promise of great benefits, both directly in improving habitat and salmon production, and indirectly by generating new information that can be transferred to restoration projects on other rivers in the region. The latter benefit could be greatly enhanced if the three projects actively share information and created new knowledge through collaborative experimental and comparative studies (see Section 4.3 also).

Until the Forum provided the opportunity, it appeared that relatively little communication and data exchange had taken place among the three tributary efforts, yet the similarities of the projects makes them ideal for sharing information. The restoration efforts on all three tributaries are attempting to address similar issues, e.g., the quality of spawning and rearing habitat, stranding, and predation of fall-run Chinook salmon, re-establishment of riparian habitat, etc. Clearly there are opportunities in terms of improved project management, cost savings, and more efficient construction techniques that might be realized by close coordination among the restoration teams. Given the scope and expense of many of the restoration projects, communication on project implementation alone could provide considerable benefit. Improvements in the assessment of project effectiveness could be obtained through better communication. Sharing information on the design of adaptive management experiments, the most useful attributes to measure, how to measure them efficiently, and how to analyze and interpret the data, could contribute greatly to the effectiveness of the adaptive management process on these rivers.

The Forum represented a first step in fostering improved communication among the three tributary efforts, particularly the fourth Forum meeting in March 2003. The meeting provided a good opportunity for restoration teams dealing with comparable issues to interact directly among themselves and with the Panel members. Throughout the Forum, but especially at the fourth meeting, there was a great deal of informal exchange of information among individuals. However, a more formalized structure for interaction and communication among the three restoration teams, such as regular meetings, could ensure a thorough exchange of information and data. The conduct of periodic workshops focusing on a common problem, e.g. conceptual modeling, is one approach to encouraging improved communication. Establishing processes for sharing of data among the restoration teams could be one of the most effective ways of fostering interaction. The process could be informal such as individuals comparing through email the outcomes of similar or other coordinated monitoring programs or adaptive management experiments. Other electronic methods, such as development of a bulletin board or listserv, could also be utilized for posting information, asking questions, and discussing results. A more formal mechanism for common data storage, with easy access to data by members of the restoration teams, however, would be a more certain means for cross-project data sharing.

Collecting, Analyzing, and Transferring Project Information

The Panel was concerned that there were few or no plans for accumulating data in standard formats and sharing raw data or even processed results across the projects. Aside from the CALFED Science Program's conferences and workshops and the Natural Resource Project Inventory (NRPI) coordinated by ICE (http://www.ice.ucdavis.edu/nrpi/), there are no mechanisms in place to archive, assimilate, and transfer the information and technology on river restoration that is accumulating at great public expense. More staff and funding will be required to do this but it is crucial because these projects are important investments in the creation of knowledge, not just in restoring a few reaches of three rivers.

Comparative Studies

The geomorphic restoration projects on three tributaries are all based on the same underlying restoration model. However, there are sufficient differences among them that a comparative analysis could yield insights into restoration technology. Furthermore, the opportunities for adaptive experimentation are multiplied if the projects are considered as a group rather than individually. However, none of the projects reviewed by the Forum had the staffing or funding to design a project with an experimental component, and the design and implementation of investigations across the projects is clearly beyond the scope of all the restoration teams. The Panel feels that a significant opportunity for learning about effective tributary restoration will be lost if the restoration teams and supporting agencies are unable to take advantage of the potential for experimentation within and among these projects.

Recommendations

4.4.1 Design teams should have one person in charge of the project who is clearly responsible for making final decisions. Furthermore, the AFRP and CALFED should designate a single person with the authority to make decisions for difficult construction issues such as change orders, approval of alterations of the design as a result of changed field conditions, etc.

4.4.2 Establish design teams that include all appropriate scientists and biologists, engineers, and construction personnel and have them meet together regularly from the beginning of the design process.

4.4.3 Consider ways for the project restoration teams to more regularly and effectively interact and communicate with each other, including a common process for storing project data.

4.4.4 Find the means to capitalize on the opportunity for comparative studies within and across tributary efforts.

4.4.5 Put in place the infrastructure to collect, analyze and share data and information from the individual projects and tributary efforts.

5. OVERARCHING TECHNICAL ISSUES

There were several technical issues that were common to the three tributary efforts. These ranged from conceptual modeling to the incorporation of adaptive management into project design and monitoring, to specific technical issues involving fluvial dynamics, fish, and re-vegetation.

5.1 CONCEPTUAL MODELS

It was clear from the discussion that confusion still surrounds the nature and use of conceptual models. Conceptual models can be expressed in a variety of forms. The most effective way to represent a concept depends on the purpose of the model. When communicating the general properties of a tributary ecosystem to a non-technical audience, simple pictorial or diagrammatic representations may be most effective. Such qualitative models may be less useful as a basis for decisions about project implementation or as the foundation of an adaptive management program. More explicit models representing alternative hypotheses about system function may be needed. For final decisions about specific design features, conceptual models may have to be abandoned in favor of mathematical or numerical simulation models.

The conceptual models developed for the three tributaries generally succeeded in identifying the causal linkages in the system that were the basis of restoration design. However, little attempt had been made to quantify these linkages or identify which of the linkages were of greatest importance. These models could be made more useful by specifying the nature of interactions between model components and, wherever possible, quantifying the magnitude of these interactions. Ideally, tributary-specific information on the interactions in the models would be used. However, complete information is rarely, if ever, available at the early stage of design or implementation. But in a well-designed, adaptively managed project, information is accumulated and assimilated into a continually updated model that guides the project. In the absence of local data, information can be brought in from analogous sites elsewhere. If no relevant values or conceptual models of processes are available, an estimate based on the judgment of individuals knowledgeable about the process in question can be used initially. Predictions from such a model may not be accurate but should still be useful for comparing among alternative project designs.

Assembling a model from the best technical judgments of experts is similar to the process ESSA Technologies Ltd. (ESSA) used to assemble their decision support model for Lower Clear Creek. Since the model embodies the qualitative and quantitative technical beliefs of key decision makers, it provides a powerful tool for exploring in an objective way how their decisions are likely to propagate through the ecosystem. In this application, the model allows managers to compare the consequences of alternative restoration policies and to establish testable hypotheses and adaptive management experiments for a particular watershed. Monitoring the response of the tributary to restoration projects, at both the reach and tributary scale, will provide information that can be used to improve the model.

Integration from the reach to the tributary level requires the development of model components at the reach scale, related to individual projects, nested within an overarching structure to indicate how individual projects interact to affect system attributes at the tributary scale. For example, a reach-scale model of sediment dynamics will enable the development of testable hypotheses related to expected channel responses to the application of an individual project. However, as most of the overarching objectives of the tributary restoration efforts are expressed at the level of the entire tributary, the reach-level model must be linked to a tributary-wide model of sediment dynamics in order to assess the true effectiveness of the project.

The same linkages from reach to tributary scale are applicable to the biological responses generated by the projects. For example, a tributary-scale model could be used to predict the stream reaches and the habitat factors having the greatest potential impact on survival of juvenile Chinook salmon. If stranding was identified as an important limiting factor, application of a reach-level model might suggest that project implementation would reduce stranding by some given percentage. This prediction could be tested directly by monitoring stranding before and after construction of the project. The tributary-scale significance of the project to the salmon population can then be predicted by altering the parameters in the model to reflect survival improvements from the reach-level project. These predicted responses in tributary-level population performance, like smolt outmigration or egg-smolt survival rates, could then be compared with measured changes in these parameters. If the reach-scale project did in fact bolster salmon survival, then tributary-level measures of salmon population performance would reflect this response, assuming the effect of the single project was large enough to be detectable at the tributary scale. The lack of a tributary-scale response to an individual project does not necessarily imply the project was ineffective, because a measurable response might require restoration of multiple sites or more intensive sampling to obtain more precise estimates of fish population responses. Ultimately, the success of reach-scale restoration projects will require development of monitoring criteria at both reach and tributary scales.

Recommendations

The development of conceptual models can be very useful for the identification of the most beneficial restoration projects and provide a framework for the quantitative and analytic models needed in adaptive management and monitoring. Building these models is not a trivial task and the expertise to undertake this task may not be available within each restoration team, but sharing of such expertise among restoration teams could benefit all of the projects.

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5.1.1 The conceptual models for all three tributary projects need to better address the linkages between physical and biological responses to projects and to integrate the projects from the project scale to the tributary scale.

5.1.2 All monitoring and adaptive management experiments should be explicitly linked to the models for that tributary.

5.1.3 Use the conceptual models as a framework for analytic or numerical simulations of project performance.

5.2 IMPLEMENTATION OF ADAPTIVE MANAGEMENT

None of the three tributary restoration projects evaluated by the Forum has been designed and implemented using adaptive management to the degree envisioned by the AFRP and CALFED. The projects most closely resemble passive adaptive management but lack appropriate specification of responses to manipulation and monitoring as required by adaptive management. The projects also present an important opportunity to conduct manipulative experiments to explore uncertainties in the restoration design. The Panel feels that the first priority should be to have the projects succeed as good examples of passive adaptive management by specifying, in quantitative terms where possible, the expected responses of the modified channels and incorporating proper monitoring protocols.

Monitoring is critical to the evaluation process and ensures that the results of restoration projects are consistent with the underlying model of river channel and floodplain system behavior on which the projects were based. However, the monitoring program cannot be properly designed until the ecological consequences of the restoration are expressed in terms that allow proper measurement. At present, expected behavior of the systems is specified primarily in qualitative terms and monitoring is not well designed to address the main features of the projects at the site specific or tributary scale.

An additional benefit of a well designed monitoring and evaluation plan is that it provides an objective basis for prioritizing future restoration actions and for funding requests. In the absence of rigorous monitoring and evaluation, future funding requests can only be based on vague assurances that things are going well or that particular events have been observed. Well-designed monitoring and evaluation plans, which are transparent and rigorous, provide the best arguments for future funding.

The Lower Clear Creek projects appear further along the path to passive adaptive management than the projects on either the Tuolumne or Merced rivers because the monitoring programs are better designed and developed. Even in Lower Clear Creek, however, critical expected consequences of the restoration model had not been properly specified and monitoring was not designed to quantify this behavior. A positive feature of the Lower Clear Creek project is that consultants were engaged to construct a policy evaluation model. As a result, the restoration team and stakeholders participated in a workshop to clarify conceptual models of river channel and floodplain system behavior and an overall preliminary decision support model was developed. Measurements are currently being made to develop a predictive sediment transport model for Lower Clear Creek[2].

Quantitative prediction of expected outcomes, such as the intensity of use of riffles by spawning Chinook salmon or rate of point bar formation, should be made using quantitative models where possible. Where quantitative models do not exist to predict the behavior of the projects, the designers nevertheless have certain quantitative expectations. These expectations can be used as benchmarks against which to judge the behavior of the system. This process of clarification needs to address issues at the three nested scales of integration: the tributary as a whole, the reaches within a tributary, and projects within a reach.

Given specific project objectives, a monitoring program must be developed that will permit objective evaluation of the behavior of the channel and floodplain system. The individual Forum reports contained numerous recommendations that provide a basis for the design of appropriate monitoring. In addition, the restoration teams need to plan how information about how the restoration projects performed will be fed back into decisions about future restoration actions. This is particularly important. All too frequently, if monitoring occurs at all, there is no mechanism for timely analysis of the data and no mechanism to feed the results back into future decisions.

The projects will need additional funding to accomplish retrofitting into the passive adaptive management design. Additional technical support may be needed as well.

<u>Active Experimentation</u>

Although first priority should be given to making the projects good passive adaptive management projects, numerous opportunities for active experimentation exist in these projects. In fact, experiments to explore some aspects of restoration methodology are already underway on the three rivers ranging from testing the importance of gravel conditioning to methods of floodplain re-vegetation.

Projects also provide opportunities to test theories of channel mechanics and habitat function and their application to restoration design, including such characteristics as channel width, riffle and pool size, meander radius, back channel size and alignment off-

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[2] The development of a predictive sediment transport model is an important step. However, it is a misunderstanding of the adaptive management process if this model is considered an alternative to the policy exploration model developed by ESSA. To the extent that ESSA was able to capture the conceptual models of the restoration team members and the best parameters for those models that restoration team could come up with, the model should reveal how policy decisions based on those conceptual models will propagate through the system. Sensitivity analysis will also reveal how robust the system behavior is to the various parameters. Two important insights such a model provides are: 1) how uncertainty in model parameters propagates through the system and is revealed in various aspects of system behavior, and 2) which parameters need more accurate specification if understanding of system behavior is to be improved. Both these insights are important to the design of future restoration actions and to the design of any monitoring program. If the Lower Clear Creek restoration team is not making use of this model as a tool to explore the consequences of a range of restoration decisions then the model has failed in one of its primary purposes.

channel pools, floodplain elevation, riparian community structure and other features. Such experiments could address how best to achieve the ultimate goals of the restoration (ecological function and species recovery) rather than the proximate objectives (achieving the initial design characteristics). But experimentation with restoration design is contingent upon a clear and quantitative specification of the expected relationship between design features and ecological outcomes. The specification of these relationships is weak in all the projects. For example, how are non-salmonid species expected to respond to the restoration designs that are mainly based on the needs of Chinook salmon? Are the objectives of riparian vegetation restoration to provide shade for the stream channel or habitat for particular terrestrial or avian species, to filter nutrients and contaminants so that stream water quality is maintained or all of the above? Without a clear statement of what is to be achieved, designing appropriate experiments becomes impossible. Some potential experiments to address uncertainties in both methodology and project design were described in the individual Forum reports.

One advantage of undertaking some experimentation and publicizing the value of the restoration projects as experimental platforms is that it will begin to attract interest from the academic community, which could serve as a pool of outside expertise and resources that would facilitate further experimentation. Nevertheless, a prerequisite for the accrual of benefits to the projects and to the AFRP and CALFED of active experimentation is active coordination by individuals who report to the AFRP and CALFED. In the Merced River Forum Report the Panel suggested creating a team dedicated to the investigative aspects of the projects. This still seems a practical approach to deriving experimental benefits from the projects.

Adaptive management experiments could build on what is already being done in the individual projects. Indeed, these projects provide such a diverse array of opportunities for experimentation that deciding which experiments to carry out presents a significant problem. There is no infallible set of rules for deciding among experiments; however, the following guidelines will help in deciding which experiments will be most useful:

1) Focus on those aspects of methodology or design that are most critical to the success of the restoration;
2) In the context of (1), focus on those aspects about which there is greatest uncertainty; and
3) Design the experiments so that the results will have statistical reliability.

Unless preliminary modeling has been done, it may not be obvious which aspects of the restoration satisfy guidelines 1 and 2. Modeling exercises like the CCDAM for Lower Clear Creek are a good way to help focus attention on critical aspects of methodology or design. When considering an experiment on one of the tributaries it is also useful to ask how the results of the experiment might influence what the restoration teams would actually do in restoration. If the results will have very little or no impact on methodology or design for either the current or future projects, then the experiment is probably not one on which to expend scarce resources. Guideline 3 is really a reminder that it is better to do a few experiments well than a lot of experiments poorly.

Within-project experiments might be carried out by the project restoration teams but probably not without additional resources in most instances. Additional expertise might also be needed to ensure that experimental designs are statistically appropriate. Beyond the individual tributaries, however, there is considerable opportunity for experimentation between projects, both within and among the tributaries. This prospect has already been raised in the discussion of comparative assessment among projects above. The different approaches taken to riparian vegetation establishment in the projects constitutes an incipient experiment among projects. Variation in channel gradient, flow regime, hydraulic controls, gravel composition and other features among tributaries might constitute another incipient experiment. It seems doubtful that the tributary restoration teams will be able to take advantage of these opportunities without a lot of outside help and expertise and without significant additional resources.

Active experimentation among projects is also a possibility and would provide important information on the generality of results as well as greater contrast in experimental conditions. As with monitoring, experimentation among projects might best be accomplished through the creation of an investigative team.

Project Maintenance vs. Adaptive Management

There is a difference between what might be called project maintenance or manipulation and adaptive management. During the Forum, several participants commented that, in their routine visual examination of projects, they observed channel behavior that was considered inappropriate and took actions to prevent the behavior. This was described as "adaptive management." In fact, such actions do not constitute adaptive management as adopted by the AFRP and CALFED, i.e., a formal process of information gathering, analysis, decision-making, and implementation. At best, the kind of intermittent interventions described above constitute project maintenance. At worst, however well intentioned, they represent a process of "flying by the seat of the pants" that adaptive management is intended to discourage. The analogy of adaptive management as being like a clinical trial is useful to help make the distinction.

A similar issue is how long to wait before undertaking some corrective action if the channel seems to be evolving in the "wrong" way, and in fact how it should be determined whether the system is evolving in the "wrong' way. Some concerns raised during the Forum seemed to revolve around specific features of the channel at specific places rather than an appreciation of channel form throughout a modified reach. The desire to "fix" these perceived site-specific problems implies an unwillingness to let the channel and floodplain evolve and see how the project design performs over a long enough period of time to understand if it works or not. The focus by some Forum participants on site- and time-specific issues also implies a cognitive model of fluvial systems that is not consistent with the plan to create a naturally functioning river channel and floodplain. No natural channel is "ideal" everywhere, and certain configurations in one location that seem undesirable may be contributing to conditions perceived as desirable downstream. Furthermore, if the channels are working as expected, configurations will change after every significant flow event. Nor can it be said that we really know what constitutes ideal habitat. The unexpected use of wetland habitat by juvenile Chinook salmon in Lower Clear Creek emphasizes this point.

Recommendations

A main objective of the AFRP and CALFED is that these large-scale river restoration projects should proceed and continue to incorporate an adaptive management process to yield understanding that can be used in the future and elsewhere. At present the projects most closely meet the requirements of passive adaptive management, and to adequately meet that standard, must quantify the expected outcomes of the projects and improve both monitoring and evaluation.

5.2.1 Before trying to insert active adaptive management experiments into these projects, initial emphasis should be put on making them good passive adaptive management projects.

5.2.2 As a second priority, projects could be encouraged to undertake active experimentation to reduce uncertainty in selected key aspects of restoration methodology and design.

5.2.3 All the projects might benefit from a much tighter experimental design that focuses on the dynamic expectations for the restored channels.

5.2.4 The AFRP, CALFED, and the restoration teams could consider the creation of a team of specialists to design and undertake the necessary monitoring and evaluation programs.

5.2.5 The AFRP and CALFED could consider establishing an outreach program that would work with the project proponents and restoration teams to inject the adaptive management processes into their standard operating procedures.

5.3 MONITORING

To varying degrees, the monitoring plans for the projects have not been adequately designed and implemented to evaluate the effectiveness of the restoration projects. There need to be better links between the physical and biological monitoring designs, and the projects need to be monitored across spatial scales from project to reach to tributary.

One of the fundamental requirements of an effective adaptive management program is that data needs to be collected before and after project implementation to quantitatively evaluate project success and ecosystem response. In spite of its importance to adaptive management, the design and implementation of sound monitoring programs across the projects seems to be constrained institutionally. The restoration teams have demonstrated good faith efforts to establish effective monitoring programs; however, they do not have the staffing, financial resources, or training to design and implement monitoring programs for restoration projects of this scale and complexity. In addition, the projects do not have the resources to analyze the results of a monitoring program in an ongoing, timely manner necessary to practice adaptive management. Ultimately, this will compromise the ability to scientifically evaluate the "success" of these restoration efforts.

Ideally, future restoration projects should focus on their capacity to contribute toward certain tributary-wide or basin-wide objectives, such as the restoration of healthy salmon populations. There is a need to link project-level restoration activities with tributary-scale monitoring because "success" at the project level needs to translate into measurable improvements at the scale of the whole river. The information necessary to evaluate future projects can be obtained by monitoring if steps are taken to ensure that the monitoring design is nested at multiple spatial scales, enabling integration from the project level to the whole tributary.

For example, the Merced River enjoys the advantage of efficient smolt trapping providing high quality information on smolt production for the tributary. Long-term fry and smolt trapping is also taking place on the Tuolumne River under the DFG CAMP program. The data on abundance and distribution of spawning salmon on the Tuolumne also are very good. This information can be used to form the foundation for more detailed investigations of the performance of the salmon during freshwater rearing at the scale of the tributary. Additional measurements would strengthen the ability to make inferences about localized restoration actions and help narrow the number of possible causes of success or failure. Comparisons between the tributaries would further assist with assigning causes to any apparent effects of restoration.

Given sufficient time, the spawner and smolt data alone may provide an indication of the cumulative effectiveness of all the restoration projects. If restoration efforts are successful, some improvement in the number of smolts per spawning female, accounting for density-dependent effects on survival, may be apparent after accumulation of sufficient data. Augmenting the smolt and spawner data with information on egg survival and the distribution, abundance and survival of juvenile salmon from emergence from the gravel through outmigration may provide a more rapid indication of project success and can enable salmon response to the projects at the reach scale to be linked with response at the tributary scale. Differential tagging of juvenile Chinook salmon rearing in different stream reaches and subsequent capture at the smolt trap could be used to evaluate relative survival of fish utilizing different areas of the river or different types of rearing habitat. The relative success of individual projects could be evaluated by measuring the survival rates of fry or pre-smolts rearing in areas where restoration projects have been implemented and comparing the survival and size at outmigration of these fish with these values from fish produced in un-restored reaches. Differences in survival among reaches or habitat types may provide an indication of key mortality factors operating in the river and aid in the identification of restoration efforts likely to have the greatest effect on salmon populations.

There is a need for creative thought on implementation of different monitoring approaches. For example, where a monitoring method is unsuccessful, alternative or backup methods should be employed. New ways of doing business should also be considered. Also, as mentioned in section 4.2, the funding agencies and programs need to send clear messages that monitoring is an important component of these restoration projects and that funding is available for these efforts.

Recommendations

5.3.1 Explicit ecosystem-level indicators of restoration success need to be established for each project, both at the project-scale and the tributary-scale.

5.3.2 Consider a collective approach that brings together the restoration teams and a broader group of scientists to discuss, design, and plan for implementation of monitoring plans.

5.4 FLUVIAL DYNAMICS

One of the fundamental objectives of the restoration plans for the three tributary efforts is to produce a naturally functioning river corridor that operates within an altered hydrologic regime. The expectation is that the river corridors will then proceed towards their own recovery over time. Various additional restoration actions are being used to facilitate the desired river adjustments, including: channel and floodplain reconstruction; floodplain re-vegetation; gravel augmentation; and the filling of artificial features that capture bedload. Successful incorporation of these project components requires quantitative knowledge of the hydrologic, hydraulic and sediment transport regime of the river.

A hydraulic model is an invaluable tool for assessing a wide variety of issues related to the restoration plan. Such a model allows the restoration team to quantify the variability in hydraulic conditions along the reach (i.e., flow velocities, depths, top widths), evaluate the extent of inundation in specific areas over the range of flows that are of interest, and quantify incipient motion and sediment transport along the reach. Coupled with field observations, the results allow a better integration of the information from the specific sites that have been evaluated into an understanding of the dynamics of the longer reach of river in which the restoration project must fit. This, in turn, facilitates development of a more integrated, overall Restoration Plan.

Project teams have utilized hydraulic models only to a minor degree and in a static mode for the design phases of each project. The teams used them for hydraulic computations but hardly at all for analyzing potential sediment transport and sedimentation. Since the Panel's review, however, measurement and modeling of sediment transport have continued in the Merced project. (During the same period, the flows in the Tuolumne River were specifically adjusted to allow several levels of fluvial transport to be measured to assist in refining hydraulic designs.) Consequences of hydraulics and sediment transport for channel and floodplain evolution have not been addressed, because of a prevailing belief that models could not make sufficiently precise predictions, so it was easier (and less misleading) to use a model for the initial design and then to "allow nature to take its course", based on a qualitative conceptual model of fluvial geomorphology. Given that the over-arching conceptual model on which these projects are designed is being pushed to the limit of its underlying assumptions, there is a clear need to make greater use of hydraulic models to assimilate the sparse available data and to make some predictions of probable geomorphic evolution. Tributary-scale models should be constructed in sufficient detail to allow them to identify hydraulic responses to proposed projects. Specific data needs will depend on the projects, but should include: 1) thalweg profiles; 2) cross-sections in sufficient detail and number to accurately model the river reach for design and function prediction; 3) hydraulic stage modeling for various expected discharges; and 4) characterization of the grain size distribution of the bed material and bank materials for computations of sediment transport and channel migration.

Use of predictive models, of course, is not a straightforward activity, and it requires feedback from empirical studies, both to check the accuracy of predictions and to set some model variables that cannot be predicted a priori. Thus, the monitoring studies referred to in section 5.3 are very important elements of a broad strategy for developing predictive capability about the future of these and similar restoration projects.

Recommendations

If improvement in ecosystem functioning at the tributary scale is goal of these projects, then it is important to link project designs to a tributary-scale hydraulic model.

5.4.1 Tributary-scale hydraulic models for the three tributaries, complete with a profile and representative cross-sections for various flow regimes, should be completed to: 1) determine hydraulic characteristics (depths, boundary stresses, velocities, etc.) in various reaches of the river; 2) assist in sediment transport analyses; and, 3) determine inundation frequencies for various restoration alternatives.

5.5 PROJECT DESIGN

In some places the project designers are working at the limits of conditions required for a single-thread channel. A low-sinuosity, multi-thread channel may develop, at least episodically, or a channel designed to be mobile could be come immobile unless the supply of transportable bed material is maintained. The probable effects of these constraints have not been considered in any formal way in the application of the geomorphic conceptual model to the channel design. Instead, the management strategy seems to be to accommodate uncertainties through trial and error management, i.e., making the best estimate of what will happen under the design scenario, then trying it out, and hoping to fix any unwelcome results through project maintenance.

Several important issues related to project design were discussed in the individual Forum reports, e.g., defining project objectives, prioritization of projects, the need for sediment transport models, etc. These issues relate to the three tributary efforts to one degree or another. In addition to these, two overarching project design issues surfaced during the Forum:

- Concern that other paradigms for project conceptual designs were not systematically considered and evaluated; and
- Finding a balance between simple, inexpensive project designs and more costly, complex designs.

Project Conceptual Designs

At the conceptual design level, mistakes are often made because an inappropriate paradigm is used as the basis for the project conceptual design. The Merced River Adaptive Management Forum Report (Bilby et al. 2002) highlighted the pros and cons of using reference reaches, empirical relations, and historical information as the basis for designing restoration projects. One major concern was the use of historical aerial photos as models for the restored channels. Considering that the channels were highly disturbed by placer and dredge mining prior to the 1930's when the earliest aerial photographs were taken, it is unlikely that these photos represent the natural condition of the rivers.

By using available analytical tools to evaluate the hydraulic and sediment transport conditions over the range of expected future flows in the restored reach, the designers are much more likely to arrive at an appropriate design that will respond to future flows in the expected manner, thereby increasing the odds that project objectives will be met. The projects varied in their use of an analytical approach to project design, but overall there was little evidence that state-of-the-art analyses of flow, sediment transport, and channel mechanisms were used to design either the projects or the monitoring plans.

Simple and Inexpensive vs. Complex and Expensive

In designing restoration projects of this type, a balance must be found between the ultimate complexity that is necessary to achieve proper ecosystem functioning and the simplicity that is necessary to allow the project to be constructed within the available time and budget. In more than one case, the Panel observed that budgetary constraints resulted in project designs that were overly simplified and did not include project features that might ultimately be important to the proper functioning of the restored system.

Both the floodplain and river channel designs in the Robinson Reach on the Merced River illustrate this point (Adaptive Management Forum Scientific and Technical Panel, 2002). The reasons for the design concept for the Robinson Reach are certainly understandable from a cost and constructability perspective, but the risk of project failure may increase because of uncertainty of how the channel will respond to future high flows. The argument that a simpler design is good because the channel will eventually adjust to its "desired" natural state is very attractive, but the degree to which that will actually occur depends on many factors, some of which are within the control of the project designers and some of which are not. A set of experiments could be developed to test this hypothesis by constructing different reaches to different levels of complexity, and monitoring those reaches over time to determine which point on the continuum from very simple to very complex designs provides the best chance for project success. Incorporated into this experiment would be the parallel elements of risk of project failure and cost. The results of this experiment would allows project managers to make better assessments of the trade-off between project design and cost for future restorations.

Recommendations

5.5.1 Other paradigms could be considered for the channel and floodplain reconstruction designs.

5.5.2 Adaptive management experiments could be conducted to test the way that various channel and floodplain designs will evolve to the desired level of complexity in a reasonable timeframe without jeopardizing stability of the project.

5.6 FISH

A number of technical issues related to fish populations arose in discussions about all three tributaries. These issues stem from a lack of understanding of the relative importance of various habitat features in determining their productivity and survival of the individual species. The issues include:

- The importance of the tributaries as nursery habitat for Chinook salmon;
- Food availability; and
- Tributary use by other native fish species.

<u>Nursery Habitat</u>

The importance of nursery habitat in tributaries in determining productivity of Chinook populations is a major unknown. A significant and variable population of juvenile Chinook salmon emigrated from the tributaries soon after emergence from the gravel whereas others remained in the tributaries. The relative contribution of these two components of the fry population to the numbers of returning adult fish is unknown. As a consequence, the importance of the tributaries as nursery habitat cannot be assessed.

<u>Food Availability</u>

Food supply can limit the density and growth of juvenile salmonids in streams. It seems unlikely that food limitation is a serious problem in these tributaries given that they are open to sunlight and probably receive nutrient additions from adjacent farmlands. Nonetheless, some additional work to verify that food availability is not limiting juvenile Chinook salmon productivity might be useful to ensure that this aspect of habitat is not masking tributary-level response to projects intended to increase spawning or rearing habitat. Food availability could easily be assessed using drift traps or bottom samplers.

Other Native Fish Species

Very little appears to be known about the status of non-salmonid fishes in these tributaries yet CALFED is concerned with a suite of native fish species, not just Chinook salmon. The current approach appears to be to assume that what is good for Chinook salmon is good for all the native species. This assumption may or may not be true but until better information on the life histories and habitat requirements of these species is acquired, little can be done specifically to improve their lot.

Recommendations

5.6.1 A quantitative assessment of habitat use, growth, condition and survival of Chinook fry in the tributaries could be included in the monitoring program.

5.6.2 An evaluation of food supply for fishes in the tributaries, measured either by drift or bottom sampling, could be included in the monitoring program.

5.6.3 Gaps in knowledge of the life history and habitat requirements of the native fishes in these tributaries need to be addressed.

5.7 REVEGETATION

There were two overarching re-vegetation issues that emerged from the Forum:

- The effect of the re-vegetation designs on the channel migration and shape; and
- The development of invasive weedy species and native herbs on recreated floodplains where only woody species have been planted.

River Channel Migration

A major uncertainty common to the three tributary efforts is the extent to which the reconstructed river channels will move across the re-vegetated floodplain surfaces. It is possible, especially in the absence of frequent channel forming flows, that intensively re-vegetated floodplains will resist erosion and greatly limit active channel movement. In this case, long-term human intervention will be required, and this does not conform to the goals for the restoration design.

Friedman et al. (1995) were able to promote natural seed germination and establishment from existing cottonwoods on an inactive floodplain surface by scraping the floodplain to mineral soil and then watering the exposed surfaces. Similar manipulative experiments could be implemented at the project sites on inactive floodplain surfaces.

The issue of what to plant and how much to plant is difficult to establish. Near-bank hydraulic processes are very complex. Bend radius, water velocity, depth, bed load, root density, root depth, bank texture and cohesion, bed texture and bank roughness all play a part in determining the rate of bank erosion. Geomorphic analyses indicate that all soil banks, particularly non-cohesive banks, will erode regardless of the density of vegetation that is growing along the bank. Meander scars and oxbows in well-vegetated, undisturbed, natural floodplains suggest that this movement will occur. However, the rate of movement is greatly affected by the type and density of the vegetation on the bank that is being attacked. There is no known method of predicting this, except through back-calibration of a channel shifting model conditioned on air-photo and map records. However, if the intent is that large amounts of sediment should be moved hydraulically, plantings should be at moderate density whereas high density plantings should be used if smaller amounts of sediment need to be moved. Careful consideration should be taken when electing to provide no vegetation on a bank to increase erosion. Sediment transport analysis from a volumetric standpoint should be completed to aid in determining the desired bank sediment load.

<u>Invasive Non-native Species</u>

Another major uncertainty in floodplain re-vegetation involves how invasive weedy species and native floodplain herbs develop on sites where only woody plants have been used in revegetation. On Lower Clear Creek and the Robinson Reach of the Merced River, wild grape and oaks are establishing naturally and few weedy species have been observed. This is in contrast to large numbers of weeds on the highly productive soils of the Sacramento River floodplain. The coarse substrates at the restoration sites tend to be drier and have lower nutrient levels, which may favor native species over exotics. On Lower Clear Creek there has been a need to control exotic species such as black locust, star thistle, and tree of heaven, however, tamarisk and giant reed have not been a problem. Monitoring of how the herbaceous understory develops on these projects would provide useful information in an adaptive management context, but this is not being done at all project sites. Plantings of herbs and forbs are being attempted on both the Tuolumne River and Merced River using a combination of plugs and seedlings, with and without irrigation. (The over and understory planting layout and methodology was first developed for the Tuolumne projects and then incorporated into the Merced designs. Implementation experience shows it does require at least one year of irrigation and weeding to get the plants established.) On Lower Clear Creek, blue wildrye (*Elymus glaucus*) was planted at the borrow site at the conclusion of Phase I, and though it did reasonably well initially, it had limited results and subsequently had to be removed in Phase II when it was determined that the floodplain elevation was too high to achieve the intended flood frequency. Project planners on Lower Clear Creek may recommend some winter/spring planting, starting with rhizomatous grasses in plots, and then expand from there.

Songbirds are very sensitive indicators of habitat diversity and quality and are being monitored on re-vegetated sites on Lower Clear Creek. The songbird data should provide good information on structural development and diversity of floodplain vegetation on re-vegetated sites.

Recommendations

Several experiments relating to physical site factors and planting and seeding were recommended in the individual Forum reports. Some of the experiments may be particularly relevant to one or more of the restoration projects and could be implemented. In fact, following the Merced River Forum, the re-vegetation project on the Robinson Reach was revised to reduce planting densities and to initiate manipulative experiments.

In addition, the following suggestions could be considered:

5.7.1 Monitor the extent to which the stream channel moves across re-vegetated floodplain surfaces.

5.7.2 Measure alluvial groundwater levels in conjunction with survival, growth, and structural development of floodplain vegetation.

5.7.3 Monitor the development of understory vegetation (whether planted or naturally established), especially with regard to exotic weeds versus native species.

5.7.4 Consider long-term monitoring of the bird community to provide a good indicator of the structural development and diversity of floodplain vegetation on re-vegetated sites.

5.7.5 In places where there is no active channel movement, techniques that mimic flood conditions could be used instead of manual planting to encourage establishment from natural seedfall.

5.7.6 Attention should be paid to the volume of stream sediment that the designers would like to transport and target the re-vegetation effort to this.

6. TRIBUTARY EFFORTS AND INTEGRATION AMONG THE PROJECTS

The projects being implemented in the Tuolumne and Merced Rivers and Lower Clear Creek are large, complex, and costly. Their successful implementation so far is an indication of the extraordinary capabilities of the individuals on the restoration teams. However, the teams generally include few individuals with extensive experience in complex monitoring programs or research. The lack of people with this kind of expertise may have contributed to the problems the Panel identified with respect to the tributary monitoring programs and the general absence of management experiments.

Monitoring of the collective projects on these tributaries would benefit greatly from the participation of more individuals with experience in conducting science-based field investigations. It is not reasonable to expect each restoration team to attract its own cadre of scientists to assist in monitoring and evaluation, designing experiments, and comparative assessment among the projects. However, it should be possible to pool resources from the three tributaries to establish a team of scientists to take on some of the more difficult aspects of project evaluation on all three tributaries. If such a strategy is pursued, attracting qualified scientists should not be difficult. The projects on these tributaries can be viewed as ecological experiments on a grand scale and the restoration teams do seem to have some latitude to alter project design and timing in a manner that would complement the evaluation of physical and biological responses. The nature and extent of these projects should be very attractive to scientists with interests in fisheries biology, fluvial geomorphology and river and floodplain ecology. The creation of a single group of researchers for all three tributaries would also enhance the integration of monitoring programs among the tributaries and contribute greatly to project-to-project communication (see also sections 4.3 and 4.4). For example, an team dedicated to analysis of projects from all three tributaries could compare the re-vegetation designs for the floodplains. Other aspects of the projects such as channel morphology, flow regimes, etc. also differ among the individual projects and may be worthy of careful consideration in terms of ecological response. These comparisons would not constitute planned experiments; nevertheless, considerable insight into the success of project design features would likely emerge.

<u>Comparative Assessment Among the Tributary Efforts</u>

The channel restoration projects on these tributaries are all modeled on the same general restoration design, that of a single-thread mobile channel in a floodplain that is inundated by the two-year flow. There are constraints common to the tributary efforts but also enough differences in local conditions (geology, hydrology, ecology, and initial geometry and geotechnical conditions of the restored reaches) to allow for some useful comparisons among the projects at the descriptive level. There may also be creative opportunities for deliberately designed contrasts among the restoration projects in the tributaries. For example, reduction of predation on juvenile Chinook salmon by piscivorous fishes was the objective of the SRP 9 project on the Tuolumne River, with plans to conduct additional projects with the same objective. Predation was noted as an issue on all three tributaries but the level of effort being directed towards this problem was clearly greatest on the Tuolumne. This system would offer more replication of treatments and provide a higher probability of being able to detect a tributary-level response to these treatments. Efforts to evaluate the effectiveness of methods to reduce predation might be concentrated on this system. Similarly, stranding was noted as a key concern on Lower Clear Creek and some of the channel reconfiguration projects included elements intended to address this concern. Therefore, it would make sense to concentrate evaluation efforts of experiments to reduce stranding on this tributary. As yet, no one has tried to determine how best to capitalize on the differences and similarities among the projects to develop better project designs for the future. Nor has there been any attempt to seek opportunities to modify designs to increase the contrast among the tributary scale restoration efforts.

Recommendations

Although the Forum provided a good opportunity for the restoration teams from the three tributary streams to interact, communication among the projects remains weak. The considerable benefits of sharing information and experience among the restoration teams is not being realized, which limits the opportunities for learning from the projects.

6.1 Establish a team to collaborate on monitoring, analysis, and inter-tributary comparative assessment.

7. FUTURE ADAPTIVE MANAGEMENT FORUMS

The Forum was successful in accomplishing its main objectives as defined by the AFRP and CALFED. With the assistance of the restoration teams, the Panel reviewed the conceptual models for the restoration projects at all scales, i.e., project, reach, and tributary, and they evaluated how well the multiple restoration projects were integrated. The Panel generated numerous tributary-specific recommendations on project modeling, conceptual design, implementation, and monitoring within an adaptive management framework. And finally, the Panel compared the three large-scale channel and riverine habitat restoration projects and provided recommendations on ways to address key technical uncertainties relevant to the three restoration efforts. The Forum was a good first step toward the goal of helping the AFRP and CALFED derive maximum benefit from their project funding, in terms of ecological restoration and improved restoration technology. However, there were also some bumps along the way as the Forum process unfolded.

The Forum was very successful in recruiting highly qualified and strongly interested Panel members. Having two members of the CALFED ERP Science Board on the Panel provided a strong link to the CALFED Ecosystem Restoration Program, and helped keep the Forum focused on the implementation of adaptive management. But the academic and research community and private consultants also found the idea of working with restoration teams to evaluate on-the-ground projects very enticing. The Panel members were impressed with the scale of the projects, with their potential for improving the ecological condition of tributaries, and with how much has been accomplished by the restoration teams.

Another very positive aspect of the Forum was the enthusiasm and perseverance of the restoration teams throughout this evaluation process. Core members of the restoration teams from the Tuolumne and Merced Rivers and Lower Clear Creek also committed considerable time to prepare for and attend all the Forum sessions and meetings, and review its reports. In the process they learned a lot about the projects on the other tributaries and had an opportunity to discuss their projects, with highly qualified experts. In fact, each of the restoration teams has already implemented some of the recommendations in the individual Forum reports or at least modified some of their project designs or activities.

Despite the successes, certain limitations and inefficiencies in the Forum became evident during the process. What follows are several recommendations aimed at improving any similar attempt in the future. It needs to be acknowledged from the outset that assimilation of the history, goals, and detailed characteristics of both a river and a restoration project by a review team within two days is a very imperfect process. Even after reviewing extensive and detailed technical documents for several days before each Forum, many subtle aspects of the projects were not fully comprehended by the Panel. Strategies for avoiding inaccuracies, given this limitation, include earlier delivery of technical documents, and more efficient and targeted oral presentations of project characteristics by project personnel. In the future, restoration teams need to be advised about necessary and efficient delivery of just the critical technical issues, instead of repetitious and uncoordinated descriptions of material that is already described in project documents. There was a lot of redundancy in information presented to the Panel and too little time was available for meaningful discussion and brainstorming. More advance time for document review by panel members would allow for the possibility of technical questions being submitted by Panel members prior to the Forum, which would help focus much of the discussion.

In addition, there seemed to be reluctance at times on the part of a restoration team to be candid about the uncertainties in their projects because stakeholders or regulators were attending the Forum sessions as observers. Although there may be good reasons for conducting such briefings in a public Forum, the presence of outside personnel certainly inhibited concrete discussions between the Panel and the project personnel in some instances. This may, in part, be due to the desire to design – and to present publicly - a project that will not fail, as is required in most engineering design, rather than recognizing that these projects are experimental and the designs are not fail-proof. In order to satisfy funding agencies' concerns about supporting "experiments", it may be important to better understand and define failure versus a worthwhile experiment from which much was learned even if the expected result wasn't produced.

The overall consensus of the Panel is that the Forum process yields and disseminates useful information on the status and functioning of restoration projects, as well as suggestions for their improvement. It is likely that review of projects on a two-year cycle would provide useful feedback both to individual projects and to the AFRP and CALFED on whether rivers are being restored and whether adaptive management is being usefully employed in the restoration effort.

The Tuolumne and Merced River restoration teams benefited from having at least one team member who was also a member of the Forum Planning Group. This resulted in close coordination and helped the Tuolumne and Merced restoration teams prepare for their respective Forum sessions. Unfortunately, the Lower Clear Creek restoration team did not have a member who also was on the Forum Planning Group at the time they needed to prepare for their Forum. At a minimum, the Forum Planning Group member would 1) keep the restoration team focused on the goals and objectives for the Forum; 2) help the restoration team compile a packet of Forum preparation material for the Panel; and, 3) guide the development of a tight and productive agenda for both the field tour and Forum session.

Recommendations

7.1 Assign a person from the Forum Planning Group to work directly with each restoration team to help them prepare for the Forum.

7.2 Forum sessions should include only the Panel, restoration team members and consultants, and staff from the AFRP and CALFED.

7.3 Provide an opportunity for the restoration teams to reply to the recommendations in the Forum reports before they are distributed and made public.

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