Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

Project Information

1. **Proposal Title:**

   Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

2. **Proposal applicants:**

   David Marmorek, ESSA Technologies Ltd.
   Frank Ligon, Stillwater Sciences

3. **Corresponding Contact Person:**

   David Marmorek
   ESSA Technologies Ltd.
   Suite 300, 1765 West 8th Avenue Vancouver, BC Canada V6J 5C6
   604 733.2996
   dmarmorek@essa.com

4. **Project Keywords:**

   Fishery Assessment
   Restoration Ecology
   Watershed Management

5. **Type of project:**

   Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

7. **Topic Area**:

   Channel Dynamics and Sediment Transport

8. **Type of applicant:**

   Private for profit

9. **Location - GIS coordinates:**

Latitude:

Longitude:

Datum:

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

Multi-region.

10. **Location - Ecozone:**

    4.1 Clear Creek, 13.1 Stanislaus River, 13.2 Tuolumne River, 13.3 Merced River, Code 15: Landscape

11. **Location - County:**

    Merced, Shasta, Stanislaus, Tuolumne

12. **Location - City:**

    Does your project fall within a city jurisdiction?

    No

13. **Location - Tribal Lands:**

    Does your project fall on or adjacent to tribal lands?

    No

14. **Location - Congressional District:**

    2, 4, 18

15. **Location:**

    California State Senate District Number: 6, 36

    California Assembly District Number: 2, 25, 26

16. **How many years of funding are you requesting?**

    3

17. **Requested Funds:**
    a) Are your overhead rates different depending on whether funds are state or federal?

       No

       If no, list single overhead rate and total requested funds:

Single Overhead Rate: 133

Total Requested Funds: $961,373

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

No

Have you previously received funding from CALFED for other projects not listed above?

Yes

If yes, identify project number(s), title(s) and CALFED program.

CH2M HILL delivery order #1425-98-PD-20-3041 A/043	**Scoping for Decision Analysis Framework.**	**Ecosystem Restoration Program Strategic Planning**
Mid-Pacific Regional Office of the Bureau of Reclamation, contract #00SP202122	**Flow-Related Decision Analysis Model.**	**Ecosystem Restoration Program Strategic Planning**

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

No

Have you previously received funding from CVPIA for other projects not listed above?

No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

No

Please list suggested reviewers for your proposal. (optional)

Dr. Michael Healey	**University of British Columbia**	**(604) 822-4705**	**healey@ocgy.ubc.ca**
Dr. Carl Walters	**University of British Columbia**	**(604) 822-6320**	**walters@fisheries.com**
Dr. Pete Rhoads	**Metropolitan Water District (retired)**	**(530) 642-9931**	**Prhoads@mindspring.com**
Dr. Randall Peterman	**Simon Fraser University**	**(604) 291-4683**	**Randall_Peterman@sfu.ca**

21. **Comments:**

Ive added 4 reviewers in case the first one (Healey) is unacceptable due to being on the Interim Science Board.

Environmental Compliance Checklist

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

1. **CEQA or NEPA Compliance**
   a) Will this project require compliance with CEQA?

      No

   b) Will this project require compliance with NEPA?

      No

   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

      This is a research study which uses existing and simulated data.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

   CEQA Lead Agency: None
   NEPA Lead Agency (or co-lead:) None
   NEPA Co-Lead Agency (if applicable): None

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA
   -Categorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   Xnone

   NEPA
   -Categorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   Xnone

   If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

4. **CEQA/NEPA Process**
   a) Is the CEQA/NEPA process complete?

      Not Applicable

   b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land.
Agency Name:

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.
Landowner Name:

6. **Comments.**

Land Use Checklist

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

   No

3. **Do the actions in the proposal involve physical changes in the land use?**

   No

   If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

   Research only.

4. **Comments.**

Conflict of Interest Checklist

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

Please list below the full names and organizations of all individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

David Marmorek, ESSA Technologies Ltd.
Frank Ligon, Stillwater Sciences

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

If yes, please list the name(s) and organization(s):

Frank Ligon	Stillwater Sciences
Jennifer Vick	Stillwater Sciences
Peter Baker	Stillwater Sciences
Scott Wilcox	Stillwater Sciences

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

If yes, please list the name(s) and organization(s):

Frank Ligon	**Stillwater Sciences**
Peter Baker	**Stillwater Sciences**

Michael Fainter, reviewer Stillwater Sciences

Comments:

Budget Summary

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

Independent of Fund Source

Year 1												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1.1	Preliminary survey of information & tech. Memo	90	2759	574	0	210	8504			12047.0	3682	15729.00
1.2	Project initiation meeting and follow-up	165	5933	1234	6040	453	26800			40460.0	7918	48378.00
1.3	Conduct Pilot Inventory	323	9436	1963		720	38968			51087.0	12593	63680.00
1.4	Pilot Data Analysis	345	10150	2111	3270	774	36567			52872.0	13547	66419.00
1.5	Develop Plan for Completing Inventory	225	7077	1472	3270	540	20370			32729.0	9445	42174.00
1.6	Year 1 Project Management	75	2964	616		226	9408			13214.0	3956	17170.00
		1223	38319.00	7970.00	12580.00	2923.00	140617.00	0.00	0.00	202409.00	51141.00	253550.00

Year 2													
Task No.	**Task Description**	**Direct Labor Hours**	**Salary** ***(per year)***	**Benefits** ***(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
2.1	Implement Inventory Design	285	7897	1642		602	30850			40991.0	10539	51530.00
2.2	Complete hypothesis testing database and database description.	405	10950	2277		835	28852			42914.0	14614	57528.00
2.3	Refine potential statistical methods; Tech Memo	113	3816	794	5450	291	14914			25265.0	5093	30358.00
2.4	Evaluate / develop tools to apply methods	120	3818	794		291	10453			15356.0	5096	20452.00
2.5	Apply methods to data	300	8838	1838		674	31029			42379.0	11796	54175.00
3.1	Develop simulated data sets	210	5907	1229		451	23958			31545.0	7884	39429.00
3.2	Demonstrate statistical methods using simulated data	278	8106	1686		618	27034			37444.0	10818	48262.00
3.3	Summary Report, Conference Paper and Presentation	248	7772	1616	2420	593	20991			33392.0	10372	43764.00
3.4	Year 2 Project Management	128	5291	1100		404	16747			23542.0	7061	30603.00
		2087	62395.00	12976.00	7870.00	4759.00	204828.00	0.00	0.00	292828.00	83273.00	376101.00

Year 3													
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
4.1	Meeting to review gaps, identify improvements in current projects, possible future projects; Tech. Memo	120	4238	881	6050	323	18560			30052.0	5656	35708.00
4.2	Assess potential improvements in current and future projects	248	7256	1509		554	22664			31983.0	9684	41667.00
4.3	Summary Report / Guidelines	465	14466	3009	2420	1103	65112			86110.0	19306	105416.00
5.1	Meeting to present recommendations	150	5298	1102	4840	404	23122			34766.0	7070	41836.00
5.2	Final Report, Journal Papers	450	13219	2749		1008	46502			63478.0	17642	81120.00
5.3	Year 3 Project Management	105	4444	924		339	14337			20044.0	5930	25974.00
		1538	48921.00	10174.00	13310.00	3731.00	190297.00	0.00	0.00	266433.00	65288.00	331721.00

Grand Total=961372.00

Comments.

Budget Justification

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

Direct Labor Hours. Provide estimated hours proposed for each individual.

David Marmorek 645 Clint Alexander 1,200 Ian Parnell 1,170 Calvin Peters 1,095 Christine Pinkham 735

Salary. Provide estimated rate of compensation proposed for each individual.

David Marmorek $56.32 / hour Clint Alexander $28.32 / hour Ian Parnell $28.32 / hour Calvin Peters $28.32 / hour Christine Pinkham $20.66 / hour

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

Benefits are 20.81% of salary for all employees. These benefits include employer contributions to medical plan, dental plan, disability insurance, unemployment insurance, workers compensation, vacation, sick time and statutory holidays.

Travel. Provide purpose and estimate costs for all non-local travel.

Travel costs ($33,760) are to cover 28-person trips of ESSA staff (and associated accommodation costs). These trips will be spread over 3 years, and will involve meetings of the project team with CALFED in Sacramento, meetings with subcontractors Stillwater Sciences in Berkeley, travel of ESSA staff to present findings at CALFED conferences and travel to Redding to obtain Clear Creek data.

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

Communications costs (phone, photocopying, courier) are estimated at $11,414 over the three years of the contract.

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

Stillwater Sciences staff (team and roles described in section C of proposal) will be involved in all of the tasks listed in Form VI. This effort adds up to a total of 5,336 hours, at an average rate of $84.66 per hour. Dr. Carl Schwarz (Associate Professor, Department of Mathematics and Statistics, Simon Fraser University) will provide 184 hours of statistical expertise to tasks 1.2, 1.4, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3 4.2, 4.3, and 5.2. Dr. Terrence Speed (Professor, Department of Statistics, University of California, Berkeley) will provide 176 hours of statistical expertise to these same tasks. Drs. Schwarz and Speed will both be paid at a rate of $106.67 per hour.

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

None

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, reponse to project specific questions and necessary costs directly associated with specific project oversight.

Total Project management costs (shown in Table VI) are estimated at $73,746, or 7.7% of the overall costs.

Other Direct Costs. Provide any other direct costs not already covered.

None

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

The indirect costs are computed as 133% of salary. This includes: rent, salaries and benefits for administrative, word processing and financial staff; bank interest and service charges, office costs, depreciation on office equipment including computer hardware and furniture; office insurance; rental of office equipment; furniture; staff development; temporary staff wages, stationary, and marketing costs.

Executive Summary

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

The landscape-scale of CALFEDs Ecosystem Restoration Program (ERP) presents a unique opportunity to design and treat individual restoration projects as components of larger scale, multi-watershed experiments, and thereby greatly accelerate learning. The overall goals of the proposed research project are to: 1. Assess CALFEDs current ability to conduct multi-watershed experiments by attempting to test landscape-scale restoration hypotheses against data from a strategically selected subset of current tributary restoration projects in the Sacramento and San Joaquin regions; and 2. Provide CALFED with tools and recommendations to guide the selection of future tributary restoration projects, increase the rate of learning through multi-watershed experimental design and monitoring, and optimize the cost effectiveness of restoration actions. Approach: a) Complete a pilot data inventory, reconnaissance and analysis, focusing on projects with data easily available to the project team, including Clear Creek, Merced River and Tuolumne River; b) Complete the inventory of existing projects and test restoration hypotheses of greatest interest (e.g. involving actions with high implementation cost and high scientific uncertainty, such as gravel injection, riparian re-vegetation, barrier removal); c) Use both existing and simulated data to explore the costs and benefits of increasing the power to test tributary restoration hypotheses; and d) Explore improvements in current and possible future projects, including regional reference sites. Overall hypothesis: An exploration of multi-watershed approaches can lead to significant improvements in CALFEDs tributary restoration program. Expected outcomes. Assist CALFED in: implementing multi-watershed tests of restoration hypotheses; comparing the relative effectiveness of different restoration strategies; identifying opportunities for standardizing monitoring for tributary projects; developing framework monitoring plans for particular classes of projects, helping future proposal applicants; and soliciting, selecting, or designing future restoration projects that are cost-effective, and fit with already funded projects to form a multi-watershed experiment. These outcomes meet specific goals of the ERP Draft Stage 1 Implementation Plan (Science Program pg. 14-15; Multi-regional MR-6; Sacramento SR-1 and SR-7; San Joaquin SJ-1).

Proposal

ESSA Technologies Ltd.

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

David Marmorek, ESSA Technologies Ltd.
Frank Ligon, Stillwater Sciences

Testing Restoration Hypotheses across Multiple Watersheds: Gaining Insights from Past Projects to Improve Future Learning

ESSA Technologies Ltd.[1] and Stillwater Sciences[2]

A. Project Description: Project Goals and Scope of Work

A.1 Problem

The CALFED Bay-Delta Program has provided hundreds of millions of dollars for hundreds of ecosystem restoration projects since 1996. Each of these restoration projects represents an individual experiment. However, the landscape-scale of CALFED's Ecosystem Restoration Program (ERP) presents a unique opportunity to design and treat individual restoration projects as components of larger scale, multi-watershed experiments. Individual restoration projects often involve the same types of activities (e.g., gravel injection, riparian re-vegetation, barrier removal, etc.) applied in different areas of the Bay-Delta ecosystem. However, differences in how projects are designed and applied, and differences in the variables being monitored and in monitoring protocols, can prevent comparisons of similar projects implemented in different areas of the Bay-Delta ecosystem. More thoughtful coordination and guidance of the design and monitoring of individual projects can facilitate cross-project comparisons and enable CALFED to conduct the larger-scale, multi-watershed experiments that are necessary to address critical scientific and management uncertainties.

Using a landscape-scale perspective to guide the design and monitoring of individual projects will enable CALFED to design projects (or individual restoration actions) as replicates, thereby enhancing the statistical power of data analyses. Experimental replicates will help CALFED to better discern the effects of confounding variables and natural variability on ecological trends observed from monitored data, which will be important for assessing the effects of management actions. The landscape-scale perspective of multi-watershed experiments will also allow CALFED to assess the relative effectiveness of different restoration strategies, or combinations of restoration strategies, by deliberately varying the treatments applied in different watersheds. Through multi-watershed experiments, CALFED can build treatment contrast atop spatial contrast to improve learning over a quicker timeframe.

The challenge in developing multi-watershed experiments to test landscape-level restoration hypotheses is the isolated nature of the restoration projects funded to date. Most individual projects have been designed to optimize restoration and learning within a single watershed, without the benefit of coordinating with similar restoration projects funded in other watersheds of the Bay-Delta ecosystem.

We propose to conduct a pilot investigation for a subset of restoration projects implemented, or funded and planned for implementation, on Bay-Delta tributaries. The investigation will first examine the design and monitoring of different tributary restoration projects that employ similar restoration actions, to assess the degree to which projects can be compared. This proposal focuses on a number of critical

[1] 1765 West 8th Avenue, Suite 300, Vancouver, BC Canada V6J 5C6
[2] 2532 Durant Avenue, Suite 201, Berkeley, CA 94704

questions for the tributary restoration projects within the Sacramento and San Joaquin regions (Table A1-1):

Table A1-1. General questions regarding tributary restoration projects in the Sacramento and San Joaquin regions that motivated this proposal (*Note: other tables are attached at end of document)*.

Category	Question
Quantify benefits	Can one quantify the benefits of particular classes of restoration actions across a number of existing watershed restoration projects? How long does it take to observe such benefits after actions are undertaken?
Demonstrate cause-effect relationships	Can we attribute trends in environmental indicators to watershed restoration actions? Or were they due to something else (e.g., changes in climatic conditions, other stressors)?
Determine roots of effectiveness	Are there differences in the effectiveness of restoration actions across regions, watersheds and years? Which restoration actions appear to consistently benefit particular ecosystem components? Which actions have more variable success? What combinations of actions appear to be most successful in generating intended biotic responses?
Improve experimental design / monitoring	Do projects that include similar restoration actions monitor the same variables, using compatible protocols, to facilitate cross-project comparisons? Are similar projects implemented in different watersheds designed in a manner to facilitate comparison? How can statistical power be increased?
Plan future projects	What are the priorities for selecting future restoration projects and reference sites? How can the experimental design and monitoring of current, planned, or future restoration projects be improved to facilitate cross-project comparisons?

The **overall goals** of the proposed work are to:

1. Assess CALFED's current ability to conduct multi-watershed experiments by attempting to test landscape-scale restoration hypotheses against data from a strategically selected subset of current tributary restoration projects in the Sacramento and San Joaquin regions.
2. Provide CALFED with tools and recommendations to guide the selection of future tributary restoration projects, increase the rate of learning through multi-watershed experimental design and monitoring, and optimize the cost effectiveness of restoration actions.

We have focused on looking *across* restoration projects (rather than within projects) for two reasons. First, deliberately structuring restoration projects in a multi-watershed experimental design can have enormous benefits for both decreasing the time required to demonstrate the effects of restoration actions and improving the accuracy of inferences (Stewart-Oaten et al. 1986; Walters 1988, 1989; Bowles and Leitzinger 1991; Keeley and Walters 1994; Mellina and Hinch 1995; Walters and Green 1997; Marmorek and Peters 2000). Faster and more reliable feedback from restoration actions can help CALFED to learn which actions work best (of value to both project implementors and the scientific community), to demonstrate tangible results to governments and the public, and to spend funds in a more cost-effective manner. Second, CALFED already has a technical evaluation process to assess the experimental designs and monitoring *within* each restoration project. There is no need to duplicate this effort, though we do intend to build on it by examining the CALFED tracking database information, monitoring plans and associated peer reviews for each selected project.

To accomplish the above two goals, we have developed four **objectives**:

1) Gather data to support multi-watershed assessments of tributary restoration projects;
2) Develop / apply statistical methods to these existing data to test restoration hypotheses;
3) Use both existing and simulated data to explore the costs and benefits of increasing the power to test tributary restoration hypotheses; and
4) Propose improvements in current and future tributary restoration projects, and develop tools to assist CALFED in implementing such improvements.

We expand on each of these objectives below.

1) *Gather data to support multi-watershed assessments of tributary restoration projects*

   This data assembly would include a classification of the restoration actions being undertaken, the indicators being monitored, the hierarchical spatial/temporal scales at which actions and monitoring are taking place, and potential hypothesis tests. We would begin with a subset of projects for which data acquisition should be relatively easy due to existing contacts and past work (i.e., the 'low-hanging fruit'), and build on this pilot phase to expand the inventory. While this effort would use existing data bases and information from staff in CALFED and other agencies, additional effort will be required to get the actual data. In searching for common or comparable indicators for inter-watershed comparisons, we would use the inventory to explore ways of aggregating measurements to get common metrics and spatial scales.

2) *Develop / apply statistical methods to these existing data to test restoration hypotheses.*

   We plan to work with the inventory developed under objective 1 to explore statistical approaches for testing particular restoration hypotheses at several nested spatial scales across multiple watersheds, identifying both constraints and opportunities. We would work with selected watersheds currently being restored, as well as any available data for possible 'control or reference sites' for particular restoration treatments, either within or outside the treated system (see Hughes et al. 1986 for selection criteria). The statistical methods will need to evolve from the actual data, but there is a considerable toolbox to choose from (see section A3).

3) *Use both existing and simulated data to explore the costs and benefits of increasing the power to test tributary restoration hypotheses.*

   Learning from work under objective 2, we plan to explore what improvements could be made to the suite of current projects to enhance the ability to test tributary hypotheses of interest, on a variety of spatial scales. These hypotheses are related to the questions in Table A1-1, and the conceptual model in section A2. Possible improvements could include: changes in the number of experimental units, the duration of monitoring before ad after treatments, the reliability and consistency of monitored indicators, the availability of control or reference sites for particular treatments, and adjustments in the timing of actions to decrease confounding from other factors such as changes in climatic conditions, and increase temporal contrasts. We would work with both actual historical data and simulations of a reasonable range of future responses to restoration actions.

4) *Propose improvements in current and future tributary restoration projects, and develop tools to assist CALFED in implementing such improvements.*

   In analyzing potential improvements we would consider the benefits of various approaches to increasing statistical power (outlined above), as well as their costs. Where clear net benefits are evident, we would develop tools to assist CALFED. One outcome of the proposed investigation will be an identification of opportunities for standardizing monitoring for tributary projects that use similar restoration actions. CALFED could use the recommendations for standardizing monitoring to build framework monitoring plans for particular classes of projects. The framework monitoring plans would suggest the environmental variables and sampling protocols for project proponents to consider when developing a monitoring plan for their specific project, helping future proposal applicants to design their projects to more readily address CALFED's larger-scale restoration hypotheses. Another outcome of this study would be guidance for CALFED in soliciting, selecting, or designing future restoration projects that fit with already funded projects to form a multi-watershed experiment.

The **overall hypothesis** being tested in this project is simply this:

An exploration of multi-watershed approaches to testing tributary restoration hypotheses, using both actual data from existing projects and potential data from future projects, can lead to significant improvements in CALFED's tributary restoration program.

Specific restoration hypotheses and a conceptual model are discussed in section A.2.

A.2 Justification

The CALFED ERP Draft Stage 1 Implementation Plan highlights the need for more systematic examination of already funded projects and available data, and the need for making substantial, documented improvements to the Bay-Delta ecosystem within Stage 1—the first seven years of the Program. The Strategic Plan also identifies critical scientific uncertainties that must be addressed in Stage 1 in order to facilitate important management decisions regarding water conveyance at the end of Stage 1. Many of the uncertainties identified in the Strategic Plan encompass landscape-scale issues. The individual restoration projects that the ERP generally solicits and funds are usually designed at a considerably smaller scale, so that their contribution to answering critical uncertainties is limited. Addressing landscape-scale scientific uncertainties and hypotheses will require larger-scale experiments. Designing smaller-scale, individual restoration projects as components of larger-scale, multi-watershed experiments will enable CALFED to better address scientific uncertainties and capitalize on restoration work conducted to date.

Figure A2-1 (attached) shows a simplified conceptual model of watersheds, and examples of some of the restoration hypotheses we wish to test. The biotic responses within a watershed (box 5, bottom) are a consequence of the cumulative effects of watershed inputs and fluvial geomorphic processes (boxes 1 and 2) which generate particular patterns of geomorphic attributes (box 3) and habitat structure, complexity and connectivity (box 4). In the Sacramento and San Joaquin regions, human activities have disrupted watershed inputs and fluvial geomorphic processes and attributes (top left Figure A2-1). This in turn has altered the structure and complexity of habitats, together with the direct impacts of such actions as vegetation removal. The net result is profound changes to the abundance and distribution of biota, exacerbated by the direct impacts of barriers and exotic species (bottom left of Figure A2-1).

People undertake restoration actions in the belief that they will do some good. The right side of Figure A2-1 shows examples of actions that are hypothesized to restore particular watershed components and ultimately benefit biota. We consider two different types of restoration treatments and associated *'component restoration hypotheses'*:

a) *active interventions intended to* *partially or fully restore particular geomorphic attributes or habitat structural features, ultimately benefiting biota.* An example hypothesis is: augmenting and cleaning gravel (interventions to boxes 1 and 2) will improve the quantity and quality of chinook spawning habitat (boxes 3 and 4, potentially measured by the area of spawning gravel with appropriate permeability and gravel size distribution). This in turn may be hypothesized to increase the utilization of the restored area by spawners (assuming there are enough returning adults) and improve overall egg to fry survival rates (box 5). Note that demonstrating cause-effect relationships becomes more and more difficult with an increasing number of linkages from the original action, due to other confounding factors (Bernard et al. 1993).
b) *active interventions intended to* *directly affect the abundance and distribution of biota*. An example hypothesis is that removal of a barrier to upstream and downstream salmon migration (intervention to box 5) will expand the distribution of adult spawners and their progeny, and gradually increase the abundance of both juveniles and adults.

Despite very large sums of money spent on these restoration actions, by CALFED and others, there has been no systematic assessment of their effectiveness. By collecting and analyzing data for relevant indicators across multiple watersheds, we hope to be able to test these component restoration hypotheses, or to discover what factors prevent such testing from occurring. Figure A2-2 (attached) illustrates the framework we intend to use for testing restoration hypotheses.

The *actual* post-treatment condition of an ecosystem component is a function of three things: its pre-treatment condition, the restoration actions undertaken, and the confounding natural and human disturbances which occurred concurrently with the restoration actions. The *observed* post-treatment condition and inferred benefits of the restoration action are a function of the actual post-treatment condition and the experimental design and monitoring effort put in place. Hence, failure to observe any benefit from restoration actions (i.e., unable to reject a no effect null hypothesis) could be a function of severe pre-treatment conditions, inadequate restoration actions, confounding natural or human disturbances that undermine the restoration action, or inadequate experimental design and monitoring. In the absence of monitored control or reference systems for a given treatment, positive confounding factors (e.g., good climate) could imply that an ineffective restoration action actually had some benefit. We intend to consider all of the elements in Figure A2-2 when testing hypotheses, though information for some of these elements may be only anecdotal. The project involves a pilot phase that will allow us to refine our inventory and hypothesis testing strategies.

The ERP has identified over 600 restoration actions, at a programmatic level of detail, to be implemented to restore the Bay-Delta ecosystem. Many of the proposed actions entail similar types of activities applied in different parts of the overall Bay-Delta watershed. The different types of restoration actions represent restoration strategies. For example, gravel injection, barrier removal, wetlands creation, flow manipulations, etc., are each a restoration strategy that can be applied in different Bay-Delta tributaries and areas of the estuary. The proposed project will help in evaluating the effectiveness of different restoration strategies, or combinations of restoration strategies, on different rivers.

The proposed **research and monitoring project** fits into CALFED's adaptive management process by helping CALFED and project proponents to design restoration actions prior to implementation, optimizing the learning potential of projects (Figure 1 of the Draft Stage 1 Implementation Plan). The current proposal is one of two projects initiated by ESSA Technologies to add rigor to CALFED's adaptive management process (Figure A2-3). The multi-watershed project does not prevent other pilot or implementation projects from proceeding. However, it does provide a great opportunity for devising mid-course corrections in the implementation and monitoring of existing projects, and for improving the design of future projects. The project will generate various products that help to reduce the uncertainty associated with restoration actions (e.g., standardizing monitoring approaches to facilitate multi-project analyses; development of framework monitoring plans and sampling protocols; identification of 'control' reaches and watersheds for specific treatments; assisting in identifying future projects for subsequent PSP's). In the spirit of adaptive management, this project itself involves a pilot phase to test out and refine our approach (see section A3).

A.3 Approach

We outline for each of the four objectives our general approach, followed by a point form list of specific tasks and deliverables. In general the objectives will be achieved sequentially. However, objective 1 (inventory) and objective 2 (testing hypotheses) need to co-evolve. We therefore propose to tackle these two objectives in two phases: a pilot or scoping phase and an implementation phase.

A.3.1 Pilot Data Inventory, Reconnaissance and Analysis

Recognizing the challenges of acquiring data, the pilot phase will focus on gathering data from projects familiar to the project team (i.e., Clear Creek, Tuolumne River, Merced River) and from other past restoration projects with easily available, good quality data (the 'low hanging fruit'). We will perform preliminary analyses of these data for selected hypotheses. The pilot phase will also include a reconnaissance of data availability for a broader set of projects. Based on the results of pilot data analyses and reconnaissance, we will strategically select other projects to pursue to complete the data inventory (section A.3.2).

For the reconnaissance effort, there are a variety of web sites and databases maintained by various agencies to track ecosystem restoration activities within the Bay-Delta watershed (Table A3-1). We intend to review these data sources in more detail as part of Task 1. In general, these information sources lack the data and other details needed to test restoration hypotheses and potential future experimental designs on a multi-watershed scale. To achieve the proposed project objectives, existing inventories must be enhanced to include further details on the *hypotheses* being tested, *what* was actually measured, *where* these variables were measured (both treated sites and controls, if available); *how* these variables were measured; the *frequency* of measurement; the location of the *actual data*; and how the data were / will be analyzed (e.g., the statistical evidence demonstrating a success). This additional information will allow us to identify critical information gaps, gain insights on how to enhance consistency in monitored indicators, and provide the foundation for testing restoration hypotheses and developing improved multi-watershed experimental designs (see section A.6). Developing this information base will require considerable collaboration between the ESSA / Stillwater team, project implementers and CALFED staff.

Tasks and Deliverables

1.1 Preliminary survey of information

- check potential sources of information on current projects (Table A3-1)
- **Deliverable:** Technical memo on suitability of existing databases and data sources

1.2 Project initiation meeting and follow-up

- 2-day meeting between ESSA/Stillwater team and CALFED personnel to:
  - refine objectives and scope of project, including what restoration projects to include (e.g., just major habitat restoration actions, only CALFED projects or also other projects (DWR, BoR) with easily available data)?
  - articulate ERP management and learning objectives, formalized as testable hypotheses [3]
  - define criteria for prioritizing hypothesis tests (e.g., actions with highest cost and uncertainty)
  - assign roles and interactions between Contractor team, project sponsors[4] and CALFED personnel (Contractor team's 'data-digging time' depends on CALFED staffing)
  - develop strategies for effectively acquiring data from project sponsors (see A4)
  - determine CALFED's ultimate objectives for accessibility to meta-data collected in this project (e.g., linked to existing databases, available on web, etc.)
  - develop Pilot Inventory Design (see Tables A3-2 and A3-3). Prioritize actions, hypotheses and watersheds according to ERP management and learning objectives, cost of actions, level of uncertainty and ability to test hypotheses at various scales (e.g., presence of spatial / temporal contrasts in actions, relevant indicators). Focus on cells with 'H', 'M' and '?' in Table A3-2; sample a few cells 'L' to check.
- 1-day technical meeting with CALFED database developers to understand structure of project tracking database, long-term options for database development (see section A6), availability of monitoring reports and peer reviews, data reports, contacts for priority projects
- refine Pilot Inventory Design, including: 1) sub-sample of actions, hypotheses, watersheds and reaches to be inventoried in pilot study on Clear Creek, Merced and Tuolomne; 2) other projects to be inventoried in pilot reconnaissance; 3) data forms for reconnaissance survey questions; 4) responsibility assignments (ESSA, Stillwater, CALFED).
- **Deliverables:** Pilot Inventory Design Technical Memorandum; Data Forms for Reconnaissance Survey

1.3 Conduct pilot inventory for a sub-sample of watersheds and hypotheses

- test reconnaissance survey on Clear Creek, Merced, Tuolumne; revise forms
- proceed with data acquisition for Clear Creek, Merced, Tuolumne, other 'low hanging fruit'
- implement reconnaissance of other priority projects as per Pilot Inventory Design; phone calls, emailed or faxed surveys, and if necessary site visits (track time by project, hypothesis)
- assess quality and structure of information, implications for data base structure and analysis
- weekly conference calls and project team web site to ensure strong coordination of efforts

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[3] *Example management hypothesis:* Cleaning spawning gravel will increase egg-fry survival. Example statistical hypotheses: H_o – Egg-fry survival in treated systems is equal to egg-fry survival in untreated systems. H_a – Egg-fry survival in treated systems is higher than egg-fry survival in untreated systems

[4] To ensure good relations, only one member of Contractor team should contact each Sponsor – i.e., surveyors should work down watershed columns in Table A3-1, not across action / hypothesis rows

- **Deliverable: Pilot Inventory Report -** synthesized results from data forms; revised Tables A3-2 (ability to test hypotheses) and A3-3 (indicators); estimates costs and benefits of surveying H, M, L and ? cells; key gaps in existing information; preliminary database design (don't build database yet); implications for methods of testing hypotheses

1.4 Pilot Data Analysis

- Pilot execution of tasks 2.3 to 2.5 (2-day meeting to decide on statistical methods of testing hypotheses and allocate tasks; evaluate tools, apply methods - see section A.3.2 and Table A3-4) for data in pilot inventory
- Summarize lessons learned regarding the effectiveness of component restoration hypotheses and overall restoration strategies; and problems with confounding influences, monitoring indicators, sampling, experimental designs.
- **Deliverable: Conference Paper, Presentation and CALFED Newsletter Article (#1) -** *"Testing tributary restoration hypotheses across multiple watersheds: results of a pilot study"*

1.5 Develop Plan for Completing Inventory:

- Meet to review Pilot Inventory Report and Pilot Data Analysis
- Explore options for completing inventory (various ways to meet ERP learning and management objectives, recognizing tradeoffs between # hypotheses to be tested, ability to test each one, and cost of data acquisition)
- Finalize plan and budget for completing data inventory

Deliverable: Final Plan and Budget for Completing Inventory (Technical Memo)

A.3.2 Objectives 1 and 2: Complete data inventory; develop and apply appropriate statistical methods to test restoration hypotheses

The pilot phase will provide us with the information required to complete the data inventory in the most cost effective manner for the hypotheses of greatest interest and testability. In Table A3-4 (attached), we show a toolbox of possible approaches for testing hypotheses on a multi-watershed scale, beginning with the best experimental design situation, and moving down to the least preferred. Which methods are appropriate will depend on the quality and quantity of available data, which is expected to vary with different hypotheses and projects.

Tasks and Deliverables

2.1 Implement Inventory Design

- use revised data forms; add supplementary questions for watersheds completed in pilot survey; revise summary tables of ability to test hypotheses; indicators (Tables A3-2, A3-3)
- **Deliverable: Completed Data Forms; Revised Summary Tables**

2.2 Complete Hypothesis Testing Database for Project

- finalize database design, transfer meta-data from forms to database
- link hypothesis testing database to CALFED project tracking database
- **Deliverables: Completed Database for Project; Database Description**

2.3 Refine potential methods of testing hypotheses

- analyze information in completed database to determine potential hypothesis tests, both within and among watersheds (i.e. expanded beyond those in pilot phase)

- building on pilot analysis, determine potential statistical methods for full database; review methods for applicability and relevance (Table A3-4)
- describe gaps in existing data which constrain application of better methods
- **Deliverable: Technical Memo on Statistical Methods**

2.4 Evaluate tools for implementing potential statistical approaches on complete inventory
- ideally use or modify existing tools (e.g., EXCEL, SAS, S+), or develop new tools if existing tools not suitable (less preferred)

2.5 Apply methods to data in completed inventory to test hypotheses
- Focus on hypotheses of greatest importance to CALFED, and most testable (Table A3-2)
- Summarize results; identify weaknesses; revise lessons learned in task 1.4
- **Deliverable: Updated conference paper, presentation and CALFED Newsletter Article (#2)** *"Lessons learned from testing tributary restoration hypotheses across multiple watersheds"*

A.3.3 Objective 3: Use both existing and simulated data to explore the costs and benefits of increasing the power to test tributary restoration hypotheses

In this task, we will explore what improvements to the existing, 'informal' experimental design would provide more powerful tests of restoration hypotheses (i.e., methods nearer the top of Table A3-4). An *experimental design* is the logical framework that organizes the way treatments are applied and the type of data that are collected. It is constructed to test a hypothesis, and should control for known confounding factors. Some fundamental components of multi-watershed experimental designs include:

- a nested set of *experimental units* , the basic unit to which treatments are applied, such as reaches or tributaries (see Figure A3-1, attached);
- the *treatment(s)* or action applied to each unit (e.g., adding gravel to a reach, or all the restoration activities in a watershed);
- *replication of treatments* to more than one experimental unit (e.g., testing a type of restoration action on several tributaries to gain more powerful tests of hypotheses[5]);
- *randomization* in the assignment of treatments to each unit to increase the confidence one has in extrapolating results to untreated systems; and
- *controls or reference systems*: untreated experimental units that show what would have happened to the experimental unit if it had not been treated (e.g., a reach that doesn't get gravel additions, see Figure A3-2, attached).

A specific experimental design will be some pattern and combination of treated and untreated experimental units in space and time. These spatial and/or temporal contrasts are necessary to test hypotheses. The size and uniqueness of natural systems and the presence of large-scale spatial and temporal processes make it difficult to apply these classic features of planned experimental design. However, opportunities to implement good experimental design provide many benefits: improved project coordination and consistency of data collection; more precise estimates of effects in shorter

[5] A powerful hypothesis test is one where there is a high probability of detecting an effect if it actually exists.

periods of time; more powerful tests of hypotheses and greater confidence in conclusions; greater ability to generalize results to other systems; and improved decision-making.

Tasks and Deliverables

3.1 Develop simulated data sets

- vary sample sizes, sampling frequency, measurement error
- organize example datasets to explore statistical methods identified in Task 2.3
- look for common indicators, covariation among indicators, possible replicates and controls
- simulated datasets will use available information in the database (analyzed in task 2.5) plus literature estimates of measurement error and other errors (e.g., natural variation)
- where sample sizes are limited, may bootstrap hypothetical larger sample sizes to explore methods (e.g. what if n=5 or 10 rather than 3?)

3.2 Demonstrate statistical methods using simulated data

- using tools developed in Task 2.4, apply statistical methods identified in Task 2.3 to simulated data sets developed in Task 3.1 to explore:
  - how the methods work (e.g., bias and precision in parameter estimates, detectable effect sizes, sensitivity to various sources of uncertainty (Walters et al. 1989))
  - how well data meet assumptions of different statistical methods
  - how to improve statistical power (e.g., more sampling sites, better precision of sampling methods, more frequent sampling, # years before and after treatment), while considering realistic spatial and temporal limitations of program
  - utility of various methods for addressing CALFED's learning and management objectives
- identify information gaps that constrain the application of the statistical methods, e.g.,
  - lack of controls or historical (pre-treatment) data
  - dissimilarities in the monitoring programs of similar restoration actions
  - discrepancies in how similar data are collected between projects

3.3 Summary Report

- Prepare a report summarizing results from Tasks 3.1 and 3.2, focussing on what's needed to improve statistical power and accelerate rates of learning, while maintaining CALFED management objectives
- Circulate for review prior to meeting in Task 4.1
- **Deliverables: CALFED Conference Presentation & Newsletter article:** *Increasing Learning from CALFED's Watershed Restoration Projects - Improved experimental designs, statistical methods and monitoring for testing restoration hypotheses;* **Draft Technical Report on Statistical Methods**

A.3.4 Objective 4: Explore improvements in current and possible future projects

Approach

Tasks 1, 2 and 3 will allow us to identify constraints that currently limit the rate at which CALFED can learn from current restoration projects. Understanding these constraints will allow us to identify opportunities, or experimental design alternatives, that remove or reduce the influence of these constraints. By examining a range of such alternatives, we will be able to make recommendations to

CALFED on structured ways to coordinate restoration operations within current projects and improve implementation of future projects to ensure faster, more cost-effective, rates of learning.

It is unlikely that a single design alternative will be able to address all of CALFED's learning objectives. Tradeoffs will have to be made. A range of alternative candidate designs will allow CALFED to consider additional information such as the cost of different experimental designs and the costs of making errors at the conclusion of an experiment. Formal decision analysis is a method by which these deign considerations can be combined (e.g., Walters and Green 1997). Such a process would allow CALFED to rank alternative designs based upon both expected value and statistical power. In future, such an analysis would allow CALFED to conduct a quantitative exploration of the tradeoffs associated with different alternatives.

We acknowledge that for logistical and other reasons, it may not be possible to develop an 'optimal' experimental design that reaps the full benefit of conventional statistical approaches. However, the application of consistent monitoring practices and a suite of common response variables may allow the use of various techniques (e.g., formal meta-analyses) that will vastly improve the rate of learning about the effects of restoration actions in watersheds. We therefore will focus much effort on the development of standardized methods of sampling, monitoring and experimental design.

Tasks and Deliverables

4.1 Meeting to review information gaps, identify potential improvements in current projects, and identify possible future projects

- three-day meeting with ESSA/Stillwater team, CALFED, Science Board to:
  - review summary report from Task 3.3
  - brainstorm potential improvements in *current* projects, filter based on cost / feasibility
  - brainstorm potential *future* projects and filter based on cost / feasibility
- **Deliverable: workshop technical memo**

4.2 Assess potential improvements in current and future projects, given limitations of time, # sites, money

- Use tools developed in tasks 2 and 3 to explore costs and benefits of potential changes
- Prioritize proposed improvements and future projects based learning benefits and costs
- Review past attempts at standardization of methods
- Develop guidance manual for project sponsors outlining an 'ideal' experimental design, monitoring plans and methods of data analysis, for different types of restoration actions (considering multi-watershed approaches!)

4.3 Summary Report / Guidelines to Project Sponsors

- make recommendations on improvements to current projects, including:
  - standardized monitoring procedures and indicators
  - framework monitoring plans
  - new sampling sites and reference sites / controls for specific treatments
  - recommend locations and design of future projects based on their learning benefits, ability to complement current set of projects in testing priority hypotheses
- **Deliverables for Task 4:**
  - **Draft Journal Paper 1:** *Statistical Methods for Testing Watershed Restoration Hypotheses;*

- **Draft Journal Paper 2, CALFED Conference Presentation / Newsletter Article #4:** *Improving the Design of Current and Future Watershed Restoration Projects*
- **Draft Technical Report / Guidance Manual:** easy to read translation and expansion of journal paper #2, designed for project sponsors

5. Wrap-up

5.1 Meeting to present recommendations for improvements in current and future projects

- 2-day meeting with ESSA/Stillwater team, CALFED to present recommendations, get comments and feedback, discuss next steps (e.g., how to implement future projects)
- discuss best format for products in final report to maximize impact among desired audiences

5.2 Final Papers and Report

- Final deliverables with major findings, incorporating comments from meeting in Task 5.1

Deliverables for Task 5: Final Journal Papers (2), Final Technical Report: *Improving the Design of Current and Future CALFED Watershed Restoration Projects*

A.4 Feasibility

The first major challenge in this project is acquiring the data. People are often hesitant to releasing their hard-earned numbers, even to their project funders (i.e., CALFED). They may also be concerned that the project would reveal weaknesses in their monitoring or experimental designs. We propose a set of methods to deal with these challenges:

- distribute a letter of written support from the highest levels of CALFED (e.g., Science Leader) to all targeted project sponsors, encouraging them to participate. This letter should emphasize that the project will be constructive and forward-looking, not critical of past work, and that data provided to the project team will not be published without the written consent of the data providers.
- work very closely with CALFED staff, who have been working to inventory, coordinate and standardize the monitoring of ecological components within ongoing tributary restoration projects;
- do pilot inventory and analytical work on a subset of projects for which our team already has strong local support (i.e., Clear Creek, Tuolumne River, Merced River);
- use this pilot work as a catalyst to entrain other projects' data. We have used this strategy successfully in other projects. Once a 'core' set of analyses have been completed, we believe that sponsors will be attracted by the opportunity of adding value to their data through joint comparisons with other sites, and opportunities to co-publish results.
- acquire 'low hanging fruit' from other well-documented studies, even if not completed by CALFED (e.g., DWR);
- devote considerable time to acquiring data through phone calls, use of existing contacts and site visits. Personal contact is often more successful than phone requests.

A second challenge will be that poor quality experimental designs and limited data make it difficult to test hypotheses within existing projects, even with a multi-watershed approach[6]. We have attempted to meet this challenge by selecting projects for the pilot phase that have a reasonable probability of

[6] If data quality is very poor at each site, having many sites will not increase statistical power.

yielding useful hypothesis tests, and by doing a pilot phase reconnaissance of other data sets so as to maximize the efficiency of our data hunting efforts. We firmly believe that it is necessary to make a sincere effort to test hypotheses using existing data in order to understand in depth the weaknesses of existing projects' experimental designs and monitoring. The study design anticipates these problems and has focussed objectives 3 and 4 on making improvements to both existing and future projects.

The structural organization of a project is critical to its success. We envision a Core Group from CALFED as the client for this project. The Core Group would consist of 4 to 5 people who are familiar with current and potential future watershed restoration projects in the San Joaquin and Sacramento Basins, and would include the contract manager and the manager of the project tracking database. The CALFED Core Group would attend occasional workshops. They would also provide guidance on which projects to pursue, and which not to pursue. Finally, with the blessing of the CALFED Science Board, the Core Group would also provide the initial written support to open channels for the ESSA/Stillwater team to contact sponsors of the selected projects.

A.5 Performance Measures

Table A5-1 outlines the activities, outputs, and outcomes associated with the project, as well as examples of environmental indicators that we expect to be our primary focus.

A.6 Data Handling and Storage

We intend to build on the considerable amount of effort already invested in existing databases (Table A3-1). There are several alternative approaches to enhancing existing inventories: 1. build a new relational database that is readily “linkable” to an existing CALFED database using common identifier keys; 2. add on to an existing database directly; or 3. build a new stand-alone database for the survey design information. Though we will discuss all options, we prefer option “1” for its flexibility. Other issues include how web-accessible the information should be, protocols for updating information, and ultimate spatial scale. We would develop the core database in task 1, involving 4 stages:

1) *conceptual design* based on reconnaissance information,
2) *pilot database* to support hypothesis testing for pilot inventory (end of Task 1);
3) *pre-release database* with other selected projects in Sacramento / San Joaquin region; and
4) *release database* merged with existing systems (end of Task 2).

The project team would continue to add 'exploratory layers' of information to the database in tasks 3 and 4 (e.g. simulated data to assist in evaluating multi-watershed experimental designs). This 'exploratory data base' could also be made available to interested scientists with appropriate explanations, but to avoid confusion (i.e. real vs. simulated data) it should not be linked to project tracking databases that are publicly available.

To meet the objectives of this project, the database would necessarily be more detailed than existing ERP databases on aspects of experimental designs and monitoring (compare Figure A6-1 and A6-2). This information can be organized hierarchically (Figure A6-1). For example, each action can be associated with a number of indicators that assess its benefits, and each indicator is sampled at a number of locations and times. This structure will make it easier to organize information about the restoration projects and to provide a mechanism for querying the data in different ways. For example, one could extract all actions related to barrier removal, all projects with measurements of particular indicators during 1998-2000, or all control sites being used for particular classes of restoration actions. This approach will provide a mechanism to easily alter assumptions when exploring alternative multi-watershed experimental designs in tasks 3 and 4 (Table A6-1). The database would also help to highlight gaps in existing information.

A.7 Expected Products/Outcomes

Please see Table A5-1 (attached) and Deliverables in Section A3.

A.8 Work Schedule

Table A8-1 shows the annual time line with start and completion dates of each task, as well as other key milestones (i.e. decision meetings, presentations at conferences). The tasks in Table A8-1 match those in the budget. The tasks form a logical sequence. If the project cannot be funded in its entirety, then it would make more sense to scale back tasks 1 and 2 (i.e. complete a smaller inventory). However, we anticipate that substantial legwork will be required to acquire and analyze data, which is why these tasks consume so much of the budget. The payment schedule would logically follow the tasks and deliverables outlined in section A3 (i.e. payment upon completion of a task and receipt of deliverables). Project management is shown as a separate budget item on web form VI.

B. Applicability to CALFED ERP and Science Program Goals and Implementation Plan and CVPIA Priorities

B.1 ERP, Science Program and CVPIA Priorities

Table B1-1 provides excerpts of the ERP Draft Stage 1 Implementation Plan and 2002 Proposal Solicitation Package that are directly relevant to the focus and methods outlined in this proposal. These excerpts demonstrate that this proposal meets several explicit CALFED priorities for the Science Program, the Multi-Regional program, and the Sacramento and San Joaquin regions. These identified priorities will be greatly assisted by the proposed project's efforts to take advantage of existing data and conduct multi-watershed tests of restoration hypotheses. Other CALFED priorities will benefit from this project's efforts to find common response indicators and performance measures, and to develop improved approaches to monitoring, sampling and experimental design. In task 1, we will scope the project more specifically to target those restoration actions with the greatest cost and current uncertainty, thereby ensuring the maximum benefit to CALFED. We anticipate that gravel augmentation and barrier removal will be two high priority actions.

B.2 Relationship to Other Ecosystem Restoration Projects

This project builds on all many past tributary restoration projects completed by CALFED in the Sacramento - San Joaquin regions, as well as other similar work funded by DWR and other agencies. The pilot phase will build specifically on past projects completed in Clear Creek (see Clear Creek Phase 3 PSP proposal for fy2002), the Merced River (see section B4 of this proposal), and the Tuolumne River (over a decade of work by Stillwater Sciences). We will use existing databases, monitoring reports, peer reviews, informed knowledge of the Project Team, and discussions with CALFED to strategically select a subset of other tributary restoration projects for the pilot phase reconnaissance, which will in turn allow for further scoping down of the most relevant past restoration projects. As explained in section A2 and Figure A2-3, this project relates thematically to ESSA's Clear Creek Decision Analysis Model (both past work and PSP proposal for fy2002). The Clear Creek project will also help to better articulate restoration hypotheses and narrow the range of those worth testing.

Finally, this multi-watershed project can help set the direction for improvements to both current and future tributary restoration projects in the Sacramento and San Joaquin regions, including the selection *of reference sites for particular actions.* The Stage 1 Implementation Plan notes that many streams need to "improve the scientific basis for flow-related actions" (pg. 59 and 74). These streams include the Yuba and Bear Rivers, Butte, Big Chico, Deer, Mill, Antelope, Battle, Cottonwood and Clear Creek in the Sacramento Region, and the San Joaquin, Stanislaus, Merced and Toulumne Rivers in the San Joaquin Region.

B.3 Requests for Next-Phase Funding

This is a new project, and therefore this section does not apply.

B.4 Previous Recipients of CALFED Program or CVPIA Funding

ESSA Technologies Ltd.: CALFED: *Scoping for Decision Analysis Framework.* Funded through CH2M HILL via delivery order #1425-98-PD-20-3041 A/043, Ecosystem Strategic Plan, Task 14c.; *Flow-Related Decision Analysis Model.* Funded through the Mid-Pacific Regional Office of the Bureau of Reclamation, contract #00SP202122.

Stillwater Sciences: CALFED: *Merced River Corridor Restoration Plan Phase II*, project # 98E-09; *Merced River Corridor Restoration Project-Phase III: Plan Development and Conceptual Designs*, project; *A Mechanistic Approach to Riparian Restoration in the San Joaquin Basin*, project # 99-B152. CVPIA: *Merced River: Raslaff Project*, CVPIA 11332-9-MO79; *Stanislaus River: 2 Mile Bar*, CVPIA 11332-9-MO80; *Stanislaus River: Smolt Survival*, CVPIA 11332-0-MO09

B.5 System-Wide Ecosystem Benefits

This project will have several synergistic, system-wide ecosystem benefits, which are summarized in the Outcomes row of Table A5-1. In summary, there are five significant benefits:

- a database that will provide a long term foundation for testing restoration hypotheses;
- tests of restoration hypotheses (i.e. evidence of the effectiveness of past restoration efforts);
- an analysis of how restoration effectiveness varies with different restoration actions and environmental settings (see Figure A2-2);
- concrete guidance on how to improve the experimental design, monitoring and data analysis of existing projects; and
- how to design a better set of future restoration projects and reference sites, using multi-watershed experimental designs.

B.6 Additional Information for Proposals Containing Land Acquisition

Not applicable.

Qualifications

The proposed organization of the project is illustrated in Figure C1. The relevant past experience and proposed roles of each project team member are explained below. The distribution of tasks among the ESSA-Stillwater team would be determined during the inventory phase of the project, as the set of key questions and testable hypotheses become better defined. Specific combinations of actions and performance measures (e.g., approaches to gravel cleaning and methods of assessing gravel quality) would be parceled off as distinct tasks for the development of multi-watershed approaches, within an integrative, hierarchical framework. The project team has no conflicts of interest, and is able to do the proposed work within the indicated time line.

ESSA Technologies, founded in 1979, is a 25-person firm which applies its expertise in ecological sciences, quantitative methods, and workshop facilitation to tackle both the technical and human dimensions of ecosystem problems. Key staff members are described below:

Mr. David Marmorek is Director of ESSA's North America operations, and will manage this project. His twenty-five years of experience includes facilitation of over 100 workshops, and development of models, monitoring designs, adaptive management approaches, and ecological risk assessments for a diverse range of resource management problems. He brings considerable experience to this project, including retrospective analyses and adaptive management / monitoring designs for the restoration of both large river ecosystems (e.g. Columbia and San Joaquin) and smaller watersheds (e.g. Clear Creek CA and Cheakamus River BC). He recently reviewed of B.C.'s Watershed Restoration Program. Mr. Marmorek has considerable experience in managing large, interdisciplinary teams working on complex projects, including leading a 5-year, multi-agency program regarding endangered chinook salmon stocks in the Columbia River. He has a Bachelor of Environmental Studies and Mathematics from the University of Waterloo, an M.Sc. in Zoology from UBC, and over 30 peer-reviewed publications.

Mr. Clint Alexander offers leading edge expertise in multiple-objective risk analysis and management for resource management problems. Mr. Alexander is a skilled Visual Basic and structured query language (SQL) programmer with over 5 years of active experience. His computer skills extend to relational database design, primarily Access, SQL Server, ADO, and ODBC technologies. Mr. Alexander has applied this expertise as principal architect and developer on several recent projects including: the Clear Creek Decision Analysis and Adaptive Management model (CCDAM) for CALFED and the Keenleyside Decision Analysis and Adaptive Management model (KDAM) for BC Hydro. Mr. Alexander holds a B.Sc. in Ecology from the University of British Columbia and a Masters in Resource Management (MRM) from Simon Fraser University.

Mr. Calvin Peters is a systems ecologist who specializes in applying decision analysis and other quantitative and analytical tools to the evaluation of environmental policy and practices. In this project he will focus on testing restoration hypotheses related to fish populations. He recently developed the fisheries submodel for the Clear Creek Decision Analysis Model, a comprehensive bio-physical model for assessing the effects alternative flow policies on Clear Creek (California) on downstream chinook and steelhead populations. Other relevant experience includes development of models and decision analysis frameworks to evaluate recovery actions for endangered salmon stocks in the Columbia Basin and the effects of Columbia River flows on Mountain Whitefish populations. Mr. Peters has an inter-disciplinary background in computer systems, financial management, and ecology, and a Masters degree in Resource and Environmental Management from Simon Fraser University.

Mr. Ian Parnell will contribute significantly to the hypothesis testing and experimental design themes of this project. He is skilled in conceptual modeling to support hypothesis tests, simulation modeling, data analysis, and the development of quantitative tools to support decision-making. Mr. Parnell has applied his skills to the statistical evaluation of water quality monitoring programs, the analysis of statistical relationships between fish production and indicators of freshwater habitat quality, and the use of statistical power and decision analysis to select the "optimal" design of large-scale watershed restoration experiments. He recently played leading roles in the development of decision support systems for managing Chinook salmon stocks in the Pacific Northwest, and fish habitat response models in the Cheakamus River near Vancouver. Mr. Parnell holds a B.Sc. in biology and is currently completing a Master of Resource Management degree at Simon Fraser University (completion, fall 2001).

Ms. Christine Pinkham is an Application Specialist who will assist with the acquisition of data and database work. Ms. Pinkham specialises in conducting research, technical writing (including online documentation), data manipulation and analysis, customisation of data (spatial and non-spatial), database design and model testing. Ms. Pinkham has over five years experience in the areas of forestry and aquatic sciences, adaptive management, environmental impact assessment and environmental information systems. She holds a B.Sc. in Environmental Protection from the University of Guelph and a Post-Graduate Diploma in Environmental Science from Capilano College.

Dr. Carl Schwarz is an Associate Professor in the Department of Mathematics and Statistics at Simon Fraser University. In this project he would serve to provide advice and review on statistical methods. His research program is in three areas: capture-recapture modeling of animal population dynamics; statistical consulting; and linear and generalized linear models. His interest in statistical consulting is motivated by real problems encountered by ecologists, and involves assistance in experimental design and analysis in complex experimental situations where the "standard textbook" results are not appropriate. Relevant research projects include: the development of capture-recapture methodology to estimate population parameters of temporally stratified populations, with applications to salmon escapement and smolt counts, and the development of statistical methodology to study the effects of restrictions on randomization upon analysis of variance models.

Stillwater Sciences is a 30-person firm of biological and geological scientists that focuses on developing the highest quality scientific understanding of interdisciplinary issues in watershed analysis and river restoration. Key Stillwater staff members are described below:

Mr. Frank Ligon is an aquatic ecologist and geomorphologist specializing in the role of fluvial processes and morphology in the ecology of stream fish, invertebrates, and plant communities. He would serve in this project as both a domain expert directing technical analyses and a project manager of Stillwater's team. His experience in the Central Valley includes designing, managing, and implementing a 10-year investigation of chinook salmon population dynamics in the Tuolumne River. This investigation formed the foundation of a Settlement Agreement among irrigation districts, resource agencies, and environmental groups that identified flow requirements and restoration and management strategies to restore the river's chinook salmon population to sustainable levels.

Mr. Scott Wilcox is a project manager and fisheries biologist with over 20 years of experience in California water resource investigations that emphasize assessment of physical habitat and biological impacts in riverine systems. In this project he will manage the data acquisition process, and contribute to the development of consistent monitoring and sampling protocols. His experience includes extensive work in habitat assessments for various fish species, including trout, all runs of chinook salmon, and native fish assemblages. Mr. Wilcox developed and managed a prototype tracking system for the CALFED ERP to assist the evaluation of monitoring plans for CALFED-funded restoration projects.

Ms. Jennifer Vick has extensive experience in geomorphic and ecological analysis and restoration planning throughout the Central Valley. She has conducted hydrologic, geomorphic and ecological analyses on the Merced, Tuolumne, and Stanislaus rivers that are being used to design and assess restoration programs. She is currently leading a project to develop a scientifically based restoration program for the lower 52 miles of the Merced river. On the Tuolumne River, she has worked with the Tuolumne River Technical Advisory Committee and McBain and Trush to develop and implement a rigorous monitoring program to test the effects of restoration projects on fish populations and habitat structure. Her breadth of experience in both restoration design and monitoring, as well as her familiarity with restoration efforts throughout the Central Valley, give her a unique ability to synthesize and evaluate potential adaptive management and experimental design opportunities within the CALFED program. She will be involved in the technical aspects of hypothesis testing, analysis of alternative experimental designs and project improvements.

Dr. Peter Baker has more than 10 years of experience in applying mathematics and statistics to environmental sciences. He is the principal quantitative analyst for Stillwater Sciences, and has contributed to the design and analysis of most of Stillwater's fieldwork in the San Joaquin tributaries. Dr. Baker has developed or assisted in the development of numerous simulation models for salmonid populations, representing a broad range of modeling methodologies. He has been responsible for maintenance and continued development of the EACH model for San Joaquin chinook salmon populations since 1989. He is the co-developer of Stillwater Sciences' BasinTemp water temperature model. In this project Dr. Baker will be involved in a variety of statistical analysis tasks.

Mr. Christian Braudrick is a fluvial geomorphologist with a Master's Degree in geology from Oregon State University. He has assessed channel morphology, sediment transport, and hydrology of fluvial systems in California, Oregon, Washington, and Utah. Mr. Braudrick has also managed projects on dam removal on Clear Creek, CA and stream restoration for the Chelan River, WA. On Clear Creek he helped develop and implement a monitoring plan to assess numerical modeling of sediment transport following the removal of Saeltzer Dam. In this project he will work on testing restoration hypotheses related to changes in channel form and habitat structure, and in devising more consistent methods of monitoring.

Dr. Terrence Speed is a Professor and former chair in the Department of Statistics at the Univ. of California, Berkeley. His work involves statistical design and analysis of environmental data. He has published over 100 papers, including papers on the influence of temperature on the survival of chinook salmon smolts and modeling and managing a salmon population, which were based on work conducted in the Tuolumne River. Dr. Speed has contributed his expertise to a wide range of applied statistics problems, ranging from interpretation of DNA fingerprinting to models of fisheries population dynamics.

Ms. Lauren Dusek is a fisheries and wildlife biologist who conducts ecological research on fisheries, aquatic invertebrates, and small mammals, with particular experience in fisheries field techniques and research project design. Ms. Dusek is currently the lead Field Technician for a 5-year fisheries monitoring program of the Napa River, for which she organizes field sampling efforts and data collection and management. Ms. Dusek will assist with data acquisition and data base work. for this project.

Mr. Anthony Falzone is a geomorphologist with a Master's Degree in environmental planning from the Univ. of California, Berkeley. He has several years experience in conducting stream channel field surveys, salmonid spawning gravel assessments, hydrologic and geomorphic data analysis, assessment of historical channel changes, and GIS analysis. In this project, Mr. Falzone will assist with data acquisition and data base work.

D. Cost

D.1 Budget

ESSA Technologies Ltd. would be the contracting entity for this project, and Stillwater Sciences Ltd. would operate through a subcontract from ESSA. Budget information is included in web forms VI and VII. We have carefully budgeted all tasks in this project based on our current understanding. However, we do not yet know the quantity and quality of data that we are likely to encounter in the inventory phase of this project (tasks 1 and 2). It is our intent to thoroughly 'mine and refine' these data, but only as far as is necessary to draw useful lessons from past projects. Data limitations may mean that it is unproductive to do as much data analysis as we had budgeted. The time allocated to tasks 1 and 2 is therefore the maximum that we would propose to use. Should less time be required due to data limitations, the saved time could be re-allocated to tasks 3, 4 and 5, as these limitations will imply greater emphasis on looking forward and making improvements.

D.2 Cost-Sharing

There are no cost-sharing arrangements for the work outlined in this proposal.

E. Local Involvement

This project's pilot phase will build upon good working relationships developed with local groups in the Clear Creek, Merced and Tuolumne watersheds. In developing the Clear Creek Decision Analysis Model (CCDAM), ESSA Technologies' staff have met with representatives of the Western Shasta Resource Conservation District (WSCRD) and the Clear Creek Restoration Team on five occasions: Jan 9th 2000, Jan. 24-26th 2000, April 2000, May 2001, July 2001). These meetings have helped to build good working relationships. Stillwater Sciences has had extensive interaction with local stakeholders through the Tuolumne River Technical Advisory Commission (TRTAC), including the Turlock Irrigation District, the Modesto Irrigation District, the Tuolumne River Preservation Trust, and Friends of the Tuolumne. In the Merced River, Ms. Jennifer Vick of Stillwater Sciences has worked closely with state and local agencies, the Merced Irrigation District and local landowners as part of the Merced River Corridor Restoration Plan.

The project's deliverables include four CALFED conference presentations and newsletter articles, which will be designed to reach a wide audience. In addition we will produce two journal articles and a guidance manual outlining recommendations for standardized monitoring and sampling procedures, and multi-watershed experimental designs. It is through these methods that we intend to reach out and pass on the lessons learned to project sponsors, program managers, managers, and scientists.

Compliance with Standard Terms and Conditions

We have attached some recommended changes to the standard State and Federal contract terms described in Attachments D and E (Attachment 1). These changes formalize procedures for dealing with changes in scope. They are consistent with the general intent of Attachments D and E.

G. Literature Cited

Bowles, E. and E. Leitzinger 1991. Salmon supplementation studies in Idaho rivers (Idaho Supplementation Studies). Experimental Design, Idaho Department of Fish and Game.

Bernard, D.P., D.B. Hunsaker Jr., and D.R. Marmorek. 1993. Tools for improving predictive capabilities of environmental impact assessments: structured hypotheses, audits, and monitoring. In: The Scientific Challenges of NEPA: future directions based on 20 years of experience. (Eds: S. Hildebrand and J.B. Cannon). Lewis Publishers. Ann Arbor. pp. 547-564.

Hughes, R.M., D.P. Larsen, J.M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management 10(5): 629-635.

Keeley, E. R. and C. J. Walters. 1994 The British Columbia watershed restoration program: summary of the experimental design, monitoring, and restoration techniques workshop. Vancouver, BC, British Columbia Ministry of Environment, Lands and Parks, and Ministry of Forests.

Marmorek, D.R. and Peters, C.N. In press. Finding a PATH Towards Scientific Collaboration: Insights from the Columbia River Basin. Cons. Ecol. 5 (2):xx-xx (to appear Nov-Dec, 2001)

Marmorek, D.R., C.N. Peters, I. Parnell, and C.A.D. Alexander (eds.) 1999. PATH: Scoping of candidate research, monitoring and experimental management actions: concurrently reducing key uncertainties and recovering stocks. Working draft prepared by ESSA Technologies Ltd., Vancouver, BC. 232 pp.

Mellina, E. and S.G. Hinch. 1995. Overview of large-scale ecological experimental designs and recommendations for the British Columbia Watershed Restoration Program. BC Ministry of Environment, Lands and Parks, and Ministry of Forests. Watershed Restoration Project Report No. 1: 31 pp.

Schwarz, C.J. 1998. Studies of uncontrolled events. *In* Statistical Methods for Adaptive Management Studies. Sit, V. and B. Taylor (*eds*.). Res. Br., BC Min. For., Victoria, BC. Land Manage. Handb. No. 42. pp. 19-39.

Stewart-Oaten, A., W. M. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: "Pseudoreplication" in time? 67(4): 929-940.

Walters, C.J. and R. Green. 1997. Valuation of experimental management options for ecological systems. *J. Wildlife Management.* **61**(4): 987-1006

Walters, C.J., J S. Collie, et al. 1988. Experimental designs for estimating transient responses to management disturbances. Canadian Journal of Fisheries and Aquatic Sciences 45: 530-538.

Walters, C.J., J.S. Collie, et al. 1989. Experimental designs for estimating transient responses to habitat alteration: is it practical to control for environmental interactions? Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. C.D. Levings, L.B. Holtby and M.A. Henderson. Can. Spec. Publ. Fish. Aquat. Sci.105.

Figures, Tables and Attachments on following pages

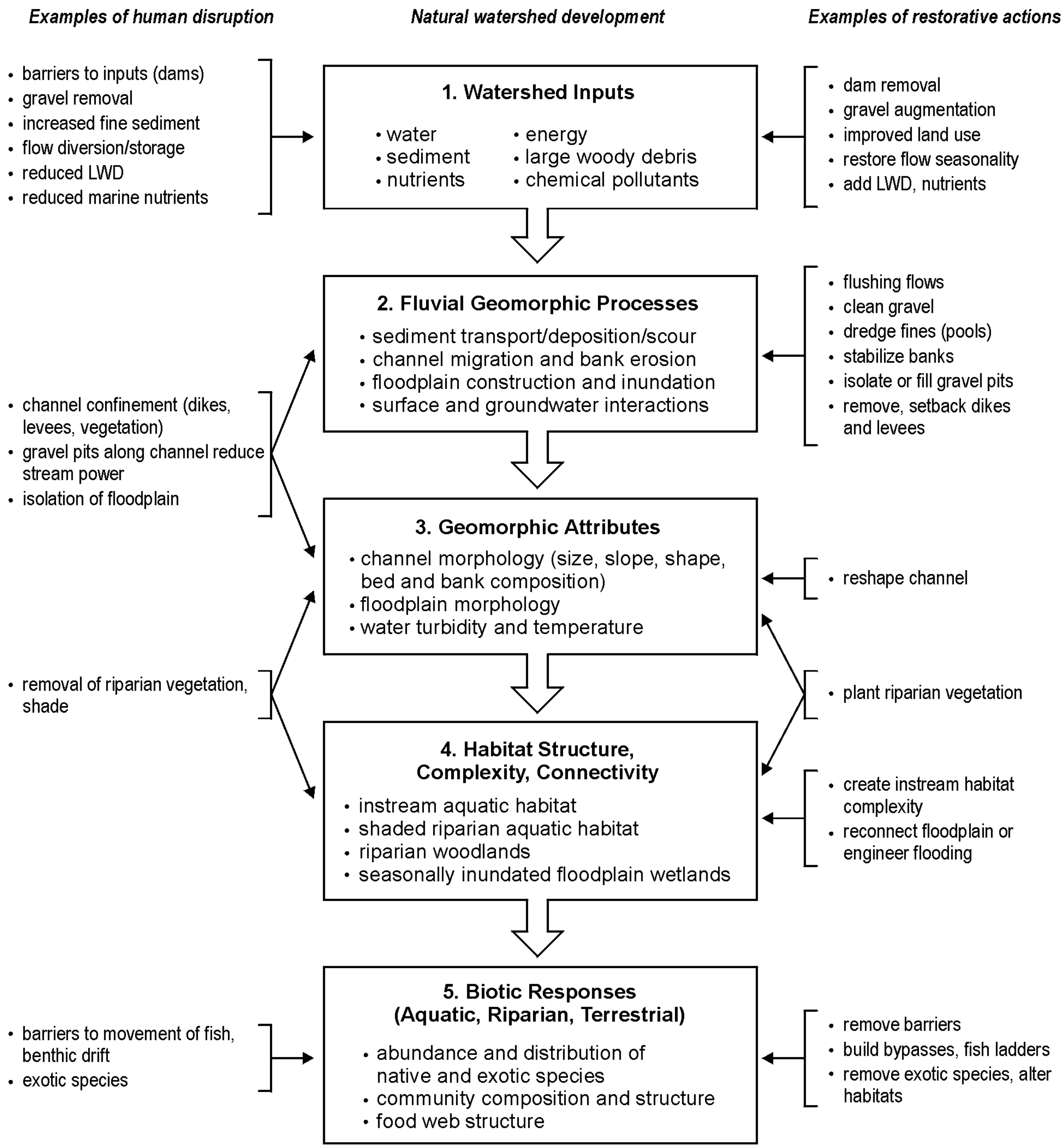

Figure A2-1. Conceptual model showing examples of human disruptions to natural watershed development, and example actions that are hypothesized to restore some of the lost habitat structure and biotic responses.

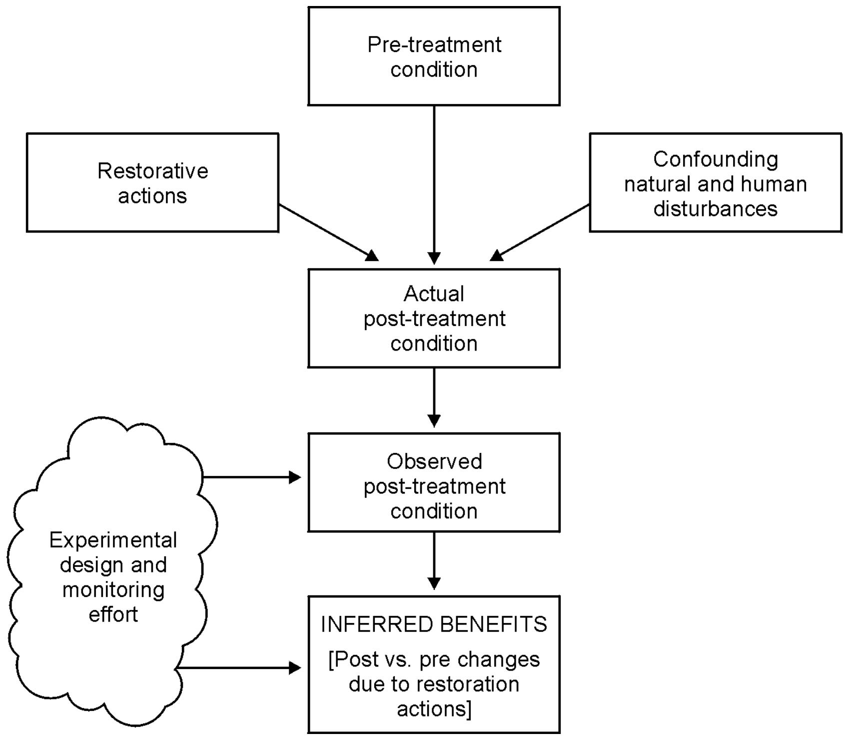

Figure A2-2. Framework for testing restoration hypotheses.

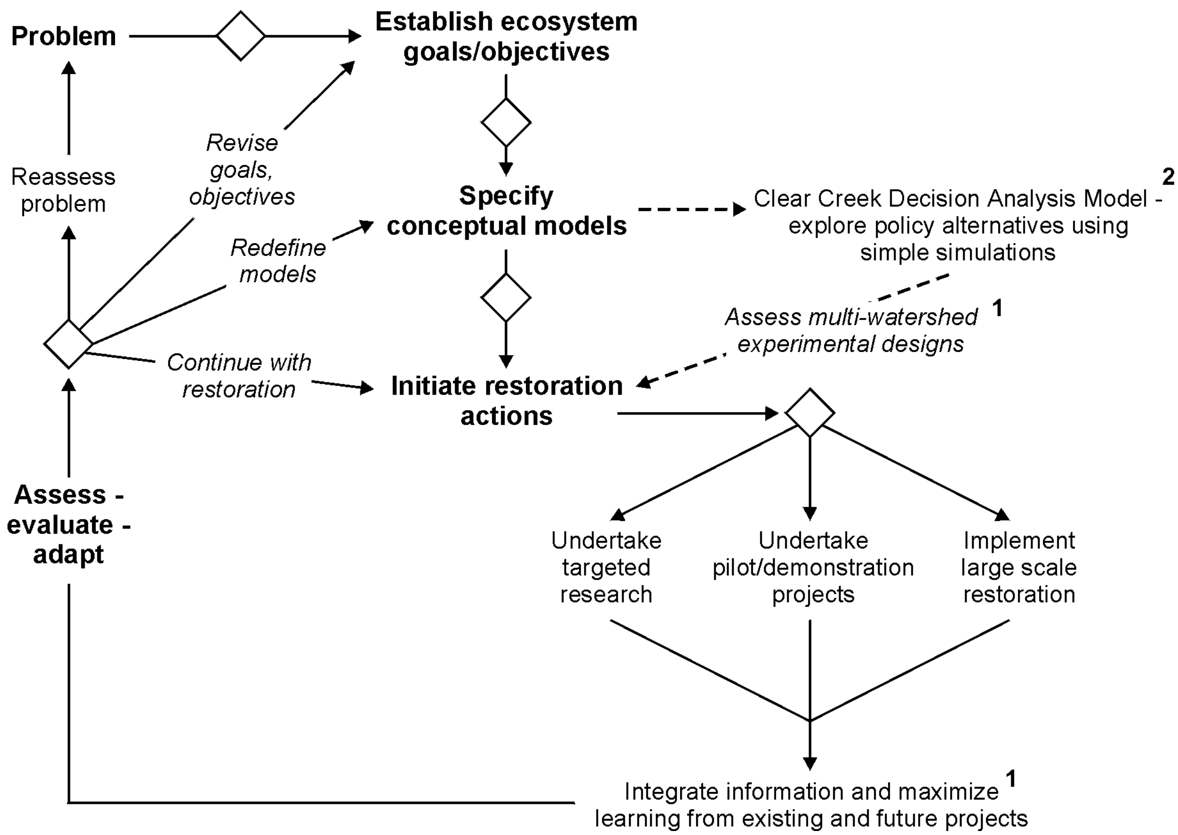

Figure A2-3. Position of proposed project (#1) in the CALFED Adaptive Management process. A complimentary project is ESSA's Clear Creek Decision Analysis Model (#2).

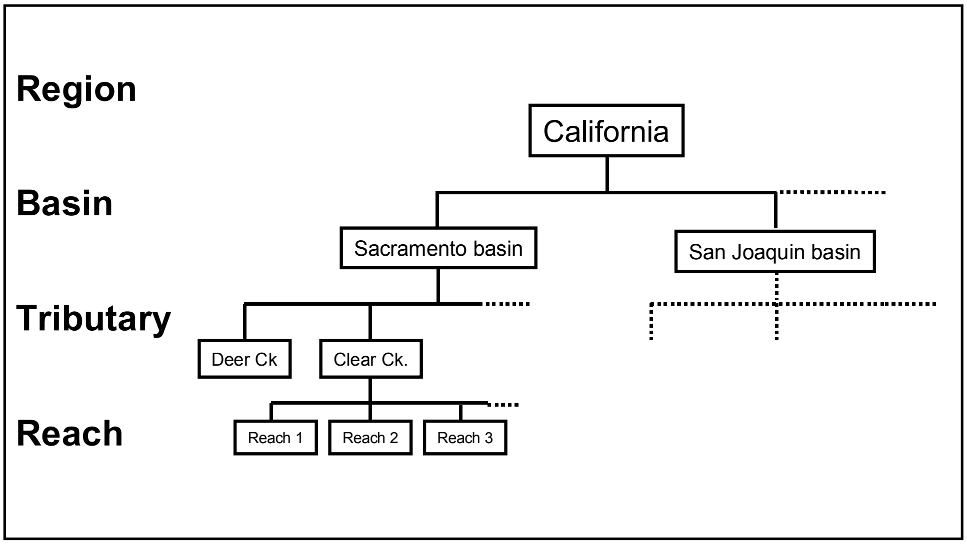

Figure A3-1: An example of a nested hierarchy of experimental units at different spatial scales in the context of a multiple-watershed experimental design. Reaches are nested within tributaries, tributaries within basins, and basins within larger regions.

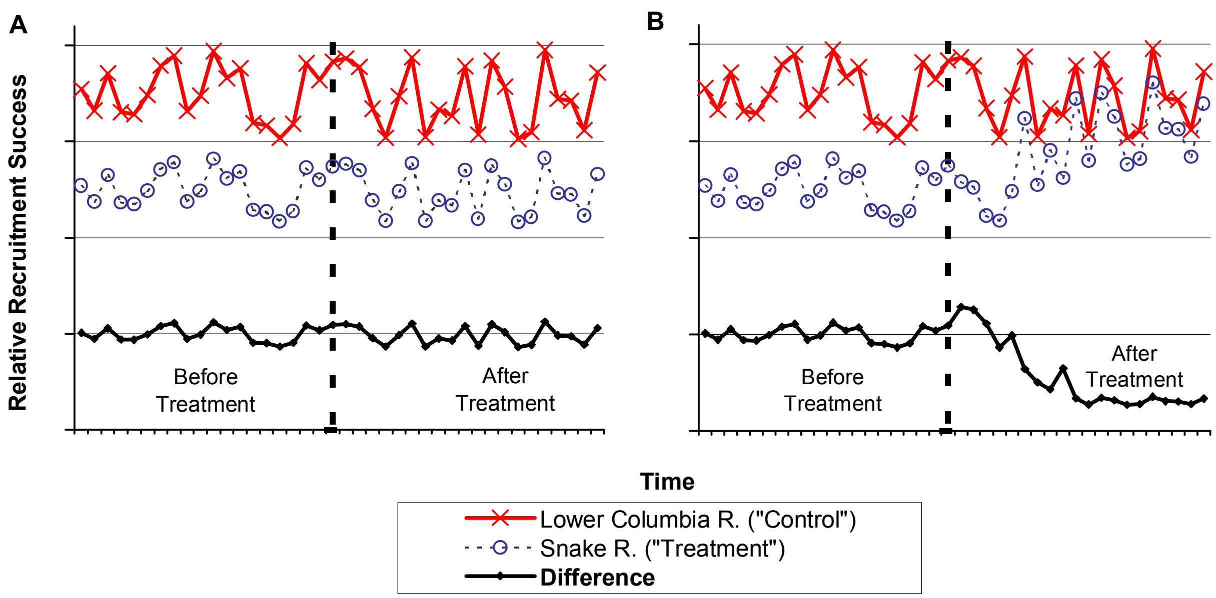

Figure A3-2. The BACI-P design. The change in a measured variable from multiple random sampling (before and after the impact) in both control and impact sites. Panels A and B represent two alternative outcomes of the same experiment. Prior to the treatment, recruitment success in the unit to be treated (Snake River) is lower than in the control (Lower Columbia River). In panel A, there is no benefit from the treatment. In panel B, the treatment has a beneficial impact, and the mean level of the difference in recruitment decreases over time. With watershed restoration experiments, one hopes to see an improvement after treatment, *relative to controls.* Adapted from Marmorek et al. (1999) and Schwarz (1998).

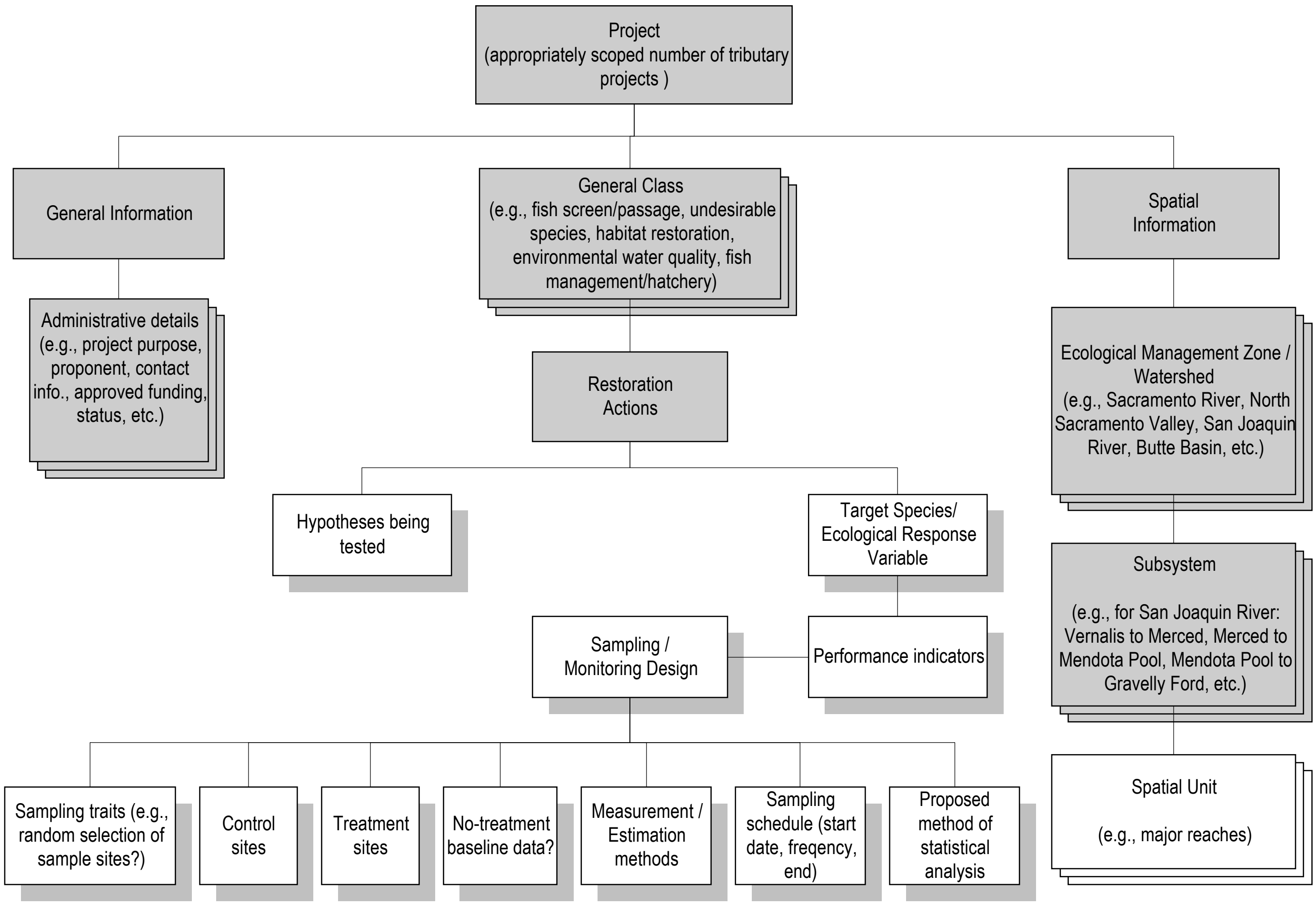

Figure A6-1: Major dimensions and components of the proposed meta-database of Bay-Delta watershed ecosystem restoration projects (ERP). Shaded boxes are typically tracked by existing databases (e.g. Figure A6-2). Unshaded boxes are not readily available. Restoration actions of interest will need to be categorized to provide treatment contrasts.

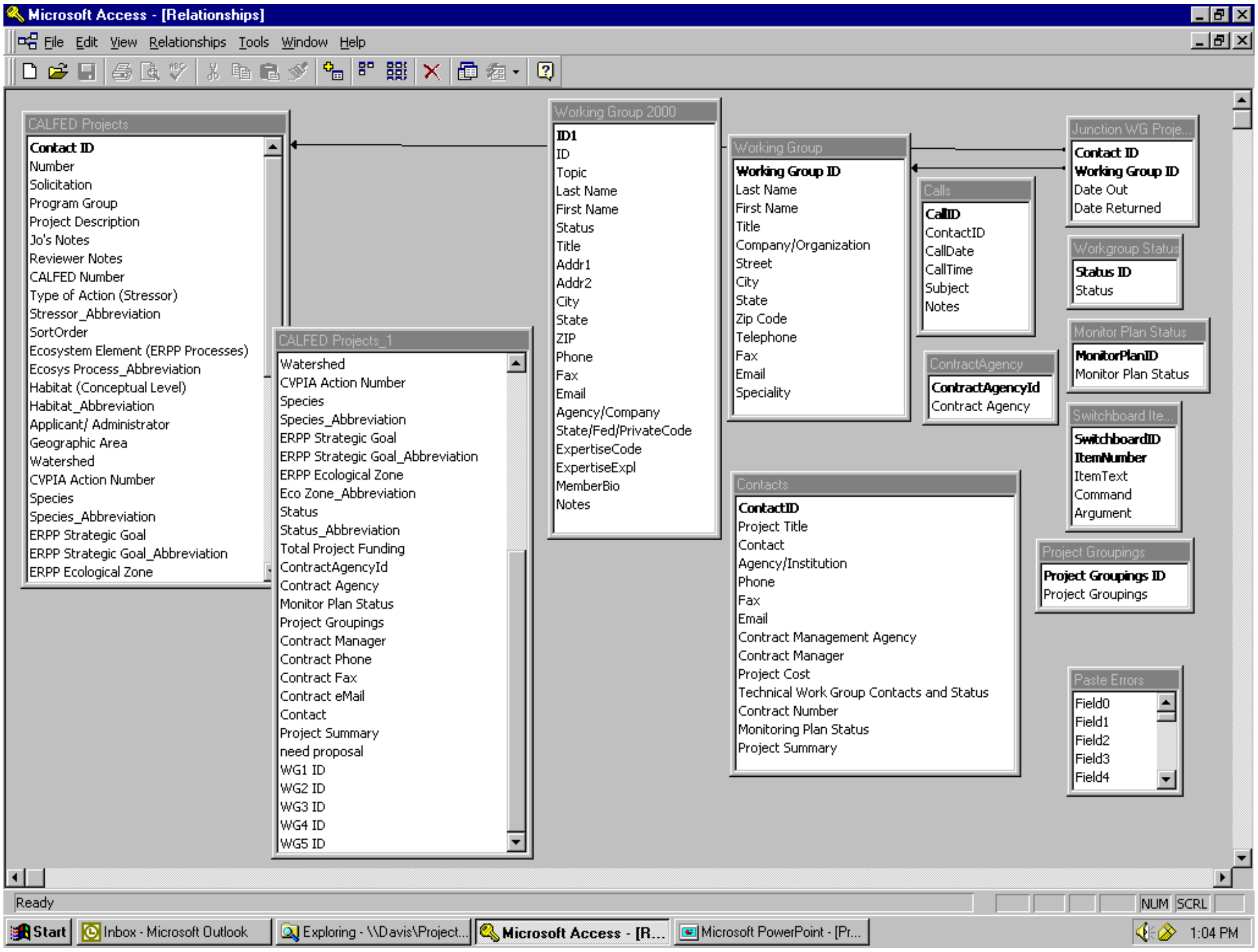

Figure A6-2. General structure of CALFED project tracking database (from preliminary database design). Current structure of this database could be linked to meta-database developed in this project (e.g. Figure A6-1) through various keys.

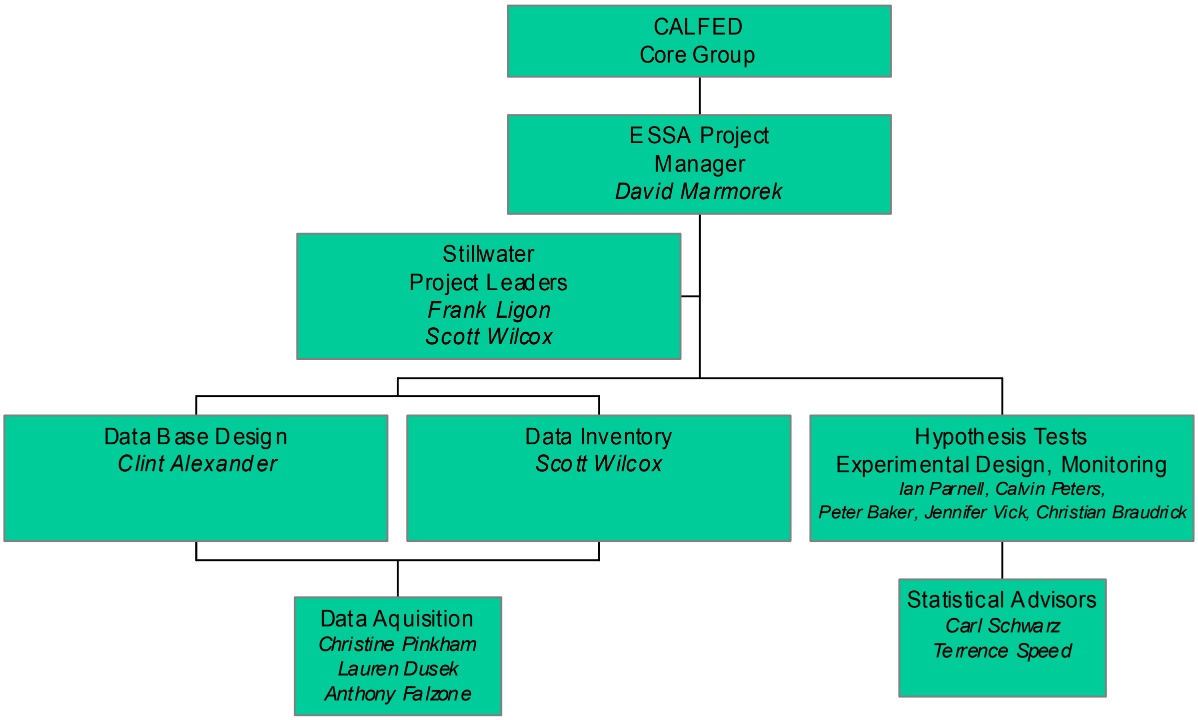

Figure C.1: Project management structure.

Table A3-1. Examples of existing information sources on restoration projects (to be reviewed under objective 1).

Source	**Location / Content**
CALFED project tracking database	Internal to CALFED, maintained by Marti Kie and Dorena Hardin. General structure shown in Figure A6-1. Linked to monitoring plans and peer reviews.
CALFED project status reports	http://www.calfed.ca.gov/programs/ecosystem restoration : narrative project descriptions, plans, budgets
TERA	*Tracking Ecosystem Restoration Activities* http://www.tera.mp.usbr.gov narrative descriptions, financial status, physical location
CERPI	*California Ecological Restoration Projects Inventory* http://endeavor.des.ucdavis.edu/cerpi : Like TERA, plus performance standards and monitoring schedules
CAMP	*Comprehensive Assessment and Monitoring Program* http://www2.delta.dfg.ca.gov/camp: Salmon population abundance, intended to assess cumulative and relative effectiveness of restoration actions on anadromous salmonid production

Table A3-2: Conceptual framework for prioritization of effort among hypotheses and watersheds. Cells would initially be filled with a H, M, L, - or ? to indicate high, medium, low, non-existent or unknown potential for testing hypotheses, taking into account information available on both actions implemented, and monitored performance measures (Table A3-3). This table would be discussed at the initiation meeting, revised during the scoping phase, and then further revised during Phase 2 Implementation. Information shown is very preliminary, based on authors' familiarity with the Clear Creek, Tuolumne and Merced rivers. Other tributaries would be added based on pilot reconnaissance survey.

Hypotheses Regarding Restoration Actions	**Clear Creek**					**Tuolumne**			**Merced**		
	Reaches					***Reaches***			***Reaches***		
	C1	**C2**	**C3**	**C4**	**C5**	**T_1-T_3,T_6**	**T_4-T_5**	**T_7**	**M_1**	**M_2**	**M_3-M_5**
Gravel: augmentation	M[1]	-	M[1]	-	M			H	M		
cleaning	-	-	-	-	-			H			
ripping	-	-	-	-	-			H			
LWD additions	-	-	-	-	-						
Riparian vegetation	-	-	-	-	?	M	M	M	M/H	M	M
Barrier removal	M[2]	M[2]	M[2]	M[2]	-						
Predator control	-	-	-	-	-	M	H	M			
Flow manipulation	H[3]	H[3]	H[3]	H[3]	H[3]			M			
Channel restoration	n.a.	n.a.	n.a.	n.a.	M?[4]		H	M		H	
Other…											

<u>Notes on Clear Creek:</u>

1. Gravel added to reaches C1 and C3 not accessible by salmonids until recently due to Saeltzer Dam.
2. Saeltzer Dam (top of reach C5) only removed in fall 2000, and flows kept low in 2001 to avoid hybridization between fall and spring chinook.
3. Flow manipulations include summer low flows only (1998, 1999) but provide clear tests of temperature-flow hypotheses down all reaches.
4. Extensive restoration of channel ongoing in reach C5 – may not have enough post-treatment data yet.

Table A3-3. Conceptual framework for organizing information on indicators to test specific hypotheses concerning restoration actions (Table A3-2). Rows would list types of information, and cell contents give an indication of quality and quantity of this information for specific watersheds and/or reaches. Examples: S = spatial contrasts; T = temporal contrasts; H, M, L for subjective measure of data quality, with a pointer to meta-data sheets / data base with more detailed information (i.e., method used, locations, sampling frequency, contact person, etc.). Information shown is very preliminary, based on authors' familiarity with the Clear Creek, Tuolumne and Merced rivers. More detailed scrutiny of available data will occur once the proposed analysis begins.

Indicators Currently Available {examples only shown below}	Clear Creek					Toulumne			Merced		
	Reaches					*Reaches*			*Reaches*		
	C_1	C_2	C_3	C_4	C_5	T_1	T_2	T_3	M_1	M_2	M_3
Gravel: *grain size distn., gravel quality, permeability*											
LWD: *maps of habitat types, juvenile fish distribution*											
Riparian Vegetation: *abundance, distribution*											
Barriers: *juvenile fish distribution, passage; adult fish distribution, passage*											
Survival Measures*: egg to fry, fry to smolt, egg to smolt, spawner to recruit, etc.*											
Fish Abundance: *juvenile densities, smolt output, spawners, recruits*											
Water Quality: *stream temperatures, flow, stream shading index*											
Channel Restoration: *fish utilization, habitat suitability indices (H.S.I.), Weighted Usable Area indices (WUA)*											

Table A3-4. An example toolbox of analytical methods for retrospective testing and evaluation of restoration hypotheses.

Type of data/design	Analytical "Toolbox"	Benefit of method	Example references
1. Same metric, measured in control and treatment sites before and after treatment.	"Before-After-Control-Impact" design (BACI).	Reduce confounding, improve inferences about treatment effect.	**Bowles and Leitzinger 1991:** experimental design and statistical power analysis for salmon supplementation in Idaho streams (multi-agency project);.involves monitoring standardized set of response variables using consistent methods in multiple watersheds in Idaho, allowing comparisons among watersheds.
	"Before-After-Control-Impact-Paired series" design (BACIP), Repeated measures (BACIR)	like BACI, plus remove variance due to common environmental effects (see Figure A3.3-1)	**Stewart-Oaten et al 1986:** describes basic assumptions of the BACIP model. **Osenberg et al 1994:** assessed impact of a nuclear power plant's cooling water release on kelp forests along the Southern California coastline. **Green 1993**: explores application of repeated measures models to environmental questions.
	Modified BACI	Incorporate multiple controls	**Underwood 1994**
	"Staircase" type designs	Detect "transient" effects by initiating treatments at more than one time.	**Walters et al 1988, 1989:** estimates "transient" response to management actions (a "time-treatment" interaction); includes treatment and control systems, with treatments initiated at more than one starting time. Method developed to address logical weaknesses of other "single-site" type designs such as the BACIP; works well for watershed restoration situations (**Mellina and Hinch 1995**). **Peters and Marmorek 2000:** explored experimental designs for applying carcass fertilization treatments and control (no actions) to 16 streams, including staircase designs. Part of PATH project on Snake River chinook.

Type of data/design	Analytical "Toolbox"	Benefit of method	Example references
2. Same metric measured Before-After treatment, no controls	Intervention analysis	Can detect before / after differences by examining time series; need many data points	**Carpenter et al 1989**
3. Same metric measured After treatment only, multiple treatment and controls	Multiple paired treatment-control watersheds	Can detect effects of treatment despite having no before-treatment measures	**Keeley and Walters 1994:** developed experimental design for B.C. Watershed Restoration Program, exploring statistical power and expected value of different multiple-watershed designs (varied number of Treatment-Control watershed pairs and the duration of experiment).
4. Same metric, after only, no control	Spatial analyses	Similar systems can serve as "pseudocontrols"	**Bradford 1994:** Effects of Nechako water diversion on chinook salmon **Schaller et al 1999, Deriso et al. submitted:** Effects of Snake and Columbia river dams on Snake river chinook salmon.
5. Different, but comparable metrics, still amenable to statistical analysis	Spatial regression models	Use existing spatial information to test hypotheses about the relationship between watershed conditions and response variable of interest.	**Sharma and Hilborn 2001:** explored coho production in relation to stream and watershed characteristics. **Thompson and Lee 2000:** explored relationship between landscape level variables and chinook salmon and steelhead parr densities.
	Spatial covariation analyses	Use existing spatial information to evaluate covariation between systems; use to select treatment and control sites.	**Botsford and Paulsen 2000:** estimated covariation in survival indices for a suite of chinook salmon index stocks in the Columbia River basin.

Type of data/design	Analytical "Toolbox"	Benefit of method	Example references
	Formal Meta-analysis	Combine results of multiple, unrelated, but similar studies to estimate the size of treatment effects.	**Osenberg et al 1999; Fukushima 2001**
6. Different metrics only comparable on a qualitative basis.	Qualitative assessment of proportion of cases with evidence for/against hypotheses.	Provides an indication of consistency of treatment effects	- used frequently in literature reviews of diverse studies (e.g. **Marmorek and Korman 1993**)

Literature Cited in Table A3-4

Botsford, L. W., and C. M. Paulsen. 2000. Assessing covariability among populations in the prescence of intraseries correlation: Columbia River spring-summer chinook salmon (*Oncorhyncus tshawytscha*) stocks. Can. J. Fish. Aquat. Sci. 57: 616-627.

Bradford, M. J. 1994. Trends in abundance of chinook salmon (*Oncorhynchus tshawytscha*) of the Nechako River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 51: 965-973.

Carpenter, S. R., T. M. Frost, et al. 1989. Randomized intervention analysis and the interpretation of experiments. Ecology 70: 1142-1152.

Deriso, R.D., D.R. Marmorek, I.J. Parnell. (Submitted). Patterns of differential mortality in Spring chinook salmon of the Columbia River. Submitted to Can. J. Fish, Aquat. Sci (in second peer review).

Fukushima, M. 2001. Salmonid habitat-geomorphology relationships in low-gradient streams. Ecology 82:1238-1246.

Green, R. H. 1993. Application of repeated measures designs in environmental impact and monitoring studies. Australian Journal of Ecology 18: 81-98.

Marmorek, D.R. and J. Korman. 1993. The use of zooplankton in a biomonitoring program to detect lake acidification and recovery. Water, Air, and Soil Pollution 69: 223-241.

Osenberg, C.W. , O.Sarnelle, S.D. Cooper and R.D. Holt 1999. Resolving ecological questions through meta-analysis: goals, metrics, and models. Ecology 80(4): 1105-1117.

Osenberg, C. W., R. J. Schmitt, et al. 1994. Detection of environmental impacts: natural variability, effect size, and power analysis. Ecological Applications 4: 16-31.

Peters C.N. and D.R. Marmorek (eds.). and 13 co-authors. 2000. PATH preliminary evaluation of the learning opportunities and biological consequences of monitoring and experimental management actions. Compiled and edited by ESSA Technologies Ltd., Vancouver, BC. 150 pp.

Schaller, H. A., C. E. Petrosky, et al. 1999. Contrasting patterns of productivity and survival rates for stream-type chinook (Oncorhynchus tshawytscha) populations of the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 56: 1031-1045.

Sharma. R. and R. Hilborn. 2001. Empirical relationships between watershed characteristics and coho salmon (*Oncorhyncus kisutch*) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58: 1453-1463.

Thompson, W.L. and D. C. Lee. 2000. Modeling relationships between landscape-level attributes and snorkel counts of chinook salmon and steekhead parr in Idaho. Canadian Journal of Fisheries and Aquatic Sciences 57: 1834-1842.

Underwood, A.J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4(1): 3-15.

Table A5-1. Plan for Project Performance Evaluation, and example performance measures.

Category of Performance Measure	Project Objective			
	1. Gather data to support multi-watershed assessments.	**2. Develop / apply statistical methods to existing data.**	**3. Explore ability to increase statistical power.**	**4. Propose improvements in current and future projects.**
Activities: specific program actions taken	- # existing databases reviewed - # watersheds reviewed - # project implementers contacted by phone, forms completed - # site visits made - # data sets acquired - # actions, indicators, analytical methods inventoried in data base	- # potential hypothesis tests and data sets assessed - # hypothesis tests completed - # problems detected with experimental design, monitored indicators, analytical methods, etc.	- # hypotheses for which simulated datasets are developed - # hypotheses for which statistical methods are developed and applied to simulated datasets	- workshop to identify potential improvements to current and future projects (technical memo) - quantitative assessment of learning benefits (e.g. statistical power) of potential improvements - review of existing literature on standardized sampling methods and experimental designs
Outputs: direct products and services delivered	- Tech. Memos on Suitability of Existing Databases, Inventory Design, Data Forms - Pilot Inventory Report - CALFED conference paper, presentation, newsletter article	- summary tables of potential hypothesis tests and available indicators - Completed Meta Data Base for restoration projects, linked to CALFED project tracking data base - Database Description - Tech. Memo on statistical methods - Journal paper 1, CALFED conference presentation and newsletter article on *Lessons learned from testing restoration hypotheses*	- Journal paper 2, CALFED Conference presentation, newsletter article and technical report on *Statistical Methods for Testing Restoration Hypotheses*	- standardized experimental designs and sampling protocols - framework monitoring plans by topic - recommended plans for future projects & reference sites / 'controls' - Conference paper, CALFED workshop, newsletter article, technical report and journal paper on *Improving Design of Current and Future Restoration Projects*

Category of Performance Measure	**Project Objective**			
	1. Gather data to support multi-watershed assessments.	**2. Develop / apply statistical methods to existing data.**	**3. Explore ability to increase statistical power.**	**4. Propose improvements in current and future projects.**
Outcomes: intermediate and longer-term results for which program is designed	- increased ability to generate performance measures on CALFED restoration projects (better quality reports) - increased ability to test restoration hypotheses using meta data in database (# testable hypotheses, statistical power) - catalyst for sharing information (# new data sets provided to CALFED by project implementers) - improved coordination and communication among watershed restoration projects (# joint multi-watershed proposals) - improved experimental design and monitoring (# high quality proposals received, statistical power of monitoring) - improved consistency in sampling (# sites / watersheds where hypotheses can be tested; statistical power of tests) - improved guidance for future PSPs leading to much stronger proposals and monitoring plans - improved project selection by CALFED (more focused PSP process with stronger rationale, integrated design) - more cost effective expenditures by CALFED funds for given environmental benefit			
Environmental indicators: quantitative measures of progress over time towards achieving site-specific or system-wide env'l goals	Examples of indicators that may be used in the restoration projects we intend to review: - ***Gravel:*** *grain size distribution, gravel quality, permeability* - ***LWD:*** *maps of habitat types, juvenile fish distribution* - ***Riparian Vegetation:*** *abundance, distribution* - ***Barriers:*** *juvenile fish distribution, passage; adult fish distribution, passage* - ***Survival Measures****: egg to fry, fry to smolt, egg to smolt, spawner to recruit, etc.* - ***Fish Abundance:*** *juvenile densities, smolt output, spawners, recruits* - ***Water Quality:*** *stream temperatures, flow, stream shading index* - ***Channel Restoration:*** *fish distribution, estimates of Weighted Usable Area (WUA)*			

Table A6-1: Reasons for collecting sampling design information on Bay-Delta ecosystem restoration projects.

Database component	**Example of how used / Why collected**
Sampling schedules	• Derive expected sample sizes (*n*)
Measurement methods	• Estimate measurement error (σ_{meas}) for statistical power calculations
"No-treatment" baseline data (yes/no)	• Reduce suspicion that something besides restoration action caused observed indicator response
Control sites/Treatment sites	• Effects of actions less reliably demonstrated if no control or reference sites
	• Structure of replication (real replicates or pseudo-replicates in time?)
	• Is there paired sampling?
Sampling traits	• Check assumptions of statistical analyses
	• Assess how representative samples are
Proposed method of statistical analysis	• List statistical assumptions associated with hypothesis test
	• Different methods provide different information / more or less powerful inferences
	• What is formal measure of effectiveness?

Table A8-1: Schedule of tasks. M = decision meeting; C = conference presentation.

Task	Year 1 - FY2003												Year 2 - FY2004												Year 3 - FY2005											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1.1 Preliminary survey																																				
1.2 Project initiation mtg. / follow-up		M																																		
1.3 Conduct Pilot Inventory																																				
1.4 Pilot Data Analysis, Conference							M			P																										
Inventory											M																									
2.1 Implement Inventory Design																																				
2.2 Complete database																																				
2.3 Refine statistical methods																	M																			
2.4 Evaluate / develop tools																				M																
2.5 Apply methods to data																						P														
3.1 Develop simulated data sets																																				
3.2 Demonstrate statistical methods																																				
3.3 Summary Report, Conference																								P												
4.1 Meeting to identify improvements																									M											
4.2 Assess potential improvements																																				
4.3 Summary Report / Guidelines																															P					
5.1 Meeting: present recommendations																																M				
5.2 Final Report, Journal Papers																																				

Table B1-1. ERP / Science Program / CVPIA priorities that are directly addressed by this proposal. Abbreviations in referencing reports: IP = ERP Draft Stage 1 Implementation Plan; PSP = 2002 Proposal Solicitation Package

Priority	**Description**
Relevant Science Program Priorities	
IP, pg. 14	"*Conduct adaptive management experiments*…retrofit elements of adaptive management and/or monitoring to existing projects, ecosystems or watersheds where multiple projects might be occurring."
IP, pg. 14	"*Compare relative effectiveness of different restoration strategies.*"
IP, pg. 15	*"Coordinate and extend existing monitoring."*
IP, pg. 15	*"Take advantage of existing data*…develop questions that can be addressed by existing data and that can build from that data to develop indicators and better understanding of processes, species and communities."
Relevant Multi-Regional Priorities	
MR-6, PSP pg. 24	"…develop common restoration performance measures for tributary streams in the Sacramento and San Joaquin river basins; … Develop performance measures that can be used to compare restoration progress across tributary streams… including environmental state variables, explanatory (mechanistic) measures, measures of success within a basin and measures comparable across basins. "
Relevant Sacramento Region Priorities	
SR-1, PSP pg. 26	*"Evaluate restoration in the Sacramento River Corridor…*systematically evaluate[s] restoration performance…include monitoring performance measures and assessments or research that allow understanding of success or limits of different restoration practices."
SR-7, PSP pg. 29	*"Compare conceptual models and develop restoration performance measures for tributary streams and rivers."*
Relevant San Joaquin Region Priorities	
SJ-1, PSP pg. 32-33	For both channel-floodplain reconstruction projects and gravel augmentation projects, "studies that compare such effects among restoration strategies are critical for future prioritization of CALFED activities"

Attachment 1: Change Management and Budget Control

Project Management

The ESSA project manager and the CALFED project manager will be jointly responsible for controlling the scope of the project. Whether fixed-price or time and materials contracting, Change Management is a necessary and expected procedure. Following any request or evolved need[7] for extension in scope of an existing task, or addition of new unplanned tasks, the ESSA project manager will prepare a Change Request outlining the scope of the change and the impacts on the project budget, schedule, and other modules or core activities. This Change Request must be approved in writing by CALFED before any new work proceeds (see template below).

The ESSA project manager will provide an on-going risk assessment for the project, such that the client understands the severity and status of any risks that might impact the schedule, budget, quality, and scope of the project. Risk is anything that could impede completing the project as specified in the time and budget allowed. One can generally identify the relative risk factors for every task of every project. We suggest avoiding management of small risks and focusing only on the significant and manageable risks. These risks would be summarized in quarterly Project Status reports or as needed. Those that have increased their risk will be identified as issues requiring mitigation.

Change Management and Budget Control

As CALFED is aware, providing a fixed-price on any modeling project of this scope and complexity involves not only estimating the activities, but assessing and managing our risks during project implementation. Although the spirit of the working relationship must be trust and fairness to eventually achieve a successful project, it is important to specify guidelines prior to commencing the assignment. In brief we suggest that:

> CALFED should be responsible for the cost of changes if the item was not explicitly included in a previously accepted work schedule, design document, formal memoranda, or Change Request. Our cost for researching these changes to a sufficient level to produce estimates will be built into a Change Request amount.
>
> ESSA will be responsible for the cost of items that were included in previously accepted work schedule, design document, formal memoranda or Change Request (that have not been moved out of scope by a prior approved Change Request).

In most fixed-price contracts ESSA is responsible for internally monitoring our time and costs and the client monitors the schedule and status of deliverables. Past experience has shown that a Project Status report and Change Request issuing procedure is a very prudent and helpful addition to this relationship. Of course, we recognize the limits of this procedure. Should the value of Change Requests exceed CALFED's available budget, ESSA and CALFED would jointly decide which previously included items will be reduced in scope or deferred to a subsequent project.

[7] e.g., an additional meeting with local experts needed to clear a critical project bottleneck.

ESSA
Change Request Form

Project: Contract no.	**Change Request Number:** **Request Date:**
ESSA Contact:	**Client Contact:**
Change Description:	
Change Impact: Estimated Impact on Project Costs: in dollars: **$** in person-days: Estimated Impact on Project Schedule: in days:	
Change of Status Request (check one): ☐ **Approved** ☐ **Rejected**	

Signatures:

Client Project Manager	Date	Producer	Date
Client Contracting Officer	Date		