Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

Project Information

1. **Proposal Title:**

   Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

2. **Proposal applicants:**

   Elizabeth Eschenbach, Humboldt State University, Department of Environmental Resource Engineering
   Bret Harvey, Redwood Sciences Laboratory, US Forest Service
   Roland Lamberson, Department of Mathematics, Humboldt State University
   Steven Railsback, Department of Mathematics, Humboldt State University

3. **Corresponding Contact Person:**

   Gregory Lee
   Humboldt State University Foundation
   P. O. Box 1185 Arcata CA 95518-1185
   707 826 4189
   HSUF@Humboldt.edu

4. **Project Keywords:**

   Anadromous salmonids
   Flow, Instream
   Reservoirs, Management and Modeling

5. **Type of project:**

   Research

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

   No

7. **Topic Area**:

   Natural Flow Regimes

8. **Type of applicant:**

   University

9. **Location - GIS coordinates:**

Latitude:	39.520
Longitude:	121.547
Datum:	NAD27

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

This is a research project with results potentially applicable to all Central Valley reservoir tailwaters that support anadromous salmonid spawning. We will use study sites to be selected after the project is initiated. The most likely candidate sites are on the Merced, Yuba, American, and Feather rivers. As advised by the CALFED Proposal Review Office, we are providing location information for one of the most likely sites, Feather River below Lake Oroville.

10. **Location - Ecozone:**

    8.1 Feather River, 8.2 Yuba River, 9.2 Lower American River, 13.3 Merced River, Code 15: Landscape

11. **Location - County:**

    Butte, Merced, Sacramento, Yuba

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:**

    2nd

15. **Location:**

    California State Senate District Number: 1

    California Assembly District Number: 03

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?

Yes

If yes, list the different overhead rates and total requested funds:

State Overhead Rate:		20% of all direct costs
Total State Funds:	$1,224,734	
Federal Overhead Rate:	45.5% of salaries, wages, and benefits	
Total Federal Funds:	$1,408,804	

b) Do you have cost share partners <u>already identified</u>?

No

c) Do you have <u>potential</u> 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?

No

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)

Peter Moyle	**Department of Fish, Wildlife, and Conservation Ecology, University of California, Davis**	**530 752 6355**	**PBMoyle@UCDavis.edu**
Jim Petersen	**USGS, Columbia River Research Laboratory**	**509 538 2299**	**jim_petersen@usgs.gov**
Hiram Li	**Oregon Cooperative Fisheries Research Unit**	**541 737 1963**	**hiram.li@orst.edu**
Jim Anderson	**Columbia Basin Research, University of Washington**	**206 543 4772**	**jim@confocal.fish.washington.edu**

21. **Comments:**

Environmental Compliance Checklist

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

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

       Yes
    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.

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

   CEQA Lead Agency: Humboldt State University Foundation
   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
   XCategorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   -none

   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.

   CEQA Class 6 exemption for research with no significant impact

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

       No

       If the CEQA/NEPA process is not complete, please describe the dates for completing draft and/or final CEQA/NEPA documents.

CEQA document will be completed upon notification from CALFED of tentative project approval.

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 Required, Obtained

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	Required
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.**

This research project will require 4 study sites of approximately 500 m length, on two rivers. Final selection of study rivers depends on agency management interests and data availability, so the site selection process will be completed after consulting with agencies and other researchers in the first few months of our project. We are therefore unable to obtain access permission now; instead it will be obtained during the site selection process.

Land Use Checklist

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

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?**

   Yes

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).

   At each of our 4 study sites we will collect aquatic habitat information (channel topography, etc.). At some sites we will conduct small, controlled fish behavior experiments, e.g., by manipulating food supplies or predation risk. These activities will require access via vehicles on existing roads and walking, or by boat from existing launch sites. No modification to land use will result.

4. **Comments.**

Conflict of Interest Checklist

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

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):

Elizabeth Eschenbach, Humboldt State University, Department of Environmental Resource Engineering
Bret Harvey, Redwood Sciences Laboratory, US Forest Service
Roland Lamberson, Department of Mathematics, Humboldt State University
Steven Railsback, Department of Mathematics, Humboldt State University

Subcontractor(s):

Are specific subcontractors identified in this proposal? No

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

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

W. Kimmerer San Francisco State University

Comments:

Budget Summary

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

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.

State Funds

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	Reservoir modeling	1248	35833	4479	3600	3900	0	0	5500	53312.0	10662	63974.00
2	Fish modeling	1560	62100	7763	1500	3900	0	0	5000	80263.0	16053	96316.00
3	Field work	3373	56444	7056	34587	3000	0	0	0	101087.0	20217	121304.00
4	Evaluation of releases	1283	56150	7019	0	0	0	0	0	63169.0	12634	75803.00
5	Project management	1040	31200	3900	3600	1000	0	0	0	39700.0	7940	47640.00
		8504	241727.00	30217.00	43287.00	11800.00	0.00	0.00	10500.00	337531.00	67506.00	405037.00

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**
1	Reservoir modeling	3033	83774	10472	3300	0	0	0	1250	98796.0	19759	118555.00
2	Fish modeling	1213	49266	6158	3000	0	0	0	5000	63424.0	12685	76109.00
3	Field work	3133	52628	6578	26027	1000	0	0	0	86233.0	17247	103480.00
4	Evaluation of releases	2531	64278	8035	4800	0	0	0	0	77113.0	15423	92536.00
5	Project management	1040	31824	3978	3600	1000	0	0	0	40402.0	8080	48482.00
		10950	281770.00	35221.00	40727.00	2000.00	0.00	0.00	6250.00	365968.00	73194.00	439162.00

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**
1	Reservoir modeling	2080	46062	5758	1500	0	0	0	1250	54570.0	10914	65484.00
2	Fish modeling	1075	44508	5564	3000	0	0	0	5000	58072.0	11614	69686.00
3	Field work	1920	35473	4434	26027	1000	0	0	0	66934.0	13387	80321.00
4	Evaluation of releases	2843	76373	9547	6600	3900	0	0	0	96420.0	19284	115704.00
5	Project management	1040	32460	4058	3600	1000	0	0	0	41118.0	8224	49342.00
		8958	234876.00	29361.00	40727.00	5900.00	0.00	0.00	6250.00	317114.00	63423.00	380537.00

Grand Total=1224736.00

Comments.

Budget Justification

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

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

Eschenbach (Lead, Task 1): 1300 hrs Railsback (Lead, Tasks 2, 5): 3120 hrs Harvey (Lead, Task 3): No labor charges (Salary paid by US Forest Service) Lamberson (Lead, Task 4): 1560 hrs Dodd (Post-doctoral assistant, Tasks 1-4): 6240 hrs Jackson (Programmer, Tasks 1-4): 4160 hrs Engineering MS student (Task 1): 2427 hrs Fisheries MS student (Task 3): 2427 hrs Mathematics MS student (Task 4): 2427 hrs Field crew chief (Task 3): 1680 hrs Field technician (Task 3): 3072 hrs

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

Estimated monthly salaries (average over 3 project years, full-time equivalent) Eschenbach (Lead, Task 1): $7480 Railsback (Lead, Tasks 2, 5): $7038 Lamberson (Lead, Task 4): $9750 Dodd (Post-doctoral assistant, Tasks 1-4): $3570 Jackson (Programmer, Tasks 1-4): $7038 Engineering MS student (Task 1): $2550 Fisheries MS student (Task 3): $2550 Mathematics MS student (Task 4): $2550 Field crew chief (Task 3): $4420 Field technician (Task 3): $2298

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

HSU Foundation’s standard fringe benefit rate of 12.5% of salary is applied to all personnel.

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

We propose travel for three purposes. 1. Meetings and agency consultations: many aspects of the project require data from, and consultation with, the agencies involved in managing reservoirs and salmon fisheries. We budget a total of 12 person-trips per year between Arcata and Sacramento, at an average cost (airfare, hotel, meals at standard state rates) of $600. Total budget for meetings and consultations: $21,600. 2. Field work: We estimate a total of 651 person-days travel for site reconnaissance, collection of habitat data for model input, and (mainly) extensive fish observations used for model validation experiments. Costs include mileage, lodging, meals, and incidental expenses at standard state rates. Total field travel budget: $86,641. 3. Professional meetings: Presenting our methods and results to professional conferences will be important for improving and establishing the credibility of our research. We budget two such conferences for each of the four investigators; and travel by our programmer to the annual users conference for the "Swarm" simulation system we use. Cost per trip (airfare, registration, lodging, meals at standard state rates) is estimated at $1500. Total budget for professional meetings: $16,500.

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

Office: $3000 for copies, postage, etc. This budget also includes costs for reports and publications, such as graphics preparation, printing, and journal page charges. Laboratory: None. Computing: Tasks 1, 2, and 4 use heavily computer-intensive simulation methods. As a compromise between computing power and cost (compared to purchasing scientific workstations), we budget two high-end personal computers in year 1 for tasks 1 and 2, and a new computer in year 3 for final simulations under Task 4. Estimated cost per computer is $3900, for a total of $11,700. Field supplies: A total of $5000 is budgeted for netting for enclosure experiments and miscellaneous supplies. Total budget for supplies and expendables: $19,700.

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.

None.

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.

Financial management costs (for cost validation and reporting, invoicing, purchasing, etc.) are included in indirect costs. Technical project management (Task 5) includes report preparation, presentations and coordination meetings, and oversight of other tasks. The Task 5 budget includes (1) half of the direct labor hours stated above for Railsback, (2) one quarter of the direct labor hours stated above for Dodd, (3) one half of the travel budget for meetings and agency consultations, and (4) the office supply budget of $3000. Total direct costs for management are $121,220; these costs are included in the direct labor, travel, and supply budgets above.

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

We will use two specialized software packages that increase cost-effectiveness by greatly reducing the amount of software we must write, test, and document. Although the packages appear expensive, the cost is far outweighted by reduced programming time, increased software usability, and avoided errors. We expect to use "Riverware" software to simulate reservoir management policies and the resulting flow releases and temperatures. Riverware is selected for its unique capabilities for coding flow management policies into the reservoir management optimization. The license for Riverware (from the Center for Advanced Decision Support for Water and Environmental Systems, University of Colorado; http://cadswes.colorado.edu/) is $5500 for the first year and $1250 for additional years (for a single-computer license). This fee includes the CPLEX optimization solver needed to accurately represent real reservoir management and find good adaptive management solutions. Our individual-based fish model uses the "Swarm" simulation library; we budget $5000 per year for a University Group Membership in the Swarm Development Group (www.swarm.org), the non-profit organization that maintains Swarm and provides user support.

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.

Indirect costs include personnel management, purchasing, invoicing, budget management and reporting, and payroll. Humboldt State University will contribute office space, office support, telephone, etc.

Executive Summary

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

This research project addresses CALFED adaptive management and natural flow regime priorities by evaluating the use of environmental water to enhance salmon production. Water is set aside for fish under CALFED's Environmental Water Account and Environmental Water Program, and CVPIA Section (b)(2). This "environmental water" (EW) is mainly used to avoid salmon entrainment in the Delta pumps, but interest in using EW to enhance salmon production by releasing it into rivers at critical times is growing. Our goals are to: (1) Develop models for evaluating benefits of EW releases for salmon spawning, incubation, and in-river fry production; (2) Develop guidance for adaptive management of EW for in-river salmon; and (3) Estimate the benefits to salmon production of using EW for in-river enhancement, compared to using EW to reduce Delta pump entrainment. Simulation experiments are proposed because field-testing EW policies would be expensive, take many years, and be complicated by uncontrolled variability and monitoring uncertainty. Project objectives are: (1) Adapt existing reservoir models to predict flows and temperatures under alternative EW release policies. Simulations will represent two study rivers to be selected; candidates include the Merced, Yuba, American, and Feather rivers. (2) Adapt and validate an individual-based model (IBM) of how flows and temperatures affect salmon spawning, incubation, fry growth and survival, and population dynamics. This model will be useful for evaluating EW releases for salmon enhancement, and for other CALFED objectives such as assessing fishery effects of channel modifications. Field studies for model validation will examine how flow affects fry growth, survival, and outmigration. (3) Develop adaptive policies for managing EW releases for in-river fry production: specifying when and where to release how much of the available EW, to maximize its benefits. (4) Simulate how the adaptive EW policies affect salmon fry production over long periods. Compare the salmon production benefits of using EW for (a) enhancing in-river fry production vs. (b) reducing Delta pump entrainment.

Proposal

Humboldt State University, Department of Environmental Resource Engineering

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

Elizabeth Eschenbach, Humboldt State University, Department of Environmental Resource Engineering
Bret Harvey, Redwood Sciences Laboratory, US Forest Service
Roland Lamberson, Department of Mathematics, Humboldt State University
Steven Railsback, Department of Mathematics, Humboldt State University

Using Environmental Water for In-River Salmon Enhancement: Methods for Planning and Evaluation

Submitted by: Humboldt State University (HSU) Foundation
HSU Departments of Environmental Resource Engineering, Fisheries, and Mathematics

A. Project Description

1. Problem

Problem statement. We propose to address a key issue in management of CALFED's water assets: how to best manage the water that is set aside for environmental purposes. The Central Valley Project Improvement Act section 3406(b)(2) provides up to 800,000 acre-feet (a-f) of water per year for environmental purposes ("b2 water"). The CALFED Environmental Water Account (EWA) purchases water in various reservoirs and uses it primarily for short-term fish protection purposes; an average of 200,000 a-f of EWA water is expected to be available per year. Similarly, the CALFED Environmental Water Program (EWP) purchases water for fisheries restoration and protection. We refer to the water set aside under programs such as these collectively as "environmental water" (EW). To date, EW (especially from the EWA) has been used primarily to allow Delta pumping to be curtailed without impairing water deliveries, when the density of salmon juveniles is especially high near the pumps. The benefits to salmon populations of this use of EW is uncertain and possibly small (Brown and Kimmerer 2001), raising the question of whether the water could have greater benefits if used in other ways.

An alternative use of EW is to manage it adaptively to enhance in-river production of salmon fry and smolts. The available EW is sufficient to significantly increase instream flows in one or several Central Valley rivers. The estimated 200,000 a-f of EWA water could provide 550 cubic feet per second (cfs) of flow augmentation over a six-month spawning and rearing period. The 800,000 a-f of b2 water could provide over 2000 cfs of flow augmentation over six months. However, there is currently little information or guidance on how EW could be managed to enhance salmon production via flow augmentation. Relations between river flow and salmon spawning, incubation, growth, and survival are complex; and these relations vary over time, among rivers and habitats, and with salmon abundance. Managing EW to enhance in-river salmon production efficiently requires an understanding of the complex effects of flow on salmon and an adaptive process for deciding how much water is best used at which sites and times, information which is not currently available to EW managers.

The problems we propose to address are (1) the lack of methods for estimating how EW use to augment river flows would benefit salmon populations, (2) the need for methods to efficiently allocate EW assets for in-river salmon enhancement, and (3) the need to evaluate potential benefits of using EW for in-river enhancement, in comparison to the benefits of using EW to reduce mortality at Delta pumps. These problems will be addressed by adapting and validating an individual-based stream salmonid model as a tool for evaluating potential benefits of EW releases; and by developing a management model to guide adaptive releases of EW for in-river benefits. We will then evaluate potential benefits of EW releases for in-river enhancement using simulation experiments that represent many of the complexities of the actual CALFED decisions. The simulation experiments will allow us to evaluate EW management alternatives without the high costs, risks, and uncertainties of full-scale experiments. The salmon model will be useful for other CALFED purposes such as assessing the effects of channel restoration and instream flows on fry production. Field studies will help understand and model important processes by which reservoir releases affect salmon.

Location. We propose developing models and analysis methods that are generally applicable to anadromous salmonid stocks spawning downstream of reservoirs throughout the Central Valley. These methods will be developed using two rivers as demonstration sites. We propose that study site selection be finalized after the project is funded so we can thoroughly investigate alternatives in consultation with CALFED and agency staff; doing so will increase the study's value by selecting sites best meeting this study's needs and also providing secondary benefits for site-specific management issues. Primary criteria for study rivers are that: (1) EW is likely to be available; (2) salmon stocks are likely to respond to the flow augmentation typically available via EW; and (3) previous studies providing some of the data for model input and validation are available. Our project is most likely to be valuable if study sites have interesting and complex effects of reservoir releases on downstream salmon, and if the two rivers differ in size. EWA staff have indicated to us that the Merced, Yuba, American, and Feather rivers may meet our study site criteria. The Tuolumne River is also appealing because the mechanisms by which flow releases affect salmon reproductive success have been investigated extensively. We anticipate fall-run chinook as the study species, although other chinook races and steelhead may be considered if appropriate for the study sites.

Review of past studies. The use of EWA assets to manage Delta pump mortality in 2000-2001 was the first year of a four-year experiment. The effects of these operations on salmon were evaluated at a workshop documented by Brown and Kimmerer (2001). This workshop arrived at no estimate of how many salmon juveniles were saved, or what the population-level benefits might be. Some participants expressed concern that benefits could be very small and that there may be more effective uses of EW assets.

To date there appears to have been little investigation of in-river vs. Delta uses of EW. Our discussions with managers and science advisors to the CALFED and CVPIA EW programs identified no previous studies on the problems we address. The need for scientific input for EW purchase and release policies was cited recently by CALFED planners (J&S 2001).

The problem of evaluating the performance of in-river releases of EW is related to instream flow assessment (assessing the benefits of alternative instream flows), but commonly used instream flow methods are inappropriate for this problem because they (1) do not directly relate flow to fish populations, and (2) are not designed to evaluate effects of short-term or variable flows (EPRI 2000). One previous model that does attempt to relate weekly flows and temperatures to salmon production is "SALMOD" (Williamson et al. 1992), which has been used several times in California. However, SALMOD has a number of weaknesses for our study objectives. Fundamentally, SALMOD was designed by encoding a number of observed relationships instead of modeling the mechanisms causing those relationships. For example, SALMOD assumes that the carrying capacity of a habitat type is indicated by the density of fish observed in that kind of habitat. New research indicates that natural complexities make observed fish density a poor measure of carrying capacity; densities can often be high in suboptimal habitat, or low in high-quality habitat, due to factors such as competition (Garshelis 2000; Rosenfeld and Boss 2001). SALMOD also does not simulate several important and well-documented natural processes, especially (1) how the value of habitat to a fish varies with factors such as fish size and condition, temperature, turbidity, and food availability; and (2) how growth and mortality vary independently among habitat types and how fish consider both in selecting habitat. The "individual-based models" (IBMs) we will use (described below, **3. Approach**.) were developed to overcome limitations such as these.

There are few precedents for the methods we propose to develop for adaptively managing EW releases. Even though a substantial body of literature on adaptive management of water projects and fisheries has arisen since the pioneering work of Holling (1978) and Walters (1986), the design of adaptive reservoir release policies has received little attention. Studies that will be useful to our research even though they do not address flow management include examination of the viability of adaptive management in the face of uncertainties in monitoring and forecasting fish populations (Ham and Pearsons 2000, Smith and Walters 1981, Williams 1999), and a simulation analysis of adaptive management of salmon harvest by Smith and Walters (1981). One CALFED project is currently addressing adaptive flow management. This study, by Essa Technologies, is developing an adaptive reservoir management program for Clear Creek below Whiskeytown Dam. Results of this project are not currently available; we will use future results of the Clear Creek study to the extent they are relevant to our project.

Project goals, objectives, and hypotheses. Our project has three goals.

(G1) Develop simulation tools that are broadly useful for evaluating the benefits of EW releases for anadromous salmonid spawning, incubation, and in-river fry production.

(G2) Develop practical guidance for adaptive management of EW for in-river salmon benefits.

(G3) Compare the salmon production benefits of using EW for in-river enhancement to the benefits of using EW to reduce entrainment in Delta pumps.

We propose to address these goals by meeting four specific objectives.

(O1) Adapt reservoir models that predict release flows and temperatures under alternative EW flow release policies.

(O2) Adapt and validate a realistic model of how reservoir release flows and temperatures affect salmon spawning, egg incubation, fry growth and survival, and long-term population dynamics. Develop this model as a tool for evaluating in-river benefits of EW releases.

(O3) Develop good policies for adaptive management of EW releases for in-river fry production. These policies specify when and where to release how much of the available EW, to maximize its benefits.

(O4) Simulate how the adaptive EW policies affect salmon fry production and long-term population trends. Compare the benefits to long-term salmon production of using EW for (a) enhancing in-river fry production vs. (b) reducing Delta pump entrainment.

This research will test three hypotheses. The first hypothesis must be accepted before the others can be addressed: (H1) Our salmon simulator can reproduce the key mechanisms by which flow releases affect freshwater life stages of salmon, with reasonable accuracy.

The other hypotheses are fundamental questions that the project is designed to address.

(H2) Under realistic conditions of uncertainty in monitoring data and EW availability, adaptive management of EW can significantly enhance in-river fry production.

(H3) The use of EW to reduce Delta pump entrainment (as practiced in 2000-2001) has lower long-term benefits to salmon populations than would use of EW to enhance in-river fry production.

2. Justification

Key uncertainties addressed. This project will address a major uncertainty in CALFED–CVPIA efforts to restore Central Valley fish populations: what uses of EW are most beneficial for salmon populations. In particular, our study will reduce uncertainty in the expected benefits of using EW for in-river production of juveniles. The models we will develop will also allow more certain estimates of the benefits to salmon populations of other CALFED actions, especially habitat restoration and channel modifications. On the Draft Stage 1 Implementation Plan's adaptive management diagram, our project is one of the "Explore policy alternatives using simple simulations" steps conducted after conceptual models are specified and before policy restoration actions are initiated in areas with a high level of uncertainty.

Project type. We propose our project as a "research" type instead of a pilot or full-scale implementation of EW flow augmentation policies. This issue requires research simulation modeling because (1) the uncertainties in how alternative EW policies will affect fisheries and water supply are high, and (2) attempting to compare alternative policies in the field would be very expensive and unlikely to produce clear results. The population dynamics of Central Valley salmon are complex, depending on ocean conditions, harvest, weather, abundance of predators and competitors, and many other uncontrolled factors. Likewise, the river flows and temperatures vary with weather, water demands and short-term management decisions, etc. The effects of flow on fisheries are also complex, and fish population monitoring data are uncertain. Because of all these complexities, uncertainties, and uncontrolled variables, field experiments likely could not be controlled well enough to allow meaningful comparison of EW management policies.

Our simulation approach also avoids the need to place valuable resources—money, water supply, and salmon—at risk while management policies are field-tested. Finally, attempting to compare EW management policies at real reservoirs would require each alternative policy to be implemented for a number of years because policies must be compared over wide ranges of water availability (wet vs. dry years), spawner abundance, and other factors that vary over long times.

Our proposed simulation approach is much more likely to succeed because (1) our models include simple representations of the key processes by which management policy affects flow releases, and by which flow releases affect fish populations; (2) monitoring uncertainties are avoided (or simulated when desired); (3) experiments will be tightly controlled by simulating the same time period repeatedly while varying only the flow management policy; and (4) the simulations will cost far less time, money, and water than would field experiments.

Conceptual models. Five general conceptual models form the underlying basis of our work. How these conceptual models are implemented in our analysis of flow management policies is described below in the **Approach** section.

(M1) Environmental water assets as a tool for real-time protection and enhancement of fisheries: EW programs are intended (in part) for short-term allocation as needed to protect or enhance native fish stocks. The basic concept of EW we address is the short-term allocation of limited water volumes to opportunities for avoiding fish losses or enhancing fish production.

(M2) Juvenile size and abundance model of flow effects: The key mechanism by which reservoir releases affect Central Valley salmon stocks is by affecting the number *and size* of juveniles produced in the river. This model includes the widely held assumption that larger smolts are more likely than smaller smolts to survive in the ocean and spawn. Consequently, successful flow policies must produce large juveniles as well as large numbers of them.

(M3) Individual-based model of flow effects on salmon: There are a number of key mechanisms by which river flow and temperature affects the abundance and growth of juvenile salmon; each of these mechanisms can be represented with a simple, well-justified model; and an individual-based simulator containing these simple mechanism models can represent many of the system's real complexities. This concept is the basis for individual-based ecological modeling, the approach we use for simulating flow effects on juvenile salmon size and abundance.

(M4) Adaptive management models: EW releases can be managed adaptively to maximize in-river benefits. Adaptive management is often envisioned as an automated feedback-and-control process that includes four elements: (1) a monitoring program to provide feedback on fishery status, (2) a simple forecasting model used to predict how fish populations respond to flow releases, (3) a control algorithm to adjust reservoir releases to meet fishery objectives, and (4) a process for using the monitoring data to update forecasting model parameters (Smith and Walters 1981; Walters and Holling 1990).

(M5) Historic operations as a model of EW use to reduce Delta pump mortality: The use of EW to reduce Delta pump mortality can be modeled using the procedures developed by CALFED in 2000-2001. The primary current use of EW is to offset curtailment of Delta pump exports during periods of high juvenile salmon density near the pumps. We model this use of EW as the current procedures (described in the document "Provisional Fall/Winter Juvenile Salmon Decision Process" available at http://wwwoco.water.ca.gov/calfedops/2001ops.html), and model its benefits by adopting the performance estimates produced by the agencies managing the EWA (described for 2000-2001 by Brown and Kimmerer 2001). We expect additional information to become available as the four-year EWA experiment continues.

Hypothesis testing and revision of experimental design. Our hypothesis H1 (that our individual-based salmon model is realistic) will be tested by applying the "pattern-oriented" validation process we have used previously for similar models (Railsback in press). The focus of validation (described in **4. Feasibility**) is using literature and field studies to test the model's ability to represent key mechanisms by which river flow and temperature affect salmon spawning, incubation, and fry rearing. When weaknesses are found, we will revise the model.

Testing of hypotheses H2 and H3 involves simulating adaptive methods for allocating EW for in-river enhancement. Methods for testing these hypotheses with simulation experiments are presented below (**3. Approach**). During these simulation experiments we anticipate learning about the dynamics of adaptively managed systems from our experiments, and revising and re-testing our management policies several times to make them as successful as possible.

3. Approach

Overview of approach. We propose to: (1) adapt and validate an individual-based population model appropriate for evaluating the performance of EW releases to enhance in-river salmon production, (2) design adaptive policies for managing EW releases, and (3) conduct simulation experiments to evaluate the performance of the adaptive EW policies. We will use a simulated two-reservoir system; policies that work well in this system should be easily extended to additional reservoirs. The following steps will be followed.

1). Establish useful measures of system performance for salmon production. These measures will consider short-term numbers and size of smolts and the long-term average and variability in populations.

2). Select and model two reservoirs and the salmon stocks that spawn in the tailwaters. The models will predict the flow releases and temperatures, and resulting salmon population dynamics, under alternative policies for managing EW releases. Models will include a simple representation of how much water is available for EW use each year.

3). Design example adaptive management policies for determining how the available EW assets should be allocated among the two rivers, and how much water should be released each month, to maximize salmon production in the two-reservoir system.

4). Conduct long-term (e.g., 20 year) simulation experiments to evaluate the performance of adaptive, in-river use of EW and compare that performance to the benefits of using EW to reduce Delta pump mortality.

The guiding philosophy for our simulation experiment is to: (1) Keep models and simulation scenarios as simple as possible while still including the mechanisms that are important in the real system, and (2) Add complexity to the analysis in a stepwise fashion, using experiments to understand and validate results at each new level of complexity. Our experience indicates that this approach maximizes information richness by allowing us to thoroughly understand the simulations while using a realistic level of complexity in the analysis.

We propose the following five tasks.

Task 1: Reservoir modeling. (Lead investigator: E. Eschenbach.) This task addresses objective O1, developing models that predict reservoir releases and temperatures in the two study reaches; the reservoir models will drive fish models developed in Task 2. The reservoir model will simulate: (1) instream flow releases under normal operations, (2) the potential availability of EW for purchase, and (3) flow augmentation by EW under alternative policies for managing EW releases. Reservoir modeling will use a monthly time step because it offers a good tradeoff between computational effort and the time scales over which EW actions take place.

This task will include developing a simple model to represent the availability of EW from year to year. The procedures and history of obtaining EWA, EWR, and b2 water will be examined to determine how predictable water availability is in our two study reservoirs and to design an appropriate model. We anticipate that EW availability will be modeled as partly random (i.e., due to factors we cannot easily simulate) and partly a function of known factors like reservoir inflow. Previous studies (e.g., DWR and USBR 2001) will be used as appropriate.

To save time and money, we will use existing models for this task, adapting them as needed for our project. The CALSIM II model developed by Department of Water Resources (DWR) and the U. S. Bureau of Reclamation (USBR) will be used for as many aspects as possible. This model was designed for long-term planning studies of Central Valley reservoirs and has previously been used to compare policies for using EW (DWR and USBR 2001). If we determine that CALSIM II is inappropriate for some aspects of this task (e.g., because it is too difficult to link to policy simulations), we will also use the *Riverware* reservoir simulation package (Eschenbach et al. 2001). *Riverware* allows site-specific models to be built quickly and inexpensively, includes optimization methods useful for realistic policy simulation, and includes a language for coding management policies. *Riverware* is used for simulation analysis and operations optimization of large reservoir systems in the Tennessee and Colorado river basins.

The temperature of reservoir releases can have strong effects on the downstream fishery and can vary with management policy, so this task includes simulating the temperature of reservoir releases. If our choice of study site allows, we anticipate using one of the models used by USBR to simulate monthly temperatures for planning studies. These models are currently available for reservoirs on the Sacramento, Feather, American, and Stanislaus rivers (personal communication, R. Yaworsky, USBR, Sacramento CA). If no temperature model is available for an otherwise desirable study site, we will apply an existing model (possibly *Riverware*, which simulates temperatures) to the reservoir, calibrating the model to the extent possible with existing data.

Task 2: Fish modeling. (Lead investigator: S. Railsback.) This task addresses objective O2, developing and validating a realistic model of how reservoir releases affect the downstream salmon stock. We will use an individual-based model (IBM) that simulates the entire salmon life cycle but focuses on mechanisms by which reservoir flows and temperatures affect spawning, incubation, and growth and survival of fry.

An important innovation of our proposed research is the use of a fish model that contains many of the complexities and nonlinearities of real fish populations. We will use our existing IBM of stream salmonids to simulate phases of the salmon life cycle that occur in the river and are therefore most affected by flow releases and EW. This model includes simple representations of the key mechanisms by which river habitat, flow, and temperature affect individual fish and, therefore, the fish population. This model has been tested thoroughly, validated at both the individual and population levels (Railsback and Harvey, in press; Railsback et al. in press), and used in previous river management research (e.g., EPRI 2000; Hicks et al. in prep). The model uses a daily time step.

Our model for the river phases of the salmon life cycle includes the following key mechanisms. The detailed methods for modeling these mechanisms, and the literature upon which the methods were based, are provided by Railsback and Harvey (2001; available at http://math.humboldt.edu/~simsys/Products.html). (1) Habitat is simulated as a grid of rectangular cells, each several square meters in size. This spatial scale was chosen considering the distances over which river habitat varies and salmonids select their habitat. (2) The depth and velocity in each habitat cell is a function of river flow. (3) Spawners select a redd site that has the best available combination of substrate type, velocity, and depth. (4) Incubating eggs develop at a temperature-dependent rate. Eggs are subject to mortality due to extreme temperatures (low or high), scouring at high flows, desiccation at low flows, and superimposition of new redds on top of existing ones. (5) Once emerged, fry select among the available habitat to find the location that optimizes their expected probability of surviving to smolt size. This expected probability is a function of mortality risks and of growth rate– higher growth increases the probability of surviving to smolt by reducing the time it takes for the fry to achieve smolt size. Fry compete with each other via a size-based hierarchy, with larger fish getting first access to food and cover. This approach produces realistic habitat choices under a wide range of conditions. (6) Fry growth rate is a function of food intake and the energy cost of swimming. Food intake is calculated using a mechanistic representation of the ability to capture food varies with fish size and habitat velocity and depth; drift-feeding and searching for stationary food are both simulated. Energy costs increase with velocity and temperature, but are lower for fish using velocity shelters to drift-feed. (7) Several important mortality risks are simulated separately, with both habitat and fish characteristics affecting risks. Risks include starvation and disease (increasing as the fish loses weight), predation by fish (decreasing as fish grow and lowest in shallow habitat), predation by terrestrial animals (increasing with fish size and lowest in deep habitat), and thermal stress at high temperatures.

Two new processes will be added to our IBM to represent mechanisms important for salmon. (1) Spawning females will be assumed to produce a number of eggs that increases with their size—size-dependent fecundity is a well-documented feedback in the salmon life cycle. (2) Adults will be assumed to guard their redds for several days after spawning. This process limits the frequency of superimposition, the laying of a new redd over an existing one.

The salmon life stages taking place outside the river will be modeled very simply. Reservoir releases (the focus of our study) have little effect on these parts of the life cycle, so a highly mechanistic modeling approach is not justified. Spatial variation in habitat will not be simulated in these parts of the model. The following processes will be included. (1) Salmon fry migrate downstream out of the river into the Sacramento-San Joaquin Delta when they are big enough to smolt or unable to find river habitat providing positive growth. (We plan to test this assumption with field studies, described below.) (2) Fry in the Delta experience a constant mortality rate and a constant specific growth rate (grams of growth per gram of fish per day). The constant specific growth rate allows the size differences among individuals obtained in the river phase to persist in the Delta. (3) The time at which fry turn into smolts and enter the ocean is a function of their size and the date. All smolts enter the ocean within the dates when real salmon have been observed to smolt, and faster-growing fish are able to smolt earlier. (4) In the ocean, salmon experience a constant mortality rate and a constant specific growth rate that decreases with size. (5) Adult salmon leave the ocean to spawn in a way that reproduces the distribution of age-at-spawning observed in Sacramento basin salmon stocks. Upstream migration will not be modeled explicitly; instead, spawning adults will be assumed to appear at their spawning sites on dates selected to reproduce observed spawner arrivals. (This approach precludes simulating the effects of reservoir operations on upstream migration, although these effects could be added to the model if they appear important.)

The salmon IBM will be designed as a stand-alone tool that can be used for other study sites, salmonid species, and management issues. Our extensive experience with IBMs identifies the following principles that will guide this task.

1). Conceptual consistency. We developed a conceptual framework for IBMs that will guide this task (Railsback 2001). In particular, we carefully consider what parts of the model are represented mechanistically vs. empirically (i.e., whether processes in the IBM simply reproduce observed relationships, or emerge from models of the causal mechanisms).

2). Validation of key mechanisms. For models as complex as the salmon IBM, it is insufficient to "validate" a model by comparing predicted populations to observed populations. Instead, it is necessary to validate the model's ability to simulate important processes contained in it. We developed a procedure for validating IBM mechanisms (discussed below, **4. Feasibility**) and will apply it to the new mechanisms added to the model. In particular, we plan to test the model's ability to predict growth and mortality rates in various kinds of habitat, and when salmon fry leave their river habitat and migrate downstream. We plan field studies (Task 3) designed to support these tests.

3). Software quality and usability. Computer software engineering is much more important for IBMs than for other environmental models. First, graphical user interfaces are essential for observing the behavior of the individual model fish; without this ability, there is no way to verify that fish behavior is realistic. Our models are coded using the *Swarm* simulation system (www.swarm.org), which provides an animation window showing fish size and location on a map of the habitat. (An example interface is at Attachment 1.) With a mouse click, users can select individual habitat cells or fish and open a window showing their status. Second, software must be tested thoroughly because errors are often very difficult to detect. We developed a set of software engineering principles, including thorough, multi-level testing methods, for IBMs (Ropella et al. in press) that will be followed in this work. Finally, we fully document both the model formulation (its assumptions, equations, and input) and its software.

Task 3: Field work for input data and validation studies. (Lead investigator: B. Harvey.) This task supports objective O2. Experience leads us to plan a significant effort for assembling existing data and collecting site-specific information to apply and validate the salmon model. Some of this information is likely to be available from previous studies. Information availability is one of our criteria for selecting study sites, but we cannot assume that other studies will completely meet our information needs for two reasons. First, we do not want our choice of study sites to be completely limited by data availability considerations. Second, our experience has been that existing instream flow studies typically do not collect all the information we need, at the correct resolution for our model. Consequently, we assume that additional information will be collected even if other instream flow studies have been conducted.

Our project will require the following major kinds of site-specific information to be assembled from previous studies or collected under Task 3. (1) Habitat characteristics. We anticipate modeling two reaches of important spawning and fry rearing habitat in each of the two study rivers. At each reach, we will define rectangular habitat cells and collect data from each on the availability of spawning gravel and several cover variables. We typically model several hundred meters of stream length in each reach. (2) Hydraulic calibration data. We propose using a two-dimensional finite-element hydrodynamic model to simulate depth and velocity in each cell. We use the FESWMS modeling system. Especially for larger rivers, hydrodynamic models are more accurate and require less field effort than the alternative of using PHABSIM hydraulic models. This task includes hydraulic model calibration and use of a geographic information system to convert hydraulic simulation output to the spatial resolution of the fish model. (If available, we will instead use hydraulic simulations from other instream flow studies.) (3) Historic data on spawner abundance and such life history variables as timing of spawning and outmigration. (4) Simple, well-controlled field experiments to improve our knowledge of the processes by which reservoir flow releases and temperatures affect salmon.

The field experiments will be designed to validate the individual-based salmon model and be of general value to CALFED. One objective will be to verify our models of how fry growth and mortality risks vary with flow-dependent habitat variables like depth and velocity. A second objective will be to improve our understanding of how the time and size at which fry migrate downstream depends on growth rates and mortality risks (and, therefore, on flow). We will use field enclosure techniques that we have had previous success with. We can use net enclosures that fry can exit from but not enter, manipulate food supply and hiding cover among the enclosures, monitor fry growth and survival within the enclosures, and trap fry as they exit. We can then estimate how growth and mortality vary with habitat and food supply, and how downstream migration timing depends on growth and mortality risks. At a larger scale, we will compare size of fry that stay longer in the river to size of fry migrating downstream to help determine if early downstream migration is an innate behavior or a consequence of failing to find good river habitat.

Task 4: Performance evaluation of adaptive releases of environmental water. (Lead investigator: R. Lamberson.) This task will address objectives O3 and O4. Adaptive policies for releasing EW for in-river salmon production will be designed and evaluated in long-term simulations that test our basic study hypotheses H2 and H3. To make the analysis usefully realistic yet cost-effective, we propose conducting it in a simulated system of two reservoirs.

To realistically evaluate the benefits of EW releases, we must develop and simulate good policies for making EW purchase and release decisions. We assume the objective of these policies is to maximize the number and size of juvenile salmon produced by the river. (Normally, reservoir releases are designed to provide good tradeoffs among uses such as water supply, hydropower production, and downstream fisheries. However, in this study we evaluate management of water set aside for environmental purposes, so maximizing fish benefits is an appropriate objective.) The management decision variables are (1) how much EW should be obtained for each of the two rivers, and (2) how the available EW is released over time (i.e., how much flow is released each month). This task will be conducted in the following stages.

1). Using the salmon IBM, simulate a variety of scenarios to develop an understanding of how EW benefits to fish vary with such factors as salmon population status (e.g., years of high vs. low spawner abundance), reservoir status (e.g., high vs. low inflow and instream releases), and the volume of available EW. This sensitivity analysis will be the first product of this task.

2). Develop a policy for adaptive management of EW releases. This policy will be designed so it could be applied to the actual Central Valley storage system, but our simulation experiments will apply the policy to our reservoir models and the salmon IBM as a simulated water system and fishery. Following conventional approaches for feedback-and-control operation of complex systems, the EW release policy will include the following four elements.

Fish population monitoring will be simulated by reporting the population status from the simulated fishery. Selecting the type of monitoring data used as feedback can be a critical part of adaptive management program design (Williams 1999). Initially, we will assume there is no uncertainty in fish population monitoring. While this assumption is unrealistic, it allows us to determine the limit of how successful the EW policy can be with the best monitoring data. In final analyses, we will examine the effects of monitoring uncertainty on adaptive management performance. Monitoring uncertainty will be simulated by treating the simulated fishery as a “virtual ecosystem” and modeling the process of collecting data from this ecosystem. Grimm et al. (1999) recognized this ability to simulate the sampling process as an important advantage of IBMs. We can, for example, specify the locations and dates on which data on fish are drawn from the IBM and used as adaptive management feedback. We can simulate processes that bias monitoring data, e. g., the use of size-selective sampling gear.

The forecasting model used by the adaptive management program will be selected from approaches in the adaptive management literature. The forecasting model will be a typical real-world management model in which many important characteristics of the "real" fish population are unknown. The purpose of the forecasting model is to predict the effect of future reservoir releases on the fish population, so the releases with best expected outcomes can be identified. For our system the management variables are the monthly reservoir flow releases, so the forecasting model must predict fish population response to flow releases. We will initially test linear or polynomial statistical models (e.g., Ham and Pearsons 2000, Carpenter et al. 1999) with parameter values initially estimated from the sensitivity analysis in Stage 1. The forecasting model may include both fishery variables (e.g., number of spawners) and reservoir variables (e.g., expected future monthly flow releases and temperatures).

The control algorithm determines how EW assets are allocated between the two rivers and adjusted over time, to maximize fishery benefits. The control algorithm is an optimization problem, and will be designed to represent the actual decision as realistically as feasible while still allowing the optimization to be solved. Algorithm inputs include the EW available for release and, from the forecasting model, the expected fishery benefits of alternative release rates.

Forecasting model parameter updating methods will be developed from the adaptive management literature. This step improves the forecasting model over time by replacing its parameters with new values derived from fishery monitoring data. Bayesian updating techniques (Pole et al. 1994, Carpenter et al. 1999) are especially promising.

3). Conduct simulation experiments to evaluate the benefits of EW releases to juvenile salmon production. The EM release policy will be linked to the reservoir models to simulate how EW releases are made over a long (e.g., 20 year) time period. The reservoir releases will be used as input to the salmon IBM, which will simulate the resulting fish population status. Output from the simulated fishery will serve as "monitoring" data to drive the EW release policy. This feedback-and-control cycle will occur once per year: we assume that EW acquisition and allocation decision (how much water to make available per river) is made annually. Similar long-term simulations will be made assuming no use of EW.

The performance of EW releases will be evaluated by contrasting the simulated production of salmon from simulations with and without EW releases. We will determine whether the EW policy produces increases in salmon production that are significant from both statistical and management perspectives. Finally, we will compare the predicted benefits of EW releases for in-river enhancement to the benefits of using EW to reduce pump mortality in the Delta, as estimated by other investigators (e.g., Brown and Kimmerer 2001).

Task 5: Project management. (Responsible investigator: S. Railsback.) This task will include tracking work progress and budgets, coordinating the other tasks to avoid delays in critical-path work, preparing progress reports, and coordinating preparation of such products as journal publications, reports, presentations to CALFED meetings, and web pages. The project manager will also be the point of contact with the CALFED program and the agencies with which we coordinate our research. Task 5 includes the public outreach plan described below.

4. Feasibility

The feasibility of tasks 1, 3, 4, and 5 is not expected to be an issue. The reservoir and temperature modeling in Task 1 will use methods and models that are widely used and well validated. Field studies to collect input data and validation information (Task 3) will use approaches that have been successful previously. The design of adaptive EW release policies in

Task 4 will be innovative, but several preceding studies (cited above) provide approaches that are clearly applicable with modification.

The feasibility of the proposed individual-based fish modeling in Task 2 is more likely to be a concern to reviewers, although our experience with salmonid IBMs gives us confidence that our approach will be successful and appropriate. Complex *population-level* models of the many processes by which reservoir operations affect salmonids do not have a good track record. A recent review of such a model for Columbia River salmon was highly critical, focusing on the problem that population data of adequate quantity and quality to parameterize and validate the model will never be available (Paine et al. 2001). However, this criticism does not apply to the IBMs we will use because our IBMs are built at the *individual level*, using the extensive literature on salmonid physiology and behavior to parameterize and validate each separate individual-level process. Our approach avoids the field-data demands of population-level models because individual-level parameters are developed from the literature on each process included in the model, not fit via calibration to population-level data.

IBMs have many potential advantages, the primary ones being their ability to predict the population-level consequences of individual traits and a wide variety of spatially explicit environmental conditions, and their easy accommodation of individual variability and nonlinearities (Huston et al. 1988). Another key advantage of IBMs is that the responses of *individual animals* to environmental conditions (e.g., how growth rates vary with food availability, temperature, velocity, etc.) are easy to measure in the laboratory, whereas such responses are very difficult to measure at the *population* scale used in aggregated models. IBMs allow us to build simple models of how important environmental and biological processes affect individuals, then simulate the population-level consequences of these processes.

Although a number of IBMs have been applied to fisheries management research, this approach also lacks a long record of success. Our research team and collaborators have identified and remedied many of the problems that previously limited the usefulness of IBMs (for more information, see our web site http://math.humboldt.edu/~simsys/). Reasons why IBM-based research has been less valuable than expected include the lack of a conceptual foundation for individual-based ecology, software limitations, and the failure to validate IBMs by showing that modeled traits of individuals produce realistic population-level responses (Grimm 1999, Grimm et al. 1999, Railsback 2001). Our progress in making IBMs practical and useful for fisheries management includes the following developments.

- *A conceptual approach for designing IBMs* was developed from the new science of Complex Adaptive Systems (Railsback 2001).
- *A family of approaches for modeling how individuals make important behavioral decisions* was developed, applied to the critical issue of how fish select habitat (Railsback et al. 1999), and validated against observed habitat selection behaviors (Railsback and Harvey, in press).
- *An approach for validating IBMs* was developed. Under our "pattern-oriented" validation process (Railsback, in press), we can test our representation of a specific mechanism in the IBM (e.g., how fish select their habitat or decide when to migrate). We identify (from literature and field studies) patterns of behavior by individual fish, or by the fish population, that result from the mechanism being validated. We then conduct simulations under which these patterns are expected to emerge in the model. Examining a wide range of patterns

provides assurance that the mechanism is modeled realistically. For example, we showed that our model reproduces six patterns of how salmonids have been observed to shift their habitat in response to factors like flood flows, competition, predation risks, temperature changes, and reduces food availability (Railsback and Harvey in press).

- *Software and software practices for fish IBMs* have been developed. We developed comprehensive software engineering practices for IBMs (Ropella et al. in press) and a library of tested, reusable code for fish IBMs. Our software provides extensive graphical interfaces, and capabilities such as (1) automated generation and execution of model runs for sensitivity analyses, (2) running multiple river reach models in one linked simulation, and (3) modeling a variable number of species or salmon races, with separate parameter sets for each.
- *A river salmonid IBM has been developed, tested, and used to analyze management issues*. This model (the basis for our proposed salmon model) simulates the full life cycle of resident trout at a daily time step, with river flow, temperature, turbidity, and food production as external driving variables (Railsback and Harvey 2001). Population-level validation studies (Railsback et al. in press) have shown this IBM to reproduce observed patterns in (1) interannual variability in abundance due mainly to flow effects on incubating eggs, (2) the scaling relationship between biomass and abundance among age classes, (3) duration of the critical period of high density-dependent mortality in newly hatched juveniles, (4) density-dependence in fry growth, and (5) effects of habitat structure (pool availability) on population age structure. These validation studies give us confidence that our IBM can represent a variety of mechanisms by which river flows and temperatures affect salmon populations. We have used the model to explore how reservoir flow releases affect population abundance, production, and persistence (EPRI 2000). Another experiment (Hicks et al. in prep.) used the model to predict effects of turbidity on population dynamics. These experiments have shown our trout model to consistently predict realistic, complex population responses to river management variables.
- *Publications and products* (in addition to those cited above) include (1) a special symposium on IBMs we presented at the Ecological Society of America's 2000 annual meeting, (2) a forthcoming book produced from the ESA symposium, and (3) our web site, which is often used by ecological modelers and instructors.

Our project requires no landowner permissions, with the possible exception of permission to conduct field studies at sites yet to be selected. We anticipate needing a Scientific Collecting Permit and NMFS ESA Section 10 Permit; investigator Harvey currently holds these permits for other projects. While our project is expected to use information from previous studies, none of it is dependent on work or events beyond our control.

5. Performance Measures and Evaluation Plan

Per Attachment G of the CALFED PSP, appropriate performance measures for research projects include publications, presentations, reports, etc. We propose the following performance measures, which are targets for completing research products by a specific date. Performance measures are identified by project objective; each objective directly supports the project goals.

Objective	Performance Measures
(O1) Adapt reservoir models that predict release flows and temperatures under alternative EW flow release policies.	Product: Letter report documenting selection of study sites, following review of available information and consultation with relevant agencies. Target T1: Complete 6 months after project start. Product: Model of study sites' reservoirs that predicts the release flows and temperatures resulting from EW management policies, with documentation report. T2: Complete 1 year after project start.
(O2) Adapt and validate a realistic model of how reservoir release flows and temperatures affect salmon spawning, egg incubation, fry growth and survival, and long-term population dynamics. Develop this model as a tool for evaluating in-river benefits of EW releases.	Product: Draft individual-based salmon population model, adapted from our existing trout model, with complete software and documentation. T3: Complete 1 year after project start. Product: Final salmon simulator, following validation and peer review. Field studies and literature will be used to validate the simulator's ability to reproduce important processes by which reservoir operations affect salmon. T4: Complete 1½ years after project start. Product: Journal article documenting field studies and their application to validation of salmon simulator. T5: Submit 3 years after project start.
(O3) Develop good policies for adaptive management of EW releases for in-river fry production. These policies specify when and where to release how much of the available EW, to maximize its benefits.	Product: Report or presentation documenting development of alternative EW management policies. T6: Complete 1½ years after project start.
(O4) Simulate how the adaptive EW policies affect salmon fry production and long-term population trends. Compare the benefits to long-term salmon production of using EW for (a) enhancing in-river fry production vs. (b) reducing Delta pump entrainment.	Product: Report documenting sensitivity simulations analyzing how salmon population benefits of EW releases vary with salmon abundance, reservoir status, and EW volume. T7: Complete 2 years after project start. Product: Complete system for long-term simulation of EW release policies, reservoir releases, and salmon populations. T7: Complete 2½ years after project start. Product: Journal article with final results: simulated population benefits of in-river use of EW and comparison to Delta use of EW. T8: Submitted 3 years after project start.

6. Data Handling and Storage

We do not propose collecting monitoring data, so a significant data handling effort is not anticipated. Field data we collect (e.g., site-specific hydraulic model input) will be handled and stored using such conventional quality assurance measures as verifying data entry, maintaining multiple archives of data and associated metadata, and database version control. We will submit any appropriate data to a public data system such as the Information Center for the Environment at University of California, Davis.

7. Expected Products and Outcomes

The specific products we propose are listed in our Performance Measures table (above). These include working models with computer code and documentation, journal publications, and reports or presentations. We also expect to make presentations at CALFED science conferences or related meetings. We will transfer our models to other researchers or agencies interested in using them.

The salmon IBM developed in Task 2 will have many potential CALFED applications in addition to this study. Because the IBM simulates how changes in microhabitat affect fry production and long-term population dynamics, it will be useful for evaluating the effects on salmon production of changes in channel geomorphology due to restoring flood flows, gravel augmentation, habitat enhancement projects, and restoration of gravel mines. The model will also be an advanced instream flow assessment tool, simulating the cumulative effects of changes in flow and other factors such as temperature, turbidity, and food production (EPRI 2000). Likewise, the model is suitable for predicting the cumulative effects of climate changes that affect the magnitude and timing of flow as well as water temperature.

The field studies we propose to support model validation will also have secondary benefits, by improving our mechanistic understanding of how reservoir operations affect salmon. We will improve our knowledge of how river flow, and flow variation, affects fry growth and survival; and how growth and survival affects the size and time at which fry migrate downstream.

Although this study is focused on salmonids (to take advantage of our existing salmonid models), similar methods and models can be applied to other native fish in future work. Under separate funding, we are currently developing a pikeminnow IBM that could be adapted to represent warmwater species inhabiting the Delta and Central Valley rivers.

8. Work Schedule

Task milestones. We plan the following milestones for each task. Milestones are in months after project start; these could be used as payment milestones. A timeline of these milestones is at Attachment 2.

Task 1 (reservoir modeling). Task start: 0 mo. Milestone 1-A Site selection: 6 mo. 1-B Working reservoir model: 12 mo. 1-C Code management policies into reservoir model: 18 mo. Model revisions (1-D) and publication (1-E) continue until task end: 30 mo.

Task 2 (fish modeling). Task start: 0 mo. 2-A Draft simulator with documentation: 12 mo. 2-B Peer review, validation, and complete simulator: 18 mo. Model revisions (2-C) and publication (2-D) continue until task end: 30 mo.

Task 3 (field work). Task start: 0 mo. 3-A Collection of habitat input: 12 mo. 3-B Completion of validation experiment field work: 30 mo. 3-C Submittal of journal article on results: 36 mo.

Task 4 (evaluation of EW release policies). Task start: 0 mo. 4-A Draft design of adaptive management policies: 12 mo. 4-B Agency review of policies: 18 mo. 4-C Report on sensitivity simulations: 24 mo. 4-D Completion of policy simulations: 30 mo. 4-E Submittal of journal article on conclusions: 36 mo.

Task 5 (project management). Task start: 0 mo. 5-A Progress reporting for first year: 13 mo. 5-B Progress reporting for second year: 25 mo. 5-C Final progress report: 36 mo.

Inseparable tasks and incremental funding. Tasks 1, 2, 3, and 4 will be relatively independent during the first year, but tasks 1-3 must be completed before task 4 can be completed and the project's goals met. If only part of the project can be funded, we recommend funding tasks 2, 3, and 5 for two years. This partial funding would allow us to build and validate the fish population model that could later be used to analyze water management policies (and for many other CALFED fishery management issues).

B. Applicability to Program Goals

1. ERP, Science Program and CVPIA Priorities

Draft Stage 1 PSP priorities. The most applicable PSP priorities are SR-3 and SJ-6, which are identical: *Conduct adaptive management experiments in regard to natural and modified flow regimes to promote ecosystem functions or otherwise support restoration actions*. Elements of these PSP priorities that our project will support are: Developing stream flow management plans for water acquisitions, and developing mechanistic models as restoration tools. The models we develop can also be applied to:

- *MR-4: Ensure restoration and water management actions through all regions can be sustained under future climatic conditions.* The methods we develop could be used to analyze the effectiveness of flow management policies in the presence of climatic trends.
- *SR-7: Develop conceptual models to support restoration of river, stream and riparian habitat.* We will develop and test adaptive EW management concepts. Our study will also develop IBMs as performance measures for restoration efforts like flow releases and channel restoration projects. Costs, uncertainties, and lag times often make it very difficult to evaluate the effectiveness of restoration actions via field monitoring; simulation of restoration effects in an IBM is a potentially valuable alternative performance measure.

Science Program Priorities. The ERP Draft Stage 1 Implementation Plan includes a number of Science Program priorities that our project would address:

- *Develop performance measures*. Our study will evaluate the performance of EW releases for in-river fry production.
- *Compare relative effectiveness of different restoration strategies* and *Conduct adaptive management experiments*. Our project will compare the effectiveness of alternative uses of water set aside for environmental purposes.
- *Build population models for at-risk species*. Our salmon population simulator will be innovative and useful for many CALFED issues.
- *Advance process understanding*. Our development and validation of a mechanistic salmon model will advance scientific understanding of the processes by which reservoir releases affect salmon, and provide a framework for testing theories of how such processes work.

2. Relationship to other ERP Projects

This project is not directly linked to other ERP projects. Our reviews of existing projects and discussions with CALFED science panel members indicates that no other ERP projects have objectives substantially similar to ours. In 1998-2000, the US Fish and Wildlife Service funded development of an IBM for Sacramento River chinook (J&S 1999); some members of our team participated in this USFWS project. The USFWS project was developing a new, broad-scale IBM of all four chinook races throughout the Sacramento basin, and was not focused on any one management issue. In contrast, this proposal is focused on realistic analysis of EW management, and adapts an existing, validated, high-resolution IBM. One current ERP project (conducted by Essa Technologies) is developing adaptive reservoir management policies for Clear Creek. While this Clear Creek project may produce concepts beneficial to our project, it addresses a substantially different objective—multi-objective management of reservoir operations for one river—whereas our project addresses allocation of EW among multiple sites for the single objective of enhancing salmon production.

4. Previous CALFED Program or CVPIA Funding

No members of our team have previously received CALFED or CVPIA funding.

5. System-wide Ecosystem Benefits

As discussed above (**Expected Products and Outcomes**; **ERP, Science Program and CVPIA Priorities**), our project will have benefits for a number of issues throughout the CALFED system: our methods and conclusions will be transferable to many Central Valley tributary reservoir systems, and our models will be useful for addressing other important issues.

C. Qualifications

This proposal is submitted by an interdisciplinary team recognized as leaders in simulation analysis of complex natural systems, especially using IBMs for fisheries. On this topic we have recently published a number of papers, presented a symposium at the 2000 annual meeting of the Ecological Society of America, prepared a special issue of the journal *Natural Resource Modeling*, hosted several international scholars, and developed software tools. Resumes are at Attachment 3; more information is at http://math.humboldt.edu/~simsys/.

Elizabeth Eschenbach (Humboldt State University Department of Environmental Resource Engineering) is active in development and application of models that simulate how water project management policies translate into project operations and habitat for downstream fisheries. She helped develop the *Riverware* system for simulating and optimizing water project management policies, and now teaches water resource management engineering.

Bret Harvey (US Forest Service and HSU Department of Fisheries) has conducted and published a number of controlled, mechanism-oriented field studies of salmonids, many of which are designed for validation of IBMs. He has taught a number of university classes in fish ecology, experimental design, and statistical analysis.

Roland Lamberson (HSU Department of Mathematics) is director of HSU's Environmental Systems graduate program and teaches classes in ecological modeling. He has published a number of studies applying IBMs and other models to ecological management issues, and currently is editor of the journal *Natural Resource Modeling*.

Steve Railsback (consulting scientist and HSU Department of Mathematics) is a water resource engineer with 20 years experience in instream flow management, including 10 years using individual-based fish models. Recent publications address theoretical, validation, and software aspects of IBMs. He managed (as a contractor, 1992-1999) PG&E's environmental research program for hydropower.

None of the proposed team has a potential conflict of interest that could affect this work. We will ensure that the project is completed cost-effectively and on time in these ways: (1) Two of the lead investigators (Eschenbach, Lamberson) are professors with teaching obligations; however, both are committed to using sabbatical and buy-out time to work on the project. (2) Two investigators (Harvey, Railsback) are full-time researchers; Railsback (responsible for fish modeling and project management) has reserved 50% of full time for this project. (3) We use an experienced programmer (S. Jackson) to do the software development. (4) We have identified a talented post-doctoral water resource engineer (A. Dodd) to work full time on the project. (5) Field studies will be conducted by graduate students working with experienced technicians.

D. Cost

The total proposed budget, over three years, is $1,225,000 (state funding) or $1,409,000 (federal funding). We propose no cost sharing funds. Investigator Harvey's salary will be paid by the US Forest Service, and Humboldt State University will pay the salary of investigators Eschenbach and Lamberson during their sabbatical time dedicated to the project.

E. Local Involvement

In developing this proposal we consulted with the following people involved in managing CALFED and CVPIA environmental water: David Fullerton (Natural Heritage Institute staff for ERP), Bruce Herbold (US EPA; chair, EWA Science Panel), Wim Kimmerer (EWA Science Advisor), and Craig Stevens (Jones & Stokes Assoc. staff for ERP). Each of these people confirmed the need to investigate and evaluate the potential benefits of using EW for in-river salmon enhancement in contrast to using EW to manage mortality at the Delta pumps.

Because our project will primarily use simulation research at sites not yet selected, we did not consult extensively with local governments or organizations prior to submitting the proposal. Our public outreach plan (part of Task 5) includes the following steps.

1). Study site selection in consultation with agency staff responsible for managing EWA, ERP, and b2 water; and reservoir owners/operators, scientists and consultants, and citizen stakeholder groups associated with candidate study rivers. These consultations will inform local agencies and stakeholders of project objectives, identify opportunities to collaborate beneficially with other activities, and avoid any conflicts.

2). Review meetings to coordinate study methods and models with agencies responsible for EW and fishery management, and local stakeholders. These reviews will provide quality control for the research, develop a constituency for our products among the agencies, and provide continuing coordination with other studies and activities. We anticipate three such meetings, possibly coordinated with the CALFED science conferences.

3). Review of study results by agencies and stakeholders before results and conclusions are finalized.

4). Maintaining a web site where project status and products are available.

F. Compliance with Standard Terms and Conditions

The HSU Foundation can comply with the standard State or Federal contract terms. However, there are four contract clauses we prefer to re-word; these are at Attachment 4.

G. Literature Cited

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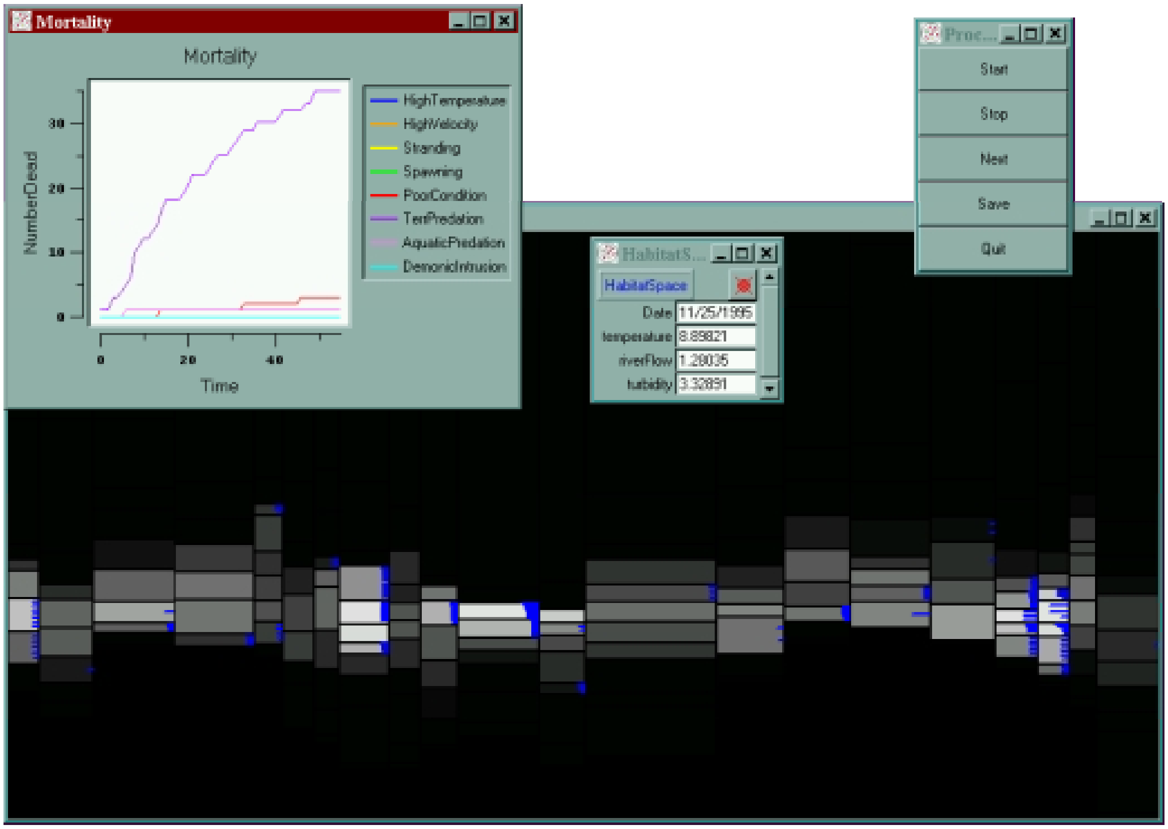
Attachment 1. Graphical Interface for the Humboldt State Individual-based Salmonid Models



Date 11/25/1995
temperature 8.89821
riverFlow 1.28035
turbidity 3.32891

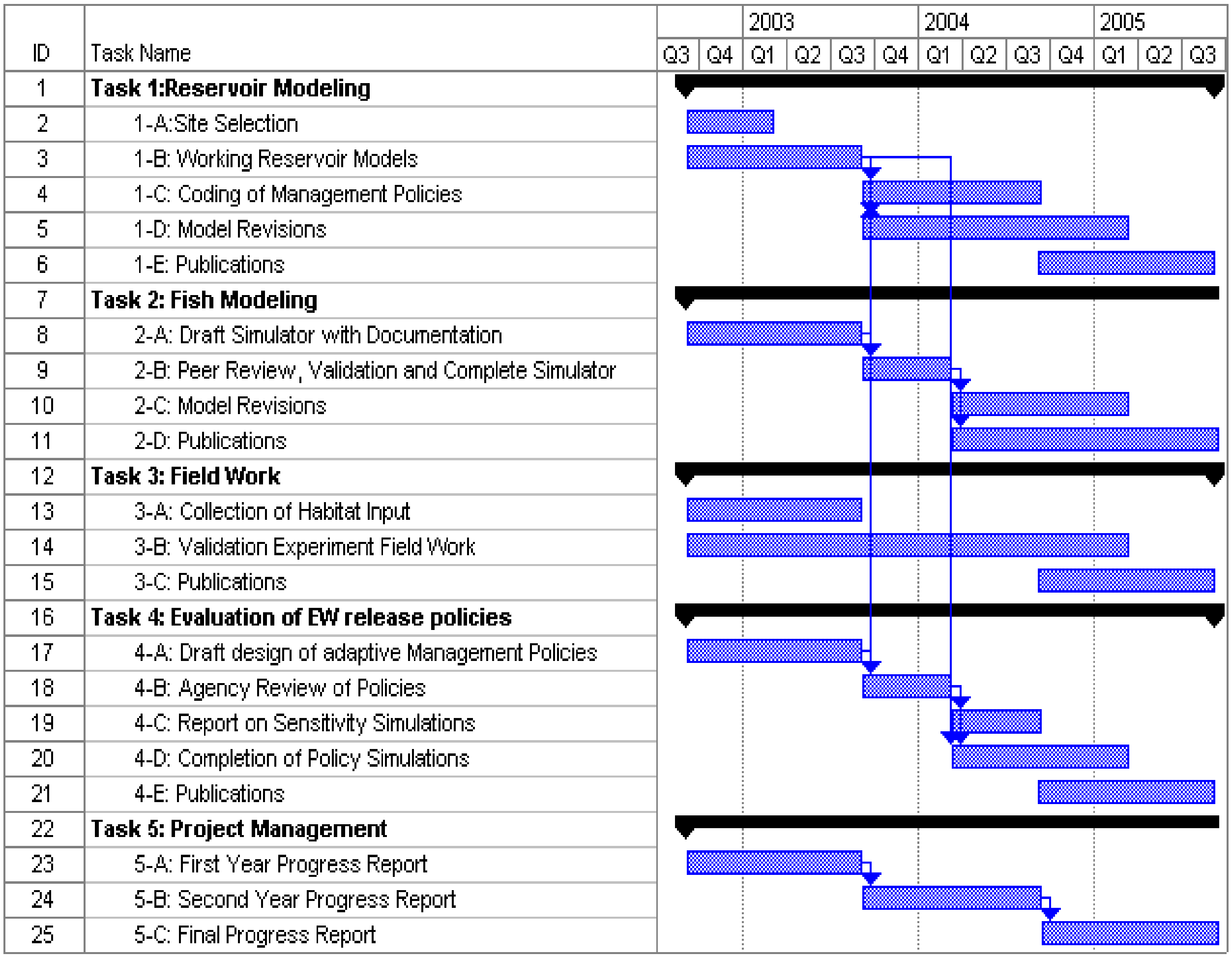
The large animation window is a plan view (from the top looking down) of the modeled river reach. Habitat is depicted as rectangular cells, shaded by depth or velocity (in this case, lighter-shaded cells are deeper). Flow is from right to left. Model fish are depicted as blue line segments on the right (upstream) side of their cell; segment length is proportional to fish size. The mortality graph shows how many fish have died of what causes during the simulation. The control panel allows users to pause and re-start the model run, or execute the model one time step at a time.

Not shown in this figure are “probes”. A mouse click on a habitat cell opens a window displaying current cell variables (cell depth, velocity, etc.). The right mouse button opens a window to each of the fish in a cell, displaying their current status (e.g., species, age, length, weight). Right mouse button clicks also open probes to redds, displaying their development status, number of live eggs, etc. (No redds are shown on this figure; they appear as ovals on the left side of a cell.)

This interface is updated continuously as the model executes, allowing users to observe and understand how fish respond to changes in flow and other variables.

Attachment 2

Project Timeline



ID	Task Name
1	**Task 1:Reservoir Modeling**
2	1-A:Site Selection
3	1-B: Working Reservoir Models
4	1-C: Coding of Management Policies
5	1-D: Model Revisions
6	1-E: Publications
7	**Task 2: Fish Modeling**
8	2-A: Draft Simulator with Documentation
9	2-B: Peer Review, Validation and Complete Simulator
10	2-C: Model Revisions
11	2-D: Publications
12	**Task 3: Field Work**
13	3-A: Collection of Habitat Input
14	3-B: Validation Experiment Field Work
15	3-C: Publications
16	**Task 4: Evaluation of EW release policies**
17	4-A: Draft design of adaptive Management Policies
18	4-B: Agency Review of Policies
19	4-C: Report on Sensitivity Simulations
20	4-D: Completion of Policy Simulations
21	4-E: Publications
22	**Task 5: Project Management**
23	5-A: First Year Progress Report
24	5-B: Second Year Progress Report
25	5-C: Final Progress Report

Attachment 3

Investigator Resumes

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PROFESSIONAL PREPARATION:

Institution	**Major/Area**	**Degree**	**Dates**
University of California Santa Cruz	Mathematics and Psychology with Honors in Mathematics	BA	1985
Cornell University	Environmental Systems Engineering	MS	1991
Cornell University	Environmental Systems Engineering	Ph.D.	1994
University of Colorado Boulder	Object Oriented Water Resources Optimization Model Development	Post–Doc	2/94-1/95

APPOINTMENTS:

2001 - Present	Associate Professor, Environmental Resources Engineering, Humboldt State University Arcata, CA
1995 - 2001	Assistant Professor, Environmental Resources Engineering, Humboldt State University Arcata, CA
1986 - 1987	Professional Research Assistant, Systems Ecology Research Group San Diego State University, San Diego, CA

PUBLICATIONS RELATED TO PROPOSED PROJECT:

Eschenbach, E. A., T. Magee, E. Zagona, M. Goranflo and R. Shane. Multiobjective Daily Operations Of Reservoir Systems Via Goal Programming. *American Society of Civil Engineers Journal of Water Resources Planning and Management.* Vol. 127, No. 2 pages 108-121.

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Bret C. Harvey

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PROFESSIONAL PREPARATION:

Institution	**Major/Area**	**Degree**	**Dates**
University of California, San Diego	Biology	------	9/76-12/77
University of California, Davis	Wildlife and Fisheries Biology	B.S.	1/78-6/80
University of California, Davis	Ecology	M.S.	9/80-6/82
University of Oklahoma	Zoology	Ph.D.	6/83-5/87
Oak Ridge National Laboratory	Stream Ecology	post - doc	6/87-8/88

APPOINTMENTS:

1993 - present	Research Fish Biologist, U.S. Forest Service, Redwood Sciences Laboratory, Arcata, CA
1993 - present	Adjunct Professor of Fisheries, Humboldt State University, Arcata, CA
1988 – 1993	Assistant/Associate Professor, Department of Zoology, Weber State University, Ogden, UT

PUBLICATIONS RELATED TO PROPOSED PROJECT:

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Professional Preparation:

Hastings College	Physics	A.B.	1963
University of Wyoming	Physics	M.S.	1965
U. of Northern Colorado	Mathematics	Dr. of Arts	1974

Appointments:

1980-Present	Prof. of Mathematics Dir., Environ. Systems Grad. Prog.	Humboldt State Univ
1974-80	Chair, Math Dept.	Des Moines Area Com. College
1967-74	Assist. Prof. of Math	Hastings College
1965-67	Physics Instructor	Minot State College

Visiting Prof: Visiting Professor (Fish & Wildlife Biology) Colorado State University 1998-99; University of Natal, South Africa 1993; Univ. of British Columbia 1979-80 and 1987; Univ. of Victoria 1986; University of Montana 1984; University of Perugia, Italy 1982.

Publications Related To This Proposal:

Lamberson, R.H., 2002, What Does It Take to Make Individual-based Models Realize Their Potential?, to appear in *Natural Resource Modeling*, vol. 15 # 1.

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APPOINTMENTS:

Present	Department of Mathematics, Humboldt State University, Faculty Associate
1992-present	Lang, Railsback & Assoc., Consulting Research Scientist
1986-1992	Environmental Sciences Division, Oak Ridge National Laboratory, Research Associate

PUBLICATIONS RELATED TO PROPOSAL:

Railsback, S. F., and B. C. Harvey. Analysis of habitat selection rules using an individual-based model. In press, *Ecology*.

Railsback, S. F. Getting "results": the pattern-oriented approach to analyzing natural systems with individual-based models. In press, *Natural Resource Modeling*.

Railsback, S. F., B. C. Harvey, R. R. Lamberson, D. E. Lee, N. J. Claasen and S. Yoshihara. Population-level analysis and validation of an individual-based cutthroat trout model. In press, *Natural Resource Modeling*.

Ropella, G. E. P., S. F. Railsback, and S. K. Jackson. Software engineering considerations for individual-based models. In press, *Natural Resource Modeling*.

Railsback, S. F. Concepts from Complex Adaptive Systems as a framework for individual-based modelling. *Ecological Modelling* 139: 47-62, 2001.

EPRI. Instream flow assessment methods: guidance for evaluating instream flow needs in hydropower licensing. Prepared by S. F. Railsback for the Electric Power Research Institute. EPRI report 1000554, December, 2000.

EPRI. Tools for individual-based stream fish models. Prepared by S. F. Railsback for the Electric Power Research Institute. EPRI TR-114006, December, 1999.

Railsback, S. F., R. H. Lamberson, B. C. Harvey, and W. E. Duffy. Movement rules for spatially explicit individual-based models of stream fish. *Ecological Modelling* 123: 73-89, 1999.

Railsback, S. F., and K. A. Rose. Bioenergetics modeling of stream trout growth: temperature and food consumption effects. *Transactions of the American Fisheries Society* 128: 241-256, 1999.

Railsback, S. F. Reducing uncertainties in instream flow studies. *Fisheries* 24 (4): 24-26, 1999.

Van Winkle, W., H. I. Jager, S. F. Railsback, B. D. Holcomb, T. K. Studley, and J. E. Baldrige. Individual-based model of sympatric populations of brown and rainbow trout for instream flow assessment: model description and calibration. *Ecological Modelling* 110: 175-207, 1998.

Railsback, S. F., R. F. Blackett, and N. D. Pottinger. Evaluation of the fisheries impact assessment and monitoring program for the Terror Lake Hydroelectric Project. *Rivers* 4: 312-327, 1993.

Chang, L. H., S. F. Railsback, and R. T. Brown. Use of a reservoir water quality model to simulate global climate change effects on fish habitat. *Climatic Change* 20: 277-296, 1992.

Attachment 4

Desired Changes in Terms and Conditions

I. State Funds

Clause 4. Expenditure of Funds & Allocation Among Budget Items: We recommend changing this clause to allow small variances in budget among tasks without written approval. Our contracts commonly allow, for example, budgets for tasks or line items to vary up to 10% without approval. This change would avoid unnecessary paperwork and delays.

Clause 11. Indemnification: We desire to revise this clause to reduce the extent to which Grantees appear liable for factors beyond their control.

Clause 13. Termination Clause: We desire to revise the last sentence of this clause. As written, it puts the Grantee at risk of paying for terminated work that could be conducted by the State or NFWF in an excessively expensive manner.

II. Federal Funds

Resolving Disagreements. Paragraph c of this clause gives the Regional Director power to make final and conclusive dispute resolution. Instead, we would refer disputes to mediation and arbitration.