DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

Project Information

1. **Proposal Title:**

   DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

2. **Proposal applicants:**

   Geoffrey Schladow, University of California, Davis
   Gary Brunner, Hydrologic Engineering Center, USACOE

3. **Corresponding Contact Person:**

   Ahmed Hakim Elahi
   Regents of the University of California
   Office of Research 118 Everson Hall One Shields Ave Davis CA 95616
   530 752 2075
   vcresearch@ucdavis.edu

4. **Project Keywords:**

   Modeling
   Sediment Generation, Movement, and Accumulation
   Water and Sediment Quality

5. **Type of project:**

   Research

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

   No

7. **Topic Area**:

   Channel Dynamics and Sediment Transport

8. **Type of applicant:**

   University

9. **Location - GIS coordinates:**

Latitude: 38.556

Longitude: -121.738

Datum:

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

The project is for the development of a hydraulic, sediment transport and water quality model that may be used throughout the ERP Geographic Scope

10. **Location - Ecozone:**

3.1 Keswick Dam to Red Bluff Diversion Dam, 3.2 Red Bluff Diversion Dam to Chico Landing, 3.3 Chico Landing to Colusa, 3.4 Colusa to Verona, 3.5 Verona to Sacramento, 4.1 Clear Creek, 4.2 Cow Creek, 4.3 Bear Creek, 4.4 Battle Creek, 5.1 Upper Cottonwood Creek, 5.2 Lower Cottonwood Creek, 6.1 Stony Creek, 6.2 Elder Creek, 6.3 Thomas Creek, 6.4 Colusa Basin, 7.1 Paynes Creek, 7.2 Antelope Creek, 7.3 Mill Creek, 7.4 Deer Creek, 7.5 Big Chico Creek, 7.6 Butte Creek, 7.7 Butte Sink, 8.1 Feather River, 8.2 Yuba River, 8.3 Bear River and Honcut Creek, 8.4 Sutter Bypass, 9.1 American Basin, 9.2 Lower American River, 10.1 Cache Creek, 10.2 Putah Creek, 10.3 Solano, 10.4 Willow Slough, 12.1 Vernalis to Merced River, 12.2 Merced River to Mendota Pool, 12.3 Mendota Pool to Gravelly Ford, 12.4 Gravelly Ford to Friant Dam, 13.1 Stanislaus River, 13.2 Tuolumne River, 13.3 Merced River, West San Joaquin Basin, 1.1 North Delta, 1.2 East Delta, 1.3 South Delta, 1.4 Central and West Delta, 11.1 Cosumnes River, 11.2 Mokelumne River, 11.3 Calaveras River, 2.2 Napa River, 2.3 Sonoma Creek, 2.4 Petaluma River

11. **Location - County:**

Alameda, Alpine, Amador, Butte, Calaveras, Colusa, Contra Costa, Del Norte, El Dorado, Fresno, Glenn, Humboldt, Imperial, Inyo, Kern, Kings, Lake, Lassen, Los Angeles, Madera, Marin, Mariposa, Mendocino, Merced, Modoc, Mono, Monterey, Napa, Nevada, Orange, Placer, Plumas, Riverside, Sacramento, San Benito, San Bernardino, San Diego, San Joaquin, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Shasta, Sierra, Siskiyou, Solano, Sonoma, Stanislaus, Sutter, Tehama, Trinity, Tulare, Tuolumne, Ventura, Yolo, 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:**

3rd

15. **Location:**

    California State Senate District Number: 4

    California Assembly District Number: 8

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:	10
Total State Funds:	764,275
Federal Overhead Rate:	48.5
Total Federal Funds:	820,591

    b) Do you have cost share partners already identified?

       Yes

       If yes, list partners and amount contributed by each:

       HEC USACOE 450,000

    c) Do you have potential cost share partners?

       No

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

       No

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

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

    No

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

Yes

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

99-B193	**McCormack Williamson Tract Planning, Design and Monitoring Program**	**Ecosystem Restoration Program**

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)

Prof. Camilla Saviz	**University of the Pacific, Stockton**	**209 946 3077**	**csaviz@uop.edu**

Tara Smith	**DWR**	**916 654 9885**	**tara@water.ca.gov**

Stephen Monismith	**Stanford University**	**650 723 4764**	**monismit@cive.stanford.edu**

Dave Clark	**HDR Engineering**	**dclark@hdrinc.com**

21. **Comments:**

Environmental Compliance Checklist

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

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

      No

   b) Will this project require compliance with NEPA?

      No

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

      This proposal is purely for model development. No data collection, monitoring or any type of field activity is envisaged.

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

   CEQA Lead Agency:
   NEPA Lead Agency (or co-lead:)
   NEPA Co-Lead Agency (if applicable):

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

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

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

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

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

      Not Applicable

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

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

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

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

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.
Landowner Name:

6. **Comments.**

Land Use Checklist

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

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

   No

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

   No

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

   No

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

   Model development and research

4. **Comments.**

Conflict of Interest Checklist

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

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):

Geoffrey Schladow, University of California, Davis
Gary Brunner, Hydrologic Engineering Center, USACOE

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

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

David Schoellhamer	USGS
Gary Brunner	USACOE

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

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

William Fleenor UC Davis

Chris Hammersmarck UC Davis

Mark Jensen HEC USACOE

Comments:

Budget Summary

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

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.

Federal 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	Hydraulic model testing of HEC-RAS versus others	168	5513	1378	0	389	18000	9000	0	34280.0	12218	46498.00
2	Review of water quality and transport models.	630	9553	411	0	389	3000	0	2296	15649.0	6454	22103.00
3	Programming of temperature model.	798	15065	1789	0	389	0	0	2296	19539.0	8334	27873.00
4	Collection of data set for model input.	630	9553	411	0	0	0	0	2296	12260.0	4816	17076.00
5	Design of the graphical user interface for temperature constituent.	105	4027	806	0	389	3600	0	0	8822.0	4264	13086.00
6	Write and implement the interface for temperature consituent.	84	2756	689	0	389	14400	0	0	18234.0	3497	21731.00
7	Design and implement the database connectivity to the temperature module.	84	2756	689	0	389	10800	0	0	14634.0	1853	16487.00
8	Programming the connection of the temperature module to the hydraulics.	84	2756	689	0	389	9000	0	0	12834.0	1853	14687.00
9	Design and implement the graphical output interface.	105	4027	806	0	389	18000	0	0	23222.0	2524	25746.00

10	Software testing to catch problems.	798	15065	1789	0	389	10800	0	2296	30339.0	8334	38673.00
11	Monthly coordination meetings between HEC and UCD.	126	5298	923	0	0	6600	0	0	12821.0	4457	17278.00
12	Field trips and site evaluations for calibration and verification simulations.	84	2756	689	3640	0	1800	0	0	8885.0	3425	12310.00
13	Project management of above tasks.	336	12657	2361	0	0	0	0	0	15018.0	7259	22277.00
		4032	91782.00	13430.00	3640.00	3501.00	96000.00	9000.00	9184.00	226537.00	69288.00	295825.00

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	Design of interface for water quality constituents.	105	4229	861	0	438	4200	0	0	9728.0	2681	12409.00
2	Programming and implementation of interface.	483	10803	1692	0	438	16800	0	1205	30938.0	6272	37210.00
3	Design and implementation of graphical output interface.	346.5	12138	1814	0	438	21000	0	1205	36595.0	6979	43574.00
4	Software testing to find problems.	798	15818	1907	0	438	12600	0	2411	33174.0	8809	41983.00

5	Coordination meetings between HEC and UCD.	126	5563	984	0	0	7200	0	0	13747.0	4630	18377.00
6	Field trips and site evaluations for clibration and verification inputs.	399	7909	954	4640	0	2400	0	1205	17108.0	6549	23657.00
7	Project management of all tasks.	336	13290	2519	0	438	0	0	0	16247.0	7880	24127.00
8	Programming of water quality consituent calculations.	399	7909	954	0	438	14100	0	1205	24606.0	5238	29844.00
9	Implementing and programming water quality constituent module to the hydraulics.	483	10803	1692	0	438	11700	0	1205	25838.0	7000	32838.00
10	Develop temperature modeling applications for software manual.	399	7909	954	0	438	21000	0	1205	31506.0	4511	36017.00
		3874	96371.00	14331.00	4640.00	3504.00	111000.00	0.00	9641.00	239487.00	60549.00	300036.00

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	Design of graphical user interface for water quality constituent.	84	3039	790	0	438	4200	0	0	8467.0	2069	10536.00

2	Program and implement water qualty interface.	483	11343	1807	0	438	16800	0	1266	31654.0	6590	38244.00
3	Design and implement graphical output interface.	504	12745	1936	0	438	21000	0	1266	37385.0	7332	44717.00
4	Software testing for problems.	483	11343	1807	0	438	12600	0	1266	27454.0	6590	34044.00
5	Coordination meetings between HEC and UCD.	126	5841	1048	0	0	7200	0	0	14089.0	4796	18885.00
6	Field trips and site evaluation for calibration and verification input.	399	8305	1017	4640	0	2400	0	1266	17628.0	6771	24399.00
7	Project management of all tasks.	336	13955	2687	0	438	0	0	0	17080.0	8283	25363.00
8	Progrmming of database input to water quality module.	399	8305	1017	0	438	14100	0	1266	25126.0	5460	30586.00
9	Program water quality module to hydraulic component.	399	8305	1017	0	438	11700	0	1266	22726.0	5460	28186.00
10	Develop water quality modeling applications for software manual.	399	8305	1017	0	438	21000	0	1266	32026.0	4733	36759.00

11	Workshop of completed model to 100 participants.	420	9706	1145	0	0	0	0	9266	20117.0	9143	29260.00
		4032	101192.00	15288.00	4640.00	3504.00	111000.00	0.00	18128.00	253752.00	67227.00	320979.00

Grand Total=916840.00

Comments.

The direct costs of the development of the sediment transport sub-model will be funded through a cost-share with the Hydrologic Engineering Center. The value of the cost-share for the three years of the project is $450,000. The portion of the funds requested by HEC under this proposal is to cover the seamless integration of the hydraulic, sediment transport and water quality sub-models into a single modeling package.

Budget Justification

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

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

Schladow 504 hours total over 3 years; Fleenor 3528 hours total over 3 years; RA1 3780 hours total over 3 years; RA2 3780 hours total over 3 years; Arnold (Tech.) 504 hours total over 3 years

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

Schladow $54.38 per hour; Fleenor $33.01 per hour; RA1 $14.51 per hour; RA2 $14.51 per hour; Arnold $27.86 per hour

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

Schladow 9.2%; Fleenor 24%; RA1 4.3%; RA2 4.3%; Arnold 37%

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

Travel will be required for field trips related to site inspections of the areas to be modeled and some meetings and conferences to obtain peer-review of on-going work. It has been budgeted at 24 person days per year at $60 per day with vehicle rental on 15 days per year at $80 per day. The total 3-year budget is $12,920.00. Attendance at relevant conferences is also budgeted at $1000 for Year 1 and $2000 for each of Years 2 and 3.

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

Office supplies not included in overhead costs will be fax requirements, shipping, phone, and computer supplies. These have been estimated at $2000.00 per year. Addtionally, software site licenses have been budgeted at $1500 per year. Total supplies for the 3-year project are $10500.00.

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.

Schoellhamer, USGS has been budgeted for 10 days per year to provide expertise in the area of sediment transport. The breakdown is as follows: Year 1 Task 2 - oversite of review of sediment and water quality models - 5 days at $600 per day. Task 11 - participation at coordination meetings for all tasks - 5 days at $600 per day. Year 2 Task 5 - participation at coordination meetings for all tasks - 5 days at $600 per day. Task 8 - oversite of sediment transport connectivity to input database- 2.5 days at $600 per day. Task 9 - oversite of sediment transport connectivity to hydraulic model- 2.5 days at $600 per day. Year 3 Task 5 - participation at coordination meetings for all tasks - 5 days at $600 per day. Task 8 - oversite of sediment transport connectivity and integrated water quality modules to input database- 2.5 days at $600 per day. TAsk 9 - oversite of sediment transport connectivity and integrated water quality model to hydraulic model- 2.5 days at $600 per day. HEC - USACOE Year 1 Task 1 - Testing of the newly developed unsteady flow model against hydraulics of available sediment transport and water quality models. 30 person days at $600 per day. Task 5 - Interface design for the temperature module phase of model - 6 days at $600 per day. Task 6 - Implementation of the temperature module interface - 24 days at $600 per day. Task 7 - Integration of the input database to the temperature module - 18 days at $600 per day. Task 8 - Connecting the temperature module to the hydraulic model - 15 days at $600 per day. Task 9 - Design and implementation of the temperature output interface - 30 days at $600 per day. Task 10 - Software testing to catch any problems with the computation - 18 days at $600 per day. Task 11 - Participation in the coordination meetings for all tasks - 6 days at $600 per day. Task 12 - Field trip for site inspections of systems to be modeled - 3 days at $600 per day. Year 2 Task 1 - Interface design for the water quality module phase of model - 7 days at $600 per day. Task 2 - Implementation of the water quality module interface - 28 days at $600 per day. Task 3 - Design and implementation of the water quality output interface - 35 days at $600 per day. Task 4 - Software testing to catch any problems with the computation - 21 days at $600 per day. Task 5 - Participation in the coordination meetings for all tasks - 7 days at $600 per day. Task 6 - Field trip for site inspections of systems to be modeled - 4 days at $600 per day. Task 8 - Integration of the input database to the water quality module - 21 days at $600 per day. Task 9 - Connecting the water quality module to the hydraulic model - 17 days at $600 per day. Task 10 - Develop modeling application and begin documentation for software manual - 35 days at $600 per day. Year 3 Task 1 - Interface design for the water quality module phase of model - 7 days at $600 per day. Task 2 - Implementation of the water quality module interface - 28 days at $600 per day. Task 3 - Design and implementation of the water quality output interface - 35 days at $600 per day. Task 4 - Software testing to catch any problems with the computation - 21 days at $600 per day. Task 5 - Participation in the coordination meetings for all tasks - 7 days at $600 per day. Task 6 - Field trip for site inspections of systems to be modeled - 4 days at $600 per day. Task 8 - Integration of the input database to the water quality module - 21 days at $600 per day. Task 9 - Connecting the water quality module to the hydraulic model - 17 days at $600 per day. Task 10 - Develop modeling application and complete documentation for software manual - 35 days at $600 per day.

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.

Equipment required for the project will consist of three desktop computers capable of programming computationally and graphically intensive software. Total for 3 computers is $9000.00. The University of California's threshold for equipment is $1500. The computers have therefore been budgeted as equipment (not subject to indirect costs). If budgeted as supplies, they would attract indirect costs.

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.

Since this work involves a strong collaboration between UCD and HEC, sufficient time has been budgeted in specific tasks to allow for coordination of the work. The work is computer intensive so the management portion of the budget allows for one month per year to account for the computer administrator's (Arnold) time requirement of installing and updating software, virus protection, and trouble shooting. Pace of the on-going work will be facilitated by the required completion by the student to advance and the regularly scheduled presentations to peer-reviewed groups. Overall project supervision will be by Schladow (15 days per year). Day-to-day management of the UC Davis component will be by Fleenor (15 days per year). Day to day management of the HEC portion will be by Brunner. Cost and time for presentations etc are covered in the Travel budget.

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

University tuition fees are included for two graduate students and prorated against each task in proportion to the student time. Total student fees for two students for three years is $29262.00. In addition, a Workshop will be held near the conclusion of the project for approximately 100 people to demonstrate the availability and functionality of the model. The Workshop has been budgeted at $8000.00.

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

The indirect cost rate is set by the University and is to cover stand office supplies, space etc. We have asumed the Federal oherhead rate. For Year 1 this is 48% for 4 months, and 48.5% for 8 months. For Years 2 and 3, the rate is 48.5%. For State Funding, the indirect cost rate is 10%.

Executive Summary

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

This proposal seeks to develop and test a freely accessible modeling tool to meet the needs of predicting both the features of flow quantity together with water quality and sediment transport in riverine systems composed of branching rivers with provision for overbank flows. Flow quality, where we take this to mean dissolved and suspended material in the flow together with water temperature, while implicit in the ERP foundation "restoration of ecological processes associated with streamflow, stream channels, watersheds and floodplains", is not presently well represented in models. The flow quantity (hydraulic) modeling will be based on the unsteady flow version of HEC-RAS. This model is widely used and accepted by the engineering community and many regulatory agencies. An extensive infrastructure already exists for training courses and free distribution of the model. This model will be directly coupled to a suite of water quality sub-models that presently form the basis of a UC Davis reservoir and lake model. A suite of sediment transport sub-models, encompassing both cohesive and non-cohesive soils, will be developed as part of the proposed project. Thus the fundamental, underlying hypothesis is not that the hydraulics of riverine systems can be reasonably well represented by one-dimensional models - this is already widely acknowledged. Rather, it is that such models can be greatly extended through the incorporation of water quality and sediment transport - information that is vital to the ecosystem restoration program. This proposal will provide a necessary tool to investigate changes in the flow quantity and quality in rivers and streams. These may be produced by a variety of factors, including changes in reservoir storage and release practices, modification to streambeds by the removal of non-native vegetation, and modification to levees. Though the benefits of this project are not limited by geographical scope, the model will be tested with data from three specific river systems which exhibit a large range of flow and quality issues. These are the Sacramento River, Cache Creek, and the Cosumnes River. The Adaptive Management Process can be related to this proposal in numerous ways. The model may be used to "Establish ecosystem goals/objectives" by allowing these goals to be quantified. Our strategy of allowing end-users to add water quality sub-models and components that pertain to their own systems, provides a tool for the user to not only "specify conceptual models" but to directly test them. "Policy alternatives" can be readily explored, and the ability to "Assess, Evaluate, Adapt" is what a model enables one to efficiently and objectively do.

Proposal

University of California, Davis

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

Geoffrey Schladow, University of California, Davis
Gary Brunner, Hydrologic Engineering Center, USACOE

DEVELOPMENT AND TESTING OF AN UNSTEADY RIVER MODEL WITH WATER QUALITY AND SEDIMENT TRANSPORT

S. Geoffrey Schladow, Department of Civil and Environmental Engineering, U.C. Davis
Gary W. Brunner, Hydrologic Engineering Center, US Army Corp of Engineers, Davis

A. Project Description: Project Goals and Scope of Work

1. Problem

The planning and evaluation of any changes to flow and storage in the ERP geographic region requires careful and thorough examination of riverine flows – both the quantity of these flows and the concomitant change in quality and sediment transport. The importance of flow quantity has long been recognized, and spans the entire spectrum from flood mitigation, to agricultural and municipal water supply, to preservation of sufficient low flows to meet ecological end-points. A variety of modeling tools presently exist to describe unsteady flow quantity. Flow quality, where we take this to mean all dissolved and suspended material in the flow together with water temperature, while implicit in the ERP foundation "…restoration of ecological processes associated with streamflow, stream channels, watersheds and floodplains" is not presently well represented in models. Few models provide the ability to couple flow quantity with flow quality, and those that do are proprietary products that are both expensive as well as difficult, if not impossible, to modify to suit local conditions.

This proposal seeks to develop and test a freely accessible modeling tool to meet the needs of predicting both the features of flow quantity (for example, volume flow rate, stage, hydrograph) together with water quality (for example, temperature, dissolved oxygen) and sediment transport (TSS and bedload) in riverine systems composed of branching rivers with provision for overbank flows. This will be accomplished through collaboration between the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers and the Department of Civil and Environmental Engineering at U.C. Davis.

The flow quantity (hydraulic) modeling will be based on the present, unsteady flow version of HEC-RAS. This model is widely used and accepted by the engineering community and many regulatory agencies. For example, this model is the standard for U.S. Army Corps of Engineers projects; FEMA has accepted HEC-RAS for performing national flood insurance studies; the NRCS has adopted it as their main river hydraulics model; the FHWA has accepted it for their use on highway hydraulics studies; and many state and local agencies across the country have also adopted it for use in hydraulic studies. An extensive infrastructure already exists for training courses and free distribution of the model. This model will be directly coupled to a suite of water quality sub-models that presently form the basis of a UC Davis reservoir and lake model (Hamilton and Schladow 1996; Schladow and Hamilton, 1996; McCord 1999; Losada 2001). A suite of sediment transport sub-models, encompassing both cohesive and non-cohesive soils, will be developed as part of the proposed collaboration.

2. Justification

This proposal will provide a necessary tool that may be used to investigate changes in the flow quantity and quality in rivers and streams. Such changes may be produced by a large variety of factors. Three examples serve to illustrate just some of the potential applications:

- changes in reservoir storage and release practices will alter downstream temperatures and dissolved oxygen concentrations. The impact at different times of year, for different flows and for different river orientation and shading, can best be quantified using a modeling approach.

- modification to streambeds, for example the removal of non-native vegetation or the skimming of gravel bars, will change the flood conveyance characteristics of a river. This may also affect the sediment transport, and with the downstream transport of sediment -associated contaminants such as mercury (see for example Marvin-Dipasquale et al.2000;). The American Society of Civil Engineers Task Committee on Sediment Transport and Aquatic Habitats (1992) found that as bed mobility increased the diversity of the benthos decreased. Void space between bed particles and slack water zones are important habitats within riverine channels. The proposed model will allow for the quantitative prediction of both the change in sediment transport as well as the resulting contaminant flux. The model could also be used to design an optimal stream modification strategy, and to test competing remediation strategies.

- modification to levees, for example deliberate breaching or the use of setback levees, will change the characteristics of a flood wave propagating downstream. Therefore the likelihood of inundation of overbank areas, the spatial extent of flooding and its depth and time duration will also change. These factors are important for fish rearing habitat (see for example Mathias and Moyle 1992; Marchetti and Moyle, 2001) and need to be predicted. At the same time, water quality changes (such as temperature, DO, sediment deposition) within these overbank areas also need to be predicted.

It is not the purpose of this proposal to explore any of these example scenarios in great detail. Rather, we wish to provide, in a timely manner, a methodology and a tool that may allow others to start fully addressing problems where water quantity and water quality are closely intertwined. We will, however, be testing the model with data from 3 river systems from which these examples were drawn. These are the Sacramento River, where reservoir-fed tributaries provide water of varying temperature to the main stem; Cache Creek, where existing high concentrations of mercury in the sediment may be mobilized by changes in streamflow and sediment transport; and the Cosumnes River, where frequent flood flows are being investigated for their potential for providing wetland habitat.

By basing our model on HEC-RAS we believe that we can also provide a tool that is familiar to and available to many Agencies, researchers and other stakeholders, and that has already gained wide acceptance. Further, the graphical user interface of HEC-RAS, its linkage to widely used databases, and its GIS output modes make it amenable to a host of new users for projects related to the Bay-Delta system. Although universal acceptance of this model is not a specific goal, the fact that it is likely to have broad appeal may allow for greater coordination between existing disparate modeling efforts.

A review of existing models shows that each is in some way less desirable for meeting the goals of the present proposal. These models include MIKE 11, WASP5, QUAL-2E, CE-QUAL-RIV1, CE- QUAL-W2, WQRSS, and RMA-11.

The MIKE 11 unsteady flow model, developed by the Danish Hydraulic Institute, has modules available for predicting water quality, advection, dispersion as well as cohesive and noncohesive sediment transport. However, these modules are in many instances too simplistic (particularly those that describe water quality), and not readily tailored to the conditions that pertain to the Bay-Delta system. Adding new modules that may better describe water quality and sediment transport is not possible. The fact that MIKE 11 is a proprietary model and, therefore, has a large up-front cost for each new user is also a distinct disadvantage.

The WASP5 system consists of two stand-alone computer programs, DYNHYD5 and WASP5, that can be run in conjunction or separately. The hydrodynamics program, DYNHYD5, simulates the movement of water while the water quality program, WASP5, simulates the movement and interaction of pollutants within the water. DYNHYD5 solves the one-dimensional equations of continuity and momentum for a branching or channel-junction (link-node), computational network. However, DYNHYD5 does not incorporate the effects of hydraulic structures (bridges, weirs, culverts, control structures, etc.) on the modeled hydrodynamics. This is a major drawback, as these structures exert a tremendous influence on the hydraulics, particularly under flood conditions. The available user interface with this program is also difficult.

The Enhanced Stream Water Quality Model (QUAL2E) is a steady state model for conventional pollutants in branching streams and well mixed lakes which simulates up to 15 water quality constituents. Hydraulically, QUAL2E is limited to the simulation of time periods during which both the stream flow in river basins and input contaminant loads are constant, therefore, the effects of dynamic forcing functions, such as flood flows cannot be modeled. For this reason alone, QUAL2E is an unsuitable platform. Two variations to QUAL2E have been developed. CE-QUAL-RIV1 is a one-dimensional, dynamic flow and water quality model for streams developed by the Waterways Experiment Station Experimental Lab of the U. S. Army Corps of Engineers. CE-QUAL-RIV1 was developed for highly unsteady flow conditions, but is currently available for U.S. Army Corps of Engineers use only. In any event, its level of acceptance, its ability to handle a broad range of hydraulic structures, and its ease of use are all considered to fall well short of HEC-RAS. The other variant, CE-QUAL-W2, is a water quality and hydrodynamic model in 2-D (longitudinal-vertical) for rivers, estuaries, lakes, reservoirs and river basin systems. The heavy computational overhead required for a 2-D model, makes this model undesirable for the representation of stream hydraulic processes, which can generally be satisfactorily represented in a one-dimensional framework. The disadvantages described for CE-QUAL-RIV1 also apply.

WQRRS is a one-dimensional modeling system that evaluates water quality (ecological cycle) conditions in river systems. The hydraulic components of this model are now quite dated, and many of its features are incorporated and considerably extended in HEC-RAS.

RMA-11, is a finite element model for the simulation of water quality in systems where one, two, or three dimensional approximations are appropriate. RMA-11 may be executed in steady-state or dynamic mode. The model was originally developed under contract to the Corps of Engineers, and in its earlier version (RMA-4) has been established as an integral part of the Corps' TABS-2 modeling system. As was the case with CE-QUAL-W2, the additional overhead associated with a multi-dimensional model is unwarranted for the types of problems to be addressed here. Similarly the range of hydraulic structures that can be handled, and the awkward user interface count against the adoption of this model for the present purposes.

The proposal embodies the facets of a research proposal and a demonstration proposal. To the extent that we seek to create a model that is unique, and if successful will provide a powerful new tool means that this is clearly research. At the same time, in the testing and development of this model, we are using three existing data sets and with them demonstrating that the final product is both a sufficiently accurate and robust model, and that it will be of value for the types of questions posed. Clearly if particular sub-models do not represent the systems well, they will be improved or, if necessary, replaced by more appropriate ones. It is one of our intentions that the final model be written in such a manner that end-users be free to select those sub-models that are most appropriate for the system, or have the flexibility to incorporate their own sub-models.

The Adaptive Management Process, as conceptualized in Figure 1 of the Draft Stage 1 Implementation Plan, can be related to this proposal in numerous ways. The model may be used to "Establish ecosystem goals/objectives" by allowing these goals to be quantified. Whether these goals are to achieve a particular temperature regime or to limit flood inundation to a certain duration and depth, these objectives can be quantified and numerous model runs employed to examine how (if at all) the objectives can be met. Our strategy of allowing end-users to add water quality sub-models and components that pertain to their own systems, provides a tool for the user to not only "specify conceptual models" but to directly test them. "Policy alternatives" can be readily explored, and the ability to "Assess, Evaluate, Adapt" is what a model enables one to efficiently and objectively do.

3. Approach

Hydraulic model

As noted previously, we intend to use HEC-RAS as the backbone of the proposed model. HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities.

The HEC-RAS system currently contains two one-dimensional hydraulic analysis components for: (1) steady flow water surface profile computations; and (2) unsteady flow simulation. A key element is that both components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the hydraulic analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

The HEC-RAS package also contains a component for GIS interfacing. This product is called HEC-GeoRas. GeoRas works with ArcView, and allows the user to extract the necessary geometric data for performing hydraulic analyses. Additionally, HEC-RAS results can be sent back to the GeoRas software to perform flood inundation mapping, as well as mapping other parameters (e.g. water depths and velocities).

Water quality model

In the first instance, we intend to focus on a limited set of water quality parameters. These are temperature, salinity, dissolved oxygen and mercury. (The inclusion and testing for a broader range of parameters, including several individual algal species (as chlorophyll), bacterial contamination, and organic chemical and heavy metal contamination, will be deferred for the second phase of the model development.)

Using the widely accepted bulk aerodynamic formulations, it is relatively straightforward to calculate heat exchange across an air-water interface, and through this to model water temperature. Rivers and streams, however, are complicated in that their orientation is constantly changing, and so the effect of riparian shading is not constant. The precise sun angle at any time of day, at any day of the year and at any location can be calculated from solar geometry, and by knowing the vegetation height on a reach-by-reach basis, as well as stream orientation, the precise effect of shading determined (Lowney 2000).

To adequately model dissolved oxygen (DO) it is necessary to represent all the sources and sinks of oxygen, including sediment exchanges, algal (water column) production and loss, and transfer across the air-water interface. To do this we propose to link a set of sub-models for phytoplankton production, dissolved oxygen concentration, and nutrient cycling to HEC-RAS. The water quality sub-models will consist of 13 state variables that may include up to three algal groups, BOD (both carbonaceous and benthic), dissolved oxygen and nutrients (including PO_4-P, NO_3-N, NH_4-N, TP and TN). Phytoplankton growth is limited by a combination of light, phosphorus or nitrogen. Respiration and mortality are to be modeled as first order loss terms while loss by grazing varies with phytoplankton biomass and temperature. Uptake by phytoplankton of dissolved inorganic phosphorus and nitrogen (as both nitrate and ammonium) is related to both external and internal nutrient concentrations. Release of phosphorus and ammonium from the sediments becomes a maximum as dissolved oxygen concentrations approach zero. For complete details on how these models have been used previously and the full equation sets that they comprise, see Hamilton and Schladow (1997), Schladow and

Hamilton (1997) and Losada (2001). In the present application we intend to link the model to the output of the HEC-RAS and run it in post-processing mode.

Mercury has been chosen as an example metal because of its importance to the bay-delta system (see for example, SFEI 2000; Davis and May 2000; Slotton et al. 2000). The actual modeling of mercury transformations will not be undertaken as part of the present work. Though numerous approaches exist for such modeling (see for example Rajar et al. 2000; Bale 2000; Diamond 1999; Hudson 1998) and could be readily incorporated into the framework described, we believe that the nature of the transport and environmental conditions must be correctly prescribed as a first step. Therefore the extent of the mercury modeling we intend to include at the present time is to link it directly to the sediment transport sub-models, and to describe the potential for mercury methylation by identifying conditions under which low DO concentrations are likely.

All the water quality components require calibration because the rate and coupling parameters are site specific. We note that some of the necessary parameters may be obtainable from other CalFed funded projects, as well as from ongoing USGS research on the organic carbon sources in the Delta. Nonetheless, calibration through simple trial-and-error is extremely tedious and time consuming, may be skewed by the necessarily limited choices made by the user, and the goodness of the match may be prone to subjectivity. We have developed a different approach to calibration, whereby a Genetic Algorithm has been adapted to perform the calibration (Perez-Losada 2001). Genetic Algorithms (GAs) are a class of evolutionary algorithms, based on the concept of the evolution of the best "fitted", i.e. adapted, individuals to the environmental conditions (Goldberg, 1989; Beasley et al. 1993). This is done by the creation, within the algorithm, of a population of individuals represented as chromosome-type sequences, in essence a set of character strings analogous to the base-4 chromosomes in DNA. If this character string encodes the values of the different parameters to be optimized, then as the character string evolves different combinations of parameter values are represented. Character strings that provide poor matches to the real conditions tend not to survive, overtaken instead by the more successful combinations. Reproduction takes place between more successful individuals and a form of "mutation" is permitted in order to help diversify the "gene pool". This approach has been adapted for use in a water quality model of Lake Tahoe, and the calibration time was reduced from several months by trial and error, to a matter of days using a GA (Perez-Losada 2001). We intend to incorporate a GA-based calibration module as part of the model package.

Sediment Transport Modeling

Sediment transport models calculate the rate at which sediment is moving in a channel and the rates at which the channel is aggrading (depositing) or degrading (eroding). This differs from geomorphic models that calculate channel geometry (width, depth, slope, bed material, and sinuosity) (e.g. Greimann and others 2001).

Sediment transport is a function of water flow so sediment transport models must be coupled with a hydrodynamic model. Sediment transport models simulate suspended load (fine sediments moving at the same speed as water) and bedload (sand and gravel moving at a slower rate along the bed) (Wiele and Franseen 2001, Bennett 2001). Many bedload equations have been developed and evaluated (e.g. Stevens and Yang 1989, Lopes and others 2001). Suspended load is simulated either by calculating a near-bed suspended-sediment concentration and vertically mixing the sediment (Smith and McLean 1977, Bennett 2001) or by determining a sediment entrainment rate (Garcia and Parker 1991). Other approaches to sediment transport modeling include stochastic modeling and turbulence-scale modeling, but these approaches are more computationally intensive and are less common.

Existing one-dimensional sediment transport models are typically DOS-based computer programs; they have no graphical user interface, and are very inflexible in making use of multiple data sources. The incorporation of sediment transport modeling within the HEC-RAS modeling system will allow these types of analyses to be performed more readily. Our work in this area will consist of evaluating the current state-of-the-art in one-dimensional sediment transport modeling; designing the sediment transport component of the HEC-RAS system; developing the software; and then testing the new algorithms.

The Hydrologic Engineering Center (HEC) has an ongoing research program in which it plans to develop state-of-the-art sediment transport modeling within the HEC-RAS modeling system over an anticipated three-year time period. This research program will be undertaken conjunctively with the proposed research effort, and will provide many of the required resources. Near the conclusion of the sediment transport development work at HEC, the developed algorithms will be applied to the case studies being used in this proposed scope of work.

4. Feasibility

The proposed project is feasible within the time frame planned. Several of the key components are already in place, *viz.*, the unsteady version of HEC-RAS is presently operational, different components of the water quality sub-model already exist as part of other models, and the sediment transport component is being developed in conjunction with an ongoing HEC effort that coincides timewise.

The largest unknown components are the assembly of data sets from the 3 test cases: the Sacramento River, the Cosumnes-Mokelumne system, and Cache Creek. The necessary hydraulic boundary and forcing conditions are largely in place for each test case, as they have previously been modeled with HEC-RAS or other hydraulic models (for example, HEC-3, MIKE 11). The water quality data sets have yet to be assembled (or fully defined for that matter), and this will constitute a significant fraction of the work of the UC Davis component of the project. Preliminary investigations for the three test cases suggest that while perfect data sets may not be available, data sets that are satisfactory for testing of the model can be developed. Sediment transport data are probably the most uncertain element. However, their scarcity for all parts of the Bay-Delta system highlights the urgent need for the development of a predictive modeling capability.

5. Performance Measures

The project has several definable identifiable interim goals to meet its overall objectives, and which can serve as measures of performance. These are listed below, [along with the responsible group]:

Year 1

- Validation of unsteady HEC-RAS (hydraulics only) against simple test cases and against other hydraulic models (e.g. MIKE 11) [UCD and HEC]
- Review of state-of-the-art in sediment modeling – produce interim report [HEC]
- Construct temperature sub-model in HEC-RAS compatible format [UCD]
- Obtain available water quality and sediment transport data for three test cases – produce interim report [UCD]
- Present results to date at Bay-Delta modeling forum [UCD and HEC]

Year 2

- Link HEC-RAS with selected sediment transport sub-models [HEC]
- Link HEC-RAS with water quality sub-models [HEC]
- Complete water quality sub-models [UCD]
- Assemble water quality data files for three test cases [UCD]
- Present results to date at Bay-Delta modeling forum [UCD and HEC]

Year 3

- Complete GUI for complete model package [HEC]
- Complete simulations for three test cases [UCD]
- Present results to date at Bay-Delta modeling forum [UCD and HEC]
- Produce User Manual [UCD and HEC]
- Present one-day demonstration Workshop for modeling community on the use of the complete modeling package [UCD and HEC]

6. Data handling and storage

HEC has developed a database (HEC-DSS) for storing time series and paired data. This system has been used and improved over the last 30 years. The system is capable of storing very large amounts of data, while still maintaining efficiency in its read and write capabilities. This database is already the storage facility for time series data used by the HEC-RAS model, as well as many other computer models in the water resources field. This database also has several utilities for importing and exporting data from other federal data sources. These include the National Weather Service and the U.S. Geological Survey. The HEC-DSS system is also currently being used in the Corps real time river forecasting system. The database system is already in the public domain.

7. Expected Products/Outcomes

Annual presentation of results will be made to our peer group through the Bay Delta Modeling Forum. A substantial portion of the work will be conducted by student Research Assistants (2 employed directly at UC Davis for the duration of the project plus additional student Interns working at HEC). The particular aspects of their work will be reflected in their theses and dissertations.

The final model will become part of HEC's suite of modeling tools. These are freely available for download from the web, along with necessary documentation. HEC and others routinely conducts training courses for HEC modeling products. Depending on demand, consideration will also be given to presenting training workshops through University Extension.

The final model will provide the entire user community with a time-varying hydraulic model that already has very wide regulatory acceptance, and that is directly linked to state-of-the-art water quality and sediment transport models. This will facilitate for the first time the modeling of the entire riverine portions of the Bay-Delta on a consistent, system-wide basis.

8. Work Schedule

Year 1

- complete testing and validation of unsteady HEC-RAS (hydraulics only) against simple test cases and against other hydraulic models (e.g. MIKE 11) [UCD and HEC]
- complete review of state-of-the-art in sediment modeling and finalize sub-models to be included in new model [HEC]
- construct temperature sub-model in HEC-RAS compatible format [UCD]
- identify and obtain all water quality and sediment transport data for three test cases [UCD]

Year 2

- link HEC-RAS with selected sediment transport sub-models [HEC]
- link HEC-RAS with water sub-models [HEC]
- construct the complete water quality sub-models [UCD]
- assemble water quality data files for three test cases [UCD]

Year 3

- complete GUI for complete model package [HEC]
- complete simulations for three test cases [UCD]
- organize a one-day demonstration Workshop for modeling community on the use of the complete modeling package [UCD and HEC]

Included in the schedule are monthly meetings of the entire project team. When appropriate, these will also be attended by Dr David Schoellhamer of the USGS. Dr Schoellhamer has agreed to provide technical review and oversight for the sediment transport portion of this project.

B. ***Applicability to CALFED ERP and Science Program Goals***

1. ERP, Science Program Goals, CVPIA Priorities

This proposal addresses directly all the goals of the ERP. It is designed to provide a freely available tool to assess the state of key components to the system, namely the water flow, the quality of the water and the sediment transport. As the model is also used in estimation of flood effects, it will be an integral component of the evaluation of levee system integrity. It may be used to evaluate flood control and restoration alternatives. Because of the wide acceptance of HEC models, it is likely that this model will provide a common tool that may be used throughout the geographic scope.

The Adaptive Management Process, as conceptualized in Figure 1 of the Draft Stage 1 Implementation Plan, can be related to this proposal in numerous ways. The model may be used to "Establish ecosystem goals/objectives" by allowing these goals to be quantified. Whether these goals are to achieve a particular temperature regime or to limit flood inundation to a certain duration and depth, these objectives can be quantified and numerous model runs employed to examine how (if at all) the objectives can be met. Our strategy of allowing end-users to add water quality sub-models and components that pertain to their own systems, provides a tool for the user to not only "specify conceptual models" but to directly test them. "Policy alternatives" can be readily explored, and the ability to "Assess, Evaluate, Adapt" is what a model enables one to efficiently and objectively do.

2. Relationship to Other Ecosystem Restoration Projects

This project will provide a tool that may be used for future projects. It may be possible to analyze past projects using the modeling package, and use the output to better understand the reasons for past failures and successes.

3. Relationship to Next-Phase Funding

None

4. Previous Recipients of CALFED Program or CVPIA Funding

Schladow is a co-PI on Calfed Project 99-B193, McCormack-Williamson Tract Planning, Design and Monitoring Program. This project is investigating alternatives for wetlands restoration, and measuring sediment supply in the Cosumnes and Mokelumne Rivers. This project is at an early stage, and results have not been published yet.

5. System-Wide Ecosystem Benefits

We believe the successful completion of this model will provide a tool that may be applied to the entire ecosystem by a broad range of stakeholders

6. Land Acquisition

None

C. Qualifications

S. GEOFFREY SCHLADOW
Department of Civil and Environmental Engineering
University of California
Davis, CA 95616

PROFESSIONAL PREPARATION

B.E. (Hons), University of Western Australia, (Civil Engineering), 1974
M.E., University of California, Berkeley, CA. (Hydraulic Engineering),1980
Ph.D., University of Western Australia, (Civil Engineering), 1986
Postdoctoral Investigator, Stanford University, CA., Environmental Fluid Mechanics, 1986-1989

APPOINTMENTS

1996 - present	Assoc. Prof., Dept. Civil and Environmental Eng., U.C. Davis.
1993 - 1996	Asst. Prof., Dept. Civil and Environmental Eng., U.C. Davis.
1989 - 1993	Snr Research Fellow, Centre for Water Research, U. West. Australia

RELEVANT PUBLICATIONS

Hamilton, D.P.and Schladow, S.G. (1996) Prediction of water quality in lakes and reservoirs. Part I - Model Description. Ecol Modelling 96: pp91-110
Schladow, S.G. and Hamilton, D.P. (1996) Prediction of water quality in lakes and reservoirs. Part II - Application to Prospect Reservoir. Ecol Modelling 96: pp111-123
Rueda, F. J. and Schladow, S. G. (2001) The internal dynamics of a large polymictic lake. Part II: Three dimensional numerical simulations. ASCE, J. Hyd Engineering (submitted).
Warner, J, S. G. Schladow, D. Schoellhamer, J. Burau (2000). Effects of Tidal Current Phase at the Junction of Two Straits. 10th International Biennial Conf. on Physics of Estuaries and Coastal Seas.
Schladow, S.G. (1992). Bubble plume dynamics in a stratified medium and the implications for water quality amelioration in lakes. **Water Resources Research**, **28(2)**, 313-321.
Schladow, S.G. and Hamilton, D.P. (1995) Effect of major flow diversion on sediment nutrient release in a stratified resevoir. **Marine and Freshwater Research**, 46, 189-195.
Lee, M. and Schladow, S. G. (2000). Visualization of oxygen concentration in water bodies using a fluorescence technique. Water Research 34 (10): 2842-2845.

GRADUATE STUDENTS AND POSTDOCTORAL SCHOLARS ADVISED

(previous 5 years, of a total of 25 students and 5 postdocs)

PhD

William Fleenor (UC Davis)	Michael Barad (present)
Sveinn Palmarsson (present)	Dr Stephen McCord (consultant)
Dr Francisco Rueda, (Cornell)	Dr John Warner (USGS)

MS

Chris Hammersmark (present)	Scott Heald (present)
Ertugrul Sogutlugil (present)	Todd Steissberg (present)
Randy Bowersox (present)	Andreas Krause (consultant)
Sonia Oton (consultant)	Kelley Thompson (consultant)
Jenny Coker (consultant)	Jessica Thomas (consultant)
Brian Heiland (government)	Stephen Blake (consultant)
Sveinn Palmarsson (grad school)	Stacie Grinbergs (consultant)

PostDoc

Dr Eric Larsen, Geology, UC Davis	Dr Bernhard Hürzeler, consultant
Dr Minhee Lee, Pukyong U., Korea	William Fleenor, present
Dr Francisco Rueda, Cornell U.	

Gary W. Brunner: Senior Technical Hydraulic Engineer, Hydrology and Hydraulics Technology Division

Education: BS 1983 and MS 1985, Pennsylvania State University

Registration/Professional Affiliations: Registered Civil Engineer, California 1987; Member Tau Beta Pi, Chi Epsilon, and the Transportation Research Board.

Experience: 1985 – Present, Hydrologic Engineering Center (HEC). In charge of the development of the HEC River Analysis System (HEC-RAS); perform research in the area of river hydraulics; provided technical assistance to Corps field personnel; Teach engineering classes in river hydraulics and surface water hydrology; perform complex riverine studies.

1983 – 1985, Penn State University. Research on overland flow processes, Teaching surveying to undergraduates.

Technical Subjects: River hydraulics; steady flow, unsteady flow, and Dam Break analyses; surface water hydrology; risk and uncertainty analysis; sediment transport processes; real time river forecasting; utilizing GIS with hydrology and hydraulic models; I also have extensive teaching experience in river hydraulics and surface water hydrology.

Wm. E. Fleenor: UC Davis postdoctoral research engineer

Education: BS 1970, Rose-Hulman Institute of Technology; MS 1993 and Ph.D. 2001, University of California, Davis

Registration/Professional Affiliations: EIT 1994

Experience: 2000 to present: Project Manager for an investigation into the current and sediment fluxes in the Cosumnes and Mokelumne Rivers. Measurements are being made in collaboration of the Woods Hole Group in San Mateo, CA to obtain information on changes in the river morphology and sediment characteristics that can be related to hydrodynamics.

2000 to present: Project Manager for hydraulic/hydrodynamic modeling efforts in support of the McCormick-Williamson Tract Restoration Planning, Design, and Monitoring program of DWR and The Nature Conservancy. The modeling is being performed using both Mike 11 and the newest HEC-RAS version of UNET.

2000 to present: Project Manager for Stockton Channel Tracer Injection performed for the City of Stockton under contract with HDR Engineering, Inc of Sacramento, CA. A tracer study in a closed-ended estuary to determine if hydrodynamic mixing was contributing to water quality problems.

1998 to preesent: Project manager in Sawtooth Mountain range in Idaho for National Science Foundation grant DEB-9727058: *Deep chlorophyll layers as export production zones in lake ecosystems: The importance of hydrodynamics and biological transport in the formation and maintenance of metalimnetic production.* A collaborative research project with Wayne Wurtsbaugh and Chris Luecke of Utah State University. Model calibration, verification, and application continue.

1997 to 1998: Research into the effects of plunging inflows on reservoir hydrodynamics and downstream releases, funded by the California Energy Institute's California Energy Studies Program

1978 to 1988: Engineering sales and marketing manager, responsible for sales force management and for developing new market areas for construction equipment and heavy duty truck distributor. Worked extensively with design and manufacturing engineers to solve customer's problems in areas of unique applications.

Technical Subjects: The study and modeling of mixing principles in rivers, lakes, and reservoirs and the relationships and consequences to water quality.

Mark R. Jensen: Hydraulic Engineer, GS-12, 530/756-1104/ext. 346.

Education: BS, Civil and Environmental Engineering, University of California, Davis, CA, 1992.
MS, Civil and Environmental Engineering, University of California, Davis, CA, 1994.

Experience: 10 years, Hydraulic Engineer, Hydrologic Engineering Center, IWR. Create graphical user interface for the HEC-RAS program; Provide technical assistance to Corp field personnel; Teach and coordinated hydraulic and hydrologic engineering courses; and perform river flood studies.

3 months, intern, at Project Design Consulting in San Diego. Designed subdivisions with Autocad and wrote programs to assist in hydrology analysis.

Technical Subjects: River hydraulics and numerical methods, development of the River Analysis System Software (HEC-RAS).

D. Cost

1. Budget and Administration

see web forms

2. Cost Sharing

Further to the budget details presented on-line, a 50% cost-share is being provided by HEC through the direct funding of the sediment transport sub-model development. This is budgeted at $450,000 over three years, compared with the present proposal's budget of approximately $900,000 over three years.

E. Local involvement

The project will obtain existing data from local bodies for the Sacramento River Watershed, Cache Creek, and the Cosumnes River. Much of these data are already available through UC Davis, the Corp of Engineers, the Bureau of Reclamation and DWR. However, survey data for bridge cross sections etc. are often only available from local government authorities. We have previously worked closely with local authorities in the Cosumnes basin to obtain such data. Local flood control districts and Regional Water Quality Control Board offices will also be engaged to ensure that the model adequately addresses known local flood issues and water quality concerns.

Letters of support for the project are included as Appendix A.

F. Compliance with Standard Terms and Conditions

Please refer to letter faxed with signature sheet, whereby the Regents of the University of California indicate ongoing discussion with CALFED regarding the Standard Terms and Conditions.

G. Literature Cited

American Society of Civil Engineers Task Committee on Sediment Transport and Aquatic Habitats, Sedimentation Committee, 1992, Sediment and aquatic habitat in river systems: Journal of Hydraulic Engineering, v. 118, no. 5, p. 669-687.

Bale A. E. (2000) Modeling aquatic mercury fate in Clear Lake, Calif. J Environ Eng-ASCE 126 (2): 153-163.

Bennett, J.P., 2001. Mixed-size sediment transport model for networks of one-dimensional open channels: Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, 2001, p. I-145 – I-152.

Davis, J. and May 2000. Contaminant concentrations in fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River 1998. SFEI

Diamond M. L. (1999). Development of a fugacity/aquivalence model of mercury dynamics in lakes. Water Air Soil Poll. 111 (1-4): 337-357.

Garcia, M., and Parker, G., 1991. Entrainment of bed sediment into suspension: Journal of Hydraulic Engineering, v. 117, no. 4, p. 414-435.

Greimann, B., Yang, C.T., and Baird, D., 2001. Numerical modeling of dynamic river adjustment: Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, 2001, p. I-47 – I-54.

Hamilton, D.P.and Schladow, S.G. (1996) Prediction of water quality in lakes and reservoirs. Part I - Model Description. Ecol Modelling 96: pp91-110

Hudson R. J. M. (1998) Modeling the fate of metals in aquatic systems: The mechanistic basis of particle water partitioning models. Crit Rev Anal Chem 28 (2): 19-26.

Lopes, V.L., Osterkamp, W.R., and Bravo-Espinosa, M., 2001, Evaluation of selected bedload equations under transport- and supply-limited conditions: Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, 2001, p. I-192 – I-198.

Losada, J. 2001 A Deterministic Model for Lake Clarity: Application to Management of Lake Tahoe, (California-Nevada), USA. PhD dissertation. Universty of Girona, Spain.

Lowney, C. L. 2000. River temperature dynamics in the Sacramento River : measurement and modeling. PhD dissertation, University of California, Davis.

Marchetti, M. P. and Moyle, P. B. 2001. Effects of flow regime on fish assemblages in a regulated California stream. ECOLOGICAL APPLICATIONS, V11(N2):530-539

Marvin-Dipasquale et al.2000 Methyl-mercury degradation pathways: a comparison among three mercury-impacted ecosystems. Environ. Sci. Technol. 34:4908-4916

Mathias, M.E. and Moyle, P. B. 1992. Wetland and aquatic habitats. Agriculture Ecosystems & Environment, V42(N1-2):165-176

McCord, S.A. 1999. The Effects of Artificial Mixing on Lake Water Quality. PhD dissertation. University of California, Davis.

Rajar R, Zagar D, Sirca A, Horvat M (2000). Three-dimensional modelling of mercury cycling in the Gulf of Trieste. Science Of The Total Environment, 260 (1-3): 109-123.

San Francisco Estuary Institute 2000: The Pulse of the Estuary: Tracking Contamination with the Regional Monitoring Program 1993-1998.

Schladow, S.G. and Hamilton, D.P. (1996) Prediction of water quality in lakes and reservoirs. Part II - Application to Prospect Reservoir. Ecol Modelling 96: pp111-123

Slotton, D.G., Suchanek, T.H. and Ayers, S. M. 2000. Delta wetlands restoration and the mercury question : year 2 findings of the CALFED UC Davis Delta mercury study. IEP newsletter. Vol. 13, no. 4 (Fall 2000), p. 34-44.

Smith, J.D., and McLean, S.R., 1977, Spatially averaged flow over a wavy surface: Journal of Geophysical Research, v. 82, no. 12, p. 1735-1746.

Stevens, H.H., and Yang, C.T., 1989, Summary and use of selected fluvial sediment discharge formulas: USGS Water-Resources Investigations Report 89-4026, 121 p.

Wiele, S.M., and Franseen, M.A., 2001, Sand transport and bed evolution modeling applications in the Colorado River, Grand Canyon: Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, 2001, p. I-115 – I-119.

APPENDIX – SUPPORTING LETTERS

SAC FLOOD CONTROL 916 874 8289 Fax:916-874-8289 Oct 5 '01 9:59 P.01/01

SAFCA

September 19, 2001

Bill Fleenor, Ph.D.
Dept of Civil & Environmental Engineering
University of California - Davis
2001 Engineering III
One Shields Avenue
Davis, CA 95616

SUBJECT: HEC-RAS

Dr. Fleenor:

Your proposal to incorporate sediment transport and water quality calculations into the HEC-RAS (UNET) model would serve the joint efforts of the stakeholders within CALFED very well.

Currently, the HEC-RAS (UNET) model is the most widely used and nationally accepted model of flood control stakeholders. Unfortunately, this model does not currently incorporate sediment transport or water quality calculations needed for those stakeholders interested in restoration work. This gap necessitates the use of a separate model for restoration work or the use of a different single model that can fulfill both purposes.

Models now available for both purposes are not currently accepted for flood control use and are proprietary models for which the costs would be prohibitive to small flood control districts and their local engineering support.

We encourage you to pursue your proposal toward providing a public domain program that has wide acceptance and can fill both the needs of flood control and restoration efforts.

Sincerely,

Pete Ghelfi
Director of Engineering

CC: Grant Kreinberg

916 874 4706
09/12/01 15:30 FAX 916 874 4706 Sac Co Water Res Div 001

COUNTY OF SACRAMENTO
PUBLIC WORKS AGENCY – WARREN HARADA, ADMINISTRATOR

Department of Water Resources

Including service to the Cities of Citrus Heights and Elk Grove

Keith DeVore, Director

September 12, 2001

Bill Fleenor, Ph.D.
Dept of Civil & Environmental Engineering
University of California - Davis
2001 Engineering III
One Shields Avenue
Davis, CA 95616

Dear Mr. Fleenor:

Subject: Adding sediment transport and water quality capabilities to HEC-RAS

The Sacramento County Department of Water Resources whole-heartedly supports your proposal to incorporate sediment transport and water quality calculations into the US Army Corps of Engineers' HEC-RAS (UNET) software. These additional modeling capabilities would greatly benefit the flood control and riverine habitat studies of the County, and those of its agency and non-profit partners on the Cosumnes River.

Currently the HEC-RAS (UNET) model is the most widely used and nationally accepted model of flood control stakeholders. Unfortunately this model does not currently incorporate sediment transport or water quality calculations needed for those stakeholders interested in restoration work and in assessment of fluvial processes that affect flood control. To answer water quality and sediment questions requires either duplicating the river model with other software, or using a model that can fulfill both purposes. However, state-of-the-art hydraulic models that possess the full range of hydraulic, sediment, and water quality capabilities are:

- not generally accepted for flood control use, and
- proprietary models with high licensing costs which preclude general use.

For these reasons, we encourage you to pursue your proposal to expand the widely-used public domain HEC-RAS (UNET) program so that it can provide the full spectrum of flood control and habitat restoration hydraulic modeling analyses.

Sincerely,

Craig Crouch, P.E.
Principal Civil Engineer (Regional Projects)

Main Office: 827 7th Street, Room 301, Sacramento, CA 95814 • Phone: (916) 874-6851 • Fax: (916) 874-8693
Field Offices: *Drainage Operations and Maintenance* – 3847 Branch Center Road, Sacramento, CA 95827 • Phone: (916) 875-7159
Water Supply Facilities Operations and Administration – 3847 Branch Center Road, Sacramento, CA 95827 • Phone: (916) 875-4913

Bill,

Thanks for this opportunity to provide input on what would a beneficial endeavor to a large number of stakeholders concerned with the long-term integrity of our water resources. Although, as an employee of a public agency, I am not permitted to provide official letters of endorsement for grant proposals, I can express through my experience of managing various projects that use or will use the UNET model that the added capabilities of sediment transport and water quality calculations would be a worthwhile improvement.

Currently, separate models are required to simulate the hydraulics and sediment transport/water quality aspects of the system of question. With an increasing number of non-structural flood control and flood plain restoration projects replacing traditional flood control solutions, the need to understand these interrelated components is essential to the effective planning, design, and operation of such multi-use projects. The Lower Cosumnes and Mokelumne Rivers feasibility study along with the North Delta modeling efforts are excellent examples of where the application of a single model to answer several challenging and regional-scale questions readily justify the evelopment of an expanded UNET model. Having an integrated model would also increase the reliability of results while reducing modeling costs in the future.

The Corps has selected UNET/HEC-RAS as its model of choice while relying on numerous secondary models to answer the relevant questions of sediment transport and water quality. It makes more sense to have a single model that can effectivley handle the range of hydrogeomorphic questions encountered in water resource studies.

Chuck Rairdan, D.Env.
Continuining Authorities Program Manager
(916) 557-7833
(916) 557-7848 fax

U.S. Army Corps of Engineers
1325 J Street
CESPK-PM-C
Sacramento, CA 95814

MBK ENGINEERS

Water Resources • Flood Control • Water Rights

Joseph D. Countryman, P.E.
Gilbert Cosio, Jr., P.E.
Marc Van Camp, P.E.

Angus Norman Murray
1913 - 1985

Consultants:
Joseph I. Burns, P.E.
Donald E. Kienlen, P.E.

October 3, 2001

Bill Fleenor, PhD
University of California - Davis
Department of Civil and Environmental Engineering
2001 Engineering III
One Shields Avenue
Davis, CA 95616

Subject: Water Quality and Sediment Transport Model Software

Dear Dr. Fleenor:

As we discussed, HEC's UNET program has been an invaluable tool for our clients over the years. As our clients experience additional responsibility in regard to water quality, due to TMDL or wildlife requirements, we will be asked to provide services addressing water quality and sediment transport. Therefore, we would wholeheartedly support your efforts to work with HEC in development of these modules to the existing software.

Sincerely,
MBK ENGINEERS

Gilbert Cosio, Jr.

GC/mv
C:\WPDOCS-2001\G C\L1003011.DOC

2450 Alhambra Boulevard, 2nd Floor • Sacramento, California 95817 • Phone: (916) 456-4400 • Fax: (916) 456-0253 • Email: mbk@mbkengineers.com