Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

Project Information

1. **Proposal Title:**

   Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

2. **Proposal applicants:**

   John Dracup, University of California, Berkeley
   Nigel Quinn, University of California, Berkeley
   Norman Miller, Lawrence Berkeley National Laboratory

3. **Corresponding Contact Person:**

   Jyl Baldwin
   University of California, Berkeley
   Sponsored Projects Office 336 Sproul Hall Berkeley CA 94720-5940
   510 642-8114
   jbaldwin@uclink.berkeley.edu

4. **Project Keywords:**

   Climate Change
   Environmental Impact Analysis
   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: 37.98476

Longitude: -121.30611

Datum:

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

San Joaquin River and major Eastside and Westside tributaries. Delta. Sacramento River and major tributaries.

10. **Location - Ecozone:**

    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. **Location - County:**

    Kings, Madera, Merced, San Joaquin, Stanislaus, Tuolumne

12. **Location - City:**

    Does your project fall within a city jurisdiction?

    No

13. **Location - Tribal Lands:**

    Does your project fall on or adjacent to tribal lands?

    No

14. **Location - Congressional District:**

    11

15. **Location:**

    California State Senate District Number: 5

    California Assembly District Number: 17

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:	$804,158
Federal Overhead Rate:	50.40%
Total Federal Funds:	929,345

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

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

No

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

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

No

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

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)

Maurice Roos	**Department of Water Resources**	**916-574-2625**	**mroos@water.ca.gov**

Lloyd Peterson	**U.S. Bureau of Reclamation**	**916-978-5471**	**n/a**
Francis Chung	**Department of Water Resources**	**916-653-5924**	**chung@water.ca.gov**
Daniel Cayan	**Scripps Institute of Oceanography**	**858-534-4507**	**dcayan@ucsd.edu**

21. **Comments:**

Environmental Compliance Checklist

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

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

      No

   b) Will this project require compliance with NEPA?

      No

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

      This is a modeling study conducted at the University of California and there are no anticipated environmental impacts.

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

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

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

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

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

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

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

      Not Applicable

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

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

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

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

Permission to access state land.
Agency Name:

Permission to access federal land.
Agency Name:

Permission to access private land.
Landowner Name:

6. **Comments.**

Land Use Checklist

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

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

   No

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

   No

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

   No

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

   Research only

4. **Comments.**

Conflict of Interest Checklist

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

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):

John Dracup, University of California, Berkeley
Nigel Quinn, University of California, Berkeley
Norman Miller, Lawrence Berkeley National Laboratory

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

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

Norman Miller	LBNL
None	None
None	None
None	None
None	None

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

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

John Dracup UC Berkeley

Nigel Quinn **UC Berkeley**

Norm Miller **LBNL**

Comments:

Budget Summary

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

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**
a	Evaluate and apply climate projections from geneeral circulation models (GCMs) used by the Intergovernmental Panel on Climate Change (IPCC) for ppolicy development	753	16416	2130	1000	166	37500	1667		58879.0	13867	72746.00
b	Use range of climate projections to develop climate change reservoir inflows for Central Valley Project (CVP) and State Water Project (SWP) operations simulation using CALSUM II	753	16416	2130	1000	167	37500	1667		58880.0	13867	72747.00
c	Improve an existing Decision Support System (DSS) that assesses climate change impacts on San Joaquin Basin water, ecosystem, and economics resources	927	23666	5176	1000	167	0	1667		31676.0	13867	45543.00
d	Use CALSIM II output as input for an enhanced DSM2-SJR that models stream water quality in the San Joaquin River main reach and major tributaries	927	23666	5176	1000	167	0	1667		31676.0	13867	45543.00

e	Use reservoir and river hydraulic models to study these relationships and develop simulation logic for CALSIM II	927	23666	5176	1000	166	0	1667		31675.0	13867	45542.00
f	Improve the CVP/SWP operator's ability to predict seasonal water supply using forecast models based on remote climate data	753	16416	2130	1000	166	0	1667		21379.0	13867	35246.00
		5040	120246.00	21918.00	6000.00	999.00	75000.00	10002.00	0.00	234165.00	83202.00	317367.00

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**
a	Evaluate and apply climate projections from geneeral circulation models (GCMs) used by the Intergovernmental Panel on Climate Change (IPCC) for ppolicy development	753	16745	2172	1000	167	37500	833	0	58417.0	11992	70409.00
b	Use range of climate projections to develop climate change reservoir inflows for Central Valley Project (CVP) and State Water Project (SWP) operations simulation using CALSUM II	753	16745	2172	1000	166	37500	833	0	58416.0	11992	70408.00

c	Improve an existing Decision Support System (DSS) that assesses climate change impacts on San Joaquin Basin water, ecosystem, and economics resources	927	24139	5279	1000	167	0	833	0	31418.0	11990	43408.00
d	Use CALSIM II output as input for an enhanced DSM2-SJR that models stream water quality in the San Joaquin River main reach and major tributaries	927	24139	5279	1000	167	0	834	0	31419.0	11990	43409.00
e	Use reservoir and river hydraulic models to study these relationships and develop simulation logic for CALSIM II	927	24139	5279	1000	167	0	834	0	31419.0	11990	43409.00
f	Improve the CVP/SWP operator's ability to predict seasonal water supply using forecast models based on remote climate data	753	16744	2171	1000	166	0	833	0	20914.0	11990	32904.00
		5040	122651.00	22352.00	6000.00	1000.00	75000.00	5000.00	0.00	232003.00	71944.00	303947.00

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**

a	Evaluate and apply climate projections from geneeral circulation models (GCMs) used by the Intergovernmental Panel on Climate Change (IPCC) for ppolicy development	753	17079	2185	1000	167	37500	833	0	58764.0	12219	70983.00
b	Use range of climate projections to develop climate change reservoir inflows for Central Valley Project (CVP) and State Water Project (SWP) operations simulation using CALSUM II	753	17079	2185	1000	167	37500	833	0	58764.0	12219	70983.00
c	Improve an existing Decision Support System (DSS) that assesses climate change impacts on San Joaquin Basin water, ecosystem, and economics resources	927	24622	5353	1000	167		833	0	31975.0	12219	44194.00
d	Use CALSIM II output as input for an enhanced DSM2-SJR that models stream water quality in the San Joaquin River main reach and major tributaries	927	24622	5353	1000	167		834	0	31976.0	12219	44195.00

e	Use reservoir and river hydraulic models to study these relationships and develop simulation logic for CALSIM II	927	24623	5353	1000	167		834	0	31977.0	12219	44196.00
f	Improve the CVP/SWP operator's ability to predict seasonal water supply using forecast models based on remote climate data	753	17079	2185	1000	165		833	0	21262.0	12218	33480.00
		5040	125104.00	22614.00	6000.00	1000.00	75000.00	5000.00	0.00	234718.00	73313.00	308031.00

Grand Total=929345.00

Comments.

Budget Justification

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

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

Prof. John Dracup: 269.7 hours Dr. Nigel Quinn: 522 hours Visiting Postdoc. Researcher: 1,670 hours Two Graduate Student Researchers @

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

Prof. John Dracup: $253/hr. Dr. Nigel Quinn: $128/hr. Visiting Postdoc. Researcher, TBN: $46.90/hr. Graduate Student Researcher, TBN: $2957 x 6 mos. and $3016 for 6 mos. which includes projected 2% Cost of living adjustment effective every October 1st.

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

Professional Investigator: summer research 12.70%. Other Academic Personnel (Assoc. Research Engineer, Visiting Postdoc.: 17% calendar year salary. Graduate Student Researcher, academic year salary: 1.30%. Graduate Student Researcher, summer salary: 3.0%. Full in-state Fee Remission for Calif. residents/per semester per student: $2269 Spring 2002-Spring 2003; $2314 Spring 2003-Spring 2004.

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

Four (4) round-trips to relevant scientific Conferences, locations to be determined.

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

Software upgrades for existing desktop and laptop computers

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.

LBNL, Dr. Norman Miller: Tasks a, b Lump sum LBNL subcontract per year: $75,000

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.

One computer workstation @ $10,000/unit. Second and third years: $5000 per year for hardware upgrades.

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.

Because the University of California, Berkeley is a teaching/research campus there exists an infrastructure to support research through administrative services and direct PI involvement as part of the academic mission.

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

None

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

The predetermined rate of 50.40% is used on grants, contracts and other agreements with the Federal Government for on-campus sponsored research. Base: modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract. Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, tuition remission, rental costs of off-site facilities, scholarlships and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000. Line items other than indirect costs will remain the same for Federal or State funding sources.

Executive Summary

<u>Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries</u>

The objectives of this project are to assess the impacts of climate change on water quality and habitat resources in the San Joaquin Basin and to develop a decision support system that will assist state and federal agencies mitigation planning efforts. The proposed research has six categories of questions and approaches. 1) What is the range of projected future climates that could be evaluated for the San Joaquin Basin? Approach: evaluate and apply climate projections used by the Intergovernmental Panel on Climate Change for policy development. 2) How will San Joaquin Basin streamflow be impacted by projected future climates? Approach: use range of climate projections to develop climate change reservoir inflows for simulating Central Valley reservoir operations using CALSIM II. 3) How can impact assessment models be linked without compromising model accuracy and flexibility? Approach: improve an existing multi-model decision support system that assesses climate change impacts on San Joaquin Basin water, ecosystem, and economics resources. 4) How will salinity in the San Joaquin River and tributaries be impacted by future climates? Approach: use CALSIM II output as input for an enhanced DSM2-SJR model that simulates stream water quality in the San Joaquin River main reach and major tributaries. 5) What is the variation of New Melones, Exchequer and New Don Pedro release water temperature and streamwater temperature in the Stanislaus and Tuolumne Rivers as a function of reservoir inflow, release requirements, and storage conditions? Approach: use reservoir and river hydraulic models to study these relationships and develop simulation logic for CALSIM II. 6) How can climate monitoring be used for mitigating climate change impacts on the basin's water quality and riparian habitat? Approach: use remote climate data to improve Central Valley seasonal water supply forecasting. This project complements the CALFED ERP program by using adaptive management tools to solve problems in ecosystem quality, water quality and water supply reliability. It also relates to the CVPIA by providing estimation of relative environmental impact on water quality and fisheries caused by operation of the reservoirs under historical and climate change scenarios.

Proposal

University of California, Berkeley

Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and its Major Tributaries

John Dracup, University of California, Berkeley
Nigel Quinn, University of California, Berkeley
Norman Miller, Lawrence Berkeley National Laboratory

ADAPTIVE MANAGEMENT OF CLIMATE CHANGE IMPACTS ON WATER QUALITY AND ENVIRONMENTAL RESOURCES OF THE SAN JOAQUIN RIVER AND ITS MAJOR TRIBUTARIES

A. PROJECT DESCRIPTION

A.1 Location

The immediate project area for assessing climate change impacts is defined by the San Joaquin Basin and the Sacramento-San Joaquin Delta (Figure 1). Since water allocation and reservoir operations in this area are affected by water supply from the Sacramento Basin, the area for simulating the effects of climate change on hydrology includes the entire Central Valley basin (i.e. San Joaquin Basin, Sacramento Basin, and Sacramento-San Joaquin Delta).

A.2 Problem Statement and Background

Increasing demands on water supply in the State of California due to urban expansion, increasing population, and a greater commitment of water supply to environmental resources, mandated by the Federal government, makes the State of California ever more vulnerable to potential future changes in climate and extreme weather events. The most recent drought that produced a sequence of dry and critically dry years from 1989 to 1994, resulted a vulnerability wake-up call to the California Department of Water Resources and the USBR's Central Valley Project. With diminishing imports of allowable water from the Colorado River and legal adjudications in the Trinity Basin against the State, contingency plans will be necessary to avoid a future water crisis. The first step in this planning effort is the development of a better understanding of the potential impacts of future climate scenarios.

Planning studies involving suites of complex models are often compromised owing to the inordinate amount of time devoted to data processing as the output from one model is manipulated to become the input to the next in sequence. This leads to frustration on the part of the decision maker, who is more apt to make mistakes if the time spent in data processing takes away from the task of setting up the modeling system to simulate the problem at hand. This is especially evident in the development of a modeling system for impacts analysis due to potential future climate change variability and extreme weather events.

Policy makers in the U.S. government are still debating the significance of global warming**.** The June 2001 report by the National Academy of Sciences (NAS 2001) commissioned by the Bush Administration summarizes the IPCC 2001 findings. Climate model simulations in the IPCC report indicate that the mean global temperature will increase by 1.4 to 5.8 ^{o}C by 2100, with a 95% probability interval of 1.7 to 4.9 ^{o}C (Wigley and Raper 2001). In June, President Bush announced the establishment of a U.S. Climate Change Initiative to study areas of uncertainty and identify priorities.

Local regions such as California will respond uniquely to this likely global warming. State and Federal water agencies in the arid western U.S. are beginning to formulate contingency plans for future events that depart from the standard hydrologic time series developed from records over the past 100 years.

There has been a number of previous California water resources studies based on projected climate 2xCO_2 scenarios using General Circulation Models (GCMs) and hydrologic models (Lettenmaier et al 1989; Lettenmaier and Ghan 1990; Gleick 1989, Dracup and

Pelmulder 1993). These studies are based on estimations of planetary climate change from Global Circulation Models (GCMs) and generated mean monthly streamflow. The majority of these studies simulated the Sacramento or San Joaquin drainage basins as a single system or evaluated only a few headwaters. None of the previous studies simulated climate change response using well calibrated hydrologic models for a large set of basins draining into the Sacramento and the San Joaquin drainage areas. These basin-scale effects can have important consequences for water storage and water quality in the San Joaquin River. In spite of this limitation, these studies concluded that the consequences of a global warming trend in California would be warmer winter storms, earlier runoff from the Sierra snowpack, and reduced summertime flow in tributary streams. Results also suggested that water resources in many arid environments, such as California's Central Valley, would become more vulnerable to climate variation than water resources in less arid regions. Several of the researchers hypothesized that basins with large numbers of tributaries would tend to increase damping of the signal generated by climate variability, resulting in smaller changes to project yield. The east-side of the San Joaquin Basin contains several tributaries (Figure 1), whereas the west-side of the San Joaquin Basin, which is in the rain-shadow of the Coast Range, has relatively few tributaries. Severe storms on the west-side of the San Joaquin Basin can produce extreme flooding events such as occurred in 1983, 1986, 1995 and 1997. These studies also suggest that groundwater resources would become increasingly stressed as a result of increased pumping, brought about by decreased surface water availability. Increased stress on the groundwater system can result in decreases in the quality of pumpage as zones of high salinity are drawn down into underlying aquifers of higher water quality.

In general, changes in the timing of streamflow in the tributaries and San Joaquin River, resulting from global warming trends, produce potentially severe impacts on water quality, aquatic productivity, species diversity, and species distribution. In instances where climate warming scenarios result in increased river temperature, fish spawning is negatively impacted. In these same scenarios early snowmelt increases early spring streamflow which disrupts fish migration patterns. In the case of the anadromous Chinook salmon the population was predicted to decrease by 50% in a $2xCO_2$ environment partly as a result of possible changes in land use. Socioeconomic impacts resulting from changes in the timing of runoff include potential reductions in fulfillment of existing water rights and entitlements potentially leading to an increase in litigation and a decline in the equity of water allocation among competing uses.

A.3 Decision Support System (DSS) for Climate Change Impact Assessment

A.3.1 Development

Evaluation of the environmental and socioeconomic impacts of climate variability and extreme weather events requires the development of a computer-based modeling system to process the large amounts of information and data required for intelligent analysis and decision making. The goals of the current software development effort are to (1) create a DSS that can assess the vulnerability of water supply, water demand, water quality, ecosystem health, and socioeconomic welfare within the San Joaquin River Basin as a function of climate variability and extreme weather events and (2) use this DSS to provide guidance in the formulation of effective management strategies to mitigate the range of potential impacts.

To accomplish these goals state-of-the-art mathematical models have been assembled from water agencies, the University of California, and private consultants that are currently being incorporated in a fully integrated Decision Support System (DSS). Problem solving capability is enhanced in the DSS by the use of Graphical User Interfaces (GUI's) and the linkage to a Geographical Information System (GIS) for spatial data visualization and processing. The DSS takes advantage of recent advances in physically based downscaled climate modeling to the sub-basin scale as well as the collective experience of the project team in using existing climate models, water supply allocation models, agricultural production and resource optimization models, fishery and ecosystem models, and economic analysis techniques. By utilizing planning models in daily use by participating institutions this development effort, upon its completion, will provide a resource to these groups as part payment for their help in installing the models and verifying their function within the DSS. The target user community of the DSS will be water agencies and key representatives of various response and decision making sectors such as agricultural water districts, refuge managers and the informed general public.

A.3.2 Features

The DSS includes models that were selected based on the following criteria: (a) general acceptance by the user community; (b) ability to adequately describe conditions in the San Joaquin River Basin; (c) availability of model codes in the public domain. A schematic of the DSS model integration is shown on Fig. 2. The DSS consists of five major components: (1) climate simulations, (2) water allocation and reservoir operations model, (3) agricultural production economics and drainage salinity model, (4) river flow and water quality model, and (5) data integration architecture.

<u>A.3.2.a Climate Simulations:</u> These simulations are performed using a Climate Downscaling Model System (CDMS). The CDMS is part of a larger suite of models making up the Regional Climate Model System (Miller and Kim 1996) that transforms regional-scale climate data derived from General Circulation Models (GCMs) to basin-scale precipitation and temperature data necessary for driving rainfall-runoff streamflow models; the term "downscaling" refers to translating information from coarser scale to finer scale spatial resolution (Figure 2). Dynamical downscaling links GCM output to rainfall-runoff input through an intermediate physically based Regional Climate Model (RCM, e.g. Mesoscale Atmospheric Simulation (Kim and Soong 1996)). The RCM simulates atmospheric circulation and climatic processes over a limited area region (e.g. eastern Pacific Ocean and western North America) at a spatial resolution higher than that of GCMs (e.g. ~10x10 km RCM grids versus ~200x200 km GCM grids). Statistical downscaling links GCM output directly to rainfall-runoff input using a statistical transfer function. The function predicts daily basin average rainfall occurrence, rainfall amount, minimum temperature, and maximum temperature as a function of atmospheric data from GCM output. The function can be developed using one of several candidate methods (e.g. stepwise regression, artificial neural networks, interpolation). Both downscaling procedures ultimately produce basin-area average precipitation and temperature data that drive rainfall runoff models, which subsequently produce snow budget, soil moisture, and streamflow output useful for short-term forecasts, seasonal-scale experimental predictions, and long-term climate scenarios (Miller et al. 1999). The CDMS includes key headwater basins in the Sacramento and San Joaquin Basins. Comparison of streamflow output for climate change scenarios relative to output under present climate conditions is used to compute a set of factors describing

streamflow response to climate change in each basin under for each climate change scenario. These response factor sets are then used to perturb inflow time series for CVP/SWP reservoirs associated with these basins in the CALSIM II simulation, discussed in next subsection. The CDMS is continually evolving. Current work is focused on using the Mesocale Atmospheric Simulation and Soil-Plant-Snow model for the dynamical downscaling mode (Kim and Soong 1996; Kim and Ek 1995). Comparison of results from using alternate basin hydrologic models is also being conducted, one alternative being a semi-distributed topographically forced hydrologic model (TOPMODEL: Beven and Kirkby, 1979), and the other being a spatially lumped, distributed parameter hydrologic model (Sacramento Model: Peck, 1973). Experimental seasonal predictions based on $2xCO_2$ simulations have been generated with earlier versions of the Regional Climate Modeling System (Miller and Kim 1996, Miller and Kim 1997, Kim et al. 1998, Miller et al. 1999, Kim et al. 2000, Miller et al. 2000). Seasonal predictions are needed for estimating spring season water supply and determining the likelihood of severe weather.

For climate change impacts assessment, we have developed upper- (warm, wet) and lower-limit (cool, dry) climatological ratios of mean monthly streamflow under climate change relative to historically observations. These ratios represent the sensitivity of runoff in the California's Sacramento-San Joaquin basin to the effects of climate change. The upper limit ratios represent the climate projection from the Hadley Center's GCM (HCM) and the lower limit ratios represent the climate projection from the National Center for Atmospheric Research's Parallel Climate Model (PCM), which are warm-wet and cool-dry, respectively, relative to the mean of the projections used by the IPCC. Streamflow ratios are shown on Figure 3. Six headwaters were simulated (Smith River at Jed Smith, Feather River at Oroville Dam, Sacramento River at Delta, American River at North Fork Dam, Merced River at Pohona Bridge, and Kings River at Pine Flat) for three future time periods (2010-2039, 2050-2079, and 2080-2099). Each plot begins with October and ends with September to represent the streamflow percent change for a climatological water year. For the 2010-2039 and 2050-2079 time periods, the warm-wet HCM indicated that there is generally a doubling in the streamflow monthly volume for October to March, and then decreases to about 80 % historical during the remainder of the year. The HCM 2080-2099 shows increases of order five times during the October to March period and decreases of about 50% historical during the remainder of the year. The cool-dry PCM shows streamflow volumes approximately equal to historical for most watersheds during the October to March period and decreases to about 50% during the remainder for both 2010-2039 and 2050-2079. During the 2080-2099 period, PCM shows large decreases (50% historical) in streamflow during the May to September period.

<u>A.3.2.b Water Allocation and Reservoir Operations Model</u>: Streamflow response factors developed from CDMS output are used to provide estimates of unimpaired streamflow under various climate change scenarios, which then become main input variables for CALSIM-II, the water allocation and reservoir operations model for the joint CVP/SWP system (Figure 3). CALSIM-II is a hybrid linear optimization model which translates the unimpaired streamflows into impaired streamflows, taking into account reservoir operating rules and water demands exerted at model nodes, modified to reflect a user-defined level of watershed development (e.g. Year 2000,Year 2020, etc). CALSIM-II is in the final stages of calibration by teams of engineers from both State and Federal governments in a unique collaboration; historically, modeling of State and Federal water projects in California was performed

independently. Calibration of this model involves setting penalty function weights to train the model to adherence to operating rules and constraints such as fish flow requirements, downstream water quality objectives and contract deliveries to agricultural and urban water districts. A matrix solver is used to determine the optimal monthly reservoir releases that meet all the system constraints. This model has distinct advantages over previous "hard-coded" Fortran models in that it allows adjustments to be made in current operating rules and policies with relative ease by changing weights in the linear constraint equations rather than rewriting Fortran code. This is of particular benefit for contingency planning under future climate change scenarios where additional storage or changes in flood storage and release policies may be explored as ways of improving the reliability of water supply under forecasts of increased future demand.

A preliminary climate change impact assessment on San Joaquin Basin water supply has been completed by members of the project team on a related climate change impacts study funded by EPA-STAR. This preliminary assessment is based on a GCM projection that is significantly wet compared to other GCM projections (i.e. the precipitation over California would be expected to increase much more significantly in this projection compared to others). Some results are depicted on Figure 4. Preliminary findings based on this projection are that reservoir inflow would increase dramatically while there would be smaller increases in stored water due to capacity limits. Other findings not depicted in Figure 4 include increases peak potential monthly flow volumes thereby making flood control in the Southern San Joaquin Basin more challenging, and decreases in necessary water releases from New Melones Reservoir required for maintaining water quality conditions at Vernalis. A limitation of this earlier assessment is that it considers only one GCM projection among many possible alternatives, and the projection itself seems to represent a wet end-member. This project addresses this limitation by including an evaluation of possible projections and a call for selection of wet, dry, and intermediate projections to drive the impacts assessment, which will produce a range of potential impacts results for decision-makers.

<u>A.3.2.c Agricultural Production Economics and Drainage Salinity Model:</u> A state-of-the-art agricultural production economics and irrigation hydrology model APSIDE is under development which will utilize available water supply predicted by the CALSIM II model to determine crop production, groundwater pumpage and irrigation return flows within the San Joaquin Basin (Figure 3). Subsurface drainage flows from agricultural lands in the San Joaquin Basin have a significant impact on San Joaquin River water quality, especially during summer months when the flow of the San Joaquin River is dominated by return flows from west-side agricultural sources (CRWQCB, 1998) Drainage flows contain a number of environmental contaminants, including selenium, boron, nitrate, and salts. On average these drainage flows contribute 60-70% of the salt and boron loading and 80-90% of the selenium loading to the San Joaquin River. In the absence of a means to export these contaminants, levels of salt and boron build up in the crop root zone and shallow groundwater aquifer. High levels of salt and boron in the crop root zone can significantly reduce crop yield, leading to reduced agricultural income and the predictable impacts on the socioeconomic welfare of farm workers and the rural economy.

A salinity model will be linked to the agricultural production and irrigation and drainage flow models to estimate the salts retained in the crop root zone after each irrigation season and the salt loading exported to the San Joaquin River. Agricultural production on the west side of the San Joaquin River is very sensitive to crop root zone salinity on account of the high levels of boron in the native soils. Hence practices that attempt to achieve salt balance with the crop root zone will result in the transport of substantial salt loads to the San Joaquin River. Likewise agricultural pumping, which will likely increase in circumstances where surface water deliveries are curtailed, will also lead to an increased salt disposal problem since groundwater supplies are invariably saltier than surface water supplies.

The California Agricultural Production Model (CARM) was developed by Howitt and others to estimate the impacts of policy, water resource supply, and climate changes on irrigated agriculture in the Central Valley of California (Howitt, 1995). The Westside Agricultural Drainage Economics Model (WADE) was an outgrowth of this modeling effort and sought to estimate the quantity and quality of agricultural drainage resulting from policies to control selenium drainage from west-side sources. The WADE model comprised three optimization sub-models simulating seasonal agricultural production decisions, groundwater hydrology and groundwater water quality. The groundwater flow and water quality sub-models considered plant water requirements, groundwater pumping and agricultural tile drainage. The APSIDE model currently under development will run with a monthly timestep to synchronize with the CALSIM-II model input and will provide monthly estimates of the volume and quality of agricultural return flows which will be directed to a river flow and water quality model (DSM2-SJR) for water quality simulations and environmental impact analysis, discussed in the next subsection.

The agricultural production models can be utilized in a descriptive mode for performing the vulnerability analysis and in a prescriptive mode for suggesting management strategies for mitigating the impacts of increased climate variability and more frequent extreme weather events. Unusual weather patterns such as occurred in 1997 El Nino produced runoff events that overwhelmed the water conveyance and distribution system within the watershed and lead to unusually high exports of salt, selenium and boron to the San Joaquin River. Increased climate variability and an increase in the frequency of unusual events could affect the long-term viability of growing certain agricultural crops on the west-side of the San Joaquin Basin.

A.3.2.d River Flow and Water Quality Model: Drainage return flows generated by the agricultural production and groundwater models must be routed to the San Joaquin River in order to determine the impact of these activities on river water quality. A monthly mass balance model, the San Joaquin River Input-Output model (SJRIO) is currently used by the San Joaquin River Mnaagement Program's Water Quality Subcommittee on a weekly basis to account for contaminant loads exported to the San Joaquin River. The model performs a mass balance accounting of discharge, TDS, boron, and selenium for a 60-mile (96-km) reach of the lower San Joaquin River. The model calculates the load contributed from each source based on its flow and concentration using a mass balance accounting method. SJR flows and water quality are calculated for every tenth of a mile. Riparian diversions are currently estimated using three types of data: acreage irrigated by each pump, cropping patterns, and crop water use. Groundwater accretions or depletions and quality are currently considered steady state and are defined by the modeler for user-specified reaches of the river. Work is underway to replace the current model with DSM2-SJR (Figure 3), a one-dimensional fully-hydrodynamic extension of the State's Delta Simulation Model (DWR-DSM2). DWR-DSM2 simulates the complex hydrology of the entire Sacramento-San Joaquin Bay-Delta estuary and use of this model would allow for study on recirculation of San Joaquin River water to the giant State and Federal pumping plants that export Delta water to agricultural water districts in the San Joaquin Basin as well as coastal cities such as Los Angeles. San Joaquin River water, with its high concentrations of salts and trace elements, is less attractive to municipal and industrial users because of the high cost of removal of these contaminants in water treatment facilities.

We will also expand the capability of the hydrodynamic DSM2-SJR model as a water quality management tool by extending the model domain from the mainstem of the San Joaquin River up the Stanislaus, Tuolumne, and Merced Rivers to the Tulloch Lake, New Don Pedro, and Exchequer reservoirs. Additionally, we will model water temperature distribution throughout the main stem of the San Joaquin River and tributaries. Water temperature is an essential parameter for the estimation of potential survival rates of aquatic life such as juvenile fish, which depend on cool oxygenated water to avoid stress. Dissolved oxygen levels in water increase with decreasing temperature.

Accurate forecasting capability is important in both the San Joaquin River Basin and the Bay-Delta on account of water quality based standards and objectives that influence actions such as export pumping via the California Aqueduct to west-side agriculture and the Los Angeles Basin. The linkages made between climatic, hydrologic and water quality models in this DSS can assist management of water quality in the San Joaquin River Basin and Bay-Delta.

A.3.2.e Data Integration Architecture: In order to link the various models that make up the DSS, a unique system of model integration software is being employed (Leavesley et al. , 1996). The Modular Modeling System - Object User Interface (MMS-OUI) is a framework of pre-processing, model run and post-processing libraries that allow individual modules to be "shrink wrapped" and hence treated as objects within a Decision Support System. The MMS-OUI was originally conceived by the US Geological Survey in cooperation with Boulder's Center for Advanced Decision Support for Water and Environmental Systems (CADSWES). Since the initial development the system has been applied to numerous DSS applications within the US and internationally (Leavesley, 1999: personal communication). The MMS-OUI has three major components: a pre-processor, the data model and a post processor. A java-based system supervisor, which takes the form of an X-window graphical user interface (GUI) provides the end user with access to all the components and features of MMS-OUI.

The pre-process component includes software designed to input, analyze and prepare spatial and time series data for use in the various model applications. Spatial data analysis is accomplished through calls to GIS libraries such as ESRI Arc-Info. Databases are used to store spatial and time series data and provide the interface between the pre-process and model components. For the current DSS application the US Corps of Engineers Data Storage System (HEC-DSS) for time series data is being used.

The MMS-OUI software serves as an ideal data browsing interfacing for model input and output. It is being used to communicate results to EPA-STAR project stakeholders. Each stakeholder will receive a data CD with the MMS-OUI software, map file, and model input/output files for easy access to impacts assessment results. As the model system evolves and analysis products are updated, new data CDs with updated input/output files will be issued.

A.4 Proposed Scope of Work

A.4.1 Overview of Tasks

A.4.1.a: Evaluate and select alternative climate change scenarios (i.e. temperature and precipitation projections) based on the Intergovermental Panel on Climate Change (IPCC)

GCM analyses. The IPCC reports that global mean temperature could increase by the Year 2100 between 1.4 and 5 ^{o}C. The expected change is precipitation is less certain, according to projections originiating from various available GCMs. California climate change needs to be assessed regionally to determine the local watershed impacts. Selection of GCM projections that represent the warmer, cooler, and intermediate projections will allow for an analysis of the possible upper and lower limits of climate change.

A.4.1.b: Translate GCM-estimated regional climate change over California and Nevada to basin-scale climate change (e.g. Shasta Lake basin) using statistical and dynamical downscaling techniques. The climate change scenarios' time series data selected in task (a) will be used as input to statistical and dynamic downscaling techniques and applied to hydrologic models at the watershed scale (see Figure 2). Sets of factors describing streamflow response to climate change relative to present climate will be produced for a set of tributary headwater basins in the Sacramento and San Joaquin valleys. These sets of streamflow response factors will be used to generate climate change inflow and hydrologic year-type time series for CVP/SWP reservoirs in CALSIM II.

A.4.1.c: Enhance the ease of use and flexibility of the decision support system used for climate change impact assessment (see Section A.4). The DSS is currently underdevelopment on an EPA-STAR funded project (grant #R827448-01-0). Modifications to CALSIM II through task (e) and DSM2-SJR through task (d) will be part of the DSS enhancements.

A.4.1.d: Expand the capability of the hydrodynamic DSM2-SJR model as a water quality management tool by extending the model domain from the mainstem of the San Joaquin River up the Stanislaus, Tuolumne, and Merced Rivers to the Tulloch Lake, New Don Pedro, and Exchequer reservoirs. This will require integration of recent water quality monitoring station data as well as improved cooperation with east-side water districts. This effort will take advantage of the recent CVRWQCB initiative to develop TMDL's for salinity and dissolved oxygen in the San Joaquin River Basin.

A.4.1.e: Expand the capability of CALSIM II as a fish habitat management tool by adding simulation logic to the model to estimate monthly average release temperature from New Melones and New Don Pedro reservoirs. This logic will be based on reservoir hydraulic modeling, based on work recently completed by the US Bureau of Reclamation, and river hydraulic modeling downstream of the reservoirs using extended DSM2-SJR. The logic will improve reservoir operation for fishery enhancement and migration of anadromous fish species.

A.4.1.f: Increase the capability of state and federal resource managers to mitigate climate change impacts on water quality and fish habitat in the San Joaquin River Valley by using remote climate information to improve CVP/SWP operators' ability to predict seasonal water supply. A secondary objective is to assess the risk of using this remote climate information on water quality and fish habitat management decisions. Variables describing remote climate conditions in the tropical and north Pacific Ocean will be screened to find the best variable(s) and variable combination(s) that most significantly affect the exceedence probability distributions for reservoir inflow to Lake Shasta, Lake Oroville, and Folsom Lake. These forecasts control an array of water allocation and reservoir operations decisions in CALSIM

II. New forecasts methods will be developed using the remote forcing information. The results from these new forecasts will be compared to traditional methods and the risk of using the proposed methods will be estimated.

A.4.2 Justification, Conceptual Models, and Hypotheses/Questions per Task

Hypothesis/Question to be Evaluated	*Monitoring Parameter(s) and Data Collection Approach*	*Data Evaluation Approach*	*Comments/Data Priority*
a. What is the range of projected future climates that could be evaluated for the San Joaquin Basin?	Obtain 100 year simulations (1999-2099) of projected climate from GCMs used by the IPCC.	Analyze the temperature and precipitation mean and variance for California watersheds.	Understanding the range of potential outcomes will help to quantify the uncertainty in potential outcomes.
b. How will San Joaquin Basin streamflow be impacted by projected future climates?	Generate statistically and dynamically downscaled watershed-mean-area temperature and precipitation timeseries representing projected climates.	Apply the calculated watershed-mean-area temperature and precipitation to soil moisture accounting and snow models to simulate streamflow volumes.	Results from the streamflow simulations will be aggregated to monthly streamflow volumes and, based on regional similarities, applied to the impacts models as input forcing.
c. How can impact assessment models be linked without compromising model accuracy and flexibility?	Cooperators in the Department of Water Resources and US Bureau of Reclamation will use, test, and evaluate the finished work product.	The MMS-OUI integrated system will be compared to traditional approaches.	This exercise may point to areas of future model integration including the inclusion of additional simulation models.
d. How will salinity in the San Joaquin River and tributaries be impacted by future climates?	Continuous, telemetered flow and electrical conductivity data at three locations along each major tributary. Geometry: Cross-sections and other geomorphological characteristics.	Extended DSM2-SJR will be used to estimate streamflow, salinity and water temperature (see task (e)) along the tributaries and the main stem of the SJR.	Results of this study may indicate additional real-time flow and water quality monitoring along each major tributary.

e. What is the variation of New Melones and New Don Pedro release water temperature and streamwater temperature in the Stanislaus and Tuolumne Rivers as a function of reservoir inflow, release requirements, and storage conditions?	Reservoir operations, bathymetry, reservoir inflow, water release, and temperature data from the US Bureau of Reclamation.	Physical analysis of reservoir and river hydraulics using new models developed for the two reservoirs and extended DSM2-SJR for the rivers. Translation of physical analysis results into simple logic for implementation in CALSIM II.	Beneficial results from this task depend on the ability to model the complex mixing processes in the two reservoirs and then statistically relate the modeling results to CALSIM parameters: inflow, release, and storage.
f. How can remote climate information be used for mitigating climate change impacts on the San Joaquin Basin's water quality and riparian habitat?	Historical tropical and north Pacific Ocean climate data, historical CVP/SWP water supply forecast data, and biological opinions on south of Delta pumping.	Statistical analysis of data in combination with interviews of State and Federal resource managers and operators	May get a number of opinions and rationales for CVP and SWP operations and fishery resource management decisions

A.4.3 Details of Approach per Task

A.4.3.a Evaluate and select alternative climate change scenarios used by the IPCC. Climate change scenarios are produced from many operational GCM's available from various academic and government institutions. Given the wide range of projection options, it is important to evaluate the alternatives and select projections that represent relatively warmer and cooler projections, thereby bounding the possible upper and lower limits of climate change. It is also important to select relatively wet and dry precipitation projections for the same reason. In addition to selecting projections to define the bounds of climate change, care will also be taken to select a GCM scenario that appears to represent an intermediate projection between the upper and lower limits, for both temperature and precipitation.

A.4.3.b Translate GCM-estimated climate change over CA/NV at the regional scale to basin scale. The climate change projections selected in task (a) will be used as input to statistical and dynamic downscaling techniques and applied to hydrologic models at the watershed scale (Figure 2). For any given regional-scale climate scenario, the Climate Downscaling Model System is designed to simulate runoff for several CVP/SWP reservoir headwater basins. By comparing runoff results using a climate change scenario to results from using a present climate scenario, sets of factors describing streamflow response to climate change relative to present climate can be computed for the headwater basins. These sets of streamflow response factors are then used to generate climate change inflow and hydrologic year-type time series for CVP/SWP reservoirs in CALSIM II.

A.4.3.c Enhance the ease of use and the flexibility of the DSS. The current EPA-STAR funded project at the University of California Berkeley (grant #R827448-01-0) has used Dr. Leavesley's MMS-OUI software to create linkage between model data and model objects.

With the advent of Arcview 8.1 and its native COM architecture, future work on the model integration will utilize this product directly allowing enhanced flexibility and a more user-friendly interface. Future work will concentrate on improving the database architecture to accommodate greater feedback streams between the various models allowing the models to achieve a more stable solution during each annual cycle. At present each model within the sequence used in a simulation runs for 12 months of each year and then writes the result to a database. The next model in sequence reads the output data from the database as model input to itself. In instances where one model, such as DSM2-SJR, overwrites the results of another, such as the Vernalis electrical conductivity estimator in CALSIM-II, there may be a need to iterate the models to some known closure condition. This feature is not well developed in the current model integration scheme.

<u>A.4.3.d Expand the model domain of DSM2-SJR to include the Stanislaus, Tuolumne, and Merced tributaries.</u> The Delta Simulation Model 2, San Joaquin River boundary extension (DSM2-SJR) will be used to estimate streamflow, salinity and water temperature along the tributaries and the main stem of the SJR. DSM2-SJR is a one-dimensional deterministic hydrodynamic/transport model developed by the California State Department of Water Resources. DSM2-SJR can calculate stages, flows, velocities; many mass transport processes, including salts, multiple non-conservative constituents, temperature, THM formation potential and individual particles. The San Joaquin River Boundary extension refers to the system domain that covers the portion of the SJR from the Bear Creek confluence near Stevinson down to the current boundary near Vernalis.

The existing DSM2-SJR model treats the main eastern tributaries of the San Joaquin under this domain (e.g. Stanislaus, Tuolumne and the Merced rivers) as input time series into the model at specific nodes. Our intend is to extend the model by including extra nodes and channel geomorphological characteristics from these tributaries up to the reservoir outlets. This will allow us to estimate streamflow, temperature and salinity fluctuations from the reservoirs to the main stem of the SJR in a more realistically based manner. At the same time, this will provide new information of the distribution of these parameters throughout the tributaries.

Although DSM2-SJR has capability for modeling water temperature fluctuations, this parameter is not included in the existing version of the model. The results from hydraulic/thermodynamic models (see part e) that estimate the temperature at the outlet of the reservoirs based on the inflow will allow us to incorporate this parameter in our analysis. Water temperature is an essential parameter for the estimation of potential survival rates of aquatic life such as juvenile fish, which depend on cool oxygenated water to avoid stress. Dissolved oxygen levels in water increase with decreasing temperature. Dissolved oxygen is especially critical in warm, slow moving bodies of water. In the Stockton Deep Water Ship Channel high biochemical oxygen demand caused by decaying algae can reduce dissolved oxygen levels below 5 mg/l where it becomes of major concern for anadromous fish passage and migration. Water temperature information around the SJR basin obtained from DSM2-SJR will be used to provide CALSIM II model with a simplified version of the thermodynamic transference processes in the SJR. This will allow CALSIM II to provide approximate estimations of water temperature (see section e).

<u>A.4.3.e Augment simulation logic in CALSIM II to estimate monthly average release temperature from New Melones and New Don Pedro reservoirs and river temperature in downstream tributary nodes.</u> The objective of this effort is to increase our capability to

manage fish habitat below New Melones, New Don Pedro, and Exchequer reservoirs under present and future climate variability. This will be accomplished by developing our capability to predict reservoir release temperatures and downstream temperature profiles based on hydrologic and water demand conditions.

This goal would accomplished through a two-phased modeling approach: (a) use reservoir and river hydraulics models to develop relationships between reservoir release temperature (and river temperature) and reservoir inflow, storage, and reservoir release variables used by CALSIM II; and, (b) translate the physically based temperature-hydraulics relationships from phase (a) into a statistical relationship that can be coded in simulation logic for CALSIM II, thereby allowing for the study of climate change impacts on reservoir release and river temperature in the San Joaquin Basin.

For phase (a), it is understood that temperature-dependent density currents and mixing processes near the outlet works affect reservoir release temperatures. Submerged old dam structures in New Melones and New Don Pedro reservoirs also affect mixing processes near the outlets. This phase will begin with the development or improvement of existing reservoir hydrodynamic models that can be used to simulate reservoir temperature distribution in the reservoir and at the outlet works as a function of: (1) inflow, (2) release, (3) storage, and (4) average evaporation. Data requirements include historical inflow, historical releases, bathymetry, and average monthly evaporation data at the reservoirs. Temperature data would also be required for reservoir releases and river inflows. The U.S. Bureau of Reclamation (USBR) would be relied upon to provide physiographic, dam operation, and temperature data. Several hydraulic modeling frameworks will be considered, including DCURL 1.0 (Density Currents in Reservoirs and Lakes) developed by the USBR's Sedimentation and River Hydraulics Group and applied at Whiskeytown Reservoir to calculate the point of plunging inflow when cold water diverted from the Trinity River Basin is discharged through the Judge Francis Carr power plant into the thermally stratified Whiskeytown Reservoir.

Release temperature output from the reservoir hydraulics models will become upstream bounding conditions for river temperature modeling downstream of the dams. River temperature modeling will be performed using the extended DSM2-SJR (see part d). River temperature is a key habitat factor affecting the health of migrating anadromous fish species and juvenile salmonids. Output from the extended DSM2-SJR will include river temperature estimates at several locations downstream of the dams coinciding with nodal locations in the CALSIM II model.

In phase (b), climate change impacts on reservoir release and downstream river temperatures will be simulated using the State Department of Water Resources joint operations model for the Central Valley Project and State Water Project, CALSIM II. The relationships identified between temperature and hydrologic-demand conditions in Phase One will be integrated into CALSIM II. The State Department of Water Resources has made the CALSIM modeling environment flexible for adding new simulation logic using the Water Resources Engineering Simulation Language (WRESL) software provided with the CALSIM modeling package. In this case, WRESL statements will be added that allow CALSIM II to simulate monthly average release temperature and downstream river temperature based on monthly inflows, storage conditions, and required releases.

<u>A.4.3.f Use remote climate data to develop improved CVP/SWP seasonal water supply forecasts.</u> All tasks prior to this task have focused on choosing possible climate change scenarios, relating those scenarios to effects in the San Joaquin River Basin, and then assessing the potential impacts. It is hypothesized that one way to mitigate the potential

effects of climate change is to improve our ability to plan for short term climate variability by improving our certainty on water supply forecasting for CVP operations. This component will assess how to best utilize information (i.e. monthly data) on remote climate processes known thought to influence California precipitation patterns to improve seasonal reservoir inflow forecast models for Shasta, Folsom and Oroville reservoirs. Although these reservoirs are not located in the San Joaquin Basin, they do provide much of the joint CVP/SWP water supply and inflow to these reservoirs affects how reservoirs in the San Joaquin Basin are operated.

This task's work plan would be accomplished using a two-phased approach. Phase (a) focuses on developing reservoir inflow forecast models for Lake Shasta, Lake Oroville, and Folsom Lake reservoirs that are partially based on remote climate data (i.e. monthly data). Reservoir inflow forecasts and water supply outlooks give fish habitat and water quality managers early indication of below-dam hydrologic conditions that they will be facing during the water year. It is theorized that remote climate monitoring can provide valuable information one or more seasons in advance for estimating hydroclimate conditions in California, and thereby improve our adaptive response capabilities for managing fish habitat and water quality in the San Joaquin Basin. Phase (b) focuses on assessing the risk and uncertainty associated with using the adjusted seasonal reservoir inflow forecasts from the perspective of fish habitat and water quality management.

For work related to phase (a), it is understood that current procedures for forecasting seasonal reservoir inflows into Lake Shasta, Lake Oroville, and Folsom Laker reservoirs are based on two components: (1) year-to-date inflow observations, and (2) a precipitation forecast for the remainder of the water year based on local climatology. In this case, the precipitation forecast is derived from a probability distribution of historically observed precipitation (i.e. climatology). The objective of this research is to improve the inflow forecast by increasing the certainty of the precipitation forecast component. This is done by including data on remote climate processes thought to affect local climatology. These remote forcing variables are monitored one or more seasons beforehand. The underlying principle is that remote climate conditions over the Pacific Ocean occurring one or more seasons in advance have influence on local climatology. This notion is supported by more than a decade of hydroclimate research in the Western United States (Ropelewski and Halpert 1986, Redmond and Koch 1991, Dracup and Kahya 1994, Piechota and Dracup 1997). Modeling precipitation based on remote climate information begins with the development of time series variables describing the remote climate processes lagging behind the precipitation time series. Remote climate processes that will be considered in this study include El Nino/Southern Oscillation and its associated tropical Pacific Ocean sea surface temperature and sea level pressure patterns, north Pacific Ocean sea surface temperature patterns, and atmospheric circulation patterns in the northern hemisphere over the Pacific Ocean. A variable screening process will then be implemented to identify the best variable-precipitation relationship(s) for each of the headwater basins above Lake Shasta, Lake Oroville, and Folsom Lake reservoirs. The best variable-precipitation relationship(s) will then be used to adjust the precipitation exceedence probability curves. For example, the value for 90^{th}-percentile exceedence probability of water year precipitation based on local climatology will increase or decrease with knowledge of the remote climate information. The adjusted precipitation exceedence probability curve will then be translated into an inflow exceedence probability curve using an empirical inflow-precipitation relationship for each basin.

Data required for variable development are freely available from various U.S. and Australian climate agencies. These data are updated monthly. Precipitation data in each basin have been collected by the State Department of Water Resources (DWR) and compiled into basin precipitation indices. The empirical inflow-precipitation relationships have also been developed by the DWR and will be used in this work.

For phase (b), the risk assessment on using the adjusted, seasonal reservoir inflow forecasts for Lake Shasta, Lake Oroville, and Folsom Lake must be framed in terms of scenarios, likelihood of occurrence, and damages. In this case, the risk under study is that taken on by fish habitat and water quality managers dependent on San Joaquin Basin CVP operations. Therefore, scenarios of undesirable outcomes will be defined from their perspectives and reflect what might occur as a result undersirable CVP operating decision(s) based on errant adjusted forecasts. The likelihood of these scenarios will be evaluated by simulating CVP operations (using CALSIM II) first using unadjusted and adjusted seasonal reservoir inflow forecasts for the three reservoirs. Measures of damage will be defined in terms of decision variables from the CALSIM II output. Interviews will be conducted with staff from the US Fish & Wildlife Service and Regional Water Quality Control Board to discuss risk assessment issues, formulate scenarios, and characterize measures for damage.

A.4.4 Feasibility

The research proposed in this submittal is in large part a significant enhancement of successful research performed during the past two and a half years under EPA-STAR funding at (grant #R827448-01-0). Given the project team's success in this previous effort and their considerable experience in this field of study and publication track record, the likelihood of success is considered high.

A.4.5 Performance Measures

This research will be conducted in collaboration with engineers and scientists within the Department of Water Resources and the US Bureau of Reclamation. Success and project performance will be judged according to the degree of technology transfer achieved to these water management agencies during the three year term.

A.4.6 Data handling and storage

A central database at the core with linked "shrink-wrapped" models as satellites to this data handling system is the main concept of the model linkage architecture. Model data and a data dictionary that provides metadata for each of the data types is a concept that has been successfully deployed by others such as the USBR's Lower Colorado office and Professor Jay Lund's CALVIN development team. These innovative features will be incorporated in the proposed decision support system.

A.4.7 Expected Products/Outcomes

As previously stated, project success will be defined by the degree of technology transfer to the major agencies and to CALFED supported entities.

B. APPLICABILITY TO CALFED ERP AND SCIENCE PROGRAM GOALS AND IMPLEMENTATION PLAN

B.1 Relationship to CalFed ERP, CalFed Science Program and CVPIA Priorities

CALFED has recently identified future climate variability and potential future climate change as new areas of focus. Moreover, the Department of Water Resources has determined that climate change be addressed in all future Bulletin 160 publications – hence analytical tools will need to be developed in short order to accommodate publication of the next Bulletin.

This project complements the CALFED ERP program by using adaptive management tools to solve problems in ecosystem quality, water quality and water supply reliability. It relates to the CVPIA by providing estimation of the environmental impact on water quality and fisheries caused by operation of the reservoirs under historical and climate change scenarios.

B.2 Relationship to Other Ecosystem Restoration Projects

The proposed project enhances two of the core simulation modeling tools used by the California Department of Water Resources. These tools are utilized by a large number of restoration projects, both for impacts analysis but also to study future project operations.

B.3 Requests for Next Phase Funding

Not applicable.

B.4 Previous Recipients of CALFED Program Funding

Of the project team only Dr Nigel Quinn has been the recipient of past CALFED funding.

B.5 System Wide Ecosystem Benefits

Successful development of the modeling tools described in this proposal will help to enhance a more integrated analysis of alternative potential ecosystem restoration projects. This system should also improve the level of confidence in the results of the analysis since model integration most often leads to consideration of project elements and impacts that may be ignored when models are applied alone.

B.6 Additional Information for Proposals Containing Land Acquisition

Not applicable.

C. APPLICANT QUALIFICATIONS

John Dracup, PhD, P.E. Dr. Dracup is a Professor at the University of California, Department of Civil & Environmental Engineering, Berkeley, California. He received his Ph.D. in Civil Engineering from the University of California, Berkeley in 1966. The focus of his research program is in the areas of hydrology and water resource systems analysis. In the area of hydrology he has been involved in the stochastic analysis of floods and droughts and the assessment of the impact of climate on hydrologic processes. In the area of water resources his research interests are in the simulation and optimization of large-scale river basin systems. Since 1966, he has been a Principal Investigator or Co-Principal Investigator on research grants from the United Nations Development Program, the National Science Foundation, the Ford Foundation, the Office of Naval Research, the Environmental Protection Agency, the Office of Water Resources Research, the California Air Resources Board, the Metropolitan Water District of Southern California, the U.C. Water Resources Center, the U.C. Pacific Rim Research Center and the National Institute for Water Resources Research. Dr. Dracup has authored over 100 research publications. He has also given presentations at over 100 conferences. At the University of California, Berkeley, Dr. Dracup is currently teaching two undergraduate courses, “Design of Environmental and Water Resources Systems” and “Engineering Fluid Mechanics.” In addition, he will teach a graduate seminar for his M.S. and Ph.D. students. Prior to teaching at UC Berkeley, he taught at the University of California, Los Angeles for thirty-five years.

Nigel W.T. Quinn, PhD, P.E. Dr. Quinn is a Water Resources Engineer and Research Hydrogeologist specializing in the application and development of watershed scale models to solve salinity, selenium and related water quality problems in the San Joaquin Valley of California. Dr Quinn holds positions at both Lawrence Berkeley National Laboratory and at the University of California, Berkeley. He has worked as a consultant to the US Bureau of Reclamation for the past 13 years and is currently under contract with that institution involved in projects on regional groundwater model development, real-time water quality monitoring and modeling of the San Joaquin River and management of private wetlands within the Grassland Basin. Dr Quinn is a principal investigator on several CALFED projects including projects dealing with Stockton Deep Water Ship Channel Dissolved Oxygen, San Joaquin River water quality management, Panoche-Silver Creek selenium load management and an EPA-funded project on impacts of Global Climate Change. He has a BSc (Hons) degree from Cranfield Institute of Technology in England, graduating summa cum laude in irrigation and drainage engineering, an MS degree in civil and agricultural engineering from Iowa State University and a PhD from Cornell University in water resource systems engineering.

Norman L. Miller, PhD. Dr. Miller is a Research Hydrometeorologist specializing in meteorology and hydrology, with published research in climate change projection analyses, downscaling techniques, and surface water hydrology. He is Staff Scientist and Leader of the Hydroclimate and Impacts Research Group in the Earth Sciences Division at Lawrence Berkeley National Laboratory and an Adjunct Professor in the Department of Hydrology and Water Resources at the University of Arizona-Tucson. Dr. Miller leads the NASA-sponsored California Water Resources Research and Applications Center and is the Principal Investigator or several hydroclimate and climate change studies. He has a B.S. in Engineering

Science from the University of Maryland, College Park, and M.S. and Ph.D. degrees in Meteorology from the University of Wisconsin, Madison.

Hugo Hidalgo, PhD. Dr. Hidalgo is a Civil Engineer with interests in Surface Water Hydrology, Atmospheric Sciences and Paleoclimatology. His main professional interest is the analysis of global climatic variability from annual to multidecadal time scales and its relation to regional hydrological processes. Dr. Hidalgo has a B.S. is the University of Costa Rica (1992), and M.Sc. (1998) and Ph.D. (2001) degrees from the University of California, Los Angeles. As part of his research, he developed methods to provide a more accurate estimation of hydroclimatic variability in the Upper Colorado river basin (UCRB) for the past ~500 years using tree-rings. These estimates are valuable for characterizing long-term climatic variability in the UCRB that can be used for water allocation planning and management. He also, has been involved in studies that will allow a better understanding of the relationship between physical processes in the Pacific Ocean basin (like El Niño-Southern Oscillation and the Pacific Decadal Oscillation) and hydroclimatic variation in the western United States. He is currently working as a Visiting Post-doctoral researcher at the University of California, Berkeley, as part of an EPA-Star project aimed to determine the hydrological, agricultural and economic impacts of global climate change in the San Joaquin River Basin.

Levi Brekke, MS, P.E. Mr. Brekke is a Civil Engineer with interests in water resources management and climate studies. His professional interests include water and wastewater treatment engineering and water resources system planning. Mr. Brekke has a B.S. in Civil Engineering from The University of Iowa (1994), an M.S. in Environmental Science and Engineering from Stanford University (1995) and is completing a Ph.D. in Environmental Engineering at University of California Berkeley (expected 2002). He has worked as a full-time and part-time water resources engineering consultant since 1995. His thesis research focuses on the risk and uncertainty of using remote climate data to improve seasonal water supply forecasting for reservoir operations. He is studying how the use of this information could improve certainty in annual delivery level and carryover storage decision making CVP/SWP operations. He is also studying the risks to CVP/SWP water contractors due to use of errant water supply forecasts based on the use of this remote climate data. His research will benefit State Department of Water Resources and U.S. Bureau of Reclamation planners by giving them likelihoods for scenarios and effects that might arise if they decide to use remote climate monitoring in their water supply forecasting procedures. Mr. Brekke is also conducting the water allocation and reservoir operations CALSIM studies as part of an EPA-STAR project aimed to determine the hydrological, agricultural and economic impacts of global climate change in the San Joaquin River Basin.

D. LOCAL INVOLVEMENT

The project team will work with the Bay-Delta Modeling Forum to disseminate results of this research project. The project team has made presentations on Climate and Impacts Modeling topics at the past two annual meetings of the Bay-Delta Modeling Forum and Interagency Environmental Program and is due to make 4 presentations at a one day public workshop on Climate Change on October 5, 2001. The researchers have support from both the US Bureau of Reclamation and Department of Water Resources in this proposal and intend to work closely with the technical staff of these institutions during the project term, if the proposal is funded.

E. PROJECT PEFORMANCE EVALUATION

This project falls in the domain of research – hence the customary means of project evaluation is peer review of work products produced. The timing of this project is fortuitous in that the Department of water Resources has recently convened a work group to deal with the inclusion of climate change in the next Bulletin 160, the State Water Plan for the year 2003. The Department is required by statute to prepare updates of this plan every five years, and to form an Advisory Committee to assist in this effort. The water plan update will describe statewide water supplies, water uses, and actions that could be taken by water agencies to improve future water supply reliability. The project team will work closely with the Bulletin 160 committees proving this group with work products that can be used directly in the Bulletin 160 planning effort. Two work items have particular relevance: (a) development of climate change scenarios, and (b)linkage of CALSIM II and DSM2-SJR, the primary models used by the Department of Water Resources for water allocation planning.

The peer review process will involve the submission of project reports and manuals describing both the statistical and dynamical downscaling techniques used to develop future climate scenarios and the system of linked models used to conduct the impacts analysis on water supply and water quality. Responses to peer review requests will be carefully considered by the project team before finalizing any project documents.

The Bay Delta Modeling Forum (BDMF) will be called on to assist in the organization of technical workshops, which have been successfully used to convey important technical information to both the informed and lay audiences. Dr Quinn, on the project team, is the current BDMF Technical Chair in charge of workshops and training classes sponsored by the BDMF. These educational and training workshops will also be used as a means of eliciting feedback from CALFED stakeholders and others interested in contingency planning for potential future climate change.

F. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

Applicant reserves the right to take exception to the "Rights in Data, Acknowledgements, and Peer Review" provision in Chapter 4.2 of the Proposal Solicitation, as well as the following standard clauses from Attachment D of the Proposal Solicitation: Section 2 (Payment Schedule), Section 3 (Performance Retention), Section 6 (Substitution), Section 9 (Rights in Data), Section 11 (Indemnification), and Section 13 (Termination Clause). We also generally reserve the right to negotiate all terms and conditions should this proposal be funded.

G. REFERENCES

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PROPOSAL ATTACHMENTS

Figures

(Pages F-1 through F-4)

Budgetary Supplement – University of California Berkeley

(Pages C-1 through C-2)

Letters of Support

Lloyd E. Peterson, U.S. Bureau of Reclamation

Norman L. Miller, Lawrence Berkeley National Laboratory

Figure 1: Project Study Area

Figure was developed at U.S. Bureau of Reclamation, and shows study area topography, river and reservoir features, irrigation district boundaries, and CALSIM II model network..

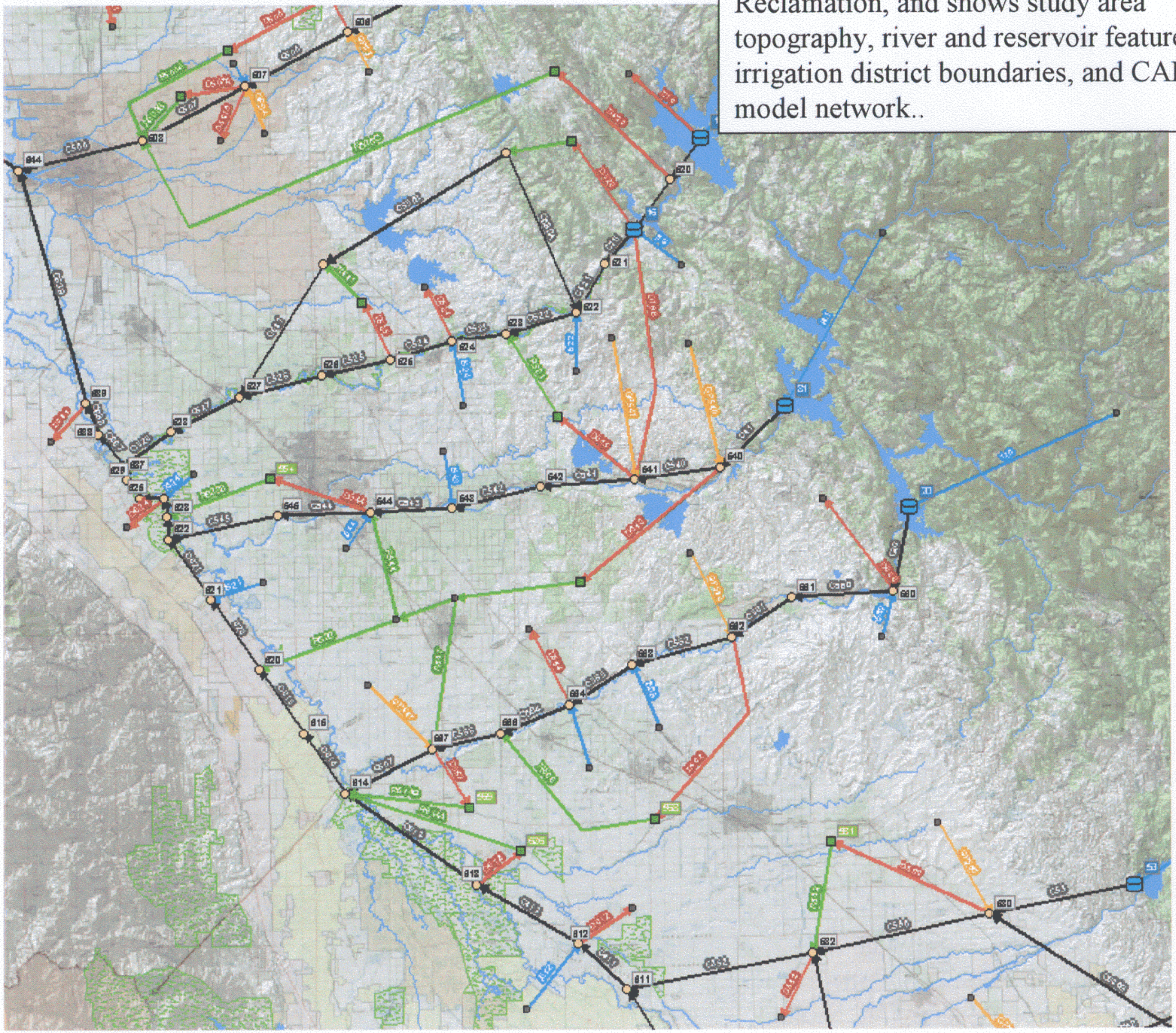


Figure 2: Climate Downscaling Model System

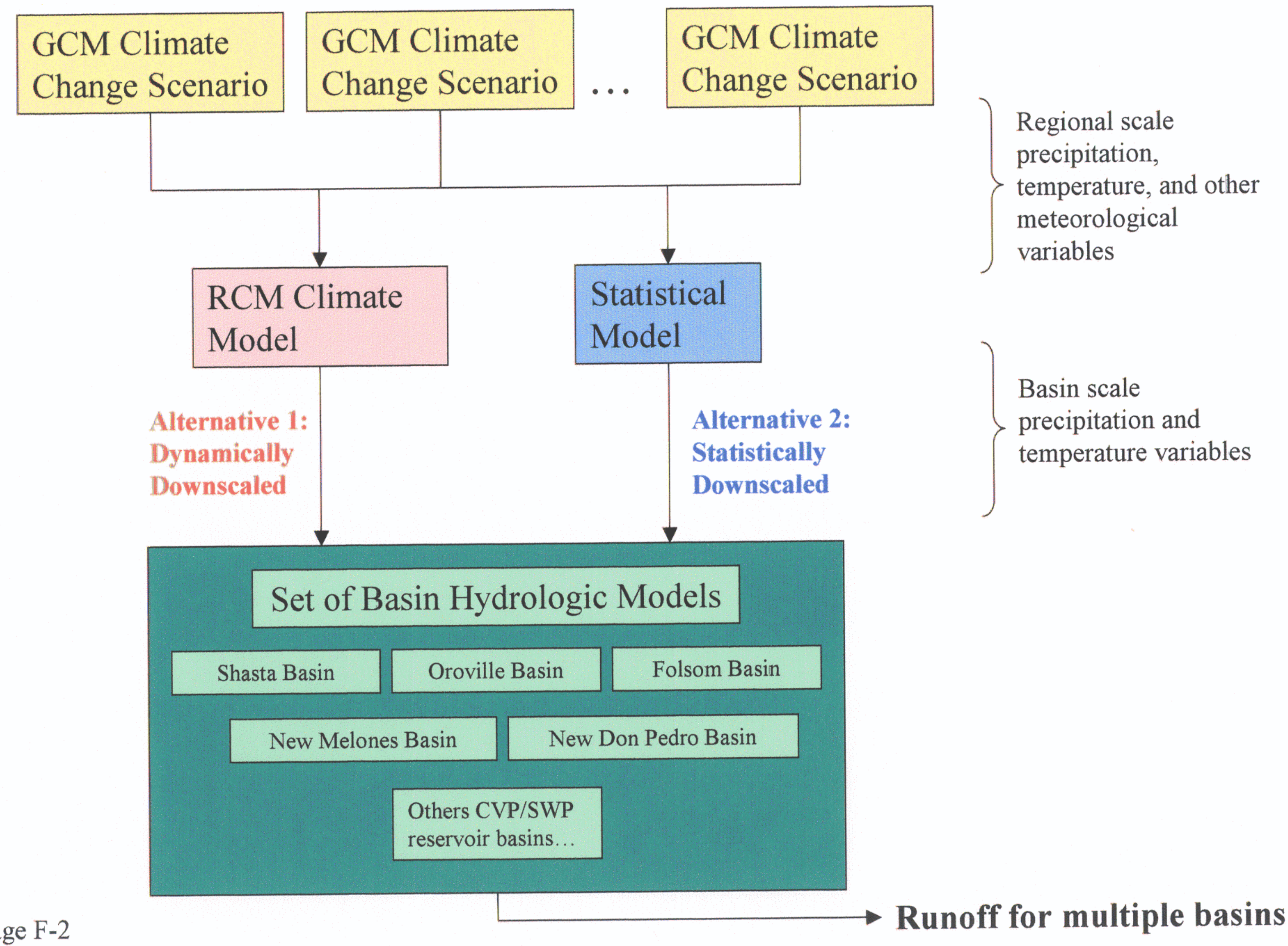


Figure 3: Upper and Lower-limit Runoff Sensitivities due to Climate Change in the California Sacramento-San Joaquin Basin

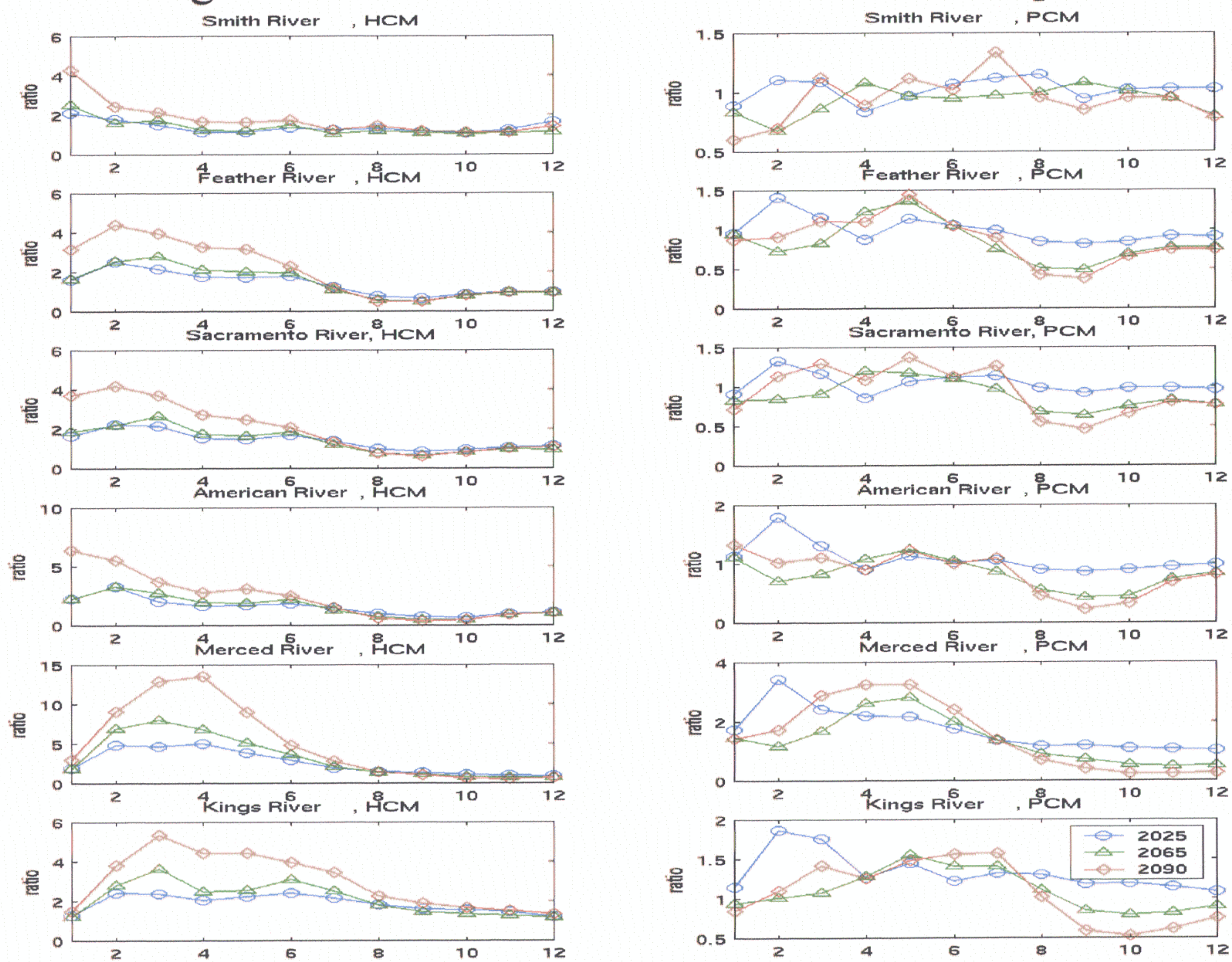
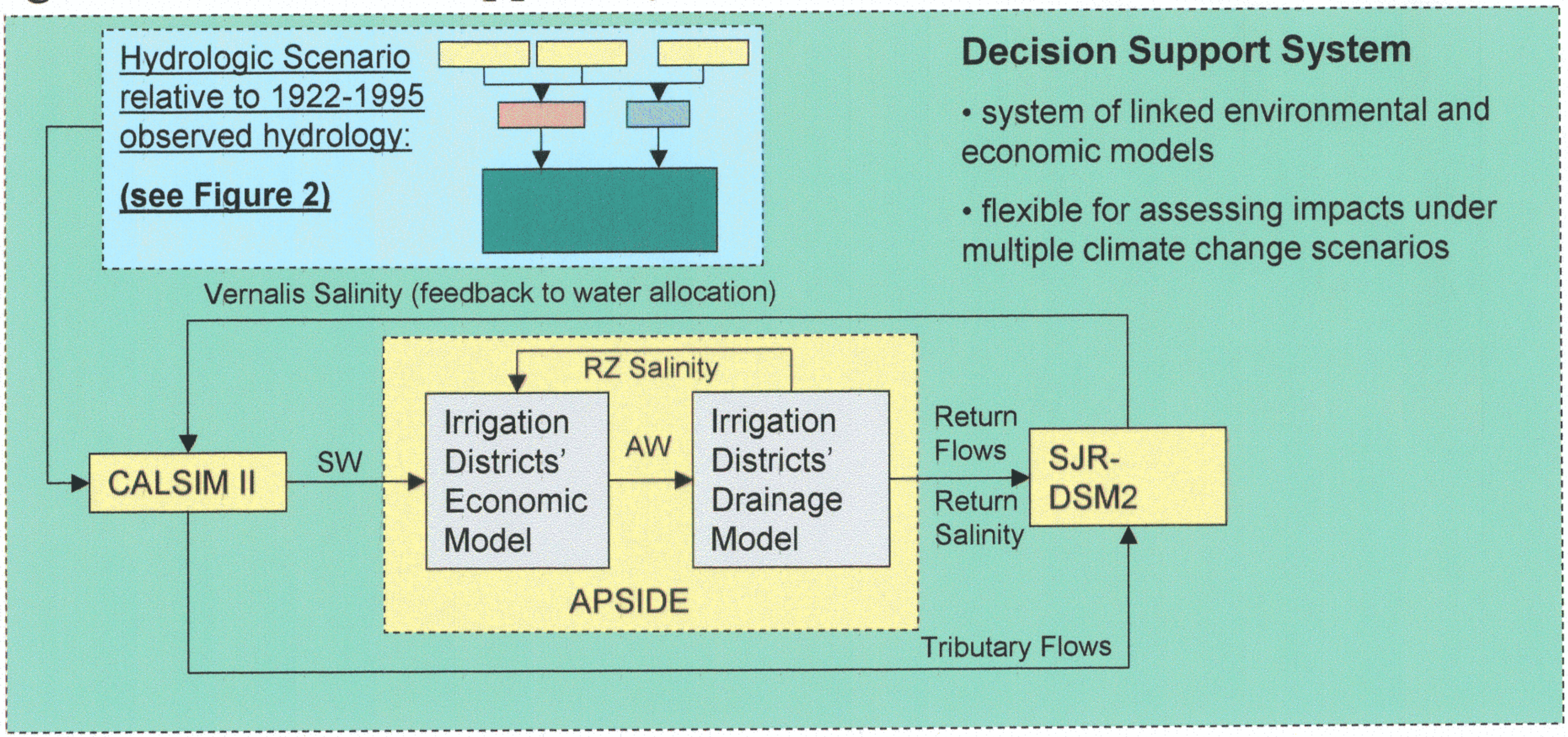


Figure 4: Decision Support System used for Impacts Assessment



Variable Notes:

SW = Surface Water delivered

AW = Applied Water (fraction of SW)

RZ = Root Zone

Return = irrigation drainage return

Tributary Flows = flow in major rivers tributary to San Joaquin River

Models:

CALSIM II: reservoir operations & water allocation model for Sacramento-San Joaquin River Basin

APSIDE: San Joaquin River Basin agriculture-production-salinity-irrigation-drainage-economics model

SJR-DSM2: San Joaquin River hydrodynamic model; developed in Delta Simulation Model 2 framework

Budget
April 1, 2002 - March 31, 2005

Alternate Budget Detail with 10% State Overhead Rate

	Monthly Rate	No of Months	%	4/1/02 - 3/31/2003	4/1/03 - 3/31/2004	4/1/04 - 3/31/2005	
Personnel							
Prof. Dracup, Prof. VIII - PI	$14,400	2 summer	100%	$28,800	$29,376	$29,964	1
N. Quinn, Assoc. Res. Eng.	$7,250	3 cal. yr.	100%	$21,750	$22,185	$22,629	1
Visiting Postdoc Res.	$3,333	12 cal. yr.	100%	$40,000	$40,800	$41,616	1
2 GSR III	$2,957	3 ac.yr.	50%	$8,871	$9,048	$9,229	1
	$2,957	3 summer	100%	$17,742	$18,097	$18,459	1
	$3,016	6 ac.yr.	50%	$18,096	$18,458	$18,827	1
TOTAL PERSONNEL				$135,259	$137,964	$140,724	

Employee Benefits	Rates Per Period						
Professor, summer research	12.70%	12.70%	12.70%	$3,658	$3,731	$3,805	
Other Academic Personnel	17.00%	17.00%	17.00%	$10,498	$10,707	$10,922	
Graduate Student Researcher, ac. yr	1.30%	1.30%	1.30%	$351	$358	$365	
Graduate Student Researcher, smr.	3.00%	3.00%	3.00%	$532	$543	$554	
Full Fee Remission/per semester	$2,269	$2,314	$2,314	$9,076	$9,258	$9,256	3
TOTAL EMPLOYEE BENEFITS				$24,115	$24,597	$24,902	
TOTAL PERSONNEL & BENEFITS				$159,374	$162,561	$165,626	
Equipment							
Computers				$10,000	$5,000	$5,000	3
TOTAL EQUIPMENT				$10,000	$5,000	$5,000	
Subcontract							
Lawrence Berkeley Laboratory				$75,000	$75,000	$75,000	4
TOTAL SUBCONTRACT				$75,000	$75,000	$75,000	
Travel							
4 RT/ to conferences, location TBD				$5,000	$5,000	$5,000	
RT Berkeley to Sacramento (300 mi. RT @ $.345/mi.) x 10 trips (apprx.)				$1,000	$1,000	$1,000	
TOTAL TRAVEL				$6,000	$6,000	$6,000	
Supplies & Expendables							
Computer software upgrades				$1,000	$1,000	$1,000	
TOTAL OTHER DIRECT COSTS				$1,000	$1,000	$1,000	
TOTAL DIRECT COSTS				$251,374	$249,561	$252,626	
Indirect Costs	MTDC						
10.0% of Modified Total Direct Costs	$182,298	$160,303	$163,370	$18,230	$16,030	$16,337	
TOTAL AMOUNT REQUESTED PER YEA				$269,604	$265,591	$268,963	
TOTAL AMOUNT REQUESTED						**$804,158**	

[1] Salary rates shown include a projected 2% cost of living increase effective every October 1st.

[3] These items are not subject to indirect costs.

[4] Indirect costs only apply to the first $25,000 of the entire contract.

Budget
April 1, 2002 - March 31, 2005

Budget Detail with 50.4% Federal Overhead Rate

	Monthly Rate	No of Months		%	4/1/02 - 3/31/2003	4/1/03 - 3/31/2004	4/1/04 - 3/31/2005	
Personnel								
Prof. Dracup, Prof. VIII - PI	$14,400	1.55 summer		100%	$22,320	$22,766	$23,221	1
N. Quinn, Assoc. Res. Eng.	$7,250	3 cal. yr.		100%	$21,750	$22,185	$22,629	1
Visiting Postdoc Res.	$3,333	12 cal. yr.		80%	$32,000	$32,640	$33,293	1
2 GSR III	$2,957	3 ac.yr.		50%	$8,871	$9,048	$9,229	1
	$2,957	3 summer		97%	$17,210	$17,554	$17,905	1
	$3,016	6 ac.yr.		50%	$18,096	$18,458	$18,827	1
TOTAL PERSONNEL					$120,247	$122,651	$125,104	
Employee Benefits	Rates Per Period							
Professor, summer research	12.70%	12.70%	12.70%		$2,835	$2,891	$2,949	
Other Academic Personnel	17.00%	17.00%	17.00%		$9,138	$9,320	$9,507	
Graduate Student Researcher, ac. yr	1.30%	1.30%	1.30%		$351	$358	$365	
Graduate Student Researcher, smr.	3.00%	3.00%	3.00%		$516	$527	$537	
Full Fee Remission/per semester	$2,269	$2,314	$2,314		$9,076	$9,256	$9,256	2
TOTAL EMPLOYEE BENEFITS					$21,916	$22,352	$22,614	
TOTAL PERSONNEL & BENEFITS					$142,163	$145,003	$147,718	
Subcontract								
Lawrence Berkeley Laboratory					$75,000	$75,000	$75,000	3
TOTAL SUBCONTRACT					$75,000	$75,000	$75,000	
Equipment								
Computers					$10,000	$5,000	$5,000	2
TOTAL EQUIPMENT					$10,000	$5,000	$5,000	
Travel								
4 RT/ to conferences, location TBD					$5,000	$5,000	$5,000	
RT Berkeley to Sacramento (300 mi. RT @ $.345/mi.) x 10 trips (apprx.)					$1,000	$1,000	$1,000	
TOTAL TRAVEL					$6,000	$6,000	$6,000	
Supplies & Expendables								
Computer software upgrades					$1,000	$1,000	$1,000	
TOTAL OTHER DIRECT COSTS					$1,000	$1,000	$1,000	
TOTAL DIRECT COSTS					$234,163	$232,003	$234,718	
Indirect Costs	MTDC							
50.40% of Modified Total Direct Costs	$165,087	$142,747	$145,462		$83,204	$71,944	$73,313	
TOTAL AMOUNT REQUESTED PER YEAR					$317,367	$303,947	$308,031	
TOTAL AMOUNT REQUESTED							**$929,345**	

[1] Salary rates shown include a projected 2% cost of living increase effective each October 1st.

[2] These items are not subject to indirect costs.

[3] Indirect costs only apply to the first $25,000 of the entire contract.

BERKELEY LAB

Earth Sciences Division

September 26, 2001

Prof. John Dracup
Dept. of Civil and Environmental Engineering
University of California-Berkeley
Berkeley, California 94720

Dear Prof. Dracup:

I am writing to state my commitment toward working with you on the CALFED proposal, "Adaptive management of climate change impacts on water quality and environmental resources of the San Joaquin River and its major tributaries." As part of this project, I will develop California basin-scale climate and streamflow simulations based on analyses of Global Climate Model projections, historical data, and our modeling tools. I believe that this proposal addresses important topics that are relevant to CALFED and to California water resources.

Sincerely,

Norman L. Miller
Group Leader and Staff Scientist

Ernest Orlando Lawrence Berkeley National Laboratory, University of California
One Cyclotron Road | Berkeley, California 94720 | Tel: 510.495.2374 | Fax: 510.486.5686

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY
REFER TO:

MP-700
PRJ-1.10

SEP 19 2001

Mr. Levi Brekke
Department of Civil and Environmental Engineering
University of California, Berkley
Berkley, California 94720

Subject: Project Proposal: "Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and Major Tributaries"

Dear Mr. Brekke:

I am pleased to have the opportunity to participate in the project, "Adaptive Management of Climate Change Impacts on Water Quality and Environmental Resources of the San Joaquin River and Major Tributaries" as a collaborator. The Reservoir Systems Analysis Group of the Mid-Pacific Region's Division of Planning has long standing experience and responsibilities on the San Joaquin River and look forward to the completion of this study.

Sincerely,

Lloyd E. Peterson
Supervisory Hydraulic Engineer
Reservoir Systems Analysis Group

Reply-to: <chung@water.ca.gov>
From: "Francis Chung" <chung@water.ca.gov>
To: "'Nigel Quinn'" <nwquinn@lbl.gov>
Subject: RE: Letter of interest/cooperation - URGENT
Date: Thu, 4 Oct 2001 16:27:20 -0700

Nigel,

I would like to express my interest and support on the proposed project, entitled:

Adaptive management of climate change impacts on water quality and environmental resources of the San Joaquin River and its major tributaries.

I believe it is important that the proposal be approved and supported to further the understanding of the potential climate change in California water management. The use of widely accepted models like DSM2 and CALSIM will particularly attract much wider audience. I will support and cooperate to the extent my schedule and resources allow.

Francis I. Chung, Ph.D., P.E.
Chief, Modeling Support Branch
DWR
916-653-5924
916-653-6077
chung@water.ca.gov
http://modeling.water.ca.gov