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**CALFED BAY-DELTA PROGRAM**
**PROPOSAL**
(July 28, 1997)

JUL 2 8 1997

# The Effects of Wetland Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System


**Applicants:**

**Thomas H. Suchanek and Darell G. Slotton**

*in collaboration with:*
Brenda S. Johnson, Douglas C. Nelson and John E. Reuter

*University of California, Davis*


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# I. EXECUTIVE SUMMARY

## A. Project Title:

# The Effects of Wetland Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System

**Applicants:**

**Thomas H. Suchanek and Darell G. Slotton**

*in collaboration with:*
Brenda S. Johnson, Douglas C. Nelson and John E. Reuter

*Division of Environmental Studies*
*University of California, Davis*

**B. Project Description and Primary Biological/Ecological Objectives:** Newly flooded wetlands are known to produce significantly elevated levels of methyl mercury. This phenomenon occurs even under conditions in which in-situ mercury concentrations are relatively low. Because some of the projected restoration projects for the San Francisco Bay-Delta system involve the breaching of existing dikes and levees, with subsequent flooding or re-inundation of adjacent areas to create "restored" (reflooded) wetlands, there is some significant risk that these restoration activities will increase levels of toxic methyl mercury entering the Bay-Delta ecosystem. This practice will likely be detrimental to water quality within the Bay-Delta system.

In this project we will work in close collaboration with an ongoing CALFED Category III project being conducted by C.A. Simenstad (University of Washington) and others to evaluate the effects of natural remediation in previously diked wetland areas where levees have failed and not been repaired (Simenstad Title: *Predicting the Evolution of Ecological Functions of Restored Diked Wetlands in the Sacramento River/ San Joaquin River Delta*). Simenstad's study will determine the potential ecological impacts of future restoration projects that use re-inundation methodology. We will augment Simenstad's work by quantifying the levels of elevated methyl mercury contamination caused by such reflooding practices and evaluate the bioavailability and impacts of this mercury to the Bay-Delta ecosystem, with the intent of providing recommendations for potentially modified restoration approaches.

**C. Approach/Tasks/Schedule:**
We will follow closely the schedule identified by Simenstad *et al.* (1996) and collaborate with his team to document the chronology of breached levees and subsequently flooded wetlands. This schedule will entail the following tasks: (1) Produce an inventory of previously reflooded wetlands, (2) Document a restoration history for these sites, (3) Verify and ground truth site characteristics, (4) Obtain a long-term sedimentological history of mercury deposition at a selected number of sites along a chronological sequence, (5) Determine the potential for production of methyl mercury for specific sites along this chronological gradient, (6) Provide recommendations for restoration plans involving re-flooding of existing diked lands.

**D. Justification for Project and Funding by CALFED:** Mercury pollution and, particularly, the bioaccumulation of toxic methyl mercury in food webs, is a global problem impacting aquatic ecosystems and all consumers of aquatic organisms. In California, the threat from this stressor is compounded by the legacy of mining-related mercury contamination across wide areas of the state. Mercury has been clearly identified by most California state agencies as an aquatic pollutant of great concern. Its toxicity to higher order consumers of aquatic organisms is well established, while its effects on reproduction, development, and juveniles of all aquatic and aquatic-feeding species is only poorly understood. Because of the widespread nature of bulk mercury contamination in California, virtually every sub-region of the Bay-Delta and its watershed is affected. All of the named CALFED priority habitats and priority species (in

addition to numerous others) are exposed to this ecosystem stressor. Mercury also constitutes a significant human health hazard through the consumption of fish throughout the Bay-Delta. This work is highly relevant and consistent with CALFED objectives of improving water quality, ecological function and long-term ecosystem health.

During the past 150 years, significant amounts of mercury coming from mines in the California Coast Range, as well as residual mercury resulting from gold and silver mining in the Sierra Nevada, have been deposited in Bay-Delta sediments. The extensive Sacramento-San Joaquin Delta levee system that originated in the 1860's effectively isolated and converted ("reclaimed") wetlands for the production of agricultural crops and other uses, and in doing so dramatically altered the natural functioning of these wetlands. Many levees were likely constructed in locations which already contained significant mercury deposits, and some of these historic mercury-laden diked wetlands have long been isolated from normal tidal inundation. With natural breaching of some of these levees (from storm/flooding events), there has likely been significant, but unquantified, increases in the level of methyl mercury production from these sediments. Future restoration projects involving deliberate breaching of existing dikes/levees will likely result in a similar production of methyl mercury as a result of new flooding. It is important that we quantify the potential risks of any future restoration project to the ecological health of the Bay-Delta system. Our project will evaluate the impacts of such future restoration projects on biologically available mercury loading in the Bay-Delta system in order to be able to make recommendations that will improve water quality in this ecosystem, and hence minimize the exposure of biological resources there to toxic mercury.

**E. Budget Costs and Third Party Impacts:**

Budget Costs: $530,617 (three years)

Third Party Impacts: None projected.

**F. Applicant Qualifications:** The applicants and named collaborators are all Ph.D. level University of California researchers with strong reputations in the various facets of ecosystem assessment. Drs. Suchanek and Slotton bring a combined 18 years experience directing basic and applied research, assessment, and remediation feasibility studies specifically focusing on the bioaccumulation and transport of mercury. Drs. Reuter, and Nelson have each been involved with ecosystem level mercury projects for 5 years or more. These and other team members bring strong expertise in areas needed for the project, including mercury methylation microbiology (Nelson) and ecological functions and GIS (Johnson). The applicants and other team members have all successfully developed and carried out related studies, many of which provide the foundation for this proposed work.

**G. Monitoring and Data Evaluation:**

This project will yield baseline data quantifying the levels of methyl mercury production from diked wetlands and reflooded wetlands. This is essential for establishing a monitoring program to evaluate predicted levels of methyl mercury produced from restoration projects that will be planned in the future. Once our data are collated, a monitoring program to quantify the changes in methyl mercury production following restoration of presently diked wetlands should be established to protect Bay-Delta ecosystem health. Our data will be evaluated by participants in the Consortium of Mercury Related Projects (see below under Section H. and the CALFED proposal submitted by Suchanek *et al.* 1977 (*Integration of Mercury Studies and Results on the San Francisco Bay-Delta System*).

**H. Local Support/Coordination with other Programs/Compatibility with CALFED Objectives:** 1) We will collaborate/coordinate with an ongoing project by C.A. Simenstad (University of Washington) who is currently conducting a study of ecological functions in a series of reflooded diked wetlands in the Bay-Delta. A letter of collaboration from Simenstad is attached.

2) We will collaborate with as many other mercury related projects as are funded during this three year period by participating in the Consortium of Mercury Related Projects being proposed by Suchanek *et al.* 1977 (*Integration of Mercury Studies and Results on the San Francisco Bay-Delta System*).

## II. TITLE PAGE

# The Effects of Wetland Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System

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**Type of Organization and Tax Status:** State Agency (University of California)

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RFP Project Group Type: Other Services

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# III. PROJECT DESCRIPTION

## A. Project Description and Approach

This project addresses one of the key areas of concern identified in the CALFED Bay-Delta Ecosystem Restoration Program Plan: water quality. We focus on the ecosystem stressor mercury (Hg), a contaminant having widespread impacts on California aquatic resources, largely as the result of historic mining for mercury, gold and silver. Specifically, this project will provide the information required (but not currently available) for state, public, and private agencies to evaluate the potential impacts of wetland restoration techniques (involving removal or breaching of existing dikes and levees) on the production and increase of toxic methyl mercury in the San Francisco Bay-Delta system. The intent of this plan is to better our understanding and reduce the impact of mercury on ecological processes, and to improve ecosystem health and the long-term quality of all fisheries and other aquatic resources in the Bay-Delta system.

Over the past 150 years, mercury in California has been mined primarily in the Coast Range and then used extensively for extracting gold and silver mining in the Sierra Nevada. During and since the intensive mining period, mercury from these operations has washed down through the watersheds of both the Coast Range and the Sierra Nevada, and been deposited and incorporated in Bay-Delta sediments in wetlands that have subsequently been isolated by the construction of levees.

Newly flooded soils and vegetation and newly created wetlands are known to produce, at least temporarily (5-10 years or more), significantly elevated levels of methyl mercury, often exceeding government advisory levels in fishes (Knight and Herring 1972, Bodaly *et al.* 1984, Morrison and Therien 1994). Flooding of formerly terrestrial soils leads to a complex of physical, chemical and biological changes, many of which may have direct or indirect effects on the biogeochemical pathways of mercury cycling and contamination (Slotton 1991). Because some of the projected restoration projects being proposed under CALFED for the San Francisco Bay-Delta system involve breaching of existing levees with subsequent flooding of adjacent lands to create reflooded wetlands, there is some significant risk that this process will increase the levels of toxic methyl mercury entering the Bay-Delta ecosystem and impact not only fisheries populations, but the health of the entire system. Our project will assess the relative importance of this process by quantifying the availability of mercury in wetlands that have been flooded by historical levee breaks (since approximately 1930) and left unrepaired.

An inventory of reflooded wetlands and a documentation of changes in ecological functions of those wetlands associated with historical levee breaks is being compiled by C.A. Simenstad *et al.* (1996) in an ongoing CALFED project (Simenstad Title: *Predicting the Evolution of Ecological Functions of Restored Diked Wetlands in the Sacramento River / San Joaquin River Delta*). We will work closely with Simenstad's team (see accompanying letter of collaboration from Simenstad) to document the chronology of mercury deposition and its current bioavailability in reflooded wetlands in order to be able to predict the level of methyl mercury that can be expected to be produced during future wetland restorations in the Bay-Delta.

**• Task 1)** Reconstruct history of Hg deposition and contamination in reflooded wetlands:
Mercury originating from the upper watershed regions has been deposited into San Francisco Bay-Delta sediments since the mid-1800s. In order to measure potential production of methyl mercury (see microcosm experiments below under Task 2) we need to quantify the loading of bulk total and methyl mercury that originally entered the wetlands. C.A. Simenstad (see above) will be collecting sediment cores within these wetlands as part of his group's documentation of the long-term sedimentary history of these reflooded wetlands. We will utilize portions of these cores to quantify the chronology of mercury deposition so that we can properly interpret the results of our mercury methylation microcosm experiments. If Simenstad's cores are insufficient, we will collect additional cores. Cores will be sectioned and analyzed at 5 cm intervals.

Some dated laminated sediment cores from the San Francisco Bay estuary system have been analyzed for chronologies of contamination by cadmium, chromium, copper, nickel, lead, zinc, PCB, PAH, and DDT

(Abu-saba 1994, Hornberger 1994, Hornberger *et al.* 1997, Pereira and Hostettler 1994, Ritson and Flegal 1994, San Francisco Estuary Institute 1995, van Geen 1994, Venkstesan 1994), but determination of mercury levels in Bay-Delta cores have been undertaken only very recently from cores representing just three locations within the CALFED study area (Grizzly, San Pablo, and Richardson Bays) (Bouse *et al.* 1997, Hornberger *et al.* 1997, Luoma *et al.* 1996). These studies suggest that mercury levels in estuary sediments increased up to eight-fold during the period 1850-1880, due to an influx of mercury-contaminated sediments mobilized upstream by hydraulic gold mining in Sierra Nevada watersheds. They also reveal that another pulse of toxicologically significant mercury entered the Delta and Bay between 1930-1960, long after hydraulic mining was banned in 1884, implicating continuing mercury mining, industrial sources, or remobilization (Bouse *et al.* 1997, Hornberger *et al.* 1997). Concentrations of mercury in Bay-Delta cores appear to have decreased between 1960 and the present, but are still at levels characteristic of the hydraulic mining era (Hornberger *et al.* 1997).

Despite these preliminary results, we know of no other cores that have been analyzed or collected from the reflooded wetlands that are being chronicled by Simenstad *et al.*. We will continue to search for already existing sediment data that can be used to elucidate the history of mercury deposition in the Bay-Delta and specifically those sites in the reflooded wetlands. We will utilize whatever appropriate existing data we find, plus new cores collected by Simenstad's group (related to the development/destruction of Delta levees) or our own to produce a chronology of mercury deposition in the wetlands in question.

• **Task 2)** Quantify levels of methyl mercury reflooded wetlands:

The history of those wetlands within the Bay-Delta system that have been "restored" (i.e. reflooded) by breaching of levees through natural processes (such as storm-related events) is already being documented (Simenstad *et al.* 1996). These relatively recently reflooded wetlands may contribute disproportionately to the input of methyl mercury into the Bay-Delta system. We will work in close collaboration with Simenstad *et al.* to 1) identify those sites where wetlands have been re-flooded, 2) identify the chronological sequence of levee construction and levee failure, and 3) collect samples (sediments and biological tissues) to quantify total and methyl mercury concentrations. Based on knowledge from other similarly flooded systems (e.g. Bodaly *et al.* 1984, Slotton 1991) our prediction is that there will be significantly elevated levels of methyl mercury in sediments and biota in those wetlands most recently "restored" (flooded), and lower levels of methyl mercury in wetlands flooded longer ago.

Once we document mercury concentrations within reflooded wetlands representing various locations, ages (since reflooding), and environmental conditions, we can produce a trajectory of predictable impacts of wetland restorations on the production of methyl mercury, and estimate the pulsed increase of methyl mercury to the system as various levee systems are breached to restore ecological functions to associated wetlands.

• **Task 3)** Conduct mercury methylation potential experiments:

A series of microcosm experiments will quantify which types of wetlands (based on the inventory produced above) have the greatest potential to produce toxic methyl mercury. This will involve a series of laboratory tank experiments (slurries and core tube microcosms) to investigate the relative mercury methylation potential of different inorganic mercury fractions in sediments from a variety of representative sites at different stages of their chronological sequence of restoration to a fully functioning wetland. We have been using these very simple, yet effective, techniques successfully to evaluate methyl mercury production in sediments from Clear Lake for the past three years (Mack *et al.* 1997, Suchanek *et al.* 1997b,c) and we will employ the same methodology here. Sediments from reflooded wetlands of various ages and from different locations with different environmental conditions (e.g. salinity and organic loading regimes, age since reflooding, varying amounts of mercury-laden sediments, etc.) will be held in microcosms to quantify the relationship between the age since flooding, these other environmental variables, and the potential for production of methyl mercury. This approach will be applied to key forms of sediment mercury with microcosms under varying environmental conditions to determine the relative availability of the different forms for methylation, across the standard range of conditions. These analytical techniques will also be applied to determine net efflux from sediments (using sediment cores). These

experiments will provide a strong indication of the types of mercury sources most critical to the methylation process throughout the system, and most appropriate for remedial attention.

• **Task 4)** Formulate remediation options to reduce contaminant effects:
Once we quantify the projected levels of methyl mercury that can be expected to be produced from a specific restoration project in a specific location within the Bay-Delta system under specific environmental conditions, we will provide an evaluative tool to assess whether the risk to ecosystem health is acceptable. Without this knowledge, water quality may be significantly worsened in the proximity of restoration. If there is no significant amount of methyl mercury that is anticipated, then this would suggest a green light for restoration with respect to mercury contamination. If there is a significant amount of methyl mercury production and any anticipated output to the Bay-Delta system, engineering methodologies may be recommended to reduce the release and/or transport of this contaminant to the rest of the system.

## B. Location and/or Geographic Boundaries of Project

Targeted wetland restoration areas subject to tidal inundation (natural remediation) within the immediate San Francisco Bay-Delta ecosystem will be analyzed for methyl mercury concentrations and production. The exact locations of these sites will be determined from the first phase of the Simenstad *et al.* (1996) CALFED study (see above).

## C. Expected Benefits

Diking of coastal wetlands within the Bay-Delta system represents one of the greatest sources of estuarine habitat loss. However, removing or breaching dikes to restore tidal inundation to historic marshes represents one of the few viable options for comprehensive coastal wetland restoration (Simenstad *et al.* 1996). It is anticipated that recommendations for such wetland restoration within the Bay-Delta system will be significant. It is important that we understand what the ecological impacts relating to water quality will be before these restoration projects begin.

Our project will determine (1) the quantity and variability of bioavailable mercury in a series of targeted Bay-Delta reflooded wetlands that were created as a result of breached dikes, (2) the fate of in-situ mercury from those wetlands and (3) a set of remedial actions relating to wetland restoration projects that could reduce mercury accumulation in target species and habitats throughout the system.

This work is highly relevant and entirely consistent with CALFED objectives. Without this knowledge, the potential benefits or consequences of various restoration actions remain unclear. The findings of this project will provide the scientific rationale for safe and appropriate restoration work involving wetlands that have previously undergone "reclamation" by diking for alternative uses.

## D. Background and Biological/Technical Justification

The ongoing California projects of our UC Davis Mercury Group have found that the bioaccumulation of mercury in biota is typically not correlated with bulk inorganic mercury concentrations in the immediate surrounding environment (Suchanek et al. 1993, 1995, 1997c, 1998a, 1998b, Mack 1997, Mack and Nelson 1997, Mack *et al.* 1997, Slotton *et al.* 1997). In fact, results from several of our projects indicate that the vast majority of the bulk mercury in the given system is essentially inert biologically, with only a very small percentage of the total sediment mercury load apparently being available for conversion to toxic methyl mercury by methylating bacteria, and subsequent movement into and through the food web.

Of the mercury fraction that is available for methylation, it is unclear where the majority of this methylation occurs. There exist vastly different physical/chemical characteristics of sediments from different regions within the Bay-Delta environment, and especially within wetlands with different reflooding histories. How

"age since reflooding" may influence the production of methyl mercury is unknown, but this information is vitally important in order to understand the fate of mercury originally derived from upper watershed source regions once it reaches the wetlands of the Bay-Delta system.

## E. Proposed Scope of Work

Year 1: We will work closely with Simenstad to identify targeted reflooded wetlands on which to focus our primary methyl mercury studies. Then we will begin our concentrated investigations aimed at producing a trajectory of methyl mercury production over a gradient of sites that vary in 'time since reflooding'. At these sites we will document a history of mercury deposition both before and after diking and reflooding, which will allow us to correlate the timing of methyl mercury production (as evidenced by absolute concentrations of methyl mercury in sediments and biota) at these sites with the timing of diking and reflooding. As we are documenting historical deposition and quantifying the levels of present-day methyl mercury in sediments and biota, we will also initiate our core tube microcosm experiments to quantify the "potential" for methyl mercury production from sediments, which will allow us to quantify the "rate" of methyl mercury production, which more accurately translates into the true amount of methyl mercury that can be transferred up through the trophic web and into higher order fish species. Year 2: In our collaboration with Simenstad we will continue to quantify the levels of present day methyl mercury in reflooded wetlands and continue our core tube microcosm experiments to quantify potential methyl mercury production rates. During Year 2, as we have accumulated sufficient data, we will also begin to analyze relationships between the potential for methyl mercury production and the actual present day methyl mercury concentrations in sediment and biota, which will enable us to develop the trajectory of methyl mercury production (see above) from which we will predict the impacts of future restoration projects on recontamination of the Bay-Delta system by toxic methyl mercury. Year 3: We will complete our assessment of methyl mercury in present day sediments and biota and conclude the microcosm experiments. In addition, we will formulate sound remediation alternatives based on the potential for recontamination of the Bay-Delta system by mercury as a result of future reflooding to restore wetland areas. The Final Report will include interpretations and conclusions of our work in the context of actual and potential future restoration projects, with a set of remedial recommendations to minimize mercury contamination. Quarterly progress reports will be provided throughout the project.

## F. Monitoring and Data Evaluation

This is not a construction or habitat manipulation project, although it is closely tied to the processes of habitat manipulation proposed to restore ecological functions for many regions within the Bay-Delta. Appropriate monitoring for methyl mercury production in, and export from, those specific wetlands being restored will be necessary once targeted restoration projects begin, but is inappropriate at this stage of the project.

Our data will be evaluated in the context of other mercury related projects funded by CALFED now and in the future by participating in the Consortium of Mercury Related Projects (as proposed separately by Suchanek *et al.* 1977a (*Integration of Mercury Studies and Results on the San Francisco Bay-Delta System*). Our data will also be evaluated by other national and international mercury experts with whom we communicate and collaborate on an ongoing basis.

## G. Implementability

Sampling will be conducted at public locales throughout the watershed and/or with the permission of landowners as necessary, and in collaboration with C.A. Simenstad as his field crew accesses sites. We hold scientific collecting permits from the California Department of Fish and Game approving the types of biological sampling proposed. No threatened or endangered species will be collected in this work. The project has widespread support from numerous public and governmental entities, the project team is largely in place, and work could commence almost immediately upon notification.

# IV. COSTS AND SCHEDULE TO IMPLEMENT PROPOSED PROJECT

## A. Budget Costs

**TOTAL FOR 3 YEARS (1998-2000)**

| Project Task | Direct Labor (person-months) | Direct Salary and Benefits | Equipment | Supplies & Expendables | Travel | Service Contracts | Miscellaneous and Other Direct Costs |
|---|---|---|---|---|---|---|---|
| **Task 1:** Reconstruct history of mercury deposition | 22.3 | $74,299 | $0 | $5,438 | $3,150 | $0 | $8,659 |
| **Task 2:** Quantify levels of mercury in reflooded wetlands | 24.4 | $81,376 | $0 | $6,180 | $3,150 | $42,000 | $8,659 |
| **Task 3:** Mercury methylation experiments | 44.6 | $148,599 | $0 | $11,123 | $3,675 | $18,000 | $8,659 |
| **Task 4:** Formulate remediation options | 14.9 | $49,533 | $0 | $1,977 | $525 | $0 | $8,659 |

**Note:** Budget breakdown continued on next page.

Budget breakdown (con'd)

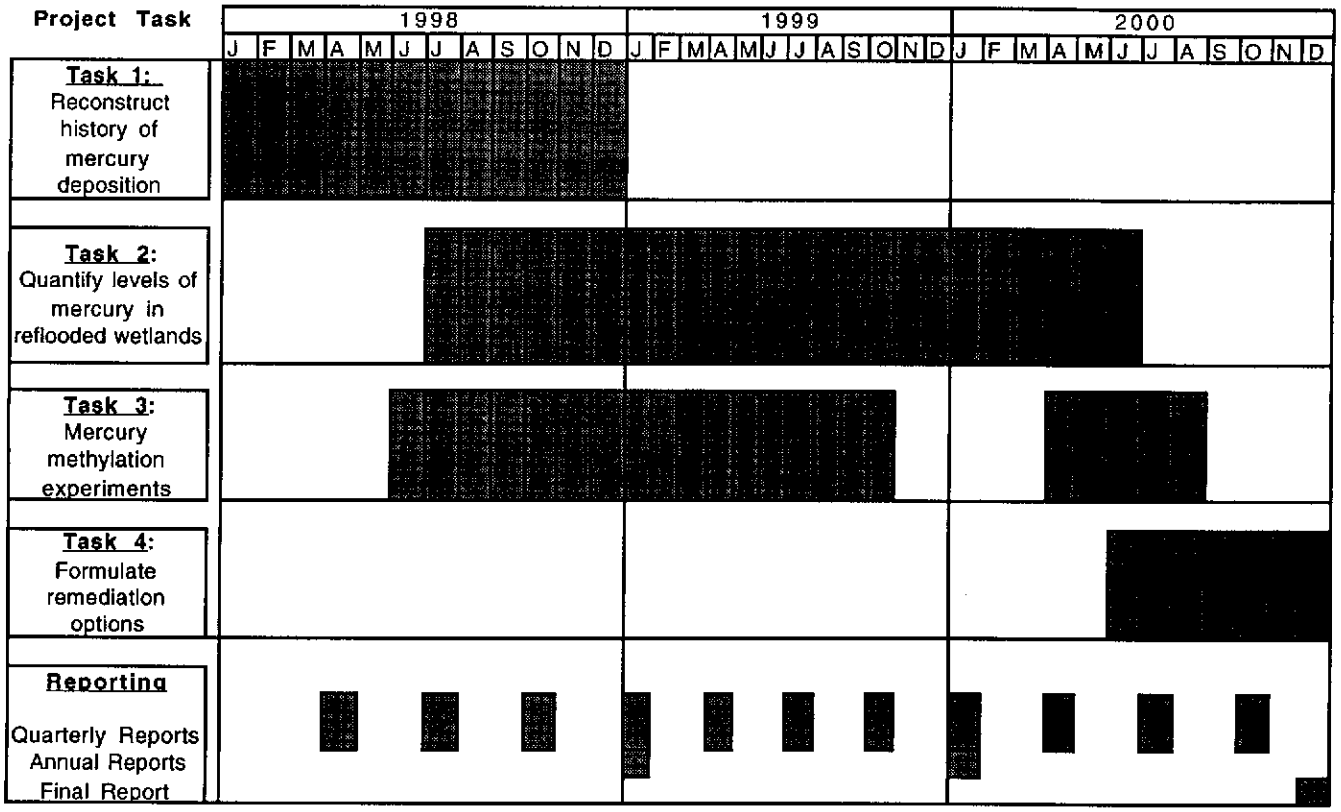
# Budget Summary Information:

**TOTAL FOR 3 YEARS (1998-2000)**

| Project Task | Direct Costs (Subtotal) | Indirect Costs (Overhead) 10% | Year 1 | Year 2 | Year 3 | TOTAL COSTS | |
|---|---|---|---|---|---|---|---|
| Task 1: Reconstruct history of mercury deposition | $91,546 | $8,802 | $100,349 | $0 | $0 | $100,349 | |
| Task 2: Quantify levels of mercury in reflooded wetlands | $141,364 | $13,784 | $38,787 | $77,574 | $38,787 | $155,148 | |
| Task 3: Mercury methylation experiments | $190,056 | $18,653 | $69,570 | $69,570 | $69,570 | $208,709 | |
| Task 4: Formulate remediation options | $60,694 | $5,717 | $0 | $0 | $66,411 | $66,411 | **Request from CALFED** |
| | | | | | | $530,617 | **$530,617** |

## B. Schedule Milestones

**PROJECT MILESTONES FOR 3 YEARS (1998-2000)**




## C. Third Party Impacts

- none known -

# V. APPLICANT QUALIFICATIONS

This research team has a vast amount of experience in mercury ecotoxicology and related fields, especially in aquatic environments.

Dr. Suchanek has led multi-disciplinary and inter-disciplinary ecosystem projects for over 18 years and has focused on the impacts of mercury on California resources since 1991. All of these programs have involved multiple investigators from many disciplines and several have involved multi-million dollar budgets. Dr. Suchanek is also western regional director of the National Institute for Global Environmental Change (a Department of Energy sponsored program) and he administers a $1.2M/yr program dealing with anthropogenic impacts on ecological systems. Dr. Suchanek is also Co-Principle Investigator for an ongoing inter-disciplinary project (which is in its final phases) studying the biogeochemistry and ecosystem impacts of mercury contamination from the Sulphur Bank Mercury Mine Superfund Site on the aquatic ecosystem of Clear Lake, CA. Numerous reports and publications (see list in References section) dealing with a variety of mercury issues have resulted from these and related studies and the final product will be a set of effective remedial recommendations (to the U.S. Environmental Protection Agency) targeted to lower mercury levels in edible fishes within Clear Lake.

Dr. Slotton has directed applied research projects addressing heavy metal contamination and bioaccumulation issues in California aquatic ecosystems for over 12 years, with a primary focus on mercury. He has led investigations of copper, zinc, and cadmium contamination at Iron Mountain Mine and Camanche Reservoir, where sediment resuspension and metals transport, solubility, and bioavailability were investigated in a multi-year project. Since 1985, he has run a mercury biogeochemistry monitoring and research program at Davis Creek Reservoir in the California Coast Range, as well as a mercury analytical laboratory at UC Davis. One area of specialization has been the use of various bioindicators to explore mercury cycling and transport questions. Since 1993, Dr. Slotton has led a research program in the foothill gold mining region of the Sierra Nevada, primarily focusing on benthic invertebrates as proxies for relative bioavailable mercury concentrations and loading in the various tributaries. He is in the third year of a study of mercury mass loading, bioaccumulation, and remedial options at the Mt. Diablo Mercury Mine and Marsh Creek watershed. Other recent projects include mercury assessment studies throughout the Cache Creek and Putah Creek watersheds, and investigations of potential mercury bioaccumulation problems in gravel mining lakes. Dr. Slotton has also been a part of the Clear Lake Superfund Mercury Project (see above) since its inception.

Dr. Johnson currently serves as Regional Integrator for the Center for Ecological Health Research at UC Davis. In this capacity, she is developing conceptual and strategic linkages among those research programs being conducted by Center scientists that focus on the ecological function of the Sacramento River and Sierra Nevada Watersheds, and Clear Lake, Lake Tahoe, and San Francisco Bay-Delta ecosystems. She has led and participated in a number of large-scale interdisciplinary ecological studies combining approaches as diverse as molecular genetics, ecotoxicology, population modeling, and GIS. In her integration role, Dr. Johnson is involved in reconstruction of the ecological history of much of the region that CALFED has delineated as the Category III Study Area.

Dr. Nelson is an internationally recognized expert on microbiology of the sulfur cycle. Both oxidative and reductive portions of the cycle are included in this multifaceted program which encompasses field research (deep-sea sulfide-rich vents and seeps; sediments of Clear Lake, CA; evaporation ponds of the San Joaquin drainage) and laboratory research (ecology and physiology of pure cultures, mixed cultures and microcosms). Funding sources include NSF, NOAA-National Undersea Research Program, Mineral Management Services of US Department of Interior and UC Salinity Drainage Program. Since 1992, he has been involved in US EPA sponsored studies of mercury methylation in Clear Lake sediments. Important findings there included: (1) a demonstration that sulfate-reducing bacteria, previously believed by others to be primary methylators of mercury in anoxic sediments, perform roughly 25% of the total sediment methylation (2) a demonstration that the vast majority of sediment inorganic mercury is not available for methylation.

Dr. Reuter is the Director of the Lake Tahoe Interagency Monitoring Program (LTIMP), a multi-agency monitoring and research effort formed to understand the effects of watershed and atmospheric processes on the water quality of Lake Tahoe. He is also directing a 5-year US EPA sponsored project to model water quality and set water quality standards for nearby Pyramid Lake, Nevada. Between 1993 and 1994, he served as the Acting Director of the UC Davis Institute of Ecology. Since 1994 he has co-managed the Sierra Nevada Watershed Program as part of the Center for Ecological Health Research. Dr. Reuter has extensive experience coordinating and interpreting the data from large, multi-disciplinary projects. He has been involved in many aspects of both research and applied limnology, with the focus of various projects including: phytoplankton and periphyton ecology, eutrophication, water chemistry, fisheries management, wetland ecology, lake restoration, water column and benthic nutrient cycling, primary productivity, paleolimnology, ecology of the Sierra Nevada, atmospheric deposition, stream nutrient loading, environmental consequences of sediment dredging, use of bioindicators to assess ecosystem health, and, since 1985 and in association with Dr. Slotton, mercury and heavy metal cycling.

# VI. Compliance With Standard Terms and Conditions

Agreement No. _____

Exhibit _____

## STANDARD CLAUSES - INTERAGENCY AGREEMENTS

**Audit Clause.** For contracts in excess of $10,000, the contracting parties shall be subject to the examination and audit of the State Auditor for a period of three years after final payment under the contract. (Government Code Section 8546.7).

**Availability of Funds.** Work to be performed under this contract is subject to availability of Category III funds.

**Interagency Payment Clause.** For services provided under this agreement, charges will be computed in accordance with State Administrative Manual Section 8752.1.

**Termination Clause.** Either State agency may terminate this contract upon 30 days advance written notice. The State agency providing the services shall be reimbursed for all reasonable expenses incurred up to the date of termination.

## NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

### CERTIFICATION

*I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.*

Sandra M. Dowdy
Contracts and Grants Analyst

OFFICIAL'S NAME: Sandra M. Dowdy
Contracts and Grants Analyst

DATE EXECUTED: JUL 24 1997

EXECUTED IN THE COUNTY OF: YOLO

PROSPECTIVE CONTRACTOR'S SIGNATURE: Sandra M. Dowdy

PROSPECTIVE CONTRACTOR'S TITLE:

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA



I-005985

## Text References (Literature Cited):

Abu-saba, K.E. and A.R. Flegal 1994. Dissolved chromium in San Francisco Bay: inorganic speciation, distribution, and geochemical processes. Eos, Transactions, American Geophysical Union 75(3):233.

Bouse, R., M. Hornberger, and S. Luoma. 1997. Sources of mercury in sediment cores from San Francisco Bay. Abstract submitted to SETAC Annual Meeting.

Bodaly, R.A., J.W.M. Rudd and R.J.P Fudge 1984. Increases in fish mercury levels in lakes flooded by the Churchill River diversion, northern Manitoba. Canadian Journal of Fisheries and Aquatic Sciences 41:682-691.

Hornberger, M.I. 1994. Records of contaminant input to San Francisco Bay: 4. Downcore concentrations of Cr, Cu, Pb, V and Zn. Eos, Transactions, American Geophysical Union 75(3):234.

Hornberger, M.I., S.N. Luoma, A. van Geen, C. Fuller, R. Anima 1997. Historical trends of trace metals in the sediments of San Francisco Bay, California. Submitted to Marine Chemistry.

Knight, L.A. and J. Herring 1972. Total mercury in largemouth bass (Micropterus salmoides) in Ross Barnett Reservoir, Mississippi -- 1970 and 1971. Pesticide Monitoring Journal 6(2):103-106.

Luoma, S.N., A. van Geen, C. Fuller, M. Hornberger, W. Pereira, F. Hostettler, K. Kvenvolden, R. Anima, P. Ritson, A.R. Flegal 1996. Historical contamination trends in sediments of San Francisco Bay. Eos, Transactions, American Geochemical Union 77(46) suppl.: F239.

Mack, E.E. 1997. The role of the microbiological community on methyl mercury production in sediments of Clear Lake, California. Ph.D. Dissertation, Department of Microbiology, University of California, Davis, CA (in progress)

Mack, E.E. and D.C. Nelson 1997. Sulfate reduction rates and mercury methylation potential in the sediments of Clear Lake. pp. 93-104, In: Suchanek *et al.*, The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Mack, E.E., D.C. Nelson, L.L. Brister and T.H. Suchanek 1997. Methyl mercury production from unamended sediment cores (core tube microcosms). pp. 105-115, In: Suchanek *et al.*, The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Morrison, K.A. and N. Therien 1994. Mercury release and transformation from flooded vegetation and soils: experimental evaluation and simulation modeling. pgs. 355-365, In, C.J. Watras and J.W. Huckabee (eds.), Mercury Pollution: Integration and Synthesis, Lewis Publishers, CRC Press.

Pereira, W.E. and F.D. Hostettler 1994. Records of contaminant input to San Francisco Bay: 7. Anthropogenic and biogenic polycyclic aromatic hydrocarbons. Eos, Transactions, American Geophysical Union 75(3):234.

Ritson, P.I. and A.R. Flegal 1994. Records of contaminant input to San Francisco Bay: 5. Sources of lead identified by stable lead isotopes. Eos, Transactions, American Geophysical Union 75(3):234.

San Francisco Estuary Institute 1995. Executive Summary from the 1995 Regional Monitoring Program (RMP) Report. Available from the SFEI Website: http://sfei.org/rmp/95execsum.htm.

Simenstad, C.A. *et al.* 1996. Funded CALFED project: Predicting the Evolution of Ecological Functions of Restored Diked Wetlands in the Sacramento River / San Joaquin River Delta.

Slotton, D.G. 1991.Mercury bioaccumulation in a newly impounded northern California reservoir. Ph.D. Dissertation, Division of Environmental Studies, University of California, Davis. 363pp.

Slotton, D.G., T.H. Suchanek, S.M. Ayers, and J.E. Reuter 1997. Mercury Bioaccumulation in Northern California: A Mining Legacy. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Suchanek, T.H., P.J. Richerson, L.A. Woodward, D.G. Slotton, L.J. Holts and C.E. Woodmansee 1993. Ecological Assessment of the Sulphur Bank Mercury Mine Superfund Site, Clear Lake, California: A survey and Evaluation of Mercury In: Sediment, Water, Plankton, Periphyton, Benthic Invertebrates and Fishes Within the Aquatic Ecosystem of Clear Lake, California. Phase 1- Preliminary Lake Study Report. Prepared for EPA-Region IX, Superfund Program. 113 pp., plus 2 attachments.

Suchanek, T.H., P.J. Richerson, L.J. Holts, B.A. Lamphere, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1995. Impacts of mercury on benthic invertebrate populations and communities within the aquatic ecosystem of Clear Lake, California. Water, Air and Soil Pollution **80**:951-960

Suchanek, T.H., D.G. Slotton and B.S. Johnson 1997a. Integration of Mercury Studies and Results on the San Francisco Bay-Delta System. CALFED Proposal submitted 7/28/97.

Suchanek, T.H., P.J. Richerson, L.J. Mullen, L.L. Brister, J.C. Becker, A. Maxson, and D.G. Slotton 1997b. The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Suchanek, T.H., L.H. Mullen, L.L. Brister, D.G. Slotton, P.J. Richerson, C.E. Woodmansee and L.A. Woodward 1997c. Trophic transfer coefficients for mercury within the Clear Lake aquatic ecosystem, California. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Suchanek, T.H., L.H. Mullen, B.A. Lamphere, P.J. Richerson, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1998a. Redistribution of mercury from contaminated lake sediments of Clear Lake, California. Water, Air and Soil Pollution **82:** (in press)

Suchanek, T.H., B.A. Lamphere, L.H. Mullen, C.E. Woodmansee, P.J. Richerson, D.G. Slotton, L.A. Woodward and E.J. Harner 1998b. Mercury in lower trophic levels of the Clear Lake aquatic ecosystem, California. In: K.M. Scow (Ed.), Integrated Assessment of Ecosystem Health. Ann Arbor Press, Chelsea, MI. (in press)

van Geen, A. 1994. Records of contaminant input to San Francisco Bay: 6. Recent cadmium enrichments in the water column from Cd/Ca ratios in Foraminifera. Eos, Transactions, American Geophysical Union 75(3):234.

Venkstesan, M.I. 1994. Records of contaminant input to San Francisco Bay: Polychlorinated biphenyl congeners and chlorinated hydrocarbon pesticides. Eos, Transactions, American Geophysical Union 75(3):234.

## References of Recent (> 1990) Mercury-Related Studies at Clear Lake:
(from the U.C. Davis Mercury Group)

Anderson, D.W., T.M. Cahill, T.H. Suchanek and R.A. Elbert 1997. Relationships between mercury and yearly trends in osprey production and reproductive status at Clear Lake. pp. 195-200, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Anderson, D.W., P.J. Richerson, T.H. Suchanek, R.A. Elbert, D.G. Slotton and S.M. Newman. Organochlorine pesticide residues in Clear Lake wildlife three decades after cessation of pesticide use. (in preparation)

Bale, A.E. 1994. Modeling mercury transport and bioaccumulation. Abstract and presentation at the "International Conference on Mercury as a Global Pollutant", Whistler, British Columbia; July 10-14, 1994.

Bale, A.E. 1995. Modeling mercury transport and transformation in the aquatic environment. Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of California, Davis, CA. 224 pp.

Bale, A.E. 1997. Preliminary report on HgUptake, a toxicant uptake model adapted to simulate the uptake and accumulation of methylmercury (MeHg) in aquatic food chains. Report prepared for EPA Region IX Superfund Program and EPA Athens, GA Modeling Center. 27 pp, + 3 appendices. Attachment #1, In: T.H. Suchanek, et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Bale, A.E. 1997. Numerical modeling of Clear Lake hydrodynamics. pp. 203-208, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Bale, A.E. Modeling the Aquatic Mercury Cycle: Part I- Transformations (in prepraration)

Bale, A.E., G.T. Orlob, and I.P. King. Modeling the Aquatic Mercury Cycle: Part II- Fate and Transport (in preparation)

Becker, J.C., P.J. Richerson, T.H. Suchanek, A.C. Heyvaert, D.G. Slotton, J.G. Kim and C.E. Vaughn 1997. The history of human impacts in the Clear Lake watershed (California) as deduced from lake sediment cores. pp. 163-182, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Becker, J.C., P.J. Richerson, T.H. Suchanek, A.C. Heyvaert, D.G. Slotton, J.G. Kim, C.E. Vaughn 1997. The History of Human Impacts in the Clear Lake Watershed (California) as Deduced from Lake Sediment Cores. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Becker, J.C., P.J. Richerson, T.H. Suchanek, A.C. Heyvaert, D.G. Slotton, J.G. Kim and C.E. Vaughn (submitted). The history of human impacts in the Clear Lake watershed (California) as deduced from lake sediment cores. In: K.M. Scow (Ed.), Integrated Assessment of Ecosystem Health. Ann Arbor Press, Chelsea, MI. (in press)

Brister, L.L., L.H. Mullen and P.J. Richerson 1997. The Sulphur Bank Mercury MIne: a continuing source of mercury input to Clear Lake. pp. 129-147, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Cahill, T.M. 1997. X-ray Analyses of Elemental Concentrations in Feathers. Masters of Science Dissertation: Department of Wildlife, Fish and Conservation Biology. 63pp, + 1 appendix

Cahill, T.M., D.W. Anderson, B.P. Perley and T.H. Suchanek 1997. Concentrations of mercury and other elements in five species of bird at Clear Lake. pp. 183-194, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Cahill, T.M., B.P. Perley, D.W. Anderson. X-ray analyses of elemental concentrations in feathers: comparison of XRF and PIXE. Submitted to: International Journal of PIXE

Cahill, T.M., D.W. Anderson, R.A. Elbert, B.P. Perley and D.M. Johnson. Elemental profiles in feathers samples from Clear Lake, California, a mercury contaminated site. (in preparation)

Choi, H. 1994. Influence of humic substances on the uptake of methylmercury in Sacramento blackfish (Orthodon microlepidotus). Abstract and presentation at the "International Conference on Mercury as a Global Pollutant", Whistler, British Columbia; July 10-14, 1994.

Choi, M.H. 1997. Methyl mercury uptake by Sacramento blackfish (Orthodon microlepidotus). Ph.D. Dissertation, Department of Wildlife, Fish and Conservation Biology, University of California, Davis, CA. pp. 60

Choi, M.H., J.J. Cech, Jr., and M.C. Lagunas-Solar 1996. Bioavailability of methyl mercury in the presence of dissolved organic carbon (DOC). Contaminant Effects on Fish, Proceedings of the International Congress on the Biology of Fishes, July 14-18, 1996, San Francisco, CA

Choi, H.M., J.J. Cech, Jr., and M.C. Lagunas-Solar. 1994. Methyl mercury uptake by the gills of Sacramento blackfish (Orthodon microlepidotus). High Performance Fish, Proceedings of the International Fish Physiology Symposium, University of British Columbia, pp. 231-235, July, 1994.

Choi, M.H., J.J. Cech, Jr., and M.C. Lagunas-Solar (in press). Bioavailability of methyl mercury to Sacramento blackfish (Orthodon microlepidotus): Dissolved organic carbon (DOC) effects. Environmental Toxicology and Chemistry.

Choi, M.H., J.J. Cech, Jr. and M.C. Lagunas-Solar (in press). Mercury uptake by Sacramento blackfish (Orthodon microlepidotus): methods and preliminary results. The 4th International Symposium on Fish Physiology, Toxicology, and Water Quality (September, 1995) Bozeman, MT.

Elbert, R.A. 1994. Mercury hazards to birds. Abstract and presentation at the "International Conference on Mercury as a Global Pollutant", Whistler, British Columbia; July 10-14, 1994.

Elbert, R.A. 1996. Reproductive performance and mercury exposure of birds at Clear Lake, CA. M.S. Dissertation. Department of Wildlife, Fish and Conservation Biology, University of California, Davis. 75 pp.

Elbert, R.A. and D.W. Anderson. Osprey nest behavior at Clear Lake. (in preparation)

Gilmartin, E. Multiple Stresses on Zooplankton in Clear Lake, California: Copper and Methyl Mercury Toxicity to Cladocerans. M.S. Dissertation (in progress)

Gilmartin, E., T.H. Suchanek, and P.J. Richerson 1997. Multiple Stresses on Zooplankton in Clear Lake, CA: Copper and Methyl Mercury Toxicity to Cladocerans. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Lynch, M.G. 1996. Clear Lake current study: mixing and transport dynamics. M.S. Thesis. Department of Civil and Environmental Engineering, University of California, Davis, CA.

Lynch, M.G. and S.G. Schladow 1996. Clear Lake current study: mixing and transport dynamics. Special Report: prepared for the U.S. Environmental Protection Agency, June 1996. Report No. EDL96-01MGL. (90pp). Attachment #2, In: T.H. Suchanek, *et al.* 1997. The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Mack, E.E. 1997. Microbiology of sulfate reduction and mercury methylation in the sediments of Clear Lake, California. Ph.D. Dissertation, Department of Microbiology, University of California, Davis, CA. (in progress)

Mack, E.E. and D.C. Nelson 1997. Sulfate reduction rates and mercury methylation potential in the sediments of Clear Lake. pp. 93-104, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Mack, E.E., D.C. Nelson, L.L. Brister and T.H. Suchanek 1997. Methyl mercury production from unamended sediment cores (core tube microcosms). pp. 105-115, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Mullen, L.H. and L.L. Brister 1997. The wetland north of the Sulphur Bank Mercury Mine. pp. 149-161, In: T.H. Suchanek, et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Mullen, L.H., L.L. Brister and T.H. Suchanek 1997. Discovery of a flocculent material associated with the Sulphur Bank Mercury Mine. pp. 117-128, In: Suchanek et al., The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Schladow, S. G., Lynch, M. G., Monismith, S. G. and Stacey, M. T. 1997. Mixing and transport in a shallow, topographically complex lake - Clear Lake, California. Presented at the ASLO Aquatic Sciences Meeting, Santa Fe, New Mexico, Feb 1997.

Shrestha, P.L. 1996. An integrated model suite for sediment and pollutant transport in shallow lakes. Advances in Engineering Software 27:201-212.

Slotton, D.G., T.H. Suchanek, L.H. Mullen, C.E. Woodmansee and P.J. Richerson. Mercury in fishes from the Clear Lake aquatic ecosystem, a mine-impacted EPA Superfund Site in California. (In preparation - soon to be submitted)

Slotton, D.G., T.H. Suchanek, S.M. Ayers, and J.E. Reuter 1997. Mercury Bioaccumulation in Northern California: A Mining Legacy. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Suchanek, T.H., P.J. Richerson, L.A. Woodward, D.G. Slotton, L.J. Holts and C.E. Woodmansee 1993. Ecological Assessment of the Sulphur Bank Mercury Mine Superfund Site, Clear Lake, California: A survey and Evaluation of Mercury In: Sediment, Water, Plankton, Periphyton, Benthic Invertebrates and Fishes Within the Aquatic Ecosystem of Clear Lake, California. Phase 1- Preliminary Lake Study Report. Prepared for EPA-Region IX, Superfund Program. 113 pp., plus 2 attachments.

Suchanek, T.H. and P.J. Richerson 1994. Ecological effects of mercury in aquatic ecosystems. Abstract from an invited paper in the symposium: Mercury Contamination in Arid and Semiarid Landscapes - Chairman: G.E. Taylor, held at the SETAC Annual Meetings in Denver CO, Oct. 30-Nov. 3, 1994.

Suchanek, T.H., P.J. Richerson, L.J. Holts, B.A. Lamphere, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1995. Impacts of mercury on benthic invertebrate populations and communities within the aquatic ecosystem of Clear Lake, California. Water, Air and Soil Pollution **80**:951-960

Suchanek, T.H., P.J. Richerson, L.J. Mullen, L.L. Brister, J.C. Becker, A. Maxson, and D.G. Slotton 1997. The role of the Sulphur Bank Mercury Mine site (and associated hydrogeological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake aquatic ecosystem. A report prepared for the USEPA, Region IX Superfund Program. 479pp.

Suchanek, T.H., L.H. Mullen, L.L. Brister, D.G. Slotton, P.J. Richerson, C.E. Woodmansee and L.A. Woodward 1997. Trophic transfer coefficients for mercury within the Clear Lake aquatic ecosystem, California. (Abstract for SETAC Annual Meetings, San Francisco, CA. November 1997)

Suchanek, T.H., L.H. Mullen, B.A. Lamphere, P.J. Richerson, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1998. Redistribution of mercury from contaminated lake sediments of Clear Lake, California. Water, Air and Soil Pollution **82:** (in press)

Suchanek, T.H., B.A. Lamphere, L.H. Mullen, C.E. Woodmansee, P.J. Richerson, D.G. Slotton, L.A. Woodward and E.J. Harner 1998. Mercury in lower trophic levels of the Clear Lake aquatic ecosystem, California. In: K.M. Scow (Ed.), Integrated Assessment of Ecosystem Health. Ann Arbor Press, Chelsea, MI. (in press)

Suchanek, T.H., L.H. Mullen, P.J. Richerson, D. Nelson, E.E. Mack, D.G. Slotton, C.E. Woodmansee, L.L. Brister and L.A. Woodward. Vertical stability of mercury in historical sediments from Clear Lake, California. (Submitted: Environmental Science & Technology)

Woodward, L.A., M. Mulvey and M.C. Newman 1996. Mercury contamination and population-level responses in chironomids: can allozyme polymorphism indicate exposure? Environmental Toxicology and Chemistry **15(8)**: 1309-1316

Woodward, L.A. Effects of mercury on the benthic macroinvertebrate community of Clear Lake, California. Ph.D. Dissertation (in progress)

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24 July 1997

Dr. Thomas H. Suchanek
Division of Environmental Studies
University of California
Davis, CA 95616

Dear Dr. Suchanek,

This letter is to express our interest and commitment to your potential collaboration with us on our ongoing CALFED project (*Predicting the Evolution of Ecological Functions of Restored Diked Wetlands in the Sacramento River/San Joaquin River Delta*). Our intent is to investigate breached-dike estuarine wetlands in the Delta to evaluate changes in ecological processes as a function of "time since reflooding." Your investigation, as outlined in your proposal (The Effects of Wetland Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System) to CALFED deals with changes in the production of methyl mercury as a function of "time since reflooding" and will both complement and enhance our work, adding a valuable dimension to our understanding of the changes that occur as a function of reflooding.

We envision two areas of close collaboration between our groups that could yield especially valuable results: (1) our producing of an inventory of reflooded wetlands from which we will choose a subset of sites where we will focus the majority of our field investigations, and (2) developing a long-term sediment history of these and undisturbed wetland reference sites through the use of sediment cores. In particular, we will be pleased to share the data we develop on the inventory of reflooded wetlands, including their ages (e.g., since diking and since dike breach). In addition, we agree to coordinate closely with you when we conduct our sediment core sampling, such that you can collect cores concurrent with our sampling and relate our isotope age data to your mercury analyses on deep sediments from these wetlands. The analyses that you propose to quantify the depositional history of mercury in these wetlands will also be useful to us both in verifying dates of reflooding, as well as documenting a history of changes in mercury input to the system and potential concomitant changes in ecological function resulting from this input.

Thank you for your interest in our ongoing CALFED research. There is much to be gained from a collaboration between our groups and we strongly support your effort to obtain funding through CALFED to accomplish this valuable study.

Most sincerely,

Sincerely,

Charles A. Simenstad

WET Coordinator

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