F1-103

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
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July 26, 1997

CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento, CA 95814

Dear CALFED:

Attached are ten copies of a proposal in response to the CALFED Bay-Delta Program Request for Proposals, 1997 Category III, Ecosystem Restoration Projects and Programs. The title of the proposal is "Assessing impacts of selenium on restoration of the San Francisco Bay-Delta Ecosystem". We are proposing a three year, multi-institution, multi-discipline effort. The products of the study will be experimentally developed models and high quality field data directed toward defining the most important sources of selenium contamination and the significance of that contamination to several species of concern to CALFED. We believe such knowledge is essential to aid management of selenium controversies and wisely remediate selenium contamination that might impede the restoration process.

We wish to thank CALFED agencies for their consideration of this proposal.

Sincerely,

S N Luoma

Samuel N. Luoma

FI-103

I. EXECUTIVE SUMMARY

ASSESSING IMPACTS OF SELENIUM ON RESTORATION OF THE SAN FRANCISCO BAY-DELTA ECOSYSTEM.
S. N. Luoma, US Geological Survey, Menlo Park, CA; *G. A. Cutter*, Old Dominion University, Norfolk, VA; *N. S. Fisher*, SUNY, Stony Brook, NY.; *D. E. Hinton*, Univ. California at Davis, CA 95616

Project Description: Some of the most contentious restoration issues in the Bay-Delta revolve around selenium (Se) contamination. Selenium has been implicated in numerous cases of reproductive failure and loss of fish, waterfowl and crustacean populations (Ref. 24). In the Bay-Delta, Se concentrations high enough to cause such damage occur in sturgeon, diving ducks and dungeness crab (Ref. 19). Restoration of the Bay-Delta could be ineffective without resolution of selenium-related issues; uninformed restoration decisions could worsen Se contamination.

The chemical speciation of Se determines its fate, cycling and biological impacts (Fig. 1). Speciation differs among the potential anthropogenic sources of Se input to the Bay-Delta. Selenium can occur in high concentrations in agricultural irrigation drainage, which is discharged to the Bay-Delta from the San Joaquin River. Selenate (Se(VI)) is the principal dissolved form in this source (and in the Sacramento River); particulate forms can include elemental Se(0) (Ref. 1). Refineries are another important source. Their waste waters include a high percentage of dissolved selenite (Se(IV)). Within the Bay this Se(IV) is efficiently converted to particulate organo selenide by biological uptake (Fig. 1). Dissolved organic selenide (Se(-II)) is regenerated internally in the Bay-Delta and biogeochemical reactions in the water column can generate particulate Se (IV+VI). These forms are indicative of recycled Se (e.g. from sediments) (Ref. 3). Thus, determinations of Se fluxes and speciation from rivers, effluents and pore waters, accompanied by Se determinations within the ecosystem at different times, allows determination of the sources of Se to the Bay-Delta. Each form of Se also has a different biological availability (Ref. 14). Quantitative understanding of how changes in form affect Se uptake by critical species allows inferences about the biological significance of the different sources. Selenium magnifies in the food web as plants are eaten by their consumers and consumers are eaten by their predators (Ref. 14, 27). The highest trophic level species are the first to be threatened. However, all predators do not appear to be equally at risk, perhaps because the efficiency of Se transfer differs among food webs. Quantitative comparisons of trophic transfer can allow identification of species most and least at risk.

Selenium issues are also changing in complex ways. Refineries are reducing their Se discharges, but contamination has worsened in clams (a critical link to the threatened predators in the food web) (Ref. 10)(Fig. 2), and perhaps in sturgeon and diving ducks (Fig. 3). The causes of the recent increases in contamination are not known, but could involve biological processes (e.g. a new resident species of benthos now dominates Suisun Bay), geochemical processes (e.g. speciation of Se may be changing), physical influences (e.g. contamination may increase at lower river inflows) or changing inputs (e.g. increased agricultural inputs). Where complex factors interact in changing circumstances, models can aid understanding of issues and can project outcomes of alternative management strategies.

We are proposing a substantial, uniquely integrated, ecosystem evaluation of Se in the Bay-Delta, that will lend itself to developing models useful in Se management strategies. The study will deliver the following products:

- A quantitative description of how the rivers, agricultural drainage, refineries, and recycling contribute to Se concentrations in the Bay-Delta.
- Determination of how changing sources might affect Se tissue concentrations in primary consumers (bivalves and copepods) under different river inflow regimes.
- Linkage of Se concentrations in primary consumers to uptake by predators and inferences about the potential for adverse effects on sturgeon, diving ducks, striped bass and delta smelt.
- A direct determination of whether Se affects reproduction and development in sturgeon.
- Models, developed from the above, that can forecast outcomes of alternative Se remediation/restoration strategies or can evaluate the status of Se issues.
- A baseline of monitoring data against which to evaluate future changes in Se contamination.

Approach/Tasks/Schedule: The study will be conducted over three years. Rivers and effluents will be sampled monthly to determine Se inputs (Fig. 4). Concentrations and subcellular distributions of Se will be determined in clams and speciation will be determined in water and suspended particles at high river flow and low river flow each year. These data will help identify sources of input (from speciation signatures) and Se trends in the food (clams) of bottom feeders like sturgeon and diving ducks. Porewater Se will be analyzed to determine recycling from sediments. Shallow water habitat will be surveyed in Suisun Bay and in the Delta to determine speciation, recycling and bioavailable concentrations in this critical habitat.

Using radiotracer protocols (Ref. 14, 16), the biological availability of each of the important dissolved and particulate forms of Se in the Bay-Delta will be experimentally evaluated (Fig. 5). Models will be developed from these studies to predict Se bioaccumulation under different input conditions in clams, copepods and oysters (a potential husbandry in a restored ecosystem). We will determine trophic transfer of Se from copepods to striped bass larvae and the mid-trophic level fish *Menidia menidia*; and from clams to sturgeon. Model projections will be compared to field data collected above and to Se concentrations determined in striped bass, smelt and sturgeon, as part of a mercury cycling study being proposed by USGS. Effects of Se trophic transfer on development of sturgeon eggs will also be evaluated.

Justification/Budget/Qualifications/Coordination: Simple elimination of all sources of Se input to the Bay-Delta is not feasible (even if it were technically possible), partly because no convincing integrated view exists of the significance of the problem and its different sources. We are proposing to work with CALFED to resolve knowledge gaps and use models and monitoring to aid management of Se controversies that might impede the restoration process. The PI's have stature, substantial experience and no vested interests in the local Se issues. This study will bring to bear their specific experience with Se and the Bay-Delta. It will take advantage of local USGS infrastructure and matching support. Drs. Cutter and Fisher are recent recipients of a National Science Foundation grant wherein they will be examining some mechanistic details of Se cycling in the SF Bay. We are asking CALFED to build on the opportunity provided by the fundamental NSF and USGS research, and support a related study directly applied to questions of Se impacts on restoration of the Bay-Delta. We will coordinate this study with other programs funded by CALFED, especially including other USGS proposals. We are requesting from CALFED, spread over three years, a total of $1,588,709.

ASSESSING IMPACTS OF SELENIUM ON RESTORATION OF THE SAN FRANCISCO BAY-DELTA ECOSYSTEM

---a proposal to the CALFED Bay-Delta Program---

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ORGANIZATION: US Government in collaboration with University or University Foundations [Separate contracts recommended]

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	SUNY: 14-1368361	**UCD:** 94-6036494

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RFP PROJECT TYPE: #3; Other Services

I-002329

PROJECT DESCRIPTION AND APPROACH

The overall objectives for this study are:

1. *Determine the relative importance of different sources of Se to the Bay-Delta*, including rivers, agricultural drainage, refinery effluents, and recycling from sediments. 2. Evaluate how contamination of the water column and food web are affected by flow regime and biogeochemical trapping. 3. Compare, experimentally and in the field, the bioavailability of the important forms of dissolved and particulate Se to critical species (i.e. is Se equally bioavailable from all potential sources?), and to different food webs. 4. From objectives 1 - 3, develop integrated models that can be used to aid management of Se issues and restoration decisions.

TASK 1: Determine contributions of Se to the Bay-Delta from rivers, refineries, agricultural inputs and recycling from sediments; determine how contamination is influenced by river inflows. We will construct a description of Se distributions in the water column of the Bay-Delta at different times, characterize inputs from the important sources, and study cycling between the water column, suspended particles, and the underlying sediments. The forms of dissolved and particulate Se will be determined during each sampling. Samples will be collected in different seasons and different years (Fig. 4) to determine how Se contamination is affected by hydrologic conditions (Ref. 10). Estuarine modeling techniques (Ref.1) will be applied to these data to quantify inputs and fluxes. Data will be compared to the 1980's to evaluate long-term changes.

Water column sampling will be from USGS vessels using pressurized Go Flo bottles to collect filtered water as well as suspended particles for Se analyses. Salinity, nutrients, chlorophyll a, and particulate carbon and nitrogen will also be determined to aid interpretations. Dissolved and particulate Se speciation will be analyzed by high sensitivity techniques using selective hydride generation, liquid nitrogen-cooled trapping, and atomic absorption detection (Ref. 2,3,4,5). All samples are analyzed in triplicate to evaluate precision and the standard additions method of calibration is used to ensure accuracy. For dissolved samples, total Se, Se(IV), and Se(IV+VI) are determined directly, and selenate is the difference between Se(IV+VI) and Se(IV), while organic selenide is the difference between total Se and Se(IV+VI). The detection limit is 0.02 nmol/L and precision is better than 5%. Particulate total Se in sediments, suspended particles, or biogenic samples are solubilized using an oxidative digest; adsorbed selenite and selenate are leached from particles using a basic leach (Ref. 4); elemental Se is solubilized with a 0.5 M sulfite leach, followed by oxidative digest (Ref. 5).

Approach: 1.1 *Signatures and variability of inputs.* Concentrations and speciation of Se in the Sacramento River (above tidal influences), the San Joaquin River (near Vernalis) and industrial effluents will be monitored monthly. The unique speciation signature of each source term will be verified and followed through time and Se inputs will be used in the models applied to the estuarine transect data. We will compare speciation in the Bay-Delta to speciation in the San Joaquin to verify inputs from this source, because concentrations at Vernalis may over-estimate mass inputs. We will also test use chloride isotope or strontium isotope ratios, in one estuarine transect, to determine if SJR inputs can be verified.

Approach: 1.2 *Compare the contributions of the sources and evaluate influences of river flow regime.* Traditional estuarine transects of Se concentrations and speciation will be conducted along the Bay-Delta axis during low river flow (long residence time) and high river flow (short residence time), each year from Fall 1997 through Fall 2000. Up to 25 surface stations will be occupied in each transect (Ref. 1). About 20 sites in shallow water habitat, especially in the Delta, will be surveyed three times during different flow regimes.

Approach: 1.3 *Recycling from sediments.* Selenium concentrations in pore waters will be determined from box cores collected at 12 locations along the axis of the Bay-Delta on four occassions (Fig. 4) and diffusive fluxes from sediments to the water column will be calculated. Three box core surveys will also be conducted in shallow water habitat. Immediately after retrieval, subcores are taken using a whole core squeezer (Ref. 6). Porewaters are hydraulically extracted and filtered into polyethylene syringes. From sediment porosity and the volume collected, a depth resolution of 1-2 millimeters is possible, allowing accurate measurements of the porewater concentration gradient at the sediment-water interface.

Approach: 1.4 *Biogeochemical trapping and recycling of selenium.* In 1999 the phytoplankton bloom in South Bay will be studied in order to evaluate if blooms affect Se cycling. Phytoplankton blooms are common in the Delta, but their influences are difficult to study because the timing and locations are poorly known. A predictable one month phytoplankton bloom occurs each spring in South Bay (Ref. 7). Phytoplankton growth reduces dissolved concentrations of some metals, increases concentrations in suspended particulate material and changes speciation (Ref. 8, 9). By intensely sampling water and biota before, during and after the bloom in South Bay, as shown by Luoma et al (Ref. 8), we can infer whether blooms in the Delta might affect fluxes, Se speciation and bioavailability.

TASK 2. Biomonitoring. Selenium trends in predators like scoter, sturgeon, and dungeness crab are difficult to monitor with sufficient frequency, and difficult to interpret with regard to sources. Prey species, like filter feeding bivalves, are more feasible to monitor and can be indicative trends in predator exposure to Se, since food is the primary route of predator uptake (Ref. 27). We will monitor selected prey species along with the water column studies. These data will also complement experimental studies of the bioavailability of dissolved and particulate Se species.

Approach: 2.1. *Selenium trends in prey species and predator exposures.* Using previously published biomonitoring protocols (Ref. 11, 12, 13) Se concentrations will be determined monthly on large samples ($n \geq 50$) of resident *Potamocorbula amurensis* from Carquinez Strait (the area of highest Se concentrations) to keep track of temporal trends and evaluate influences of river inflows. Subcellular distributions of Se in *P. amurensis* will be determined to evaluate trends in the fractions of Se most bioavailable to predators of the clam.

Approach: 2.2. Resident species will be collected three times from shallow water habitat in Suisun Bay (zooplankton, larval anchovy, striped bass, and the bivalves *Macoma balthica* and *P. amurensis*) and in the Delta (the freshwater bivalve *Corbicula fluminea*) for Se analysis and determination of subcellular Se distributions (Fig. 5). This will provide the first coordinated water column, tissue and predator exposure data from shallow water habitat in the Delta where restoration projects are underway.

TASK 3: Bioaccumulation of the different forms of Se. Laboratory experiments will be conducted to carefully examine the transfer of different forms Se through the major food webs of the Bay-Delta (Figure 5). All experiments will employ protocols which we have developed for gamma-emitting radio tracers (Ref. 14, 15, 16). These enable experimentation with low, environmentally realistic Se concentrations. They determine assimilation efficiencies (AE) of Se from different food and particulate sources, dissolved uptake rates of different Se species, and release rates from organisms. The three are first-order parameters that are directly comparable among species and are the basis for bioaccumulation models that allow unambiguous comparisons of bioavailability from different forms of Se under complex circumstance like those encountered in nature (Ref. 14).

Approach: 3.1 *Evaluate the bioavailability of the major dissolved and particulate forms of selenium to primary consumers.* Uptake rates of dissolved selenite and organo selenide will be determined for phytoplankton, bacteria and primary consumers (selenate is of little bioavailability - Ref. 14). Trophic transfer, the primary pathway of Se exposure for nearly all animals, will be quantified for each major particulate form animals could encounter in the Bay-Delta. Pulse-chase techniques will determine assimilation efficiencies (AE, Ref. 14). AE can vary as much as four fold among some food types, greatly affecting bioaccumulation (Ref. 14). AE of Se in *P. amurensis* and *C. fluminea* will be determined from: diatoms (which dominate many blooms in the Bay and Delta); free-living bacteria; detritus derived from freshwater algae and aged for different times (simulating detritus input to Suisun Bay from the Delta); particulate elemental Se (which is formed by microbial dissimilatory reduction and is likely to be characteristic of agricultural drainage); and Se IV+VI adsorbed to particles (which can be formed by bacterial oxidation of elemental Se and could be generated during residence in the Bay-Delta). The microbially-derived forms of Se will be generated in microbiological experiments in collaboration with Dr. R. Oremland, USGS (see also Ref. 14). In addition, AE from natural suspensions collected from the Delta and the Bay will be determined.

Approach: 3.2 *Do primary consumers differ in their abilities to bioaccumulate Se?* We will evaluate Se bioaccumulation processes in *P. amurensis*, to determine if high selenium uptake efficiency by this recent invader of the Bay-Delta is a possible explanation for the increased Se in scoter and sturgeon found in 1990. We will compare Se bioaccumulation among *P. amurensis; Corbicula fluminea* (the dominant filter feeder in the Delta); a dominant amphipod, *Ampelisca*; a dominant primary consumer in the water column (copepods): and two oysters that have historically been used in commercial husbandry in the Bay-Delta (*Crassostrea virginica; Ostrea lurida*). From these experiments we will develop bioaccumulation models for each species.

Approach: 3.3. *Bioaccumulation by fish that feed from the water column.* Striped bass, delta smelt and chinook salmon are examples of species of concern to CALFED that feed from the water column. High concentrations of Se are not always found in these species (Ref. 19) where they have been determined), possibly because Se is inefficiently transferred through their food web. In order to test Se transfer through the water column food web, copepods, after being fed Se-labeled algae, will be fed to adult *Menidia menidia* (silversides) following protocols described above and modified for fish larvae (Ref. 17, 18). The Se threat to the larvae of these species is also unknown, so similar experiments will be conducted with larval striped bass (*Morone saxatilis*). If it is verified that Se is a less important threat to species that feed in the water column, or their larvae, the Se can be eliminated as a consideration in their restoration .

Approach 3.4. *Bioaccumulation and effects on fish that feed on benthos.* Sturgeon (*Acipenser transmontanus*) may be the species most threatened by Se contamination in the Bay-

Delta. The high concentrations of Se in sturgeon from the Bay-Delta (Ref. 19) could result if trophic transfer is highly efficient. Transfer of Se to sturgeon will be directly studied by exposing the fish to clams from the Bay (their natural food source). Among oviparous vertebrates like sturgeon, reproduction and development is highly sensitive to Se (Ref. 20). Aquaculture producers capture feral female sturgeon and after hormonal stimulation for oocyte maturation, remove mature eggs. When fertilized by milt from feral males, offspring are produced; 1 and 2 yr old juveniles are available at UC Davis. We will determine the kinetics of uptake and the distribution of Se in the fish when these juveniles are fed Se-laden clams (*P. amurensis*) from populations with known concentrations and subcellular distributions of Se. Oocyte, liver, blood and skeletal muscle Se will be determined to evaluate the kinetics of uptake, the link between uptake and subcellular distributions in prey, and specific organs involved in sequestration. By collaboration with producers, we will determine Se levels in a portion of the green eggs from sturgeon and follow progeny of specific females to determine if Se affects the success of their development using biochemical, immunochemical and high resolution microscopy. Finally, we will determine levels of Se in muscle, liver, and oocytes of wild sturgeon obtained from Cal F&G. Comparison of levels in liver and oocytes will help to assess maternal transfer of Se (bound to yolk protein precursor, vitellogenin). By comparing levels taken up experimentally with levels in wild caught older fish, we can predict the concentration in diet necessary to reach levels that could adverse effects.

TASK 4: Models. An important goal of the proposed study is to construct a qualitative and quantitative model of Se cycling between the water, suspended particles, the underlying sediments in the Bay-Delta and Se passage through the estuarine food web. A model that evaluates Se fate, uptake and trophic transfer is a necessity in the Bay-Delta where restoration strategies could be affected by changing Se sources, speciation and issues. The geochemical modeling will assign quantitative values to inputs and fluxes and use relatively standard estuarine modeling techniques that accommodate varying end member concentrations (e.g. Ref. 21, 22) and include inputs from benthic reflux (derived from the high resolution porewater data and simple diagenetic modeling, e.g. Ref. 23). The experimental studies with benthos and fish will allow us to quantify the rates of transfer from different mixtures of Se forms to individual biotic species and food webs and to consider uptake from both food and water pathways (Ref. 14). The experiments will also allow us to estimate trophic transfer to predators and, from the literature (Ref. 24) and experiments with sturgeon, infer tissue concentrations that could affect reproduction or parameters that can feed into individual-based population models for the predators. We will evaluate the accuracy of our modeling approach by comparison with field data and by tests with other simulation model approaches (e.g. ECOS from the Plymouth Marine Laboratory, U.K. (Ref. 25), and possibly a model from the Electric Power Research Institute which simulates Se cycling (Ref. 26)).

GEOGRAPHIC BOUNDARIES: Vernalis on the San Joaquin River, tidal reach of the Sacramento River, Golden Gate Bridge. Most study concentrated in the Delta and Suisun Bay.

EXPECTED BENEFITS: Knowledge from our study will help CALFED prioritize Se

I-002333

remediation relative to other Bay-Delta restoration alternatives; and choose the best strategies for reducing the Se threat to sturgeon, scoter, dungeness crab, marsh and shallow water habitat. Objective evaluations of this nature may be the best way to improve prospects for resolving long-contentious Se issues relevant to restoration. The realistic, quantitative models we can develop from this study can prioritize inputs of Se for mitigation and compare biological implications among different Se management strategies. The baseline of data we will provide and the demonstration of useful approaches for future studies will be beneficial for all future studies of Se issues. Effective Bay-Delta restoration will require sufficient knowledge to make Se-mitigation decisions that all parties will accept. We expect to work with CALFED throughout the study to meet that goal.

BACKGROUND/JUSTIFICATION: A variety of complex, interacting factors affect the fate, cycling, and ultimately, the threat of Se to the Bay-Delta ecosystem. Anthropogenic inputs will be changing during the CALFED restoration process. Refineries are reducing their Se inputs. But agriculture recently began releasing Se-laden irrigation return waters directly to the San Joaquin River and a new Water Accord has mandated that more San Joaquin water be released to the Bay-Delta. Physical changes planned for the water management system may affect how much Se reaches the Bay-Delta. Each source of Se has a unique dissolved and particulate speciation, and speciation is the ultimate process controlling the ecosystem implications of Se (Fig. 1). Thus, the combination of Se forms that reach the Bay-Delta, as well as concentrations, will change as sources change, with substantial and complicated biological implications. An added complication is that neither speciation nor trophic transfer are adequately considered in EPA criteria for Se. Since these are the two most important factors determining adverse effects of Se, the usefulness of such criteria, alone, in protecting the Bay-Delta ecosystem is questionable. The field data and modeling effort that we are proposing here will provide additional evaluation criteria.

Concentrations of Se appear to be increasing in the tissues of the organisms that may be the best indicators of food web exposure to Se in the Bay-Delta. Populations of the animals that may be most affected by Se (sturgeon and the diving duck, scoter) are in decline. Piece-meal studies of the Se problem have established a base of general knowledge, but that knowledge is insufficient to help resolve the causes of changing Se concentrations or guide resolution of restoration-threatening Se problems. Our study will fill major knowledge gaps that could otherwise impede wise and effective restoration strategies: How much Se from the San Joaquin River reaches the Bay-Delta? How do dissolved and particulate forms of Se differ in their bioavailability to Bay-Delta food webs? How much reduction in refinery inputs is enough? Is recycling of Se from underlying sediments important? Are there circumstances when recycling from sediments is accentuated? Are all food webs equally vulnerable to Se contamination? Specifically, are fish that feed from the water column less threatened than fish that feed from the benthos? Can Se impede sturgeon reproduction via trophic transfer from clams and maternal transfer to eggs? Do higher exposures to Se occur during lower river flows; and does this have implications for flow diversions or physical changes in the water management system? Why are Se concentrations in bivalves higher now than in 1986? What is the status of Se contamination in the Delta and what are the implications for island restorations? We are proposing to collect data and provide environmentally realistic modeling tools that will provide answers to each of these questions. These data and models will specifically help managers evaluate the technically complex scenarios that are likely to develop as restoration proceeds and our baseline of high quality data and knowledge will be useful in the future evaluations as issues change.

SCOPE OF WORK: Fig. 4 and 5 describe the time course for the different aspects of this study. Because the field and laboratory studies are interrelated, many different tasks will be accomplished simultaneously. For each task we will produce a progress report once per year, a final report and financial reporting as requested. After two years we will organize a Bay-Delta workshop on Se, in conjunction with the Interagency Ecological Program workshop or some other multi-discipline forum, to inform other CALFED participants of our findings and to obtain feedback that might influence our final year of study. Our final products will include scientific presentations and publications, as well as oral and written products for managers as requested. At the end of the study, a "white paper" will be prepared that will summarize for managers the status of Se contamination in the Bay-Delta as it might affect restoration, and use models to evaluate alternative actions. These applied results will be summarized in a USGS fact sheet for managers and the public.

MONITORING AND DATA EVALUATION: Analytical and experimental procedures will follow the strictest quality control/quality assurance approaches, as detailed in our published papers (see Reference List). To provide the essential scientific credibility to our findings, they will be published in first line journals in the peer-reviewed scientific literature. We expect to continue our strong history of interaction with management agencies. Our study will be coordinated with the USGS study of mercury cycling (Marvin-DiPasquale et al, proposed in this round of the CALFED process). Because mercury-selenium interactions are possible (see mercury proposal) it is beneficial to intensively study both elements simultaneously. We hope to use findings from Dubrovsky (USGS) and Schwartzenbach (USFWS) (proposal to CALFED) to help us evaluate the complex San Joaquin River inputs to the Delta. Our study is planned to complement the proposal of Kuivila et al (USGS proposal to CALFED) who will be studying hydrodynamic influences on pesticide and trace element contamination. We will provide our Se monitoring data to the Regional Monitoring Program, and will provide a chapter for their annual report if requested (our effort involves speciation and resident animal analyses that are not conducted by the RMP). We will also evaluate each of our field approaches for its value as a monitoring tool in the broader CALFED program.

IMPLEMENTABILITY: This study will be augmented by a ~$600,000 fundamental study of mechanisms that affect Se cycling (Cutter and Fisher PI's) recently supported by the National Science Foundation. It will take advantage of local USGS infrastructure, and USGS will be a full partner by providing ship time, laboratory infrastructure and salaries of full time employees, including the first PI (~$700,000 matching effort). The methods we are proposing to use in this study, including the models, are the most modern available and are supported in reviewed publications. Our optimism about the success of this study stems from our extensive experience with Se and in the Bay-Delta and our confidence in this integrated multi-discipline approach.

Proposed Biogeochemical Pathways for Selenium in Estuaries

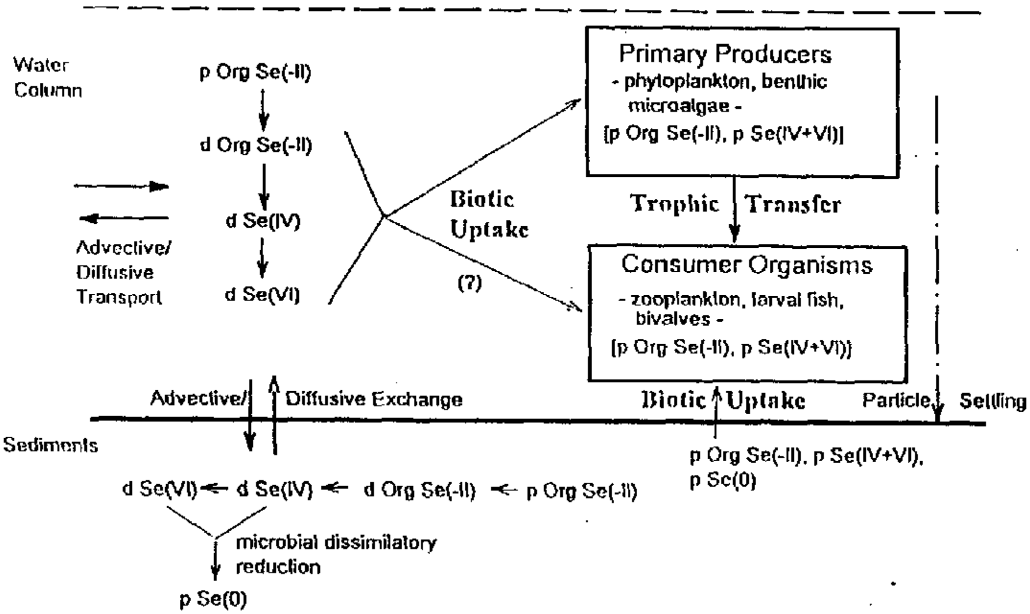

Figure 1: The biogeochemical pathways for selenium: in the water column and sediments, particulate (p) organic selenide is converted to dissolved (d) selenate in a multistep process; selective uptake of dissolved species by primary producers, and perhaps by higher (consumer) organisms, occurs, with particulate organic selenide being the product; consumer organisms eat primary producers, resulting in trophic transfer of selenium; consumer organisms (bivalves) also take up particulate selenium from sediments; dissolved and particulate selenium are transported in the estuarine water column by horizontal advection/diffusion; dissolved selenium species in sediment porewaters exchange with those in the overlying water via advection/diffusion; particulate selenium in the water column can also deposit in the sediments. Not shown are riverine, atmospheric, and point source (pollutant) inputs.

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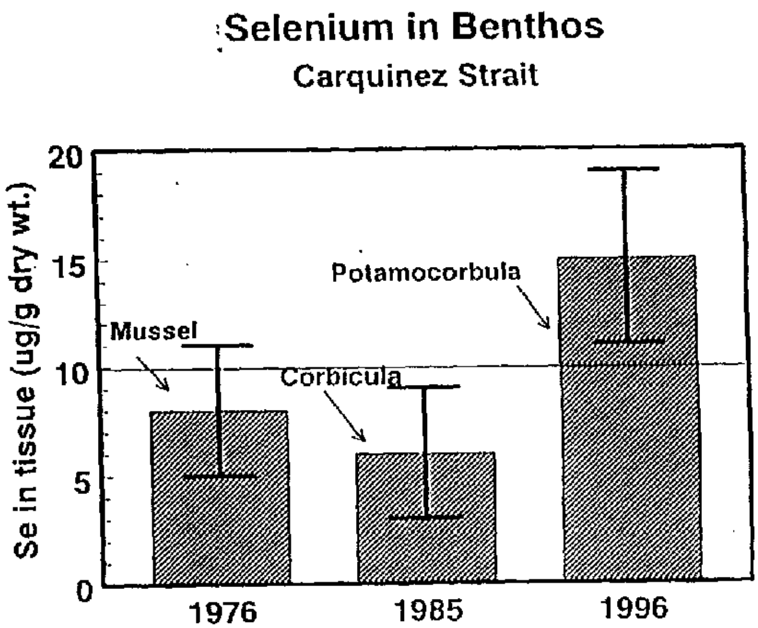

Figure 2. A comparison of selenium concentrations in extensive samplings of bivalves near Carquinez Strait conducted in 1976, 1985, and 1996. Mussel (*Mytilus edulis*) were studied in 1976 in a study supported by ABAG; these data are from transplanted mussels placed at stations near Carquinez Strait. The 1985 data are from samples of the predominant clam in Suisun Bay (i.e. the predominant food source for predators like sturgeon or scoter) at that time, *Corbicula fluminea* as observed by the Water Resources Control Board and by Johns et al, 1988. The 1996 data are from the bivalve that is presently predominant (and presently the predominant food source for sturgeon and scoter) and are from monthly samplings between October 1995 and October, 1996, as reported by Luoma and Linville, 1996.

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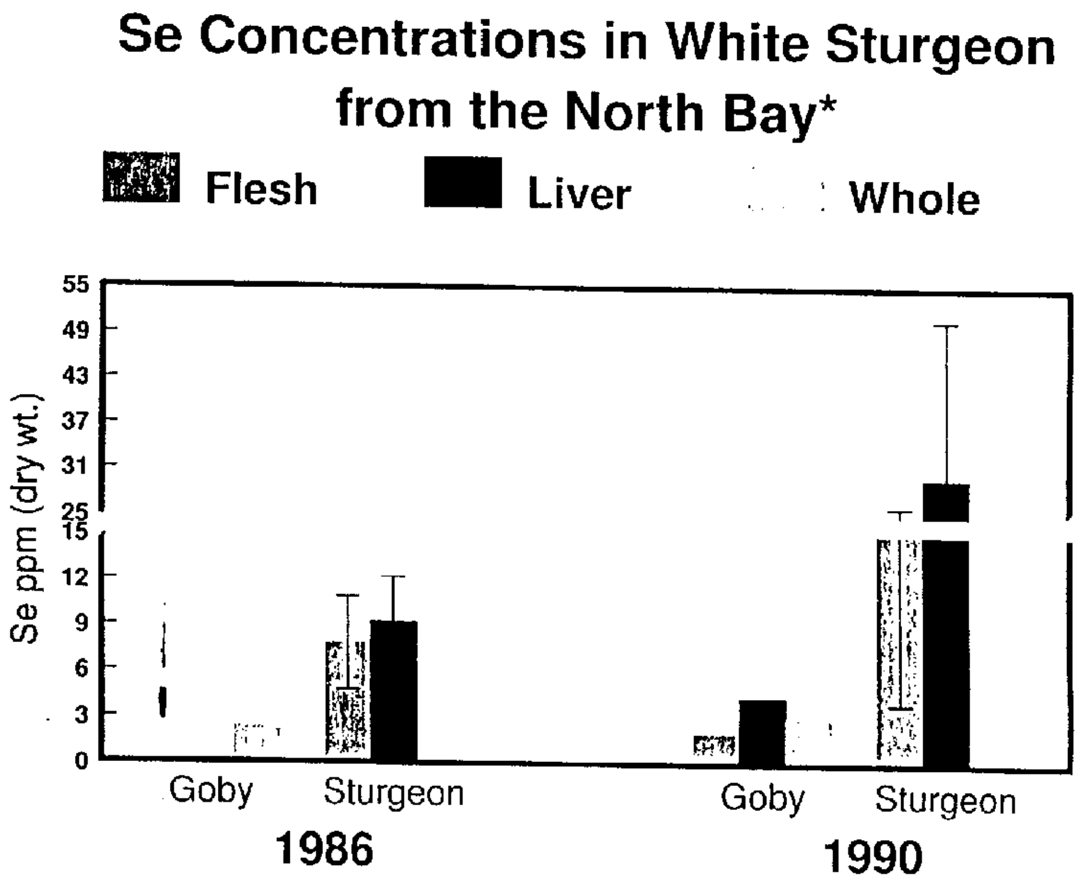

Figure 3. A comparison between 1986 and 1990 of selenium concentrations in sturgeon and goby, as determined by the Water Resources Control Board. Selenium concentrations are highest in sturgeon, of all fish determined and appeared to be higher in 1990 than in 1986 (although concentrations are variable). The last systematic sampling of Se in the Bay-Delta food web was conducted in 1990.

Figure 4. SELENIUM STUDY -FIELD COMPONENT							
Sampling Location	1997 LOW FLOW	1998 HIGH FLOW	1998 LOW FLOW	1999 HIGH FLOW	1999 LOW FLOW	2000 HIGH FLOW	2000 LOW FLOW
1) WATER COLUMN - Cutler							
❖Bay-Delta Axis Transect	☒	☒	☒	☒	x	x	x
❖Off Axis-shallow habitat		x	x		x		
❖Delta-shallow habitat		x	x		x		
❖South Bay				Bloom: 8 monthly samples			
2) SEDIMENT CORE (recycle) - Cutter							
❖Bay-Delta Axis (transect)	☒	☒	☒	☒	x		
❖Off axis (shallow habitat)		x	x		x		
3) RIVERS- Cutter/Luoma							
❖Sacramento R.		10 - 12 samples: monthly		10 - 12 samples: monthly		10-12 samples: monthly	
❖San Joaquin R.		10 - 12 samples: monthly		10 - 12 samples: monthly		10- 2 samples: monthly	
❖Effluents		10 - 12 samples: monthly		10 - 12 samples: monthly		10-12 samples: monthly	
4) PRIMARY CONSUMERS- Luoma							
❖*Potamocorbula*							
•Carquinez Strait	X	10 - 12 samples: monthly		10 - 12 samples: monthly		10 - 12 samples: monthly	
•Grizzly, Honker Bay-shallow		x	x		x		
•South Bay				Bloom: 8 monthly samples			
❖Zooplankton (Larvae)		x	x	x			
❖*Macoma*							
•Carquinez Strait	☒	☒	☒	☒	☒		
•South Bay				Bloom: 8 monthly samples			
❖*Corbicula*							
•Delta-shallow water		x	x		x		
☒ Supported by National Science Foundation and US Geological Survey							

Figure 5. SELENIUM -- EXPERIMENTAL & MODEL DEVELOPMENT			
PRIMARY CONSUMERS	**DISSOLVED SOURCES**	**PARTICULATE (FOOD SOURCES)**	**Schedule**
● *Portamocorbula* (Asian clam)	1) selenite 2) organo-Se	1) phytoplankton 2) bacteria 3) Detritus (+speciation) •Freshwater algae ↘age 1, 2, 3 •Se^0 •Se(IV) 5) Natural (+speciation) • Fall: Delta, Suisun • Spring: Delta, Suisun 6) Phytoplankton & Hg/Se	Luoma- 1998 - 2000
● *Crassostrea virginica* (Eastern oyster)	1) Se(IV) 2) Organic Se	1) phytoplankton 2) selected detritus 3) bacteria	Fisher - 1998-2000
● *Corbicula fluminea* (Brackish clam)	1) Se(IV) 2) Organic Se	1) phytoplankton 2) detritus (as for *P.amurensis*) 3) bacteria	Luoma 1999-2000
● *Macoma balthica* (Clam)	1) Se(IV) 2) Organic Se	1) phytoplankton 2) selected detritus 3) bacteria	Luoma & Fisher 1998-99
● Ostrea lurida (Native oyster)	1) Se(IV) 2) Organic Se	1) phytoplankton 2) selected detritus 3) bacteria	Luoma 1999
● Copepods	1) Se(IV) 2) Organic Se	1) phytoplankton 2) selected detritus 3) bacteria	Fisher- 1998-2000
● Amphipod	1) Se(IV) 2) Organic Se	1) selected detritus 2) bacteria	Luoma - 2000
PREDATORS			
Menida menida	1) Se(IV) 2) Organic Se	copepods	Fisher- 1998-2000
Striped Bass Larvae	1) Se(IV) 2) Organic Se	copepods	Fisher 1998-2000
Sturgeon		benthos (*P.amurensis*)	Hinton 1998-2000

IV. COSTS & SCHEDULE

Budget Costs: Budget requests by task and institution, and matching USGS contributions, are detailed in Tables 1a - 1d. We will run this program as a joint partnership, but Dr. Luoma at USGS in Menlo Park, CA will be ultimately responsible for coordination, deadlines, task completion and products. We are assuming that CALFED will issue separate contracts to each institution, thereby saving double overhead charges that can accompany a single contractor with subcontracts. The CALFED program offers a unique opportunity to integrate programs from four institutions and thus develop a uniquely comprehensive view of selenium in the Bay-Delta. Each task proposed is essential to developing the models and knowledge necessary to evaluate rational alternatives within the long-contentious selenium issues. While piecemeal research on selenium will continue without CALFED, support from CALFED is the only way to bring this work into a common focus relevant to effective restoration of the Bay-Delta ecosystem.

Responsibilities and relation to budget request: USGS will lead Task 2 and Tasks 3.1, parts of 3.2 (see Fig. 5) and provide some collaboration for Task 3.4. USGS is requesting support for a postdoctoral associate or equivalent to accomplish the field biomonitoring study and another postdoctoral associate to conduct the benthic food web trophic transfer study and collaborate with Dr. Hinton on the sturgeon study. A student will be supported to work with the sturgeon study in the first year, and one to help with the trophic transfer study. Some support of laboratory costs is necessary because USGS cannot divert all its resources to only the study of selenium study. With the exception of some time for field coordination and ship-board chief scientist time directly applicable to the field requirements of the Se study (20% Cynthia Brown), USGS will contribute all time from permanent employees and all ship time, including a substantial effort from the PI and the equivalent of one GS-11 person-year to help with both field and laboratory studies.

Dr. Hinton is requesting one student fellowship for three years to run the sturgeon studies, and some support for laboratory supplies.

Dr. Fisher is requesting salary for one month per year to design, participate in and interpret all experiments, as well as participate in the modeling effort. A full time postdoctoral associate with assistance from a technician will conduct the bioaccumulation studies with oysters and Task 3.3, the study of Se transfer through the food web leading to water column-feeding fish. Travel funds are necessary to facilitate collaboration and coordination of experiments, interpretations and modeling.

Dr. Cutter will be responsible for Task 1. He is requesting salary for one month per year to design, participate in and interpret all experiments, as well as participate in the modeling effort. Specifically, he will supervise the research technician and graduate student, participate on at least half of the sampling expeditions, prepare reports and manuscripts for publication, perform much of the estuarine modeling tasks, and interface with the other PI's. Since there is considerable field work in Years 1 and 2, with resulting large number of samples for selenium and ancillary parameters, 6 months in Years 1 and 2, and 3 months in Year 3 have been budgeted for a senior research technician. This individual will perform most of the ancillary determinations and particulate selenium speciation work, as well as handling all the field preparation and participating on all the sampling trips. A graduate research assistant salary (half time academic year, full time summer) has been budgeted for all three years. This student will work on the dissolved selenium speciation work as a part of their MS dissertation and interface with the graduate student in Fisher's lab on uptake experiments. Finally, a part time undergraduate lab assistant has been budgeted to assist with field gear preparation, glassware cleaning, and reagent preparation. Additionally, the high sample load dictates that we devote an atomic absorption spectrometer solely to this work, and we have therefore budgeted ($15,000) for the purchase of an inexpensive instrument capable of accommodating hydride determinations.

Cost Sharing: The proposal offers substantial cost sharing with a newly funded National Science Foundation Grant ($500,278 from NSF Environmental Geochemistry and Biogeochemistry). Cost sharing will also occur with USGS, which will contribute substantial resources, capabilities and local infrastructure (Table 1d).

Implementation Schedule: Scheduled activities, time lines for each set of experiments, and distribution of tasks are detailed in Fig. 4 and 5. The study will start January 1, 1998 and tasks will be completed by December 31, 2000. Modeling efforts are not included in the Tables. It is expected that preliminary model development will begin in the second year of the study, so that preliminary results (e.g. scenario evaluations) can be presented at the workshop at the end of the second year (see above). The primary measure of accomplishment will be annual progress reports, which will be presented for each task. Each institution will accommodate billing schedules preferred by CALFED. No third party impacts are anticipated from this work.

Table 1a. Request for funding from CALFED for USGS tasks in study.

CALFED REQUEST	Year 1 ($)	Year 2 ($)	Year 3($)	Total
Task 2. Luoma-USGS				
1. Direct Labor				
A.Post-doctoral assoc.	48,886	50,352	51,863	151,101
2. Benefits				
A. Postdoctoral Assoc.	14,666	15,106	15,559	45,331
3. Ship-board Assistance	3,000	3,000	3,000	9,000
4. Analytical Services - USGS	6,000	4,000	3,000	13,000
Task 3. Luoma-USGS				
1. Direct Labor				
A. Postdoctoral Assoc.	48,886	50,352	51,863	151,101
B. Students (50%)	24,000	12,000	12,000	48,000
C. Cynthia Brown (20%)	8,280	8,350	8,460	25,090
2. Benefits (summed)	17,000	17,400	18,900	53,400
3. Microbiological Services	10,000	10,000	–	20,000
4. Supplies	9,000	9,000	9,000	27,000
TOTAL DIRECT	189,818	179,560	173,645	543,023
TOTAL INDIRECT	99,980	94,557	91,462	286,020
TOTAL	**289,798**	**274,137**	**265,107**	**829,043**

Table 1b. Request for funding from CALFED for tasks performed by Drs. Cutter, Fisher and Hinton's laboratories.

	Year 1 ($)	Year 2 ($)	Year 3($)	Total
Task 3. Fisher-SUNY				
1. Direct Labor A. Fisher	8,000	8,500	9,000	25,500
B. Postdoctoral Assoc.	35,000	36,000	37,000	108,000
C. Technician	9,000	9,500	10,000	28,500
2. Benefits (summed)	14,840	15,663	16,505	47,008
3. Supplies.Travel, Pubs	13,000	17,500	14,000	44,500
6. Other Misc.	6,000	6,000	7,000	19,000
TOTAL DIRECT	85,840	93,163	93,505	272,508
TOTAL INDIRECT	26,932	29,230	29,337	85,499
TOTAL	**112,772**	**122,392**	**122,842**	**358,007**
Task 3. Hinton- UCD				
1. Direct Labor & Benefits A. Graduate Student	15,500	15,500	15,500	15,500
2. Supplies	10,000	10,000	10,000	30,000
3. Analytical Services	5,000	5,000	5,000	15,000
TOTAL DIRECT	30,500	30,500	30,500	91,500
INDIRECT	3,388	3,388	3,388	10,164
TOTAL	**33,888**	**33,888**	**33,888**	**101,664**
Task 1. Cutter-ODU				
1. Direct Labor A. Cutter	7,411	7,670	15,876	30,957
B. Sr. Technician	19,200	19,872	10,284	49,356
C. Students	20,100	20,100	20,100	60,300
Benefits (summed)	6,748	6,953	4,969	18,670
2. Supplies, Travel, Pubs, Shipping	16,500	13,500	10,000	40,000
3. Equipment (AAS)	15,000			15,000
TOTAL DIRECT	84,959	68,095	61,229	214,283
INDIRECT	30,082	29,281	26,329	85,692
TOTAL	**115,041**	**97,376**	**87,560**	**299,997**

Table 1c. Summary of total funding requests for CALFED from the four partners.

Task	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Task 1: Cutter - Old Dominion	115,041	97,376	87,560	299,997
Task 2 + Task 3: Luoma - USGS	289,798	274,137	265,107	829,043
Task 3: Fisher - SUNY, Stony Brook	112,772	122,392	122,842	358,007
Task 3: Hinton - UC Davis	33,888	33,888	33,888	101,664
TOTAL	**$551,499**	**$527,793**	**$509,397**	**$1,588,689**

Table 1d. USGS contributions to the proposed study. This is not a request for support from CALFED, but specifies what USGS funding would be applied to the study.

USGS Expenditures	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total
1. Direct Labor				
A. Luoma, 50%	53,924	55,200	57,000	166,124
B. 100%- GS11	442,373	453,400	46,200	135,973
2. Benefits (summed)	11,700	11,700	11,700	35,100
3. Ship Time	25,000	25,000	25,000	75,000
4. Publications, Illust, Computer	5,000	10,000	10,000	10,000
5. Supplies	20,000	20,000	20,000	15,000
6. Travel	5,000	5,000	5,000	15,000
TOTAL DIRECT	144,997	152,300	154,900	452,197
TOTAL INDIRECT	76,372	80,219	81,589	238,180
TOTAL	221,369	232,519	236,489	690,377

V. APPLICANT QUALIFICATIONS

SAMUEL N. LUOMA

Highest Education: 1972-74 , PhD, Dept. of Zoology, Univ. Hawaii, Honolulu, HI.
Present Position: Project Chief, Senior Research Hydrologist (ST-3104-1), Water Resources Division, US Geological Survey, Menlo Park, CA
1985-87, Chief, Branch of Western Region Research, WRD, USGS Menlo Park,
Research Interests and Selected Service: Bioavailabililty and biomonitoring of trace elements in aquatic environments. Involved with management-related issues in Bay-Delta since 1976. Studies in partnerships with cities and state agencies, and frequent participation in local workshops and committees. Work with US Bureau Reclamation identified distributions of bioavailable Se in Suisun Bay in the 1980's. Results, along with Dr. Cutter's, suggested refineries were a more important source of Se biocontamination than agriculture. Advised RWQCB on present guidance for Se regulation; Partnered with RWQCB on recent studies of changes in Se contamination. Chair, Science Advisory Group, Interagency Ecological Studies Program, SF Bay; Other Science Advisory Committees: Center for Environmental Health Research, Univ. Calif. Davis; SF Estuary Institute. Editor, *Marine Environmental Research*; Editorial Bd., *Marine Ecology Progress Series*; USEPA SAB Subcommittee on Sediment Quality Criteria.

SELECTED PUBLICATIONS (Selected from a list of >100)

1. Johns, C.E., Luoma, S.N. and Elrod, V., 1988, Selenium accumulation in benthic bivalves and fine sediments of San Francisco Bay, the Sacramento-San Joaquin Delta, and selected tributaries: *Estuarine, Coastal and Shelf Science*, v. 27, p. 381-396.
2. Luoma, S. N., C. Johns, N. S. Fisher, N. A. Steinberg, R. S Oremland & J. Reinfelder, 1992. Determination of selenium bioavailability to a benthic bivalve from particulate and solute pathways. *Environ. Sci. Technol.*, Vol. 26, pp. 485-491.
3. Luoma, S. N. 1996. The developing framework of marine ecotoxicology: Pollutants as a variable in marine ecosystems? *J. Exptl. Mar. Biol. Ecol.* v. 200, p. 29 - 55.
4. Wang, W.-X., Fisher, N. S. and Luoma, S. N. 1996. Kinetic determinations of trace element bioaccumulation in the mussel, Mytilus edulis. *Mar. Ecol. Prog. Ser.* v. 140, p. 91 - 113.
5. Luoma, S. N., 1989. Can we determine the biological availability of sediment-bound trace elements? *Hydrobiologia*, Vol. 176/177, pp. 379-401.
6. Luoma, S. N., 1995. Prediction of metal toxicity in nature from bioassays: Limitations and research needs. In *Metal Speciation and Bioavailability in Aquatic Systems*, Ed:Tessier & Turner, John Wiley & Sons, LTD, Sussex, England, pp. 610-659.
7. Luoma, S.N. & N.S. Fisher. 1997. Uncertainties in assessing contaminant exposure from sediments: Bioavailabililty. In *Ecological Risk Assessment of Contaminated Sediments*, Ed Ingersoll, Biddinger & T. Dillon, SETAC Press, Pensacola, FL.

GREGORY A. CUTTER

Department of Oceanography, Old Dominion University, Norfolk, VA 23529-0276
Highest Education: 1982, Ph.D., chemistry; University of California, Santa Cruz
Present Position (at Old Dominion University since 1982): Professor, Department of Oceanography, Joint Professor of Chemistry and Biochemistry, Old Dominion University

Research Interests: Processes affecting trace element speciation and distributions in natural waters and sediments; air-sea transport and exchange of gases and trace elements; analytical methods for aquatic chemistry; computer modeling of geochemical processes. Example of Mgt. Collaboration: Dr. Cutter's studies in the Bay-Delta, in collaboration with CA DWR, were the first to use high sensitivitiy analytical techniques to identify the unique speciation characteristics of Se in the different inputs to the Bay and were instrumental in identifying refineries as the primary source of Se contamination in Suisun Bay in the 1980's.

Selected Publications:

1. Cutter, G.A. 1982. Selenium in reducing waters. Science 217: 829-831.
2. Cutter, G.A. and K.W. Bruland. 1984. The marine biogeochemistry of selenium: a re-evaluation. Limnol. Oceanogr. 29: 1179-1192.
3. Cutter, G.A. 1989. The estuarine behavior of selenium in San Francisco Bay. Estuarine Coastal Shelf Sci. 28: 13-34.
4. Cutter, G.A. 1989. Selenium in fresh water systems. In: *Occurrence and Distribution of Selenium* (M. Ihnat, ed.). CRC Press, Florida, Chap. 10.
5. Cutter, G.A. and San Diego-McGlone, M.L.C. 1990. Temporal variability of selenium fluxes in the San Francisco Bay. Sci. Total Environ. 97: 235-250.
6. Velinsky, D.J. and Cutter, G.A. 1991. Geochemistry of selenium in a coastal salt marsh. Geochim. Cosmochim. Acta 55: 179-191.
7. Bowie, G.L., J.G. Sanders, G.F. Riedel, C.C. Gilmour, D.L. Breitburg, G.A. Cutter, and D.B. Porcella. 1996. Assessing selenium cycling and accumulation in aquatic ecosystems. Water Air Soil Pollut., 90: 93-104.

DAVID E. HINTON, PHD

Highest Education: Univ. Mississippi, Medical Center, Jackson, MS. PhD., Anatomy, 1969.
Present Position: (At UC Davis since 1986). Professor Fish Pathology, Aquatic Toxicologist in the Agricultural Experiment Station, Department of Anatomy, Physiology and Cell Biology, School of Veterinary Medicine, University of California, Davis, CA.
Research Interests: Extensive experience with modern methods of studying subcellular and developmental effects of contaminants in fish. Interests in relating such effects to ecotoxicity risk assessments, using life stage models that feed into individual-based population models.
Selected Publications: (From last four years and a total list of 139 full length papers.

1. The, S.J. and Hinton, D.E. (1993). Detection of enzyme histochemical markers of hepatic preneoplasia and neoplasia in medaka (Oryzias latipes). Aquat. Toxicol. 24:163-182.
2. Hinton, D.E., Guest Editor. 1996. Pollutant Responses in Marine Organisms (PRIMO 8). Special Issue of Marine Environmental Research, Vol. 1-4, June-October, 1996, 405 pp.
3. Hinton, D.E. (1993). Cells, cellular responses, and their markers in chronic toxicity of fishes. In: Aquatic Toxicology: Molecular, Biochemical and Cellular Perspectives. G.K. Ostrander and D.M. Malins, eds. Lewis Publishers/CRC Press, pp. 207-239.
4. Hinton, D.E. Cells, cellular responses, and their markers in chronic toxicity of fishes. In: Aquatic Toxicology: Molecular, biochemical and cellular perspectives. G.K. Ostrander and D.M. Malins. eds. Lewis Publishers/CRC Press, pp. 207-239.
5. Spies, R.B., Stegeman, J.J., Hinton, D.E., Woodin, B., Smolowitz, R., Okihiro, M. and Shea,

D. 1996. Biomarkers of hydrocarbon exposure and sublethal effects in embiotocid fishes from a natural petroleum seep in the Santa Barbara Channel. Aquat. Toxicol. 34:195-219.
6. Wiedmer, M., Fink, M.J., Stegeman, J.J., Smolowitz, R., Marty, G.D. and Hinton D.E. 1996. Cytochrome P450 induction and histopathology in preemergent pink salmon from oiled spawning sites in Prince William Sound. Am. Fish. Soc. Symp. 18:509-517.
7. Washburn, B.S., Vines, C.X., Baden, D.H., Hinton, D.E. and Walsh, P.J. 1996. Differential effects of brevetoxin and -naphthoflavone on xenobiotic metabolizing enzymes in striped bass (*Morone saxatilis*). Aquat. Tox. 35:1-10.

NICHOLAS S. FISHER

Highest Education: Ph.D., Biology, SUNY-Stony Brook, 1974.
Present Position: Professor, Marine Science Research Center, SUNY, Stony Brook (since 1991)
Selected Activities: Editorial Bds: *Mar. Ecol. Prog. Ser.* ; *Mar. Environ. Res.* ; IUPAC Commission on Environmental Analytical Chemistry; Review panels: NSF, NOAA, Sea Grant; Invited participant in GESAMP, IAEA, ICSEM, EMAP, NRC committees and working groups.
Research Interests: Physiology and ecology of phytoplankton, phytoplankton-herbivore interactions; biogeochemistry of trace elements in the sea; particle flux in marine systems; marine radioecology. Specific experience with Se trophic transfer in fish and invertebrates; Consultant for Se litigation in Bay-Delta, numerous mgt. issues in Long Island Sound.
Selected Publications: (From a list fo >100)
1. Wang, W.-X., J.R. Reinfelder, B.-G. Lee, & N.S. Fisher. 1996. Assimilation & regeneration of trace elements by marine copepods. Limn. Oceanogr. 41: 70-81.
2. Fisher, N.S., J.-L. Teyssie, S.W. Fowler, and W.-X. Wang. 1996. The accumulation and retention of metals in mussels from food and water: a comparison under field and laboratory conditions. Environ. Sci. Technol. 30: 3232-3242.
3. Fisher, N.S., V.T. Breslin, and M. Levandowsky. 1995. Accumulation of silver and lead in estuarine microzooplankton. Mar. Ecol. Prog. Ser. 116: 207-215.
4. Fisher, N.S. and J.R. Reinfelder. 1995. The trophic transfer of metals in marine systems. In: Metal Speciation and Bioavailability in Aquatic Systems (A. Tessier and D.R. Turner, Eds.), John Wiley & Sons, 363-406.
5. Reinfelder, J.R. and N.S. Fisher. 1994. The retention of elements absorbed by juvenile fish (*Menidia menidia, M. beryllina*) from zooplankton prey. Limnol. Oceanogr. 39: 1783-1789.
6. Fisher, N.S. and M. Wente. 1991. Release of trace elements by dying marine phytoplankton. Deep Sea Res. 40: 671-694.
7. Reinfelder, J.R. and N.S. Fisher. 1991. The assimilation of elements ingested by marine copepods. Science 251: 794-796.

Specific responsibilities of partners are detailed in Fig.'s 4 and 5 and in the budget description. The four PI's will collaborate as partners, but Dr. Luoma will be responsible for overall coordination and will be the primary CALFED contact for administrative matters, other than billing and budgets which will be handled by each institution individually.

Appendix

- List of References Cited in this proposal.
- Financial letters from SUNY-Stony Brook and Old Dominion Univ.

I-002349

REFERENCES CITED IN THE PROPOSAL

1.Cutter, G.A. 1989b. The estuarine behavior of selenium in San Francisco Bay. Estuarine Coastal Shelf Sci. 28: 13-34.

2. Cutter, G.A. 1978. Species determination of selenium in natural waters. Anal. Chim. Acta 98: 59-66.

3.Cutter, G.A. 1982. Selenium in reducing waters. Science 217: 829-831.

4.Cutter, G.A. 1985. Determination of selenium speciation in biogenic particulate material and sediments. Anal. Chem. 57: 2951-2955.

5. Velinsky, D.J. and Cutter, G.A. 1990. Determination of elemental and pyrite-selenium in sediments. Anal. Chim. Acta, 235, 419-425

6.Bender, M., Martin, W., Hess, J., Sayles, F., Ball, L., and Lambert, C. 1987. A whole core squeezer for interfacial pore- water sampling. Limnol. Oceanogr. 32: 1214-1225.

7. Cloern, J.E., 1996. Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Francisco Bay, California: Reviews of Geophysics 34:127-168.

8.Luoma, S. N., van Geen, A., Lee, B-G, and Cloern, J. Metal Uptake by Phytoplankton During A Bloom in South San Francisco Bay: Implications for Metal Cycling in Estuaries. Limnology & Oceanography, submitted.

9. Wrench, J.J. and Measures, C.I. 1982. Temporal variations in dissolved selenium in a coastal ecosystem. Nature 299: 431- 433.

10. Luoma, S. N. and Linville, R. 1997. A comparison of selenium and mercury concentrations In transplanted and resident bivalves from north San Francisco Bay. p. 160 - 171. Annual Report of Regional Monitoring Program, 1995. SF Estuary Inst.

11. Brown, C. L. and S. N. Luoma. 1995. Use of the euryhaline bivalve Potamocorbula amurensis as a biosentinel species to assess trace metal contamination in San Francisco Bay. Mar. Ecol. Prog. Ser. 124: 129-142.

12. Luoma, S.N., Dagovitz, R. and Axtmann, E. 1990. Temporally intensive study of trace metals in sediments and bivalves from a large river-estuarine system: Suisun Bay/Delta in San Francisco Bay. Sci. Total Environ., 97/98: 685-712.

13 Luoma, S.N., Cain, D.J. and Johansson, C. 1985. Temporal fluctuations of silver, copper, and zinc in the bivalve *Macoma balthica* at five stations in South San Francisco Bay. Hydrobiologia,129: 109-120.

14. Luoma, S.N., Johns, C., Fisher, N.S., Steinberg, N.A., Oremland, R.S., Reinfelder, J.R. 1992. Determination of selenium bioavailability to a benthic bivalve from particulate and dissolved pathways. Environ. Sci. Technol. 26: 485-491.

15. Fisher, N.S., Teyssie, J.-L. 1986. Influence of food composition on the biokinetics and tissue distribution of zinc and americium in mussels. Mar. Ecol. Prog. Ser. 28: 197-207.

16. Wang, W.-X., Fisher, N.S., Luoma, S.N. 1995. Assimilation of trace elements ingested by the mussel, Mytilus edulis: effects of algal food abundance. Mar. Ecol. Prog. Ser. 129: 165-176.

17. Reinfelder, J.R., Fisher, N.S. 1994b. The retention of elements absorbed by juvenile fish (Menidia menidia, M. beryllina) from zooplankton prey. Limnol. Oceanogr. 39: 1783- 1789.

18. N. S. Fisher, The trophic transfer of long-lived radionuclides in Arctic marine food chains., in prep.

19. Water Resources Control Board. 1991. Selenium Verification Study: 1988 - 1990. Report 91-2-WQ, Sacramento CA, 170 pp.
20. Skorupa, J. P. 1996. Selenium poisoning of fish and wildlife in nature: Lessons from twelve real-world examples. In preparation.
21. Kaul, L.W. and Froelich, P.N. 1984. Modeling estuarine nutrient geochemistry in a simple system. Geochim. Cosmochim. Acta 48: 1417-1433.
22. Cutter, G.A. and San Diego-McGlone, M.L.C. 1990. Temporal variability of selenium fluxes in the San Francisco Bay. Sci. Total Environ. 97: 235-250.
23 Berner, R.A. 1980. Early Diagenesis. Princeton University Press, Princeton, NJ., pp. 31-42.
24 Beyer, W. N., Heinz, G. H. and Redmon-Norwood, A., 1996. Environmental Contaminants in Wildlife. SETAC Special Publ., CRC Press, Boca Raton. 492 pp.
25 Andreae, M.O. and Andreae, T.W. 1989. Dissolved arsenic species in the Schelde estuary and watershed, Belgium. Est. Coastal Shelf Sci. 29: 421-433.
26 Bowie, G. L., Sanders, J. G., Riedel, G. F., Gilmour, C. C., Breitburg, D. L., Cutter, G. A. And Porcella, D. B. 1996. Asessing selenium cycling and accumulation in aquatic ecosystems. Water, Air and Soil Pollution 90: 93 - 104.
27. Lemly, A. D. 1993. Teratogenic effects of selenium in natural populations of freshwater fish. Ecotoxicol. Environ. Safety 26: 181 - 204.
28. Johns, C.E., Luoma, S.N. and Elrod, V., 1988, Selenium accumulation in benthic bivalves and fine sediments of San Francisco Bay, the Sacramento-San Joaquin Delta, and selected tributaries: Estuarine, Coastal and Shelf Science, v. 27, p. 381-396.

I-002351

The Research Foundation
of State University of New York

State University of New York at Stony Brook

June 24, 1997

CALFED Bay-Delta Program
1416 Ninth Street, ~~Suite~~ 1155
Sacramento, CA 95814

Dear Colleagues:

The enclosed proposal is being submitted for your consideration by The Research Foundation of State University of New York for and in conjunction with the State University of New York at Stony Brook.

In the event action on the request is favorable, The Research Foundation of SUNY will serve as fiscal administrator of the award and depository for all funds in support of such award. Award notices or contracts resulting from this submission should be sent to the attention of Ivar Strand at:

The Research Foundation of
State University of New York
Office of Research Services
Stony Brook, New York 11794-3366

Any questions or negotiations regarding this submission should be directed to Mr. Strand at (516) 632-9039.

Sincerely,

Barbara L. Harris
Contracts and Grants Administrator

xc: file

Sponsored Programs Division
Office of Research Services, Stony Brook, New York 11794-3366
Telephone (516) 632-9039 Fax (516) 632-6963

Old Dominion University Research Foundation

July 14, 1997

CALFED Bay-Delta Program Office
1416 Ninth Street, Suite 115
Sacramento, CA 95814

Dear Sir or Madam:

Enclosed is information relevant to Old Dominion University's participation in a project entitled "Assessing Impacts of Selenium on Restoration of the San Francisco Bay-Delta Ecosystem," which is submitted on behalf of the proposed principal investigator, Dr. Gregory A. Cutter, Department of Oceanography.

Please note that if an award is made as the result of this proposal, it should be made payable to the Old Dominion University Research Foundation. The Research Foundation is the fiscal and administrative agent for Old Dominion University for sponsored program agreements. The Research Foundation is a not-for-profit corporation, tax exempt under section 501(c)(3) of the Internal Revenue Code.

We are pleased to forward this proposal for your review and consideration. Please address any questions of a technical nature to Dr. Cutter at (757) 683-4929 (email: GAC100F@ludwick. ocean.odu.edu and contact me at (757) 683-5685 (email: maxine@ pobox.hprf.odu.edu), referencing our proposal number cited below, for inquiries on administrative and fiscal matters and for purposes of negotiation.

Sincerely,

Maxine Lippman
Contracting Officer

Encl: ODURF Prop No. 98008

cc: Dr. Cutter
Dr. Dunstan
Dean Rule
AVP Ash
DB Files
MAL Files

/mal

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