F1-200

# I. Executive Summary

## Effects of Contaminants in the Sacramento-San Joaquin Delta on Survival and Reproductive Success of Chinook Salmon (*Oncorhynchus tschawytscha*)

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**Project Description:** Native populations of chinook salmon (*Oncorhynchus tschawytscha*) in California have declined drastically over the past 50 years. Of the four runs of chinook salmon found in the Sacramento-San Joaquin system, the winter-run has been reduced from an estimated 200,000 fish in the early 1940's to generally less than 200 fish per year, resulting in an endangered listing. The fall-run, currently the most abundant, has been reduced from a pre-1967 average of 179,000 to an average of 77,000. The spring-run has been reduced to an annual escapement of less than 900 fish and has been the subject of a petition for listing as endangered . The late-fall run has been reduced by over half. Although poor water quality, water diversions, and habitat loss and degradation, all resulting from human activity, have contributed to declines in finfish stocks, there is increasing concern that contaminants from commercial, domestic, and agricultural sources may also be involved.

The maintenance of a population of fishes is ultimately determined by the ability of its members to reproduce. For a species that has already declined drastically, survival and reproductive success have a profound ecological significance. When exposed to various stressors, as from contaminant exposure, the fish may not even survive to carry out the ultimate function of reproduction. Furthermore, chronic dysfunction of reproduction in the surviving fish might ultimately result in decreased fecundity and fertility, indirectly impacting the population level. Therefore, the objectives of this proposal are to: 1) assess the potential effects of contaminant exposure on the survival and behavioral performance of juvenile salmon out-migrating through the Sacramento-San Joaquin Delta; 2) assess the reproductive success of adult salmon returning to the Sacramento River to spawn in relation to contaminant exposure; 3) correlate contaminant exposure with a suite of biomarker expressions and determine No Observed Adverse Effect Levels for cadmium, mercury, and selenium and mixtures of those elements. A comprehensive study to quantify the impacts of contaminants in reproduction success of adult chinook salmon migrating upstream and in early life stages of chinook salmon out-migrating through the Sacramento-San Joaquin estuary into the delta, will be investigated.

**Approach/Tasks/Schedule:** The proposed research will attempt to establish causative links between contaminant exposure and poor juvenile recruitment into chinook salmon populations, and to adult fertility and fecundity. Specific tasks are: 1) to correlate biomarker expression and behavioral performance with contaminant levels (in sediment, water, and tissues) in field-caught salmon during downstream migration; 2) under laboratory condition, to assess xenobiotic trophic transfer from food sources, such as amphipods (*Corophium spp.*) and opossum shrimp (*Neomysis spp.*), and from test diet with known environmentally relevant concentrations of contaminants, to juvenile chinook salmon; and 3) to determine reproductive success and biomarker expression in adult chinook salmon exposed to environmental contaminants while migrating upstream. Tasks 1 and 3 will be carried out over three years. Task 2 will be completed the first two years. Progress reports will be submitted to CALFED each year, and a final report at the end of year 3 will statistically correlate biomarker expression, contaminant levels, reproduction success, and deleterious effects at the individual, population, and community level.

**Justification for Project and Funding by CALFED:** Environmental contaminants may severely impact a salmon life support system already degraded from upstream

diversions of water and physical habitat alterations within the estuary and the upstream spawning grounds. Although the sensitivity of salmonid species to poor water quality, particularly in early life stages, has long been recognized, integrated studies assessing the exposure of juvenile salmon to multiple contaminants in water and food during incubation, rearing, and out-migration in the Sacramento-San Joaquin system have not been conducted, and potential contaminant effects on adult reproductive success have not been evaluated. The lack of contaminant information has been noted as a planning deficiency in the U.S. Fish and Wildlife Service s *Recovery Plan for Sacramento-San Joaquin Delta Native Fishes.*

Concentrations of metals, pesticides, PCBs, and other contaminants known to cause adverse effects in fishes have been documented in water, sediments, and invertebrate prey throughout the Sacramento-San Joaquin system . All of these contaminants have the potential to adversely affect salmon in the San Francisco Estuary and in the upstream tributaries as well. The continued decline of salmon and other anadromous fish species in the Sacramento-San Joaquin system in spite of the best efforts of a number of state and Federal resource agencies represents a potentially severe ecological and economic loss to the State of California. A thorough understanding of the role of environmental contaminants and their involvement in salmon declines is essential if restoration efforts are to succeed.

Budget Costs and Third Party Impacts: To ensure the completion of this combined field, laboratory, and modeling study, we are requesting a total funding of $1,549,507 for three years. There are no third party impacts.

Applicant Qualifications: Mr. James Haas has five years experience with the U.S. Fish and Wildlife Service Environmental Contaminants Program, during which he has designed and/or carried out four field studies assessing the effects of contaminants on salmonid species. Dr. Swee J. The has ten years of research experience on environmental toxicology and fish pathology. He is currently managing the internationally known Aquatic Toxicology Laboratory at UCD. Mr. Brian Finlayson is Chief of the California Department of Fish and Game Pesticide Investigations Unit, where he manages a field and laboratory program for CDFG that establishes policy and procedures for assessing the impacts of pesticides on fish, plant, and wildlife resources. Our experience in field evaluation, aquatic toxicology, biochemistry, fish nutrition, fish pathology, and husbandry will facilitate completion of this study.

Monitoring and Data Evaluation: Manuscripts from the proposed research will be submitted to a high quality scientific journals for peer review and publication. Results will be disseminated widely through participation in workshops and seminars, and presentation of papers at an international/national meeting.

Local Support/Coordination with other Programs/Compatibility with CALFED Objectives: The study will complement proposed studies by the United States Fish and Wildlife Services (USFWS) and other agencies attempting to address contaminant issues in the Sacramento-San Joaquin system and increase stocks of chinook salmon. These agencies and public institutions include: the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the California Division of Mines and Geology, the State Water Resources Board and several Regional Water Quality Control Boards, the Contra Costa County Public Works Department, Lawrence Berkeley Laboratory, and the University of California at Davis. This project specifically supports the CALFED objectives of providing good water quality for all beneficial uses and improving and increasing aquatic and terrestrial habitats and improving ecological functions in the Bay-Delta to support sustainable populations of diverse populations of diverse and valuable plant and animal species. The project will address uncertainties regarding the biological effects of mercury, selenium, and cadmium contamination on survival and reproduction of the high-priority chinook salmon. Successful completion of the project will aid significantly in setting or evaluating water and sediment contaminant criteria, and facilitate management decisions regarding source control and restoration.

## II. Title Page

# Effects of Contaminants in the Sacramento-San Joaquin Delta on Survival and Reproductive Success of Chinook Salmon (*Oncorhynchus tschawytscha)*


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**Type of Organization:** One Federal and Two State Agencies

**Participants/Collaborators in Implementation:**

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**RFP Project Group Type:** Other Services

## III. PROJECT DESCRIPTION

a. **Project Description and Approach:** Water quality in the Sacramento-San Joaquin system has been impacted by contaminants from multiple sources that include agricultural runoff, mining wastes, paper and pulp mills, oil spills and oil refinery discharges, hazardous material spills, numerous permitted point sources such as petroleum refineries, and storm water runoff. As many as 65 pollutants, primarily pesticides, metals, PCBs, and PAHs, from this system have been identified as entering the San Francisco Bay estuary at a rate of 5 to 40,000 tons per year (SFEP 1991). Concentrations of metals, pesticides, PCBs, and other contaminants known to cause adverse effects in fishes have been documented in water, sediments, and invertebrate prey throughout the Sacramento-San Joaquin system (SFEI 1991). Contaminants known to be elevated above EPA criteria protective of aquatic life include chromium, copper, nickel, lead, selenium, mercury, PCBs, PAHs, DDTs, chlordanes, dieldrin and diazinon. All of these have the potential to adversely affect salmon in the San Francisco Estuary and in the upstream tributaries as well (SFEI 1995). The continued decline of salmon and other anadromous fish species in the Sacramento-San Joaquin system in spite of the best efforts of a number of state and Federal resource agencies represents a potentially severe ecological and economic loss to the State of California. A thorough understanding of the role of environmental contaminants and their involvement in salmon declines is essential if restoration efforts are to succeed (USFWS 1995a&b).

Biomarkers in fish are meaningful tools for environmental health assessment, particularly for determining the extent of exposure to toxic chemicals (Adams et al 1989; Hinton et al 1992). The biomarker approach is particularly useful where understanding the bioavailability of toxic compounds is of utmost importance. Direct or indirect transfer of toxic chemicals from water, sediments, and contaminated food to organisms are considered to be major routes of exposure for many species, and these trophic and nontrophic transfers have been associated with deleterious effects in many fish species (Adams et al 1989; The et al 1997). Previous investigations with larval striped bass (*Morone saxatilis*) indicated many larvae had been exposed to toxic compounds, potentially leading to slower growth and mortality. These results might suggest that contaminants also contribute to mortality of salmon, and potentially regulate juvenile recruitment. Effective management to facilitate the survival of this threatened species will require understanding the relative and interactive importance of exposure to contaminants along with the various other factors that may regulate salmon abundance.

We propose a tiered 3-year investigation during which multiple specific approaches (contaminant exposures, patterns of biomarker expression, reproduction success, and fish performance) will be assessed, evaluated, and validated for individual juvenile and adult salmon. The study will utilize a combination of field surveys, laboratory exposures, and chemical and biomarker/performance evaluation in three tasks as follows:

*Task 1.* *Assessment of out-migrating juvenile salmon for contaminant burdens, biomarker expression, and behavioral performance in relation to contaminant concentrations in sediment, water, and prey (3 yrs).*

Out-migrating juvenile chinook salmon will be sampled once a year for three years from five sites: 1) Sacramento River above the Colusa drain; 2) Sacramento River below the Colusa drain; 3) Sacramento River between the confluences of the American River and the San Joaquin River; 4) the upper delta just below the confluence of the San Joaquin River; and 5) the lower delta in the vicinity of Suisun Bay. Prey organisms and sediments from the same sites will also be collected. Contaminants will be assessed in sediment, water, and tissues at each site. A subset of the fish collected at each site will be taken to the laboratory and tested against control fish for swimming performance, prey capture, and predator avoidance. Fish condition measures,

contaminant burdens, biomarker results, and performance measures will be compared to chemical concentrations in sediments and prey. Patterns of response will be compared to those obtained from laboratory exposures.

*Task 2.* *Evaluation of biomarkers and performance following laboratory exposures to field-collected test diets (2 yrs) and laboratory prepared test diets (yr 1-3) to assess trophic transfer and calculate No Observed Adverse Effect Levels.*

To validate trophic transfer, prey invertebrates (amphipods, opossum shrimp, and aquatic insects) will be collected 3 times a year at each field site. Invertebrates will be composited, dried, and pelletized by site (Woodward *et al.* 1994). Diet will be analyzed for contaminant level. Laboratory-reared, unexposed juvenile chinook salmon will then be fed either a control diet or a diet consisting of pelletized invertebrates from each field sites for a period of 90 days. The same biomarkers used previously will also be assayed for in field samples. Contaminant bioaccumulation and biomarker expression will be assessed, and results compared with data from field-caught salmon and those fed test diets containing contaminants.

Laboratory-reared juvenile salmon will also be exposed for 90 days to prepared diets. Test diets will be prepared with methyl mercury chloride, seleno-DL-methionine, and cadmium chloride singly and in combination. Interactive roles will be investigated by using mixtures of cadmium, mercury, and selenium, and running exposures at two salinities (1 and 15 ppt). Fish will be analyzed for contaminant body burdens. Biomarkers assessed will include indices of health, genetic injury (single-cell gel assays), metallothionein, P450 enzymes, stress proteins, acetylcholinesterase (AChE) inhibition, histopathology, swimming performance, prey capture, and predator avoidance. (Biomarkers appropriate for organochlorine and organophosphate exposure are included for comparison to field-collected fish and laboratory fish exposed to field-collected diets). The results of these dietary exposures will be used to calculate No Observed Adverse Effect levels.

*Task 3.* *Evaluate reproductive success of adult salmon migrating upstream in relation to contaminant concentrations in gametes and fertilized eggs (3 yrs).*

Adult fall-run chinook salmon will be sampled once a year for three years from two sites: 1) the Central Bay to determine baseline exposure; and 2) Coleman National Fish Hatchery to evaluate exposure after transiting through the Sacramento-San Joaquin Delta. Collected fish will be held at the Hatchery until ready for spawning . Samples of sperm from 10 males and eggs from 20 females from will be collected for each site. The sperm will be pooled and a subsample analyzed for contaminant levels. Eggs of individual females will be fertilized with the pooled sperm and a subsample of the fertilized eggs will be analyzed for contaminant levels. Correlation of reproductive success (percent fertilization and survival to hatch) and contaminant levels will be assessed and evaluated. After collection of gametes, adult fish will be analyzed for contaminant body burden and biomarker expression. A subset of the hatchlings from each site will be tested for swimming performance, prey capture, and predator avoidance.

**b. Location of Project:** The project will take place in San Francisco, Marin, Contra Costa, Solano, Yolo, Sacramento, Colusa, and Tehama Counties, Sacramento River watershed, Sacramento-San Joaquin estuary.

**c. Expected Benefit(s):**

Laboratory exposures will refine assay protocols, assess biomarker sensitivity and specificity, and define target organs and biological effect in salmon. Field surveys will allow biomarkers to be correlated with contaminant

type and load (in sediment, water, and tissues), and will enable us to develop biomarker profiles in response to complex contaminant mixtures. We anticipate biomarker expression in individual salmon will correlate with changes at the population level, and that trophic transfer experiments will validate a dietary route for xenobiotic exposure to salmon. Working in concert with USFWS, this study will help establish causative links between contaminant exposure and biological effects in the San Francisco Estuary, and will pioneer an approach that can generally be applied to other aquatic ecosystems. The study will evaluate the utility of biomarkers (used singly and in combination) in assessing xenobiotic impact on embryo, larval, juvenile, and adult salmon, and will generate data which can form the basis for a model system defining fate and impact of contaminants on salmon as they pass from marine to freshwater system (adult) and freshwater back into estuarine and marine environments (juvenile). Results of this study also have practical application, as laboratory data linking specific contaminants with adverse effects (as well as field data correlating biomarker expression with contaminant load) could help guide management decisions with respect to determining acceptable contaminant levels in the environment. Finally, many of the proposed biomarkers could potentially be used to monitor xenobiotic exposure and effect in animals from a variety of contaminated aquatic habitats, and help evaluate progress of remediation efforts.

**d. Background and Biological Justification:** Native populations of salmon in California have declined drastically over the past 50 years. Of the four runs of chinook salmon found in the Sacramento-San Joaquin system, the winter-run has been reduced from an estimated 200,000 fish in the early 1940's to generally less than 200 fish per year, resulting in an endangered listing. The fall-run, currently the most abundant, has been reduced from a pre-1967 average of 179,000 to an average of 77,000 . The spring-run has been reduced to an annual escapement of less than 900 fish and has been the subject of a petition for listing as endangered . The late-fall run has been reduced by over half (USFWS 1995b). Other anadromous species such as steelhead trout (*O. mykiss*), white and green sturgeon (*Acipenser transmontanus* and *A. medirostris*), delta smelt (*Hypomesus transpacificus*), and Sacramento splittail (*Pogonichthys macrolepidotus*) have experienced similar declines (USFWS 1995a). Although poor water quality, water diversions, and habitat loss and degradation, all resulting from human activity, have contributed to declines in anadromous fish stocks (USFWS 1995a&b), there is increasing concern that contaminants from commercial, domestic, and agricultural sources may also be involved, particularly in the critical early life-stages of the declining species.

Bailey *et al.* (1994) correlated a decline in juvenile striped bass (*Morone saxatilis*) recruitment to the amounts of pesticides applied annually to agricultural fields. Juvenile chinook salmon are exposed during approximately the same time period as striped bass and utilize the same prey base, and the sensitivity of salmonid species to poor water quality, particularly in early life stages, has long been recognized. However, integrated studies assessing the exposure of juvenile salmon to multiple contaminants in water and food during incubation, rearing, and out-migration in the Sacramento-San Joaquin system have not, with a few exceptions (Saiki *et al.* 1995; Varanasi *et al.*1993), been conducted. The lack of information regarding the effects of contaminants on juvenile recruitment of fish has been noted as a planning deficiency in the Service s *Recovery Plan for Sacramento-San Joaquin Delta Native Fishes* (USFWS 1995a). Furthermore, little is known on the effect of contaminants on reproductive success of salmon. Considerable evidence has shown that contaminants can be transmitted from parent fish through the yolk lipids, and these then cause direct mortality of the fry or increased sensitivity of the fry to stress. Therefore, a thorough understanding of the role of environmental contaminants and their involvement in declines of salmon and other anadromous species is therefore essential if restoration efforts are to succeed (USFWS 1995a&b).

**e. Proposed Scope of Work:** We propose a 3-year investigation during which several lines of evidence will be pursued and integrated for individual and population of juvenile and adult salmon. Five lines of evidence will be examined to establish patterns of biological response in the fish to different concentrations of contaminants in water, sediment, and prey from each location. Lines of evidence will consist of : 1) Concentrations of contaminants in juvenile and adult fish; 2) reproductive success and biomarker expression in adult chinook salmon; 3) responses of a suite of biomarkers; 4) genetic injury measured by single-cell gel assays of salmon blood, liver tissue, and fertilized eggs; and 5) behavioral indicators, including swimming performance, prey capture, and predator avoidance. Each line of evidence has been successfully employed in other contaminant studies. Body burdens are indicative of exposure to a wide range of contaminants (McFarland and Clarke 1989; Woodward *et al.* 1994; Varanasi *et al.* 1993). Reproductive success are indicative of transfer of contaminants into eggs from adult exposing to the contaminants. Biomarkers in juvenile and adult fish are particularly useful for determining the extent of exposure to toxic chemicals (Adams *et al.* 1989; Hinton *et al.* 1992). The single-cell gel assay (generally referred to as the comet assay because of the comet-like appearance of the cells following electrophoresis) represents a sensitive measurement of genotoxicity (Singh *et al.* 1988; McFarland *et al.* 1995) that can be developed as a non-lethal test for contaminants exposure of field-collected fish and provide data regarding the need for additional study of genetic/reproductive injury in adult salmon. Impaired swimming performance (Little and Finger 1990, Mesa 1994), prey capture (Woodward *et al.* 1987), and predator avoidance (Woodward *et al.* 1987, Mesa 1994) are ecologically relevant behavioral indicators of sublethal toxicity.

Selection of Contaminants: Eight contaminant diets will be used for laboratory exposures during this study: a control, three metals (mercury, selenium and cadmium), and mixtures of mercury plus selenium, mercury plus cadmium, selenium plus cadmium, and mercury plus selenium plus cadmium. These same contaminants will also be the focus of field studies. Contaminant selections were based on the compounds being present in the Estuary at significant levels; 2) the compounds being bioaccumulative ; and 3) the compounds being the subject of other proposals being submitted to CALFED for funding. Selenium (Se) , Mercury (Hg), and cadmium (Cd) are listed as pollutants of concern in the San Francisco Estuary by SFEI (SFEP, 1991). Because PCBs are also listed as pollutants of concern in the Estuary by SFEI (SFEP, 1991) and organophosphate pesticides such as diazinon occur in a well-defined contaminant "pulse" which comes into the Estuary from the Sacramento and San Joaquin Rivers during the dormant spray season, a subset of all field collected samples will also be analyzed for organochlorine and organophosphate contaminants to assess comparability whether additional work with those classes of compounds is needed.

Selection of Biomarkers: An investigative approach utilizing a suite of biomarkers was selected for this study because of problems involved with resolving confounding factors (natural and anthropogenic) common to all complex ecosystems. Biomarker measurements reflect bioavailability of contaminants, provide a mechanistic approach to understanding contaminant toxicity, and can be early indicators of stress at the population and community level. In addition, biomarkers can be highly sensitive indicators of individual health, and help identify target organs and biological effect. The biomarker selections for this study were based on: 1) finding biomarkers capable of selectively recognizing different types of contaminants (eg. metallothionein induction and metal exposure; P450 induction and PCB exposure; P450 reduction and cadmium exposure) and 2) utilizing biomarkers specific for both exposure and deleterious effect (eg. AChE inhibition and histopathology; calcium deficiency and abnormal spinal column). Biomarkers appropriate for assessing organochlorine and organophosphate exposure are included to evaluate differences between field-collected and laboratory exposed fish.

Scientific Objective(s). The principal goal of the proposed research is to evaluate the effects of metal contaminants on juvenile and adult chinook

salmon to assess whether poor recruitment and productivity related to contaminant exposure are responsible, at least in part, for recent declines in salmon in the Sacramento-San Joaquin system. Specific objectives to meet the principal goal are: 1) To determine concentrations of organic and inorganic contaminants in water, sediment, and juvenile chinook salmon prey from five sites in the Sacramento-San Joaquin system; 2) To determine concentrations of contaminants in juvenile salmon collected concurrently from the same sites; 3) To evaluate biomarker expression and results in relation to contaminant levels in sediment, water, prey, and tissues in field-collected juvenile and adult salmon during downstream and upstream migration; biomarkers assessed will include indices of health, metallothionein, P450 enzymes, stress proteins, acetylcholinesterase (AChE) inhibition, and histopathology; 4) To evaluate genetic injury in field-collected juvenile salmon in relation to contaminant levels in sediment, water, prey, and tissues; 5) To evaluate behavioral indicators in field-collected juvenile salmon in relation to contaminant levels in sediment, water, prey, and tissues; 6) To determine whether patterns of response in body burdens, biomarkers, genetic injury, and behavioral indicators occur in juvenile salmon that can be correlated with specific mixtures and concentrations of contaminants in water, sediments, and prey; 7) To evaluate the potential effects of contaminants on reproductive success of adult fall-run chinook salmon.

f. **Monitoring and Data Evaluation:** A three year investigation will be performed, during which multiple specific approaches (contaminant exposures, reproductive success, patterns of biomarker expression, genetic injury, and fish performance) will be assessed, evaluated, and validated for individual and grouped juvenile and adult chinook salmon. The study will utilize field collections, chemical analyses, and laboratory performance and biomarker evaluation to determine whether patterns of biological responses in juvenile and adult salmon can be identified and correlated to contaminant concentrations in water, sediment, and prey in the Sacramento-San Joaquin system.

The results of this study will be used to evaluate and monitor contaminant effects on the biota of the Sacramento-San Joaquin River system and estuary by focusing on the upper trophic level chinook salmon and invertebrate prey species. Specific management actions that will be facilitated by the results of this study include the following: 1) Focus restoration efforts for the Sacramento-San Joaquin ecosystem at the appropriate individual, population, or community level based on assessment of contaminant effects on recruitment of juvenile chinook salmon. 2) Support ongoing efforts by the United States Fish and Wildlife Service and other resource agencies in recovering threatened and endangered anadromous fish populations in the Sacramento-San Joaquin system. 3) Evaluate the utility of biomarkers (used singly and in combination) in assessing xenobiotic impacts on larval and juvenile salmon, and generate data which can be used to assess the need for more comprehensive studies on genetic injury and reproductive success in adult salmon returning to the Sacramento-San Joaquin system to spawn. 4) Evaluate data linking specific contaminants with adverse effects to help guide management decisions with respect to determining acceptable contaminant levels in the environment, particularly in evaluating water quality objectives and clean-up levels at CERCLA and RCRA sites. 5) Monitor xenobiotic exposure and effects in animals from a variety of contaminated aquatic habitats, and help evaluate progress of remediation and restoration efforts. 6) Evaluate the single-cell gel assay as a non-lethal screen for contaminant exposure in field-collected fish.

g. **Implementability.** The project is fully implementable within the guidelines of the cooperating agencies.

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## IV. Costs and Schedule to Implement Project

**a. Budget Costs**

Three years of support are requested. Budget costs are broken down by Task (Table 1).

Table 1. Project Cost Summary by Task.

| Project Phase and Task | Direct Labor Hours | Direct Salary and Benefits | Overhead Labor (General, Admin and fee) | Service Contracts | Mat 1 and Acquisition Contracts | Miscellaneous and other Direct Costs | Total Cost |
|---|---|---|---|---|---|---|---|
| Task 1 CALFED; no O&M | 1,857 | $ 95,340 | $18,606 | $282,756 | 0 | $3,720 | $400,422 |
| Task 2 CALFED; no O&M | 13,422 | $345,180 | $39,054 | $134,400 | 0 | 0 | $518,634 |
| Task 3 CALFED; no O&M | 2,505 | $ 79,040 | $22,556 | $525,135 | 0 | $3,720 | $630,415 |
| Grand Total | | | | | | | 1,549,507 |

Partial funding for Year 1 this project is also being sought from the U.S. Fish and Wildlife Service Off-Refuge Contaminants Study Program; however, selection of projects for funding by that program has not yet occurred. Because this is a joint venture project using agency in-house resources, no subcontractors will be used. The U.S. Fish and Wildlife Service will be responsible for receiving funds and further distributing them to the University of California, Davis, and the California Department of Fish and Game in accordance with all applicable Federal laws and regulations. The proposed schedule of payment by year is presented in Section b. Schedule Milestones.

**b. Schedule Milestones**

The phasing/scheduling of specific tasks is shown in Table 2.

Table 2. Project Schedule

| Task | year 1 | year 2 | year 3 |
|---|---|---|---|
| **Task 1.** Field sampling and assessment of juvenile salmon | [--------- | ---------- | -------] |
| **Task 2.** A. Trophic transfer | [--------- | ---------] | |
| B. Laboratory exposure | [--------- | ---------- | -------] |
| **Task 3.** Reproductive success of adult salmon | [--------- | ---------- | ------] |
| Final Report | | [--- | ----------] |

Table 3 outlines the proposed schedule of payments to support project implementation and execution:

Table 3. Proposed Schedule of Payment by Year.

| FY 98 | FY 99 | FY 00 | TOTAL |
|---|---|---|---|
| $516,502 | $516,502 | $516,503 | $1,549,507 |

c. Third Party Impacts

There are no known third party impacts associated with this proposal.

## V. Applicant Qualifications

### A. Principle Investigators

**JAMES HAAS**

Mr. James Haas received his B.S. in Wildlife and Fisheries Resources from the University of Idaho in 1974, and his M.A. in Biology (Ecology and Systematic Biology) from San Francisco State University in 1995. Since 1992 Mr. Haas has worked for the U.S. Fish and Wildlife Service in the Sacramento Field Office, Environmental Contaminants Division, where he has conducted or participated in natural resource damage assessments for chemical releases, oil spill response activities, restoration planning, ecological risk assessments, and general contaminants investigations throughout northern California. He has designed and/or coordinated four field studies dealing with the effects of contaminants on salmonid species, including chinook salmon. Prior to his employment with the USFWS, Mr. Haas served as the Environmental Coordinator at Naval Air Station, Moffett Field, California, responsible for managing all aspects of the station s environmental compliance program, including Superfund cleanup, hazardous waste management, Clean Air and Clean Water Act compliance, and natural and cultural resources management. There he supervised an interdisciplinary staff of 13 personnel, with an annual budget of over 1 million dollars. In recognition of his performance on behalf of the station, Mr. Haas was awarded the prestigious Department of the Navy Meritorious Civilian Service Medal. Through his education and work experience, Mr. Haas has developed an active professional and personal interest in the ecology of the San Francisco Bay estuary.

**Swee Teh**

Dr. Swee Teh received his Ph.D. in Comparative Pathology from the University of California, Davis, in 1996. As a UC Davis Staff research Associate, he has for the past ten years managed the internationally known Aquatic Toxicology Laboratory in the School of Veterinary Medicine. His research experience includes histology, fish anatomy and pathology, aquatic toxicology, care and maintenance of fish for chronic experimentation, and stereology. Since 1987, Dr. Teh has published 15 articles in peer reviewed journals on fish pathology, physiology, and responses to contaminant exposure.

**Brian Finlayson**

Mr. Brian Finlayson received his B.S. in Fisheries (with a minor in chemistry) from Humboldt State University in 1974, and his M.S. in Fisheries (Water Quality Emphasis) from Humboldt State University in 1977. He is currently Chief of the California Department of Fish and Game Pesticide Investigations Unit, where he supervises and manages a field and laboratory program that establishes policies and procedures for assessing the impacts of pesticides and other contaminants on fish, plant, and wildlife resources. The activities of the unit include investigation of fish and wildlife incidents involving pesticides; assessment of the hazards of pesticides to fish and wildlife resources; protection of threatened and endangered species; assessment and environmental analysis of pest control and eradication programs; and coordination and approval of CDFG pesticide uses and training of CDFG personnel using pesticides. Mr. Finlayson has published numerous articles in a variety of peer reviewed journals. He is also a Certified Fisheries Scientist with the American Fisheries Society, and chairs the Fish management Chemicals Subcommittee of the Task Force on Fishery Chemicals.

**B. Collaborators**

**David Hinton**

Dr. David Hinton received his Ph.D. in Anatomy from the University of Mississippi in 1969. He is currently Professor of Fish Pathology in the School of Veterinary Medicine at the University of California, Davis, where he has established an international reputation in aquatic toxicology. During his long academic career, Dr. Hinton has published over 139 full length papers and 99 abstracts examining various aspects of fish pathology, physiology, anatomy, and toxicological responses.

**Mark Okihiro**

Dr. Mark Okihiro received his D.V.M. from Colorado State University in 1984 and his Ph.D. in Comparative Anatomy in 1996 from the University of California, Davis, where he is currently a post-doctoral researcher. He has extensive experience with histopathological assessment and biochemical assays. During his career he has published over 16 articles in peer-reviewed journals.

**Inge Werner**

Dr. Inge Werner holds a Ph.D. in Environmental Toxicology, and as a post-doctoral researcher at the University of California, Davis, has over four years experience in working with biomarker assessment in aquatic vertebrate and invertebrate organisms.

Specific responsibilities of the principle investigators and collaborators are outlined as follows:

| Name | Project Management | Technical | Administrative |
|---|---|---|---|
| Mr. Jim Haas | X (Field; Performance testing) | X | X |
| Dr. Swee Teh | X (Biomarkers) | X | X |
| Mr. Brian Finlayson | X (Bioassays; chemical analyses) | X | X |
| Dr. David Hinton | | X (Overall Advisor) | |
| Dr. Mark Okihiro | | X (Histopath.) | |
| Dr. Inge Werner | | X (Biomarkers) | |

There are no potential conflicts of interest.

**VI. Compliance with Standard Terms and Conditions.**

The financially responsible applicant is a representative of a federal agency, the U.S. Fish and Wildlife Service. The Fish and Wildlife Service agrees to comply with terms and conditions to the extent allowed by federal law. It is the applicant s understanding from table D of the RFP that no supplemental forms are required of federal agencies at the time of proposal submittal.