Impacts of Boating on Aquatic Resources in the Delta

A Proposal Submitted In Response To
1997 Category III
Request for Proposal
Ecosystem Restoration Projects and Programs

By

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RFP Project Group: Other Services

July 28, 1997

PROJECT DESCRIPTION

Project Description and Approach

The purpose of this project is to evaluate the impacts of boating in the Sacramento-San Joaquin Delta on declining aquatic resources and to identify methods to mitigate them. Boating has dramatically increased in the Delta over the past three decades. Studies in other estuaries indicate that boating causes a wide range of adverse impacts. Substantial numbers of fish eggs and larvae are killed from shear, turbulence, and pollution. Unburned fuel, exhaust byproducts, and raw sewage are discharged directly into the water column. Toxic chemicals including copper and tributyltin are leached from bottom paints into waters. Boat wakes and propeller wash elevate turbidity, cause shoreline erosion, and destroy submerged aquatic vegetation and shallow-water habitat. Dredging to maintain commercial shipping channels increases salinity intrusion and turbidity and releases toxic contaminants. These factors may have contributed to the decline in Bay/Delta aquatic resources and could limit the success and viability of proposed in-Delta restoration efforts.[1] None of these factors has ever been evaluated or seriously considered in the Bay/Delta.

The impacts of boating on Delta aquatic resources will be evaluated through a comprehensive literature survey, laboratory studies to evaluate impacts of pollution and turbulence on the mortality, growth, and reproduction of sensitive species, and statistical, engineering, and risk assessment calculations to quantify and assess the relative importance of boating impacts. Methods to mitigate and control any impacts will be identified and evaluated.

Location of Project

The proposed project will focus on the Sacramento-San Joaquin Delta. This area is a heavily used and popular recreational area. Eggs, larvae, and juvenile fish of many species pass through this area during periods of intensive boating activity.

Expected Benefit

This project will assess the impact of two ecosystem stressors, pollution and physical damage from boating, on in-stream aquatic habitat and fish that have experienced the greatest declines, including all races of chinook salmon, steelhead, delta smelt, splittail, and striped bass. If boating is found to significantly impact resources, control measures developed by the project would eliminate or minimize these stressors, increasing the likelihood of success of in-Delta restoration projects.

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[1] CalFed Bay-Delta Program, Ecosystem Restoration Program Plan, Volume I. Visions for Ecosystem Elements, Review Draft, June 13, 1997.

Background and Biological/Technical Justification

Recreational and commercial boating in and through the Delta have dramatically increased over the past three decades and may have contributed to the decline in aquatic resources. Boating causes a wide range of negative impacts to aquatic resources. These include pollution from engine emissions, leaching of bottom paint, discharges of raw sewage, and fuel spills in marinas. Boat wakes and propeller wash elevate turbidity, cause shoreline erosion, and destroy submerged aquatic vegetation and shallow-water habitat.[2] None of these impacts has been investigated as potential factors contributing to the decline of Bay-Delta aquatic resources.

Recreational craft plying Delta waters are primarily propelled by two-cycle engines. Combustion byproducts and unburned fuel are discharged directly into the water on the majority of these engines to eliminate the need for mufflers. Significant amounts of engine lubricating oil are mixed with the gasoline at ratios that range from 16:1 to about 50:1. Recent studies have shown that up to 50 percent of these gasoline and oil mixtures is not combusted and passes through the engine directly into the water column.[3] Department of Motor Vehicle (DMV) data indicate that there are about 100,000 boats and personal water craft operating in the Bay/Delta region. Estimates indicate that every year, these craft discharge about 4 million gallons of gasoline, 300,000 gallons of lubricating oil, and an unquantified amount of combustion byproducts.[4] Assuming the gasoline is uniformly mixed into the top 2 feet of the water column, the average annual concentration would be 9 mg/L and peak concentrations could be substantially higher. The oil would rise to the surface in 3 to 4 days and appear as a visible oil slick. Slicks are widely reported throughout the Delta.

The effects of these two-cycle engine emissions on the aquatic environment have been poorly studied. However, recent Swedish studies using rainbow trout, perch, sea trout, fathead minnows, and northern pike demonstrate that these emissions produce adverse effects including changes in DNA adducts, histopathological changes, and induction of hepatic microsomal oxygenase enzymes. The authors concluded that serious disruption of reproduction among feral

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[2] N.E. Stolpe, A Survey of Potential Impacts of Boating Activity on Estuarine Productivity, Paper Presented at Marine Engines and Vessels Public Workshop, Ann Arbor, MI July 29, 1992 and T.P. Jackivicz, Jr. and L.N. Kuzminski, The Effects of the Interaction of Outboard Motors with the Aquatic Environment -- A Review, Environ. Res., v. 6, 1973, pp. 436-454.

[3] Anonymous, The Use of 2-Cycle Engine Watercraft on Lake Tahoe: Water Quality and Immunological Considerations. Tahoe Research Group. University of California, Davis, 1997; U.S. EPA, Nonroad Engine and Vehicle Emission Study -- Report, Report 21A-2001, November 1991; U.S. EPA, Summary Report: Analysis of Pollution from Marine Engines and Effects on Environment, 1973.

[4] Memorandum from Lance Johnson, Westlands Water District, to Elaine Archibald, Archibald & Wallberg Consultants, Re: Ag/Urban Water Quality Issues, Recreational Boating Emissions.

fish seems likely and that two-cycle exhaust poses "a serious threat to the environment."[5] These discharges are currently unregulated.

Aquatic organisms are also affected by physical impacts, including direct propeller damage and those induced by turbulence, shear, wakes, and propeller wash. A propeller 14 inches in diameter sweeps an area of approximately one square foot. At 30 miles per hour, it would affect 3.6 acre feet of water every hour. If the 100,000 boats registered in the Bay/Delta were to operate for only four hours, a volume of water equivalent to the entire Delta would be completely swept by their propellers.

Shear and rotational forces generated by propellers and the movement of boats through the water can kill 20 to 50 percent of the fish eggs and larvae in their path.[6] A laboratory study found that exposure of striped bass eggs to a shear of 350 dynes/cm^2 killed 36 percent of the eggs in 1 minute, 69 percent in 2 minutes, and 88 percent in 4 minutes. A shear of 350 dynes/cm^2 killed 9.3 percent of the larvae in 1 minute, 30 percent in 2 minutes, and 68 percent in 4 minutes. Similar results were obtained for white perch eggs and larvae.[7] Commercial and recreational craft using Delta waters routinely generate shear forces orders of magnitude higher than 350 dynes/cm^2.

Boats wakes and propeller wash also erode shore lines,[8] destroy submerged aquatic vegetation and shallow-water habitat, and generate substantial turbidity.[9] The disturbance created when a boat or ship moves through the water travels outward and downward, carrying with it a considerable fraction of the total energy released by the engine. If the vessel is moving in shallow water, or if the outward traveling disturbance reaches shallow water or shore lines, it will

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[5] U. Tjarnlund, G. Ericson, E. Lindesjoo, I. Petterson and L. Balk, Investigation of the Biological Effects of 2-Cycle Outboard Engines' Exhaust on Fish, Marine Environ. Res., v. 39, 1995, pp.313-316; U. Tjarnlund, G. Ericson, E. Lindesjoo, I. Petterson, G. Akerman and L. Balk, Further Studies of the Effects of Exhaust from Two-Stroke Outboard Motors on Fish, Marine Environ. Res., v. 42, 1996, pp. 267-271; L. Balk, G. Ericson, E. Lindesjoo, I. Petterson, U. Tjarnlund, and G. Akerman, Effects of Exhaust from Two-Stroke Outboard Engines on Fish, Laboratory for Aquatic Ecotoxicology, Stockholm University, 1994.

[6] Leslie E. Holland, Effects of Barge Traffic on Distribution and Survival of Ichthyoplankton and Small Fishes in the Upper Mississippi River, Trans. Am. Fish. Soc., v. 115, 1986, pp. 162-165.

[7] R.P. Morgan II, R.E. Ulanowicz, V.J. Rasin, Jr., L.A. Noe, and G.B. Gray, Effects of Shear on Eggs and Larvae of Striped Bass, *Morone saxatilis*, and White Perch, *M. americana*, Trans. Am. Fish. Soc., no. 1, 1976, pp. 149-154.

[8] I.J. Collins and E.K. Noda, Causes of Levee Damage in the Sacramento-San Joaquin Delta, Report P-218-1, Tetra Tech, Pasadena, CA, 1971.

[9] H. Gucinski, Sediment Suspension & Resuspension from Small Craft Induced Turbulence, U.S. EPA Report EPA 600/3-82-084, September 1982.

cause particle suspension and erosion of shorelines. The resulting turbidity can smother sessile organisms, prolong hatching times, reduce fish growth rates, lessen feeding efficiency, impair schooling ability, and impair the growth of bottom vegetation due to reduced light penetration. In the Delta, vegetated berms on the inside of channel bends have been destroyed during the last two to three decades by boat wakes.[10] Further, the area of channel islands in some areas of the Delta has been reduced by 53 percent between 1937 and 1993 and 36 percent between 1967 and 1993. Although the cause of this loss is unknown, it is likely due in part if not wholly to boat wakes and dredging to accommodate commercial shipping.

Proposed Scope of Work

Task 1. Literature Survey on Effects of Boating. The current status of knowledge on the impacts of boating on aquatic resources will be determined. The review will include pollution, dredging, and impacts from direct propeller damage, boat wakes, propeller wash, and shear, including fish mortality, increased turbidity, erosion, and disruption of nearshore and island habitats. A literature survey will be conducted using commercially available databases, such as DIALOG. Current information will be obtained from agencies involved in the regulation of boating, including the Department of Boating and Waterways, the U.S. EPA, trade organizations such as National Marine Manufacturers Association, and engine manufacturers. Researchers currently working in this area will also be contacted and interviewed.

Task 2. Document Use Patterns and Trends in Boating. Temporal trends and use patterns of boating in the Delta will be established using registration data and surveys and used in Task 5 to assess aquatic impacts. Temporal trends in Delta boat use will be determined by decade or more frequently if feasible using DMV boat registration data, which includes the size and type of boat, engine type, and address of owner. Other sources of use data will be explored, including marina fuel sales, parking use at launching ramps, marina construction and utilization data, and survey data collected for the State Comprehensive Outdoor Recreation Plan. Information compiled by other state and federal agencies including the Department of Boating and Waterways, Department of Parks and Recreation, and the Delta Protection Commission will also be evaluated to determine boating trends and use patterns.

Surveys will be conducted during periods when eggs and larvae of each species of concern are present in the Delta and during peak use periods to establish Delta boating use patterns and to develop data to adjust registration statistics. Annual registration statistics will be converted to hours of use in the Delta per class of craft per year using survey data. The survey will determine seasonal traffic densities, hours of operation per year in the Delta, areas most frequently used, and fraction of registrants by county that recreate in the Delta. Aerial photographs will be used to identify areas where boating activity is concentrated. GIS mapping will be used to superimpose boating concentration areas and major fish migration routes and/or species distribution information. Inquiries will be made to determine whether similar data can be compiled on

[10] Physical/Engineering Options for Habitat Improvement In and Upstream of the Delta, Notes from 12/28/95 and 1/12/96 Meetings, Prepared by B.J. Miller.

commercial boating traffic. If a source for commercial boating activity is identified, trends and use patterns for this traffic will also be developed.

Task 3. Toxicity Tests. The toxicity of two-cycle engine exhaust water to sensitive estuarine test organisms will be evaluated in laboratory studies. Test water will be produced using a 75 hp outboard motor operated at approximately 70% power for 30 minutes in a collection tank containing laboratory water adjusted to a typical Delta salinity. Short-term chronic bioassays will be conducted using chinook salmon smolts, steelhead juveniles, larval fathead minnows and striped bass, top smelt and, if feasible, any available early life stage of delta smelt and splittail. Representative food organisms, including *Eurytemora*, *Ceriodaphnia*, *Holmesimysis costata* or *Mysidopsis*, and the alga *Selenastrum* will also be tested. The endpoints evaluated will include algae growth, invertebrate survival, growth and reproduction, and fish survival and growth. These studies will identify concentrations of exhaust water that produce effects on the bioassay endpoints. Toxicity thresholds developed in Task 3 and estimates of exhaust water ambient exposure levels will be integrated into a risk assessment in Task 5 to determine Delta-wide mortality to fish species that have declined from boating-induced pollution.

Task 4. Shear Studies. Laboratory velocity chambers, similar to those used by Morgan et al. (1976), will be used to determine the effect of shear on fish species and their food organisms. Tests will be conducted on eggs and larvae of chinook salmon, steelhead, fathead minnows, striped bass, and, if feasible, delta smelt and splittail, as well as *Eurytemora*, *Ceriodaphnia*, *Holmesimysis costata* or *Mysidopsis*, and the alga *Selenastrum*. Test conditions (exposure times and shear levels) will be selected based on the results of the in-Delta use survey in Task 3 and preliminary analyses in Task 5. A minimum of three replicates and three controls will be used for each exposure time, life stage, and shear level. Lethal shear levels that result in 50 percent mortality will be determined. Regression equations will be developed for each species and life stage that relate mortality to shear level and exposure time.

Task 5. Data Evaluation and Analysis. The data compiled and developed in Tasks 1 through 4 will be evaluated and analyzed to determine the impact of boating on in-stream aquatic habitat and declining fish species. Mortality of fish eggs and larvae in the Delta due to boating-induced shear and turbidity and engine exhaust emissions will be estimated using aquatic risk assessment techniques and compared to losses from other factors. Standard hydraulic calculations and published measurements will be used to estimate the shear generated by different types of boats. These estimates will be used in the mortality equations developed in Task 4 to estimate average mortality experienced by fish eggs and larvae within the Delta. Concentrations of two-cycle exhaust in Delta waters will be estimated from the boating activity data compiled in Task 2 and used to estimate mortality from the discharge of exhaust fumes directly into the water column. Boating trend data will be correlated with abundance indices for declining fish species and/or incorporated into early life-stage fish models developed by others (e.g., salmon smolt survival model) to determine the relative importance of boating compared to other factors. Turbidity data collected by the Interagency Monitoring Program will be evaluated to determine whether seasonal patterns could be due to boating and whether biological thresholds are being exceeded.

If these risk analyses demonstrate the potential for a significant impact on any of the species of concern, the results will be confirmed in an optional pond study conducted at a local aquaculture facility. Suitable facilities are available in both Chico and Galt. Control and treatment ponds would be stocked, a representative boat would be run in the treatment pond, and the ponds sampled to compare toxic effects and long-term survival.

Task 6. Control Strategies. If boating impacts are found to be significant, methods to minimize these impacts will be identified and evaluated. Control measures that will be considered include: (1) setting speed limits; (2) restricting boating in critical areas and during critical periods of passage; (3) working with regulatory agencies to establish boating emission limits; and (4) using water hyacinths, other aquatic vegetation, or physical anchors to break boat wakes. Anchors are rock barriers just under water at the outer limits of natural underwater berms that are generally found on the inside bends of Delta channels. The effectiveness of each will be evaluated and preliminary costs developed.

Task 7. Report Preparation. A draft report will be prepared that summarizes the results of Tasks 1 through 6. The draft report will be submitted for review to at least three independent scientists who are actively working in the area and three Bay-Delta researchers with expertise in aquatic toxicology, fishery biology, and water resources. Comments will be incorporated and a camera-ready copy of the final report submitted for reproduction and distribution. The results will also be published in one or more peer-reviewed journal articles.

BUDGET COSTS

The total cost to Category III is $395,000. Of this amount, $75,000 is optional and will only be expended if the analyses in Task 5 indicate that boating is causing a significant impact to aquatic resources in the Bay/Delta. The cost is broken down by task in Table 1. This is a personal services project and overhead is rolled into hourly fees and unit testing costs and are not separately reported by category. Thus, most of the cost categories requested in the RFP are not relevant (e.g., service contracts, material and acquisition contracts, overhead labor). Costs will be billed monthly. A related project, the documentation of significant changes in Delta shallow water vegetation, has been approved for funding by CUWA and will be performed simultaneously by Fox Environmental Management and the results used to supplement the studies conducted under this contract.

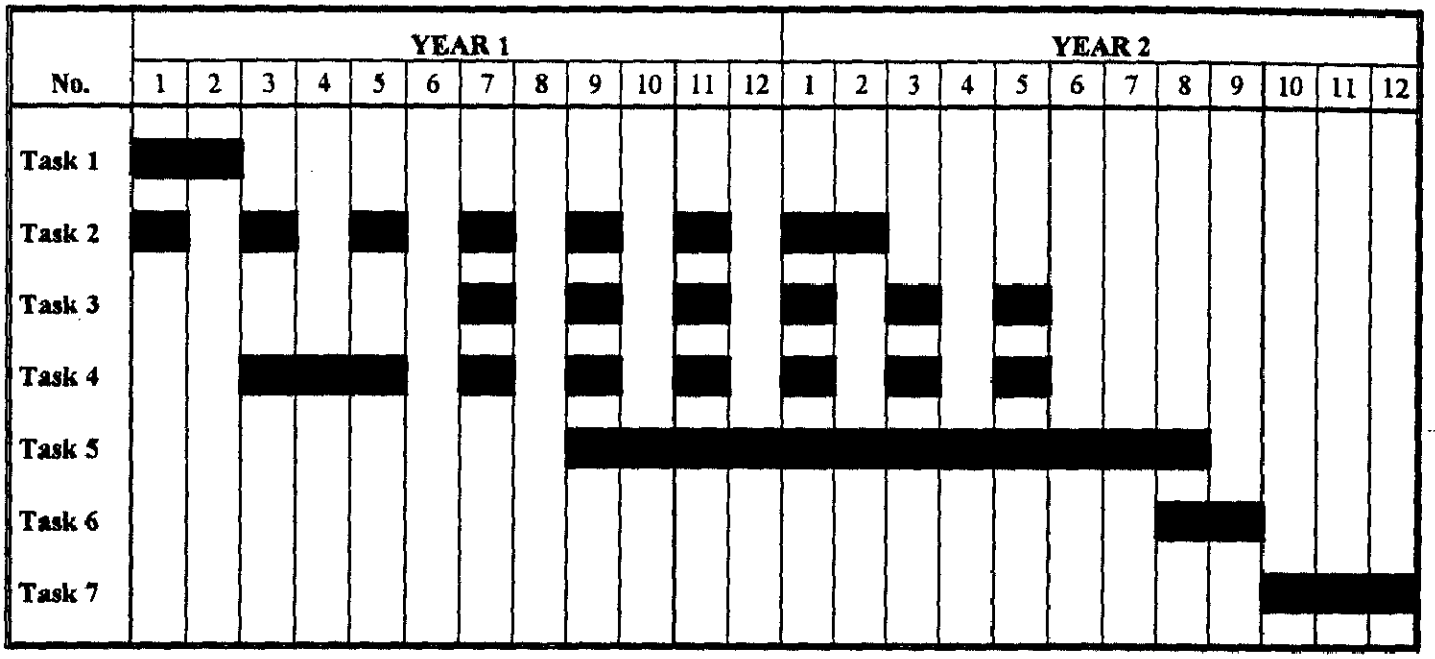
Table 1. COST BREAKDOWN
(costs in $1,000s)

Task	LABOR			Expenses	Total Costs	Optional Costs
	Fox	AQUA-Science	EDAW			
1. Literature Survey on Effects of Boating	30	--	5	5	40	--
2. Document Use Patterns and Trends in Boating	20	--	40	10	70	--
3. Toxicity Tests	--	60	--	--	60	--
4. Shear Studies	--	40	--	10	50	--
5. Data Analysis and Evaluation	50	45	10	--	70	35
6. Control Strategies	20	--	20	--	--	40
7. Report Preparation	20	5	5	--	30	--
TOTALS	140	150	80	25	320	75
				GRAND TOTAL	**395**	

SCHEDULE

This project will be started within one month of signing the contract and will take about two years of elapsed time to complete. The work must be staged to coincide with the availability of test organisms (e.g., salmon and striped bass are only available in spring) and critical periods selected for surveying (i.e., peak use and critical habitat periods) and coordinated with the weather and results of tasks. Therefore, a schedule cannot be precisely defined until the contract start date is known. A tentative schedule, subject to availability of test organisms, weather, and results of preliminary tasks, is shown in Figure 1.

Figure 1. SCHEDULE



QUALIFICATIONS

This project will be carried out by Fox Environmental Management with subcontracts to AQUA-Science and EDAW, Inc. The qualifications of the principals who will perform the work are described below. References will be supplied on request.

Phyllis Fox

Phyllis Fox, President of Fox Environmental Management, is the Project Manager. She will coordinate the work and perform portions of Tasks 1, 2, 5, 6, and 7. Phyllis has a Ph.D. in Environmental Engineering from the University of California at Berkeley with minors in Hydrology and Mathematics. She has over 25 years of experience providing environmental analysis and planning services on Bay-Delta issues. She has recently completed several reviews of toxic issues in the study area, including a comprehensive review of the literature on toxicity and pesticides in surface waters of the Central Valley, a review of the toxicity of surface waters in the Sacramento River to fathead minnows, a review of the annual striped bass die-off, and an analysis and review of the effects of rice pesticides on striped bass. Phyllis has conducted numerous projects similar to that proposed here for state and federal agencies, water districts and industry, including the U.S. EPA, Department of Energy, U.S. Bureau of Land Management, CUWA, MWD, and DWR.

Jeff Miller

Jeff Miller is President of AQUA-Science, an aquatic toxicity testing laboratory in Davis established in 1985 that has performed hundreds of toxicity studies in the Bay-Delta. Jeff will perform Tasks 3 and 4 and assist with Tasks 5 and 7. Jeff has a Ph.D. from the University of California at Davis in Environmental Toxicology and is a board-certified toxicologist. He has over 15 years of experience designing, conducting, and reporting on water-related environmental problems, including extensive hands-on experience in the design and conduct of ambient and effluent bioassays and toxicity identification evaluations. He has been responsible for the design and implementation of numerous broad-based environmental toxicology programs throughout the study area. He has completed many similar projects for a wide range of municipal and industrial clients, including the Sacramento Regional Wastewater Treatment Plant, Central Contra Costa Sanitary District, Regional Water Quality Control Boards, USS Posco Industries, Ciba-Geigy, and Dow-Elanco. He recently completed an investigation for CUWA on ambient toxicity of the Sacramento River near Freeport to chinook salmon. He and Dr. Fox also recently won funding from IEP to investigate the role of metallodithiocarbamate fungicides in the toxicity of the Sacramento River to fathead minnows.

Bruce DiGennaro

Bruce DiGennaro is a Senior Associate at EDAW, a 55-year-old environmental planning firm with extensive experience in recreational planning and Bay-Delta issues. Bruce will direct Task 2, conduct the boating use survey, and assist with Tasks 5 through 7. Bruce is an outdoor recreation planner with 12 years of experience designing and conducting recreation studies including numerous surveys focused on documenting boating use levels and demand. He is trained in the design, development, implementation, and analysis of public surveys and has directed recreation surveys in Alaska, California, Colorado, Georgia, New Mexico, Oregon, Virginia, Washington, and West Virginia. Bruce has completed numerous similar studies for federal and state agencies and utilities, including the U.S. Bureau of Reclamation, U.S. Forest Service, Oregon Department of Parks and Recreation, Tuolumne County, New Mexico State Park and Recreation Division, PG&E, and Southern California Edison, among many others. Recent boating studies have included a use allocation study for the Deschutes River, reservoir boating use and demand analysis for two large reservoirs in Montana, studies of use at Pardee Reservoir, and whitewater use studies for the Mokelumne and Feather Rivers.

STANDARD TERMS AND CONDITIONS

The standard terms and conditions applicable to the other services group are acceptable as detailed in Attachment D of the RFP. The non-discrimination compliance form is attached.

Item 8

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

FOX ENVIRONMENTAL MANAGEMENT

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

CERTIFICATION

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

OFFICIAL'S NAME

Phyllis Fox

DATE EXECUTED

July 27, 1997

EXECUTED IN THE COUNTY OF

Alameda

PROSPECTIVE CONTRACTOR'S SIGNATURE

Phyllis Fox

PROSPECTIVE CONTRACTOR'S TITLE

President

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

Fox Environmental Management