

F1-247

II. TITLE PAGE

A) Project Title:

Evaluation of Abandoned Mines: Mass Loadings of Mercury and the Cost Effectiveness of Remediation

DWR MATRIALQUEST

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B) Principal Investigator(s):

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C) Type of Organization and Tax Status:

State of California

D) Tax ID Number and/or Contract License (as applicable):

Not Applicable

E) Technical and Financial Contact Person (phone, address, etc.):

Ron Churchill

F) Participants, Collaborators in Implementation:

Department of Conservation, Department of Fish and Game, Moss Landing Marine Laboratories

G) RFP Project Group Type:

Our project falls into the RFP Group Type 3, under the category of nonconstruction habitat restoration.

JUL 28 1997

I. EXECUTIVE SUMMARY

A. Project Title:

Evaluation of Abandoned Mines: Mass Loadings of Mercury and the Cost Effectiveness of Remediation

Applicants:

Ron Churchill, Department of Conservation, Mines and Geology

Mark Stephenson, California Department of Fish and Game

B. Project Description and Primary Ecological/Biological Objectives:

We are proposing a study that will evaluate abandoned mines within the SF Bay Delta Watershed that are possible sources of mercury contamination. Most of these mines have not been studied to date. We intend to assess the level of the environmental stressor mercury that is contaminating the SF Bay Delta from the approximated four hundred mercury, thermal spring, and copper, lead, and zinc mines that are within the watershed boundaries. Our data will serve the CALFED objective of restoration in that we will provide baseline information from which to determine cost-effective remediation strategies. Many of the priority species and their food sources could be effected by mercury in the water, which is currently above the NAS recommended limits at many mine sites that have been evaluated.

C. Approach Tasks/Schedule

The objectives of this study are as follows:

- 1. Mine site screening to determine high priority sites.** This will be the first step in the priority mine identification process. We expect to screen approximately 400 sites within the first year.
- 2. Determination of Mass Loadings at High Priority Sites.** Samples will be collected at the previously determined sites, which will be analyzed for mercury and methylmercury to determine loadings. We expect to complete this phase within the first two years.
- 3. Mine Evaluation for Determination of Best Remediation and Cost Effective Strategies for Reducing Mercury inputs to the Delta.** This section will involve developing effective remediation plans, and determining preliminary costs of remediation at each of the 20 sites. This phase will be completed during year three.
- 4. Availability of Different Mercury Species for Methylation.** Inorganic mercury in sediments is potential fuel for methylation conducted by sulfide-reducing bacteria in anaerobic sediment (Compeau and Bartha, 1987). All forms of mercury, however, are not equally bioavailable to bacteria (Compeau and Bartha, 1987). Since most of the mass loadings of mercury to the delta are from suspended sediment, it is of great importance to determine if the mercury in coastal range sediments (primarily HgS) or Sierra Nevada sediment (primarily as elemental Hg or Hg++) have different degrees of availability for the methylation process. This phase will begin in year two and will be finished in year three.
- 5. Habitat Effect on Mercury Speciation.** In response to recent results that show wetlands as a source of methylmercury (Rudd, 1995), this portion of the study is proposed. Mercury and methylmercury in dissolved or particulate fractions derived from mine inputs will be measured, before and after water passes through four different types of habitats. This phase will begin in year two and will be finished in year three.

D. Justification for Project and Funding by CALFED

It has been estimated that as much as 7,600 tons of mercury was mined in the coast range in the California Gold Rush and much of it is still in the environment. There are currently fish consumption warnings posted in Clear Lake, Lake Berryessa, Marsh Creek Reservoir, the Delta (CVWQCB, 1987) and San Francisco Bay (SFRWQCB, 1995) to protect human consumers from mercury contamination. Bottom-feeding sturgeon were identified in the San Francisco Bay study as having high levels of mercury and are listed as a species of special concern by DFG and by USFWS. In addition, levels of mercury in fish eating birds are high in Clear Lake and have been determined to be the cause of Western Grebe deaths in Lake Berryessa (CVWQCB, 1987; California Dept. Fish and Game, 1984). Virtually all the mercury inputs in the San

Francisco Delta system are thought to derive from mining operations (CVRWQCB, 1987, Jones et al. 1996, Gill and Bruland, 1990, Slotton et al 1995, 1996). However, the Central Valley Regional Water Quality Control Board (CVRWQCB) has recently found high levels of mercury in hot springs (Chris Foe, personal communication). Despite this knowledge, there has been studies on a few of the larger mine sites, but the majority of mine sites have yet to be evaluated as to their potential to contribute mercury to the Delta. We estimate that there are approximately 60 mercury mines, 250 lead, copper and zinc mines, and 100 thermal hot springs that could contribute mercury to the watersheds (see maps), most of which remain unevaluated.

E. Budget Costs and Third Party Impacts

The estimated total costs for the three year study is \$765,303. Payment will be based upon tasks as they are completed throughout the study. There are no anticipated third party impacts.

F. Applicant Qualifications

Ron Churchill is a Ph.D. level Scientist at the Department of Conservation's (DOC) Division of Mines and Geology (DMG) and has over twenty years of experience in mineralogy and petrology, with an emphasis on economic geology. He is involved with the detailed compilation of mercury mine and prospect data to improve DMG databases, to create a new mercury site database, and report that provides additional information for environmental and hazardous mercury sites in California.

Mark Stephenson is Director of the California Department of Fish and Game Marine Pollution Studies Laboratory. He has over twenty years of experience in the analysis of fish and sediment for mercury. He is currently project manager for the California State Mussel Watch program, Bay Protection and Toxic Cleanup program, and approximately eight other projects.

G. Monitoring and Data Evaluation

This project is different from other studies in that the DMG has the most complete database available on abandoned mines in the state of California. As most of these mines have not been studied, the degree to which they are contaminating the environment is unknown. The data collected in this study will be compatible with data collected on mass loadings in other programs. There will be a high level of quality assurance/quality control, and the data will be available for integration into other databases. Our analytical techniques and monitoring methods will be similar to those used by other programs currently monitoring mercury in the delta area. We will send a proposal and reports out to experts in the field of mercury monitoring for peer review to attain suggestions and comments, which we will incorporate into our work and reports. We will also submit results to peer reviewed journals for publication.

H. Local Support/Coordination with Other Programs/ Compatibility with CALFED Objectives

We will coordinate our program with other perspective CALFED researchers such as Jim Rytuba and Darrel Slotton, so that there will be minimal duplication of effort. We will be coordinating our mass loading studies with the State Water Resources Control Board, Bay Protection and Toxic Cleanup Program, San Francisco Estuary Institute, Central Valley Regional Water Quality Control Board, and the Sacramento River Watershed Program. This project is compatible with all of the CALFED objectives, as our study could result in the decrease of mercury input and an improvement in water quality, which could help restore all the priority habitats and protect all priority species within the SF Bay Delta. The ultimate goal of our study is the restoration of mine sites, which is in agreement with the CALFED mission.

III. PROJECT DESCRIPTION

A. Project Description and Approach

Knowledge of the field of exploration geochemistry and mineralogy give DMG staff a unique perspective on how elements of environmental concern, such as mercury, are typically distributed in rocks, soil, stream sediments, and water at mineral deposit locations and mine sites. Such knowledge is particularly useful in decisions on sampling locations, numbers of samples necessary for site characterization, what analytical methods are appropriate, and for identifying normal and abnormal analytical results. This expertise coupled with the chemical and biological qualification of the DFG staff, give this study a unique perspective.

1. Mine site screening to determine high priority sites.

Detailed information will be compiled from DOC/DMG published and unpublished reports and databases for the approximately 400 (250-550) mercury, thermal spring, Cu, Pb and Zn mines within the Sacramento and San Joaquin River watersheds. DMG has the largest currently maintained (periodically updated) digital databases on abandoned mines and mineral prospects in California and published and unpublished mine information back to the 1800's. DMG staff regularly work with these digital and paper copy reference materials and can locate and compile historical mine information more quickly than non DMG researchers. Some historical mine information, such as detailed production records is proprietary and can only be reviewed by DMG personnel. This historical information compiled for the 400 mine and spring sites will be used to identify those mines and springs with the highest priority for follow-up study, based primarily on evidence or strong likelihood of processed ore tailings on site and size of operations for mines, and water chemistry and geological setting for springs. Secondary information used to prioritize will include; type of mine, whether the river is dammed, sensitivity of habitat, presence of endangered or threatened species, and proximity to San Francisco Bay delta.

The one hundred sites identified as high priority in above effort will be located, visited, mapped, photographed. Water samples will be collected at each site for mercury using the "clean hands dirty hands technique" necessary to collect uncontaminated mercury samples and measured for total and dissolved mercury (Frontier Geoscience, 1996). Samples of ore, dump, and tailings materials will also be collected for assay. Samples of sediment and water will be taken from mine water leachings or from the nearest water body. Water will be analyzed by cold vapor atomic fluorescence (Gill and Bruland, 1990; Frontier Geoscience, 1996) by DFG with 20% QA/QC duplicates analyzed by Frontier Geoscience or Brooks Rand. The on site screening will be performed primarily by Ron Churchill of DOC/DMG with the aid of DFG staff who will train DCDMG staff on the mercury collecting technique. We anticipate through this effort that twenty mine sites will be selected for further study.

2. Determination of mass loadings at high priority sites.

Two samples will be collected during the dry and four during the wet season at each of the twenty sites selected from 1. above, which will be analyzed for total and dissolved mercury. Methylmercury will be analyzed once at each site during the wet season by Frontier Geoscience and/or Brooks Rand, (DFG will develop methylmercury analysis capabilities during the course of this study, in which case they will assume all analytical responsibility). In addition, suspended solids, flow rate, mass of water transported, pH, salinity, and temperature will be measured. DFG will conduct all non-mercury chemistry. With this data, loading estimates can be compared to existing loading information from other areas such as Cache Creek, Marsh Creek and some of the rivers from the Sierra Nevada. Loading estimates are needed to prioritize mine sites as to their potential to pollute the Delta. This will be a joint effort by DOC and DFG.

3. Mine evaluation for determination of best remediation and cost effective strategies for reducing mercury inputs to the Delta.

This section will involve developing effective remediation plans, and determining preliminary costs of remediation at each of the twenty sites. The remediation cost analysis will be accurate to within a factor of

2 or 3, as a more rigorous analysis would be too costly for the scope of this study. A cost benefit analysis will be conducted at each of the major mine and/or hot spring sites to determine the most cost effective method and protocol for removing mercury inputs. The results of this analysis will be expressed in terms of cost per unit of mercury removed per mine. The DOC will conduct this part of the study.

4. Availability of different mercury species for methylation.

Inorganic mercury in sediments is potential fuel for methylation conducted by sulfide-reducing bacteria in anaerobic sediment (Compeau and Bartha, 1987). All forms of mercury, however, are not as bioavailable to bacteria (Compeau and Bartha, 1987). Cinnabar (HgS) for example, may not be available for methylation (Slotton et al., 1996). This raises the issue that all sources of mercury to the delta may not be equally important as the precursor species to methylmercury. Availability of methylmercury is important because it is this species that bioaccumulates in fish at elevated levels in the Delta, San Francisco Bay, and many lakes. Since most of the mass loadings of mercury to the delta are from suspended sediment, it is of considerable importance to determine if the mercury in coastal range sediments (primarily HgS) or Sierra Nevada sediment (primarily as elemental Hg or Hg⁺⁺) have different degrees of availability as fuel for the methylation process. The methodology we will employ involves adding suspended sediments from mine sites to relatively clean Delta sediments and measuring the methylmercury content of the sediments and overlying water over time. The mercury added to the San Francisco Bay sediments will be equalized from all the mine sources so that only the bioavailability of mercury will be different among the treatments. Total and methylmercury will be measured in the sediments and overlying water at time 0, 1, 2 and 4 weeks. All treatments will be kept at 15° C. Three replicates from 4 mine sites (2 from the Sierras and 2 from the coast range) will be measured for methyl and total mercury. Methodology will follow either Rogers et al., 1995 with modifications to include methylmercury in sediments, or alternately after further review of methylmercury production measurement techniques, we may use radiolabelled mercury, following the methods similar to Stordal and Gill, 1995. Total mercury will be analyzed by DFG and methylmercury will be analyzed by Frontier Geoscience, Brooks Rand, or the Department of Fish and Game if capability is demonstrated. This part of the study will be conducted by DFG.

5. Habitat effect on mercury speciation.

In response to recent results that show wetlands as a source of methylmercury (Rudd, 1995), this portion of the study is proposed. Mercury and methylmercury in dissolved or particulate fractions derived from mine inputs will be measured, before and after water passes through four different types of habitats. These habitats will be lakes, small ponds, fast flowing creeks, and wetlands (bullrush and tule). Differences, which have been shown to effect methylation (Slotton et al., 1996) that are the basis for the different habitat choices are depth, flow velocity, oxygen, salinity, and temperature. At least 10 samplings (different times) with three replicates each will be conducted at each of the chosen sites. Samples will be collected by DFG and analyzed by Frontier Geoscience, Brooks Rand or the Department of Fish and Game (if capability is demonstrated) for methylmercury, or DFG for total and dissolved mercury. This part of the study will be conducted by DFG.

B. Location or Geographic Boundaries of Project

This project will take place in the San Francisco Bay Delta, and particularly at various sites of abandoned mines. (See Maps)

C. Expected Benefits

The primary benefit of this study is the long term health and stability of at risk fishery species such as leopard sharks, sturgeon, and striped bass, which are currently bioaccumulating toxic levels of methylmercury in the SF Bay-Delta. We intend to provide data which will target hot spot mines, so as to begin remediation efforts on the most contaminated areas of the Delta first, and therefore to decrease the elemental mercury in the water and sediments that is being taken up by the previously mentioned fish species, as well as their bird and mammal predators. Secondary benefits from this study will include water

quality improvement, decrease of mercury flowing into the marine environment, lowered human health risk, and fishery preservation. Third parties that will benefit from this study are SFEI, fishermen, and consumers of the Bay-Delta watershed fish.

D. Background and Biological/Technical Justification

The rate at which sturgeon, striped bass, leopard sharks, trout, and various others take up mercury depends on mercury availability (water and sediment concentrations), length of exposure (depends on migratory patterns), temperature and pH, as well as the species of fish and the animal's role in the food chain. Bird, fish, and mammal bioaccumulation occurs almost totally through predation (Clear Lake Health Advisory Report; Slotton et al., 1996). The National Academy of Sciences (NAS) has established a recommended maximum concentration in aquatic organisms of 0.5 mg/kg of mercury to protect humans from ingesting harmful levels of mercury. Of particular concern are sturgeon and striped bass in San Francisco Bay Estuary. Recently a restricted consumption of striped bass has been recommended in the Estuary, posted in a mercury health advisory (Foe, Pers. Comm.). As levels in upper creeks near the mines are currently exceeding these limits (Foe, Pers. Comm.), the need for research into this area is clear. There has been previous work which has assessed mercury in terms of concentrations, but none has quantified mass loadings, directly attributed to the numerous abandoned mines in the watershed. If implemented, this study will assure valid priority determination of mines, which will govern all remediation schedules. We believe that we must first establish which sites are the most destructive, and mark those as first priority for removal or capping. The project has been extensively researched through literary review, and sampling methodology has been developed. Technique for sample collection, location, and analysis has been established, and comparisons have been made with the work of other researchers. We have found that the project we are proposing is both unique and essential to the success of remediation in the Bay-Delta.

E. Proposed Scope of Work

- 1. Mine site screening to determine high priority sites.** This will be the first step in the priority mine identification process. We expect to complete this phase within the first year.
- 2. Determination of Mass Loadings at High Priority Sites.** Samples will be collected at the previously determined sites, which will be analyzed for mercury and methylmercury. Suspended solids, flow rate, mass of water transported, pH, salinity, and temperature will also be measured. We expect to complete this phase within the first two years.
- 3. Mine Evaluation for Determination of Best Remediation and Cost Effective Strategies for Reducing Mercury inputs to the Delta.** This section will involve developing effective remediation plans, identifying responsible parties, and determining costs of remediation at each of the 20 sites. This phase will be completed during year three.
- 4. Availability of Different Mercury Species for Methylation.** Inorganic mercury in sediments is potential fuel for methylation conducted by sulfide-reducing bacteria in anaerobic sediment (Compeau and Bartha, 1987). All forms of mercury, however, are not equally bioavailable to bacteria (Compeau and Bartha, 1987). Since most of the mass loadings of mercury to the delta are from suspended sediment, it is of great importance to determine if the mercury in coastal range sediments (primarily HgS) or Sierra Nevada sediment (primarily as elemental Hg or Hg++) have different degrees of availability for the methylation process. This phase will begin in year two and will be finished in year three.
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F. Monitoring and Data Evaluation

This project is different from other studies in that the Division of Mines and Geology has the only database available on abandoned mines in the state of California. Most of these mines have not been studied, therefore the degree to which they are contaminating the environment is unknown. The data collected in this study is compatible with data collected on mass loadings in other programs. There will be a high level of quality assurance/quality control, and the data will be available for integration into other databases. Our analytical techniques and monitoring methods will be similar to those used by other programs currently monitoring mercury in the delta area. We will send a proposal and reports out to experts in the field of mercury monitoring for peer review to obtain suggestions and comments, which we will incorporate into our work and reports. We will also submit results to peer reviewed journals for publication.

G. Implementability

Positive cultural impacts. Fishery and fisherman culture sustainability is currently threatened due to fish and spawning habitat contamination. The success of this project would enable an increase in the health of the fishery species sturgeon, shark, striped bass, as well as their habitat and prey populations. This study will have complete compliance with laws and regulations posed by the CALFED guidelines, as water sampling would be the only field manipulation conducted. We will coordinate our program with other perspective CALFED researchers such as Jim Rytuba and Darrel Slotton, so that there will be minimal duplication of effort. We will be coordinating our mass loading studies with the State Water Resources Control Board, Bay protection and Toxic Cleanup program, San Francisco Estuary Institute, Central Valley Regional Water Quality Control Board, and the Sacramento River Watershed program. This project is compatible with all of the CALFED objectives, as our study could result in the decrease of mercury input and an improvement in water quality, which could help restore all the priority habitats and protect all priority species within the SF Bay Delta. The ultimate goal of our study is the restoration of mine sites, which is in agreement with the CALFED mission.

LITERATURE CITED

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Central Valley Region Report, 1987.
San Francisco region Report, 1995.
- Compeau, G.C., R. Bartha. 1987. Applied Environmental Microbiology 50, 26.
Clear Lake Health Advisory Report
- Frontier Geoscience Laboratory Quality Assurance Manual, 1996. Version 2.1.
- Gill, G., K. Bruland. 1990. Mercury Speciation in surface freshwater systems in California and other areas. Environmental Science and Technology 24 (9), 1392-1400.
- Jones, a., D. Slotton. 1996. Mercury effects, sources, and control measures. San Francisco Estuary Institute report, November 1996.
- Rogers, D., M. Dickman, X. Han. 1995. Stories from old reservoirs: sediment mercury and mercury methylation in Ontario hydroelectric developments. Water, Air and Soil Pollution 80, 829-839.
- Rudd, J. 1995. Sources of methylmercury to freshwater ecosystems: a review. Water, Air, and Soil Pollution 80, 697-713.
- Slotton, D., S. Ayers, J. Reuter, 1996. Marsh Creek Watershed 1995 Mercury Assessment Project, Final Report. March, 1996.
- Slotton, D., J. Reuter, C. Goldman. 1995. Mercury uptake patterns in a seasonally anoxic northern California reservoir. Water, Air and Soil Pollution 80, 841-850.
- Stordal, M.C., G. A. gill, 1995. Determination of mercury methylation rates using a 203-Hg radiotracer technique. Water, Air, and Soil Pollution 80, 725-734.

IV. COSTS AND SCHEDULE TO IMPLEMENT PROPOSED PROJECT

A. Budget Costs

The estimated total costs for the three year study is \$765,303. These include service contracts for methylmercury analysis and for gold analysis (See attached table for specific costs). Payment will be based upon tasks as they are completed throughout the study. Task four and five may be funded separately from the other tasks.

B. Schedule Milestones

Tasks one through five have been scheduled for completion at specified periods. (See attached schedule). Task one will be completed in year one, tasks two will be completed in year two, and tasks three, four, and five will be completed in year three.

C. Third Party Impacts

There are no anticipated third party impacts.

V. APPLICANT QUALIFICATIONS

Ron Churchill is a Ph.D. level Scientist at the Department Conservation (DOC), Division of Mines and Geology (DMG) and has over twenty years of experience in mineralogy and petrology, with an emphasis on economic geology. He is involved with the detailed compilation of mercury mine and prospect data to improve DOC databases, to create a new mercury site database, and report that provides additional information for environmental and hazardous mercury sites in California.

Mark Stephenson is Director of the California Department of Fish and Game Marine Pollution Studies Laboratory. He has over twenty years of experience in the analysis of fish and sediment for mercury. He has recently developed analytical capabilities for detecting low level mercury in water. He has been conducting studies involving low level analysis of trace metals in the SF Bay Delta with the California Regional Water Quality Control Board since 1992. In addition, he is currently project manager for the California State Mussel Watch program, Bay Protection and Toxic Cleanup program, and approximately eight other projects.

VI. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

All terms and conditions are agreeable, except that state agencies are self-insured.

BUDGET FOR DEPARTMENT OF CONSERVATION AND FISH AND GAME

DIRECT LABOR HOURS	DIRECT SALARY AND BENEFITS	OVERHEAD CONTRACTS	SERVICE ACQUISITION	MATERIAL/ DIRECT COSTS	MISC. AND OTHER DIRECT COSTS	TOTAL COSTS
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DEPARTMENT OF CONSERVATION

TASK 1	1640	42567	25375		250	68192
TASK 2	1504	54369	24307	3600 **	15800	98076
TASK 3	1504	66304	32837		2500	101641
TOTAL						267909

CALIFORNIA DEPARTMENT OF FISH AND GAME

TASK 1	967	33657	8443		2000	44100
TASK 2	1281	34666	12708	5000 *	14000	66374
TASK 4	2141	57939	40146	108000 *	3600	209685
TASK 5	2709	73302	33933	60000 *	10000	177235
TOTAL						497394

* Service contract for Frontier Geoscience or Brooks Rand for methyl/mercury analysis, however may be converted to DFG salaries.

**Service contract is for gold analysis.

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SCHEDULE

		YEAR 1	YEAR 2	YEAR 3
TASK 1	MINE SCREENING	XX		
TASK 2	MASS LOADINGS	XX	XX	
TASK 3	BEST REMEDIATION			XX
TASK 4	METHYLATION		XX	XX
TASK 5	HABITAT/ METHYLATION		XX	XX

THERMAL SPRINGS

CALHOT DATABASE

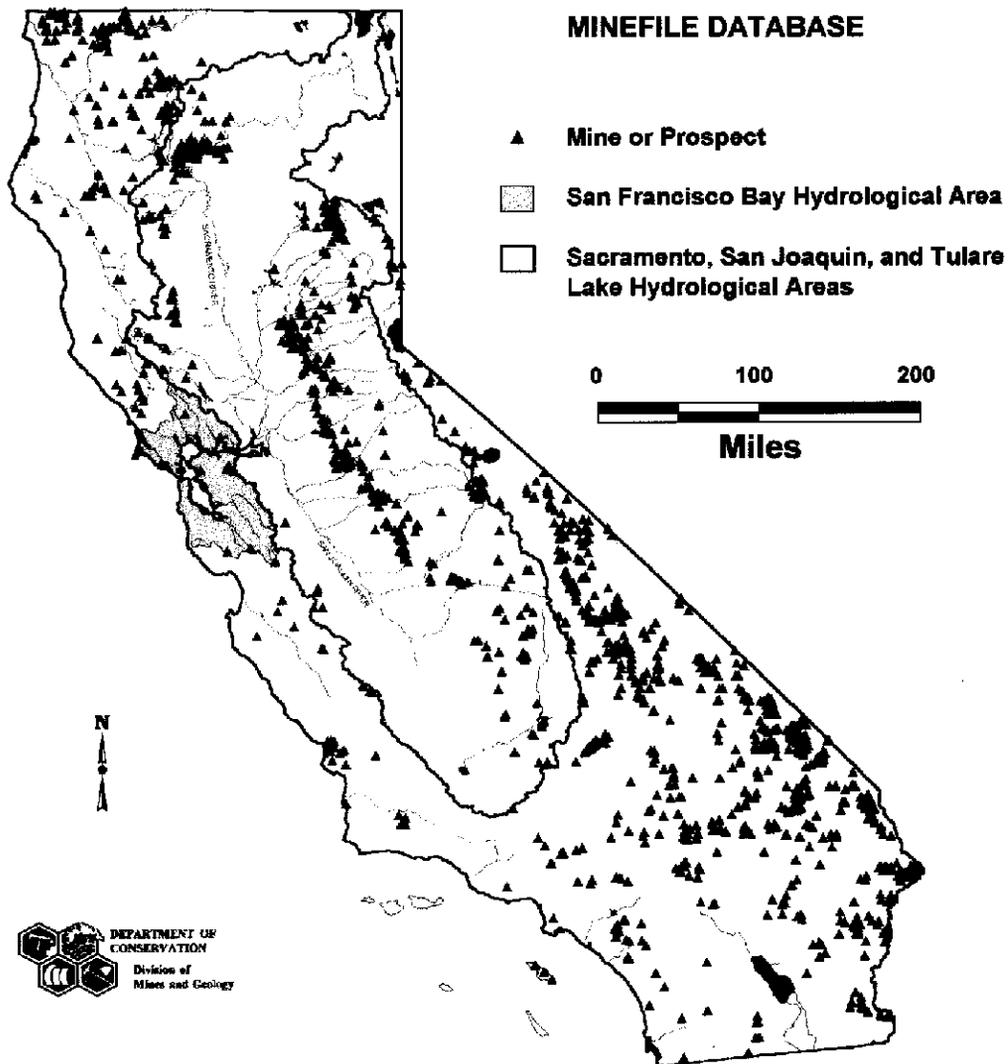
- Thermal Springs
- San Francisco Bay Hydrological Area
- Sacramento, San Joaquin, and Tulare Lake Hydrological Areas



KEG 7/17/97

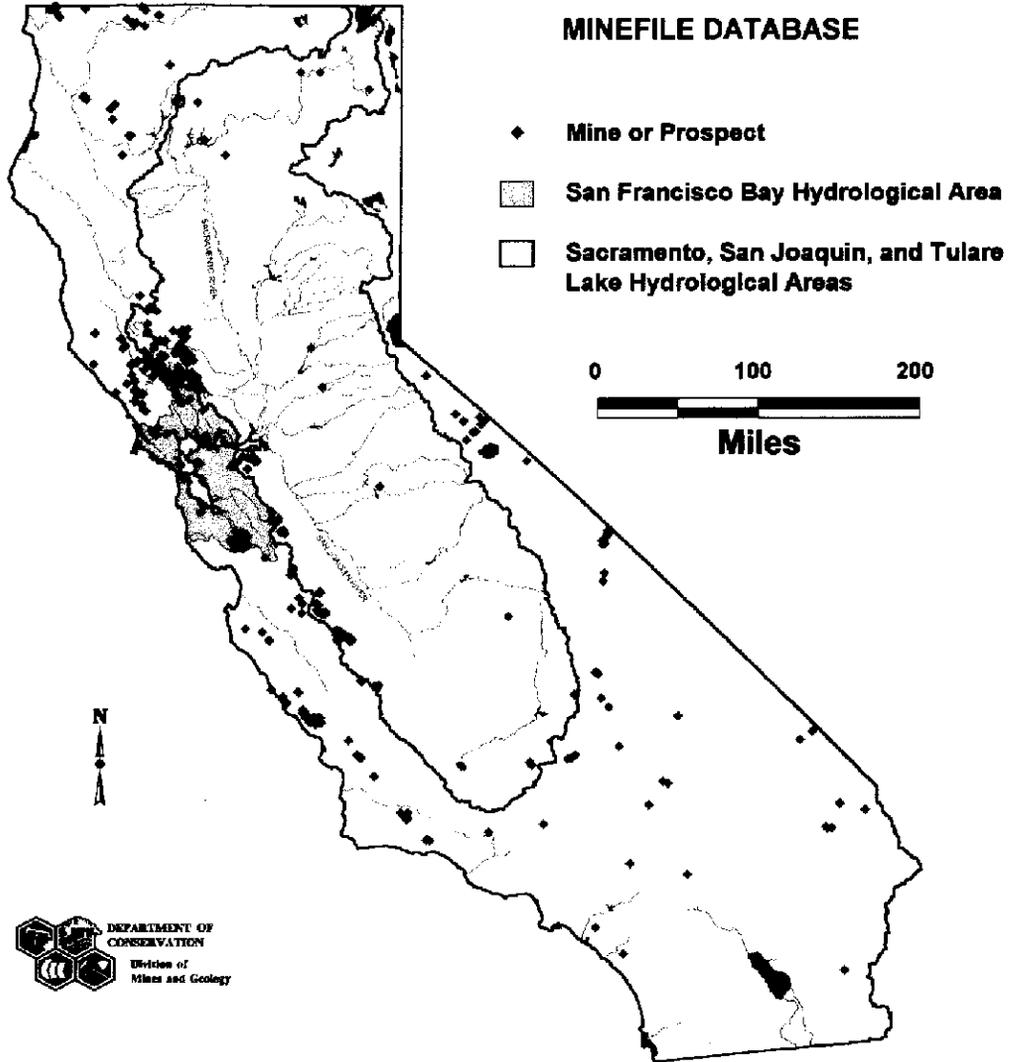
COPPER, LEAD, AND ZINC MINES AND PROSPECTS

MINEFILE DATABASE



KEG 7/17/97

MERCURY MINES AND PROSPECTS MINEFILE DATABASE



KEG 7/17/97

Item 8

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

DEPARTMENT OF CONSERVATION

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

Trinda L Bedrossian

TRINDA L BEDROSSIAN

DATE EXECUTED

7-25-97

EXECUTED IN THE COUNTY OF

SACRAMENTO

PROSPECTIVE CONTRACTOR'S SIGNATURE

PROSPECTIVE CONTRACTOR'S TITLE

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

DEPARTMENT OF CONSERVATION