CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIMIENTO

Contract No. 1-069-130-0

Prepared for the
California Regional Water Quality Control Board

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COVER PHOTO: Lake Nacimiento Dam when lake was 72% capacity, 2/25/93.

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Disclosure Statement

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Limitations and Uniformity of Conditions

The recommendations in this report are based on the assumption that environmental conditions do not deviate significantly from those that existed at the time of field sampling and observation. If any important natural or anthropogenic (human-induced) changes occur to the alluvial floodplains, dams, lake, mine sites, reservoirs, roads, soils, or other locations mentioned in this report, the State Water Resources Control Board should conduct additional on-site investigations to refine any of our recommendations.

The data contained in this report for sediments, soils, and water relative to the sampling locations are valid as of the date the materials were collected. Some environmental changes occur with the passage of time at each sampling location, whether they are due to natural or anthropogenic processes. In addition changes in applicable or appropriate standards or practices may occur, whether they result from legislation or the expansion of knowledge. Accordingly, the findings and recommendations of this report may be modified wholly or partially by changes outside our control. Therefore, we recommend that this report be subject to review and modification as necessary.

EXECUTIVE SUMMARY

On April 26, 1955, the voters of Zone 2 of the Monterey County Flood Control and Water Conservation District approved a $7,000,000 general obligation bond issue for the construction of a 350,000 acre-foot reservoir on the Nacimiento River for municipal and irrigation water supply, flood control, and recreational purposes. The dam construction project, completed in April, 1957, has fostered the expansion of irrigated lands on terraces and upland areas below the Nacimiento dam as a result of a sustained groundwater recharge program.

Lake Nacimiento is presently an important local recreational area that provides opportunities for fishing, water sports, and permanent and vacation living. There is also increasing interest in expanding water usage from the lake for direct human consumption.

The California Department of Health Services (DHS) has posted a health advisory calling for reduced consumption of largemouth bass and white bass because of high tissue mercury concentrations, up to 1.80 $mg \cdot kg^{-1}$ in the filets, exceeding the Food and Drug Administration (FDA) action limit of 1.00 $mg \cdot kg^{-1}$ (Rasmussen and Starrett, 1987).

Two routes for sediment-borne mercury conveyance from watershed sources to Lake Nacimiento were investigated: 1) fluvial transport, and 2) eolian transport. Sediment and water sampling strategy and laboratory protocol are discussed in the Quality Assurance Project Plan for this study which is on file at the RWQCB offices in San Luis Obispo. The estimate developed for the average annual mercury transport rate via each route indicated total estimated contributions for the entire Lake Nacimiento watershed of about twenty one (21) pounds of mercury per year from fluvial transport. The estimated mercury contribution from eolian transport to the lake was found to be negligible; although local eolian contributions to topsoils immediately adjacent to mercury mines and associated roads can be significant (Bigley, 1993).

The primary sediment mercury sources in the Lake Nacimiento watershed that were identified in this study (listed in order from the highest contributing source to the lowest) include the inactive Buena Vista mercury mine, the inactive Klau mercury mine, a dam east of Klau Mine on the Klau Branch of Las Tablas Creek that was constructed of a mixture of mercury-rich materials, the abandoned Bonanza Group mercury mines, the abandoned Pine Mountain Group mercury mines, roads in the vicinities of some of these mines that were paved with mine wastes, the abandoned Sycamore Creek (Botts) mercury mine, soils in the vicinities of abandoned and inactive mines and/or close to geologic source areas, and naturally occurring geologic deposits that are enriched in mercury but were never exploited by mining.

Additional monies became available through the RWQCB in 1993 to assess possible mercury contamination in certain components of the biotic community of the Las Tablas creek drainage. The biological sampling and analysis were largely restricted to aquatic organisms in the Las Tablas Creek watershed. A total of 120 fish representing 10 species were captured and sampled for biochemical assay for total tissue mercury. The biological data demonstrate a significant bioaccumulation of mercury in several fish species.

The biological results and analyses clearly show that elevated mercury levels exist in the fish communities of Las Tablas Creek. Data from FGL laboratories show total mercury from 35 fish samples range from 6.4 to <0.01 ppm. The parallel CDFG laboratory data based on 81 samples show a range of 2.0 to 0.03 ppm. The locations where the highest biological mercury contamination occurs are the Buena Vista reservoir and the Harcourt reservoir. The biological data suggest a continuing supply of mercury-bearing materials entering Las Tablas Creek system. The results of this biological study confirm the conclusions of the prior sediment sampling study that the primary mercury contamination source locations in the Las Tablas Creek watershed are the two inactive mercury mines, the Buena Vista and the Klau.

Prevention of additional lake mercury loading from waterways, especially Las Tablas Creek, appears to be the best strategy to decrease mercury levels in the lake sediments and water column and, subsequently, in the lake fish population (Chamberlin et al., 1990; Gavis and Ferguson, 1972; Rudd et al., 1983). Consequently, effective source control measures should result in reducing rates of fluvial transport of mercury-bearing suspended sediments to Lake Nacimiento.

The focus of the source control remediation measures is on two inactive mercury mines, the Buena Vista and Klau, which have been previously identified as "problem mines" (Mining Waste Study Team, 1988) and which we have identified as the primary point sources for mercury and acid mine drainage pollution in the Lake Nacimiento watershed.

Specific remediation measures that were considered include:

1. Physical Remediation Methods

A. cut back slopes to reduce erosion and prevent slope failures on tailings piles;
B. vegetate bare soil surfaces to reduce erosion;
C. riprap streambanks to protect them from undercutting;
D. mine seals placement;
E. grout the mine wastes;
F. cap the mine wastes with soil-cement;
G. cover the mine wastes with a flexible geotextile cap;

  H. cover the mine wastes with a concrete blanket;
  I. cover the mine wastes with a webbed geotextile;
  J. solidify the mine wastes;
  K. vitrify the mine wastes;
  L. excavate and dispose of the mine wastes;
  M. sediment trap construction and maintenance; and
  N. wetlands establishment.

2. Chemical Remediation Methods
  A. acid mine drainage neutralization;
  B. bactericides; inhibition of sulfur oxidation;
  C. oxidation processes;
  D. reduction processes; and
  E. ion exchange methods.

3. Biological Remediation Methods
  A. biological oxidation.

Control of mercury-laden sediment loads to the lake from abandoned and inactive mercury mines and contaminated roads will provide direct source control strategies for improving Lake Nacimiento water quality. However, the mercury already stored in watershed stream alluvium and in the sediments of the lake may continue to cause mercury bioaccumulation by fish and wildlife species for many decades, or even centuries. Therefore, in-lake pollution abatement measures have also been developed and evaluated.

A wide range of pollution abatement and control options for the lake was considered:

A. Do nothing;
B. Implement a source control program at the mine sites but do nothing in the lake;
C. Dredge, remove and treat contaminated Lake Nacimiento and/or Harcourt Reservoir sediments;
D. Cover mercury-rich Lake Nacimiento sediments *in situ*.; and
E. Establish a bounty system to reduce human consumption of the most mercury-contaminated fish.

1.0 INTRODUCTION

Lake Nacimiento is an important recreational area that provides opportunities for bass fishing, water sports, and vacation living. The California Department of Health Services (DHS) has posted a health advisory calling for reduced consumption of fish because of high mercury concentrations found in largemouth bass and white bass. Largemouth bass taken from the Las Tablas Creek Arm of Lake Nacimiento showed Hg concentrations up to 1.80 $mg \cdot kg^{-1}$ in the filets, exceeding the Food and Drug Administration (FDA) action limit of 1.00 $mg \cdot kg^{-1}$ (Rasmussen and Starrett, 1987). Any increased bioaccumulation of mercury in the fish population could cause serious health effects for humans and predatory animals consuming the contaminated fish. On the other hand, if fishing is curtailed, then some local sport fishing interests may suffer economically.

1.1 Location & Features of Lake Nacimiento and Watershed

Lake Nacimiento is located in San Luis Obispo County, California. The approximate center location of the lake is 120^o 56' north latitude and 35^o 40' west longitude. At full water capacity, the maximum depth is about 55 meters (180 feet) with a mean depth of 30 meters (98 feet). The maximum water surface area is 2,173 hectares (1,758 acres) with a maximum volume of 4.32×10^8 cubic meters (about 350,000 acre-feet). Nacimiento Lake water temperatures result in a summer thermocline. The major hydrologic inflows and outflows are from the Nacimiento River.

The Nacimiento River has long been considered one of the most productive streams in the California Central Coast area. The Nacimiento and San Antonio Rivers together contribute over 75 percent of the flow of the Salinas River at Monterey Bay, and are responsible for a substantial portion of the historic flood damage along the lower Salinas River. Studies by the California Division of Water Resources during the period from 1952 to 1958, leading to the formulation of The California Plan, conclusively demonstrated that engineering large reservoirs on the Nacimiento and San Antonio Rivers was feasible and economically justified. Consequently, San Luis Obispo and Monterey County interests considered the Nacimiento and San Antonio rivers as potential water supply sources and dams have been constructed. (San Luis Obispo Co. Flood and Water Conservation District, 1965).

1.2 History of Development and Nacimiento Water Claims

On April 26, 1955, the voters of Zone 2 of the Monterey County Flood Control and Water Conservation District approved a $7,000,000 general obligation bond issue for the construction of a 350,000 acre-foot reservoir on the Nacimiento River for municipal and irrigation water supply, flood control and recreational purposes. The dam construction project, completed in April, 1957, has fostered the expansion of irrigated lands primarily in the Salinas Valley as a result of a sustained groundwater recharge program.

There are several existing contracts in San Luis Obispo County for Lake Nacimiento water. Small lakeside water users contract for 82 acre-feet (A.F.) of water (personal communication, S.L.O. Co. Engineering Dept., 11/15/92). Heritage Ranch development in the Snake Creek watershed is contracted for 1,200 A.F. This leaves about 16,300 A.F. of water entitled to users in San Luis Obispo County that is not presently being used due to a lack of pipelines and aqueducts to transport the water to potential contractors. A pipeline is presently being considered by the Cambria Community Services District (CCSD) to move water from the Las Tablas Creek Arm of the lake west over the crest of the Santa Lucia Range to the San Simeon Creek watershed for groundwater recharge purposes (Read, 1992). An additional pipeline construction project study to serve other county municipalities is in its preliminary stages and is being conducted by Boyle Engineering, San Luis Obispo (Bunin, 1993). County demands for Lake Nacimiento water are expected to continue into the future and many decisions remain to be made (Dalrymple, 1993).

Monterey County contractors get the bulk of Lake Nacimiento water. A maximum annual lake water withdrawal of 180,000 A.F. by release over the dam has been reported (Dupuis, 1991). Most of the water percolates into the Salinas River aquifer to be pumped out as groundwater by agricultural, municipal, and private users downstream from the dam.

1.3 General Watershed Conditions

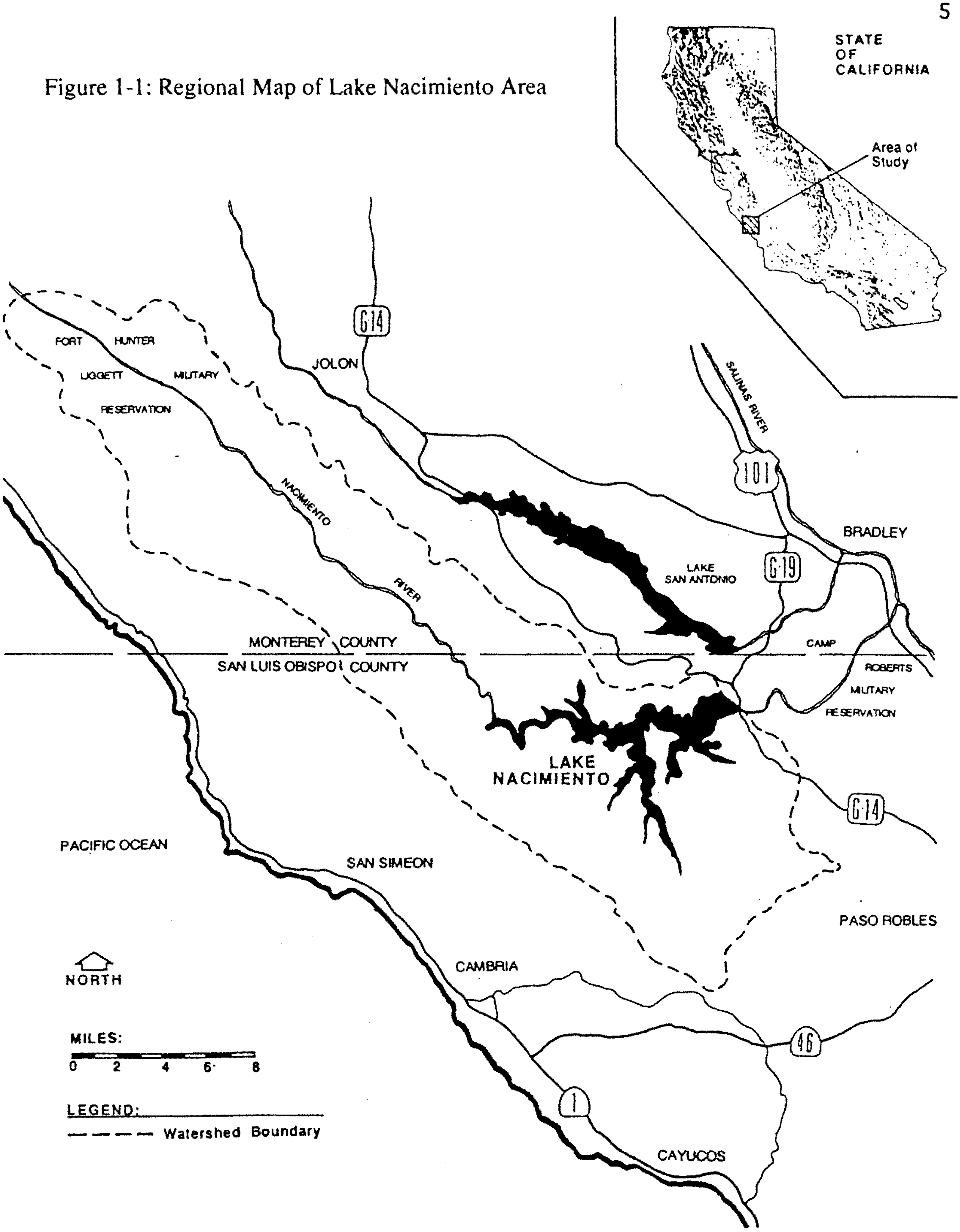
The Lake Nacimiento watershed encompasses approximately 82 square miles (52,480 acres) located about half in northern San Luis Obispo Co. and half in southern Monterey County (Figure 1-1). Land use in the watershed is about 50% grazing, 47% open space, 1% housing, 1% camping, and 1% inactive mines. Most of the land in the watershed is publicly owned as Hunter Liggett Military Reservation and Los Padres National Forest. Public access to the lake is available by way of 17 private boat launch ramps, 2 public launch ramps, and 20 launch areas from private lands accessible by four-wheel drive vehicles.

The individual drainage basins within this watershed can be divided into two groups: the lower basins that drain directly to the lake, and the upper basins that drain to the Nacimiento River which then flows into the lake. The lower basins include Las Tablas, Franklin, Town, Dip, Snake, and Kavanaugh Creeks. The upper basins include Little Burnett, Tobacco, Salmon, Las Berros, San Miguel, Stony, El Piojo, Waller, and Sapaque Creeks. The crest of the Santa Lucia Range forms the southwestern boundary of the watershed, and the San Antonio River watershed divide bounds it on the northeast (Figure 1-2).

Physiographically and vegetatively, the Nacimiento River watershed can be considered as consisting of two relatively distinct parts. The southwesterly half is that part located generally between the Nacimiento River and the crest of the Santa Lucia Range. It consists of mountainous terrain characterized by steep slopes and a thick cover of chaparral and mixed evergreen forest.

This area is primarily used as watershed with limited cattle grazing, and is being increasingly subdivided into rural homesite parcels. The northwesterly half of the watershed is characterized by more level terrain than in the Santa Lucia Range to the west, and has a vegetative cover composed typically of oak-grass savannah. This portion of the watershed is used for cattle grazing, dryland farming, rural homesite parcels and military operations on the Hunter Liggett Military Reservation.

Figure 1-1: Regional Map of Lake Nacimiento Area



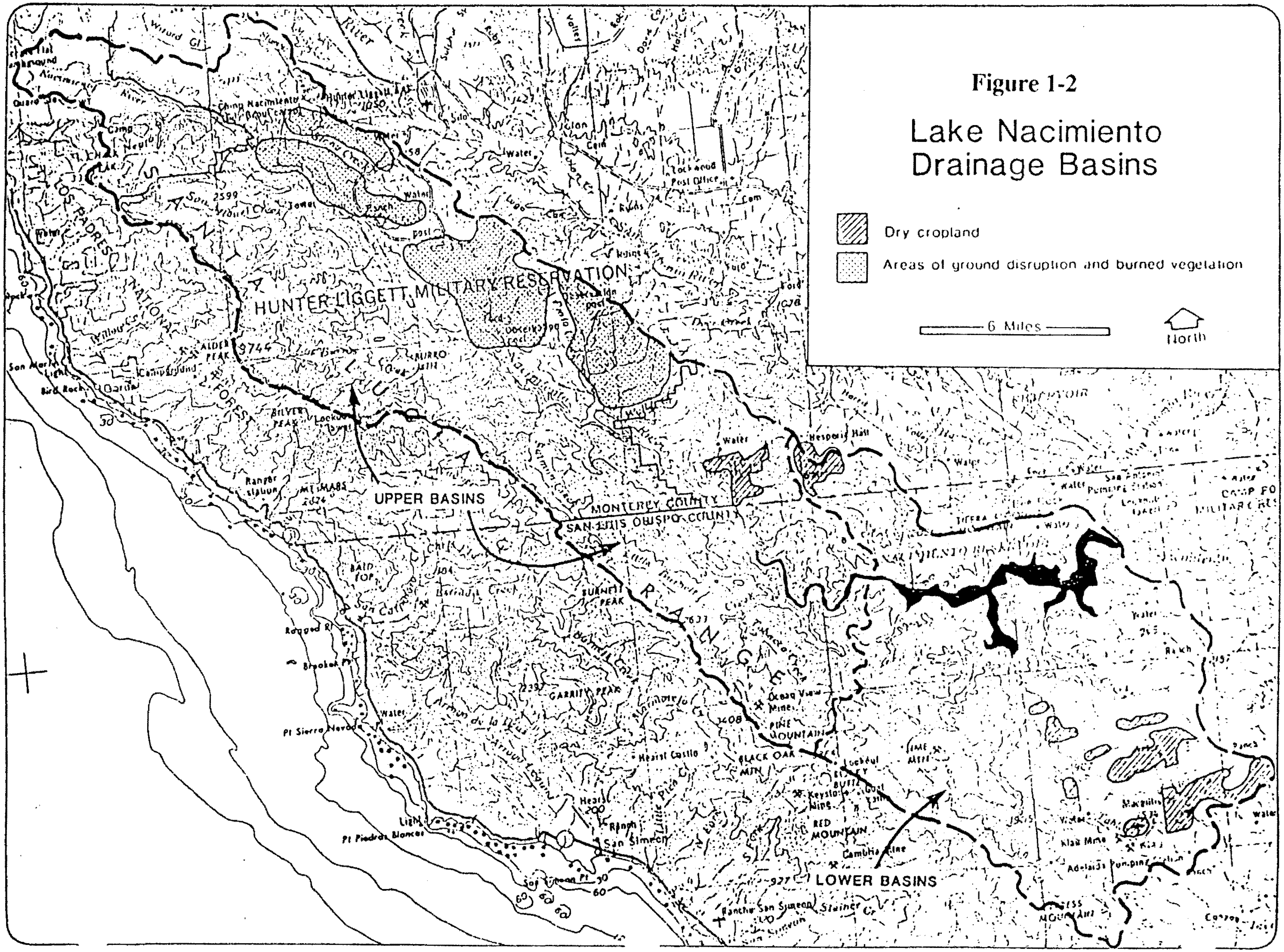


Figure 1-2

Lake Nacimiento Drainage Basins

1.4 Beneficial Uses

The "Water Quality Control Plan, Central Coast Basin," (called the Basin Plan), was adopted by the Regional Water Quality Control Board (RWQCB) on March 14, 1975, and was approved by the State Water Resources Control Board on March 20, 1975. The Basin Plan incorporates statewide plans and policies by reference and contains a strategy for protecting beneficial uses of surface waters in the Central Coast Region.

The Basin Plan lists beneficial uses for Las Tablas Creek as follows:

a. Intermittent municipal supply;
b. Intermittent agricultural supply;
c. Intermittent groundwater recharge;
d. Intermittent water contact recreation;
e. Non-contact water recreation;
f. Wildlife habitat;
g. Intermittent warm water habitat; and
h. Intermittent spawning habitat.

2.0 MERCURY LITERATURE REVIEW

2.1 Introduction

Many lakes, reservoirs, and river systems worldwide are contaminated by mercury (Hg). Both point and non-point sources of Hg contamination contribute to the Hg loading of water bodies. Soils and sediments high in Hg are known to be associated with some Hg-bearing geologic deposits, Hg mining operations, and Hg-utilizing industries. These Hg-rich soils may erode and be transported as alluvial sediment to rivers, lakes, or reservoirs where the Hg can be transformed to more toxic forms that can bioaccumulate, resulting in severe impacts on animal and human populations.

Most Hg transformations depend on various interrelated chemical, physical, and microbiological processes that operate in both the terrestrial and aquatic environments. Chemical transformations within the Hg cycle are regulated by the forms of Hg present and by the chemical, physical, and biological reactions existing in the environment.

This literature review is organized to discuss several topics in the following order: Hg toxicity concerns, Hg levels in the environment, Hg forms in the environment, and environmental Hg processes and reactions.

2.2 Mercury Toxicity Concerns

The U.S. classification of Hg toxicity is determined by the Federal EPA-EP (Extraction Procedure) Toxicity Test (SW-846, Method 1310), documented in EPA 40 CFR Part 261. In this test a sample is treated with acetic acid at pH 5, in a 16:1 acid:waste ratio for 24 hours. The pH is maintained at 5 by the addition of glacial acetic acid. If the Hg content of the sample extract exceeds 0.2 $mg \cdot L^{-1}$, the material is considered toxic and therefore hazardous.

The California Department of Health Services (DHS) classifies waste as hazardous using procedures specified in Title 22, Chapter 30, of the Code of California Regulations (CCR). Article 11 defines the criteria for the identification of hazardous wastes. Section 66696 specifies general toxicity criteria, while Section 66699 of Article 11, which deals with persistent and bioaccumulative toxic substances, is directly relevant to mining waste. Any waste is considered hazardous if its Hg levels, as determined by the Waste Extraction Test (WET), exceed a soluble threshold limit concentration (STLC) of $0.2\ \mathrm{mg \cdot L^{-1}}$, or exceed a total threshold limit concentration (TTLC) of $20\ \mathrm{mg \cdot kg^{-1}}$, (wet weight). An excellent critical review of the testing procedures for the classification of mining wastes was recently completed (Mining Waste Study Team, 1988).

The majority of Hg poisonings are due to ingestion of the short-chained alkyl mercurials, especially methyl mercury (CH_3Hg^+). These organic Hg compounds are absorbed faster by organisms than elemental mercury (Hg^0), and act as neurotoxins that attack the central nervous system (D'Itri, 1972). They can be stored in body tissues and eventually accumulate in the brain where they destroy brain cells (D'Itri, I972).

Methyl mercury (CH_3Hg^+) is a poison that builds up in biological systems by bioaccumulation. Beginning at low concentrations in the lower trophic levels of algae and phytoplankton, it is biomagnified through the aquatic food chain and results in higher methyl mercury concentrations in larger predatory fish, and, eventually in humans that consume contaminated fish. Very low concentrations of Hg are capable of completely inhibiting ovarian recrudescence in fish. Exposure of catfish to $HgCl_2$ for 180 days completely arrested ovarian recrudescence (Kirubagarum and Joy, 1988). Birds and mammals can be affected when eating Hg-contaminated fish or other Hg-tainted foodstuffs. A dietary level of 5.0 mg·kg^{-1} of CH_3Hg^+ was sufficient to cause a certain degree of neurological impairment and death in zebra finches (Schenhammer, 1988).

Elemental mercury (Hg^0), if taken orally, is not absorbed quickly by the human body, and once ingested is excreted in urine (D'Itri, 1972). However, Hg^0 vapors which are absorbed through the lungs and accumulate in brain tissues are adverse to human health (D'Itri, 1972). For example, in the early 1900's, furriers who used Hg to improve felting qualities inhaled mercury vapor and developed persistent tremors and permanent brain damage; therefore, the phrase "mad as a hatter' was coined (D'Itri, 1972). Also, some miners in San Luis Obispo County, California who smelted cinnabar (HgS) in open-air smelters were exposed to Hg vapors and were described as having the shakes (personal communication, Raymond Dodd, Sr.; 10/31/92).

Mercury is able to form solid solutions with all the common metals, except for iron and platinum, becoming alloys called amalgams. In mercuric amalgams, the chemical reactivity of the metal dissolved is lowered. The chlor-alkali industry utilizes this principle to produce chlorine and caustic soda, and has been one of the largest Hg polluters (Adriano, 1986).

Factories producing polyvinyl chloride (PVC), using Hg as a catalyst, dumped mercuric chloride ($HgCl_2$) into Minamata Bay, Japan in the 1950's. Measurements of the sediment showed Hg concentrations up to 630 mg·kg^{-1} (Kudo and Hart, 1974). The $HgCl_2$ was biologically changed to CH_3Hg^+ and bioaccumulated in the fish and shellfish of the bay. Thirty six people died and 110 people developed Hg poisoning symptoms after eating Hg-contaminated fish and shellfish (D'Itri, 1972). High levels of CH_3Hg^+ still exist in the fish and shellfish of Minamata Bay (Nakamura et al., 1988).

Hg amalgams (Hg-silver alloys) used in dentistry accounted for the largest single release of Hg into the California environment (California Dept. of Public

Health, 1973). There are many current studies being conducted on the risks to dentists and patients of the use of Hg amalgams in dental fillings. One-third of all latex house paints sold today contain some Hg. The heavy Hg vapors concentrate close to the floor, resulting in a relatively high exposure risk for young children (Agocs et al., 1990)

Unborn fetuses of pregnant women are at high risk to CH_3Hg^+ poisoning. If pregnant women consume methyl mercury it can be transferred through the placenta into the fetus resulting in birth defects (Skertving, 1988). Infants may first be exposed to methyl mercury which occurs in the breast milk of their mothers. At an intake of 0.3 $\mu g \cdot Hg \cdot kg^{-1}$ body weight per day by the mother, the CH_3Hg^+ level in breast milk will be about 1.0 $\mu g \cdot Hg \cdot g^{-1}$. An infant's intake of breast milk may be as high as 0.15 $L \cdot kg^{-1}$ body weight per day which equals a CH_3Hg^+ exposure of 0.15 $\mu g \cdot Hg \cdot kg^{-1}$ body weight per day (Skerfving, 1988).

Recent reports state that Hg poisoning of local human populations in Hg mining areas in California has not been documented (Mining Waste Study Team, 1988). It might appear that chronic Hg poisoning is not presently a problem for humans due to mining activities. Nevertheless, in study conclusions of California mines, mercury contamination was considered to be the second most serious threat posed by state mining wastes (the principal threat was considered to be acid mine drainage) (Mining Waste Study Team, 1988). Mercury was thought to be a problem due to its persistent nature and its potential to biomagnify in the aqueous environments of lakes and reservoirs.

In spite of the Minamata case in Japan, no controlled studies of humans has been conducted in California to establish whether significant Hg uptake is taking place, or whether long term chronic exposure is leading to subtle health affects in potentially vulnerable human populations. In contrast, studies of fish populations in California lakes and reservoirs have found Hg levels in their tissues that exceed the FDA action limit (i.e., >1.0 $mg \cdot kg^{-1}$) (RWQCB, 1987).

2.3 Mercury Levels in the Environment

The focus of this section is to discuss the Hg concentration values reported in the literature for Hg found in the atmosphere, rocks, soils, sediments, and water. These values will be used later in the report for comparison with the Hg values found in the sediments, soils, and water in the Lake Nacimiento watershed.

2.3.1 Mercury in the Atmosphere

Mercury enters the atmosphere in both gaseous and particulate forms. The mobility of metallic Hg is greatly enhanced by its relatively high vapor pressure (Jenne, 1970). Mineral prospectors and public health inspectors use "mercury sniffers", instruments to detect airborne Hg, to detect the presence of atmospheric Hg.

Elemental Hg (Hg^0) is released into the atmosphere as a gas during organic matter decomposition, vegetative transpiration, and by soil heating. At an air temperature of 25°C, emission rates of Hg from a bare soil near the Almaden mine, Spain were 0.32 to 0.34 $\mu g \cdot m^{-2} \cdot hr^{-1}$; much greater than for vegetated soils which showed rates of 0.07 to 0.09 $\mu g \cdot m^{-2} \cdot hr^{-1}$ (Lindberg et al., 1979). Volcanoes are a major source of gaseous Hg release into the atmosphere. Volcanic derived soils in Hawaii have Hg concentrations double that of non-volcanic soils in the same region (Adriano, 1986).

Elemental Hg (Hg^0) is highly volatile, whereas the mercuric ion (Hg^{2+}) may be adsorbed to negatively charged colloids (Hoover, 1978). Concentrations of Hg^0 as high as 20 $\mu g \cdot m^{-3}$ have been measured in the atmosphere immediately over known Hg deposits (Gavis and Ferguson, 1972). In contrast, concentrations of Hg in the uncontaminated atmosphere range from 1 to 10 $ng \cdot m^{-3}$ (Adriano, 1986).

Dimethyl mercury ($(CH_3)_2$) is very volatile and escapes directly from soil or sediment. Methyl mercury is also volatile, but can be complexed with thiol groups of protein-derived organics and adsorbed to clay mineral particles. In an aerated microbasin of the Wabigoon River, a CH_3Hg^+ release of 60 $ng \cdot m^{-2} \cdot day^{-1}$ (Wright and Hamilton, 1982).

Mercury contamination of remote lakes in Wisconsin and Minnesota, where no terrestrial Hg sources are known, has been attributed to increasing deposition of atmospheric Hg over the past one hundred years (Swain et al., 1992).

2.3.2 Mercury Levels in Rocks

Mercury concentration values in rocks, sediments, and soils are reported in many different units in the literature, including parts per million (ppm), parts per billion (ppb), $mg \cdot kg^{-1}$ and $\mu g \cdot kg^{-1}$ (where 1 ppm Hg in rock = 1 mg $Hg \cdot kg^{-1}$ rock; and 1 ppb Hg in rock = 1 μg $Hg \cdot kg^{-1}$). Throughout this report the values, $mg \cdot kg^{-1}$ and $\mu g \cdot kg^{-1}$, will be used to discuss the Hg levels in all solid inorganic or organic materials.

Levels of Hg in the environment, especially in rocks, soil, and sediment, vary according to the location and geology present. Since "background" Hg levels vary according to geographic location, it is difficult to predict what levels are normal and what levels are high. However, an estimate can made by examining reported Hg levels in the literature.

A wide range of Hg levels (0.01-6.0 $mg \cdot kg^{-1}$) has been reported for rock samples collected (Pierce et al., 1970). This variability indicates that the levels of natural Hg concentrations are relatively complex functions of geological mineralization. Therefore, criteria for either Hg mineralization or abnormal Hg contamination should be evaluated separately in any single area of interest.

Concentrations of 0.05-0.2 $mg \cdot kg^{-1}$ Hg are common in rocks. Values tend to be much higher in areas with known Hg concentrations. Data collected near a mine in the Aurora district, along the California-Nevada border, showed Hg levels in non-ore rocks of 0.01-0.8 $mg \cdot kg^{-1}$, with 90% of the samples having levels of <0.49 $mg \cdot kg^{-1}$ Mercury ore samples taken from the mine showed levels of 1,000-8,000 $mg \cdot kg^{-1}$, (0.1-0.8% Hg); this represents an increase by a order of magnitude of 4 (i.e., an increase of 10^4), comparing rocks near the mine with the ore body rocks (Pierce et al., 1970). Other reports show that Hg concentration in rock ranges from 0.005 to 1.0 $mg \cdot kg^{-1}$, averaging <0.20 $mg \cdot kg^{-1}$, with sedimentary shales showing higher concentrations than igneous rocks (Adriano, 1986). Hg levels, calculated from reports on the ore deposits in San Luis Obispo county, California, range from 1,000 to 15,000 $mg \cdot kg^{-1}$ (Eckel et al., 1941). Mine wastes have been reported to contain up to 125 to 4,500 $mg \cdot kg^{-1}$ (SWRCB, 1991).

Weathering and erosion expose the mineral cinnabar, (mercuric sulfide, HgS), to physical, chemical, and biological processes, which can alter HgS to Hg^0, Hg^{2+}, or to organo-derivatives. Transport and deposition of eroded HgS is an important factor in Hg contamination of river drainage systems (Harsh and Doner, 1981). It is estimated that ten billion (10^{10}) metric tons of rock of all kinds are weathered per year on earth (Gavis and Ferguson, 1972). Worldwide, at a conservative rock Hg content of 0.080 $mg \cdot kg^{-1}$, 800 metric tons of Hg are released from weathering rock each year into the environment (Gavis and Ferguson, 1972).

2.3.3 Mercury Levels in Soils

The average background Hg level of U. S. surface soils are estimated to be 0.071 $mg \cdot kg^{-1}$ (National Research Council, 1978; Dudas and Pawluk, 1976). Another report stated that, in most soils, background Hg levels range from 0.030 to 0.20 $mg \cdot kg^{-1}$; the amount of Hg depending on the type of parent material present (Adriano, 1986). Mean natural background levels of Hg in Ontario, Canada agricultural soils derived from Paleozoic sedimentary rocks composed of limestones and red shales were 0.080 $mg \cdot kg^{-1}$ (Lockwood and Chen, 1973).

The average concentration of Hg in California surface soils is 0.070 $mg \cdot kg^{-1}$ (Calif. Dept. of Public Health, 1973). California soils in unmineralized areas were reported to contain Hg levels from 0.02-0.04 $mg \cdot kg^{-1}$ (Williston, 1968), and up to 0.04-0.06 $mg \cdot kg^{-1}$ (Friedrich and Hawkes, 1966). The Franciscan Formation is the California geologic unit where known deposits of cinnabar occur. Hg levels in soils associated with the Franciscan Formation rocks are reported to be 0.1-0.2 $mg \cdot kg^{-1}$, up to 3 times the average Hg levels reported (Williston, 1968).

Hg is concentrated in the soils adjacent to Hg ore mining areas through atmospheric and erosional deposition. Surface soils near the Almaden mine in Spain showed a two- to three-fold increase in concentrations of Hg compared to soils in non-mined areas (Lindberg et al., 1979). Soil near a Hg mine in Nifu, Japan showed a Hg concentration of 100 $mg \cdot kg^{-1}$ (Adriano, 1986). Total Hg extracted from an alluvial soil on the banks of James Creek, Napa Co., California where Hg tailings from the Oat Hill Mine had accumulated, were recorded at approximately 540 mg·kg^{-1} (Harsh and Doner, 1981). Major sources of Hg in mining areas include the chemical weathering of residual cinnabar, wet and dry deposition of Hg^0 released during mining/roasting operations, and the fallout of resuspended mine tailings (Lindberg et al., 1979). The average Hg content of soils collected near mercury mine sources ranges from 2.5 to 10.0 mg·kg^{-1} (Pierce et al., 1970).

The mercury content of soils varies considerably. Soils unaffected by Hg contamination varied from 0.01 to 0.05 mg·kg^{-1}. In contrast, soils near Hg deposits had Hg levels from 0.25 to 2.50 mg·kg^{-1} (Warren et al., 1966). In other Hg mineralization areas, soils commonly contained 10.0 to 20.0 mg·kg^{-1} Hg, but ranged from 1.0 to 50.0 mg·kg^{-1} Hg (Jenne, 1970). It has been suggested that in regions where the soil B and C horizons (subsoils) contain more Hg than in A horizons (topsoils) it is probable that there is Hg mineralization in the immediate (Warren et al., 1966).

Mercury laden dust is removed from the atmosphere and reaches the earth's surface soils as precipitation condensation nuclei. The average concentration of Hg in rainwater is 0.2 μg·kg^{-1} (Eichholz et al., 1988). When Hg enters the soil, it can be adsorbed by soil mineral colloids or organic complexes, precipitated as insoluble compounds, leached to lower depths, evaporated back to the atmosphere, or slowly absorbed by plants.

2.3.4 Mercury Levels in Natural Water Systems and Aqueous Sediments

Mercury concentration values in water are reported in many different units in the literature, including parts per million (ppm), parts per billion (ppb), mg·L^{-1}, and μg·L^{-1} (where 1 ppm Hg in water = 1 mg Hg·L^{-1} water; and 1 ppb Hg in water = 1 μg Hg·L^{-1} water). Throughout this report the values, mg·L^{-1} and μg·L^{-1}, will be used to discuss the Hg levels in water.

Mercury enters natural water systems in various chemical forms via rainwater, dust fallout, or water and sediment runoff. Most of the Hg in natural water systems is associated with suspended particulates (Gavis and Ferguson, 1972; Mining Waste Study Team, 1988). Mercury levels are usually less in natural waters draining from abandoned Hg mines as compared with the Hg levels found in adjacent sediments (Hines, 1971).

The Hg content of freshwaters in the United States rarely exceed 5 $\mu g \cdot L^{-1}$ with typical values usually less than 1 $\mu g \cdot L^{-1}$ (Mining Waste Study Team, 1988). There have been reported instances where Hg values in water were as high as 80 $\mu g \cdot L^{-1}$ associated in active Hg mines (Mining Waste Study Team, 1988).

In stream sediments studied by the U. S. Geological Survey, less than 20% of the samples had Hg concentrations higher than 1.0 $mg \cdot kg^{-1}$. Freshwater sediment levels tend to be similar to the levels found in soils (Pierce et al., 1970). Concentrations of total Hg in most natural water systems range from 0.03 to 0.08 $mg \cdot L^{-1}$, but in polluted waters concentrations may range as high as 37.0 $mg \cdot L^{-1}$ (National Research Council, 1978).

The sediments of reservoirs and lakes act as chemical sinks, especially when located in deep troughs or cavities that restrict the removal of sediments by currents. In deep sediments of the Puget Sound, Washington, Hg concentrations were 0.511 $mg \cdot kg^{-1}$ (Crecelius et al., 1975). In Lake Powell, Arizona, Hg in bottom sediments near the dam averages 0.049 $mg \cdot kg^{-1}$, whereas rock strata near the lake averages 0.021 $mg \cdot kg^{-1}$ (Potter et al., 1975).

Inorganic and organic Hg-laden particles can settle in water and accumulate in bottom sediments. In the Southern Indian Lake-Totigi Reservoir area, Manitoba, Canada, mean total Hg concentrations (in units of $mg \cdot kg^{-1}$) of various source materials were as follows; moss, detritus, and humus (0.095), soil

A horizon (0.090), soil C horizon (0.041), lake sediment (0.036), suspended sediment (0.255), and water ($<5.0 \times 10^{-6}$) (Bodaly et al., 1984).

2.4 Forms of Mercury Found in the Environment

The following section will focus on the many mercury forms potentially found in the environment. There will be some brief discussion of the conditions and reactions that determine the presence of any one mercury form. Discussions in later sections will expand on the many processes and reactions of mercury in the environment. Much of the following discussion on the forms of mercury found in the environment is derived from Lindsay, 1979 and unless otherwise stated is from this reference.

2.4.1 Mercury Measurement

Measurement of mercury levels in the environment usually involves assaying a sample for total mercury. A speciation analysis of different mercury forms present in the sample is not a normal procedure, and is difficult to perform. However, knowledge of the speciation of mercury in the environment is often important. The type of Hg species found in water, sediment, soil, rock and the atmosphere allows a better understanding of the possible pathways of mercury interaction in the environment.

2.4.2 Mercury Elemental and Ionic Forms

Mercury can exist in three oxidation states, the mercuric ion (Hg^{2+}), the mercurous ion (Hg^{+}), and in the elemental state (Hg^{0}). The ability for mercury to exist in these three oxidation states allows for many reactions to occur under various environmental conditions. The ability for a certain species to form depends on many factors such as redox potential, pH, ion concentration, type of ions present, bacterial concentration and type, organic matter concentration, and other factors (Gavis and Ferguson, 1972). The combination of these factors makes prediction of the Hg species present under any set of environmental conditions very difficult.

In the aqueous phase, Hg^{2+} is the stable species under most conditions, while Hg^0 is oxidized under oxygenated conditions. The Hg^{2+} ion is complexed with inorganic ligands in aqueous solutions. In natural waters, Hg^{2+} behavior is dependent on precipitation, complexation, chelation, redox, sorption, and methylation (Newton et al., 1976). In oxidizing sediments that have Hg concentrations of 2 to 10 $mg{\cdot}kg^{-1}$, the rate of Hg loss appears to follow first order kinetics with a half-life of about 1.3 years (Crecelius et al., 1975).

Hg^0 is volatile with a vapor pressure of 1.2 x 10^{-3} mm of Hg. Elemental Hg is nearly insoluble, with a commonly accepted solubility limit being 70 $\mu g{\cdot}kg^{-1}$; thus soil leachates are usually low in elemental Hg (Eichholz et al., 1988). The Hg(1) state is much less stable than the Hg^{2+} ion, with Hg_2I_2 being the most stable of the Hg(1) minerals (Lindsay, 1979). Hg(1) acts as an intermediate in the oxidation or reduction of the Hg^0 and Hg^{2+} forms. The Hg^{2+} ion is the most stable of the three oxidation states, and increases with an increase in the redox potential (Lindsay, 1979).

Many mercury compounds are readily precipitated from aqueous solutions. Therefore, mercury levels are typically higher in sediment samples than in adjacent water samples. Soluble Hg compounds are mostly weak electrolytes. Hg(II) complexes are generally more stable than the same complexes of Hg(1), since the addition of complexing agents to Hg(1) compounds in aqueous solutions often leads to the disproportionation reaction to Hg^0(liq) and Hg^{2+}. Hg exists as discrete Hg_2^{2+} ions and these

Hg_2^{2+} (aq) ions are important components in aqueous solutions (Hepler and Olofsson, 1974.)

2.4.3 Mercury Halides and Oxides

In the soil, the halides of mercury, $HgCl_2$ and $HgBr_2$, are usually more soluble than the oxides and hydroxides. The oxides of Hg(II), in order of decreasing solubility, are; $Hg(OH)_2$ > HgO(red, hexagonal) > HgO(yellow, orthorhombic) > HgO(red, orthorhombic). Below a pH of 6, $HgCl_2$ and $HgBr_2$ may be more stable than the HgO minerals depending on the Cl^- and Br^- activities.

Of the Hg(II) minerals listed above, HgI_2 is the most insoluble. The ability of this compound to control the level of Hg activity in the soil depends on whether the molar ratio of Hg to I is >0.5; then the Hg would utilize all of the available I^- and HgO(red) would form and control the Hg(II) activity.

Other oxides, such as Fe- and Mn-oxides, can affect Hg levels in soils and sediments. When Fe- and Mn-oxides are formed (under high redox potentials), Hg can be co-precipitated and be included in the insoluble complexes. When redox potential is lowered, these oxides can be redissolved and Hg can be released (Fagerstrom and Jernelov, 1972).

The concentration of other anions in the solution will affect the type and amount of Hg minerals that will form. For instance, before HgO(red) can form, the complex $Hg(OH)_2^0$ must reach equilibrium. HgO(red) will form when the soil concentration is $>3.61\ mg \cdot kg^{-1}$ Hg . Therefore, important factors affecting the Hg species that will form include the types of anions present and the ambient mercury levels.

2.4.4 Mercury Inorganic Complexes

The Hg(1) minerals also form complexes in the soil, with Hg_2I_2 being the most stable. The compounds, Hg_2SO_4, $HgCO_3$, and $Hg_2(OH)_2$, are too soluble to precipitate in soils. $HgHPO_4$ can form small amounts of precipitates in most soils and formation depends on the soil phosphate activity. Hg(1) species are sufficiently weak that Hg_2^{2+} is the major species in solution.

Ammonia (NH_3) and ammonium (NH_4^+) are products of aerobic organic matter decomposition in soils. Ammonia complexes of Hg occur only after equilibrium with HgO(red) is attained. $Hg(NH_4)_2$ complex is the most stable of the different complexes that include $Hg(NH_3)_2^{2+}$, $Hg(NH_3)_3^{2+}$, and $HgNH_3^{2+}$.

The interaction of Hg(II), Hg(1), and liquid Hg to form specific complexes make prediction of Hg precipitate formation very difficult. However, under general conditions, 97.5% of the species in soil solution will be HgI_2^o, the Hg(II) form, with the remaining 2.5% being Hg(1) and liquid Hg. Under conditions of Hg levels $<0.013\ mg \cdot kg^{-1}$, Hg_2I_2 would not precipitate. Soils with higher levels of Hg will tend to precipitate Hg as Hg(1) species and liquid Hg.

2.4.5 Liquid Mercury

Elemental mercury exists as a liquid at ordinary temperatures and pressures, and as such, maintains a vapor pressure of $2x10^{-3}$ mm of Hg, which can supply a significant amount of Hg cycling into the atmospheric environment. Liquid mercury can oxidize to Hg_2^{2+}, but Hg^0 will form only at Eh>314 mV (pE>5.3). Therefore, liquid Hg can be oxidized only under highly oxidative conditions, rarely found under normal ambient environmental conditions.

2.4.6 Mercury Sulfides and Sulfates

Mercuric sulfide has an extremely low solubility in water and forms when divalent mercury (Hg^{2+}) and sulfide (S^{2-}) ions are present. HgS can also form from methyl mercury if sulfide ions are present. The equilibrium, ($2\ CH_3Hg^+ + Hg^{2+} <=> (CH_3)_2Hg$), can be moved to the right if Hg^{2+} is removed from solution through the formation of HgS. Divalent mercury ions (Hg^{2+}) can be released from HgS in connection with the oxidation of sulfide to sulfate ($HgS + 2O_2 <=> Hg^{2+} + SO_4^{2-}$) (Fagerstrom and Jernelov, 1972). When soils that contain sulfate (SO_4^{2-}) are reduced, S^{2-} levels increase, and most metals are precipitated as sulfides.

Both pH and Eh (pE) affect the formation and precipitation of Hg as sulfide complexes. At high Eh levels and increasing pH levels the most significant form is liquid Hg. As Eh and pH decrease even more, Hg precipitates as Hg_2S or Hg(1). As pH and Eh decrease, Hg precipitates in the form of HgS (cinnabar, red).

2.4.7 Organo-mercurial Compounds

Through the process of methylation, both anaerobic and aerobic bacteria transform Hg^{2+} into the methyl- and dimethyl-mercury (CH_3Hg^+ and CH_3HgCH_3) forms. The CH_3HgCH_3 form is much more volatile than the CH_3Hg^+ form. Both forms diffuse through the water, and because both forms are highly soluble in lipids, their absorption by aquatic organisms is facilitated (Gavis and Ferguson, 1972).

Formation of organomercurial compounds has been shown to occur by several different pathways. Methylation of Hg(II) to methyl mercury has received the most attention in the literature, due to the fact that methyl mercury was the first major organic compound found to be the cause of serious environmental health hazards. The Minamata Bay case in Japan discussed earlier, which involved human death by methyl mercury poisoning, brought attention to this newly identified form of mercury which could adversely affect environmental quality and human health (D'Itri, 1972).

Other forms of organic mercury found in the environment are dimethyl mercury, diethyl mercury, and other alkyl chained mercury compounds. Not as much information has been gathered on these compounds as for methyl mercury. The organomercurials listed below are several of the most common forms:
Arylmercurial: benzene ring Hg;
Alkylmercurial: R-Hg, where R can be methyl, ethyl, etc.;
Alkoxyalkylmercurial: R-O-Hg, where R can be methyl, ethyl, etc.

2.4.8 Mercury in Open Environmental Systems

Many of the chemical reactions and mercury forms discussed above were studied under controlled laboratory conditions, which will likely vary from open system conditions. Chemical remediation of Hg contamination in an open environment must take into account open system variation and realize that when conditions, such as molar concentrations of ions in solution, pH, Eh, and bacterial levels, vary, the Hg species that forms will likely be different.

A good example of the complexity of the speciation of Hg can be seen in the phase diagram shown in Figure 2-1 (Hem, 1970).

Certain forms of mercury, such as HgS, HgI, and HgO, are less damaging, more stable, and less likely to react in various environments. The ability to stabilize mercury in these less reactive forms allows control of the adverse impact of mercury on environmental quality, and may affect remediation of Hg mine waste.

2.5 Mercury Processes in the Environment

This section will focus on the various processes and reactions that determine the forms of mercury found in the environment. The many reactions that determine the Hg species which will be found in an environment are complex and some reactions are not fully understood. The discussion will also examine the processes by which mercury is able to convert between inorganic and organic forms that adversely affect environmental quality.

2.5.1 The Mercury Cycle in Freshwater Systems

An equilibrium over time exists between the Hg contents in the atmosphere, particulate matter, bodies of water, and rocks and soils of the earth's surface (Gavis and Ferguson, 1972). In areas where Hg ore is mined and processed, and in areas of industrial and agricultural Hg use, the natural Hg cycle is altered and may result in detrimental environmental damage. The Hg cycle, illustrating Hg pathways to freshwater system organisms, is represented in Figure 2-2 (Allan, 1986; Chamberlin et al., 1990).

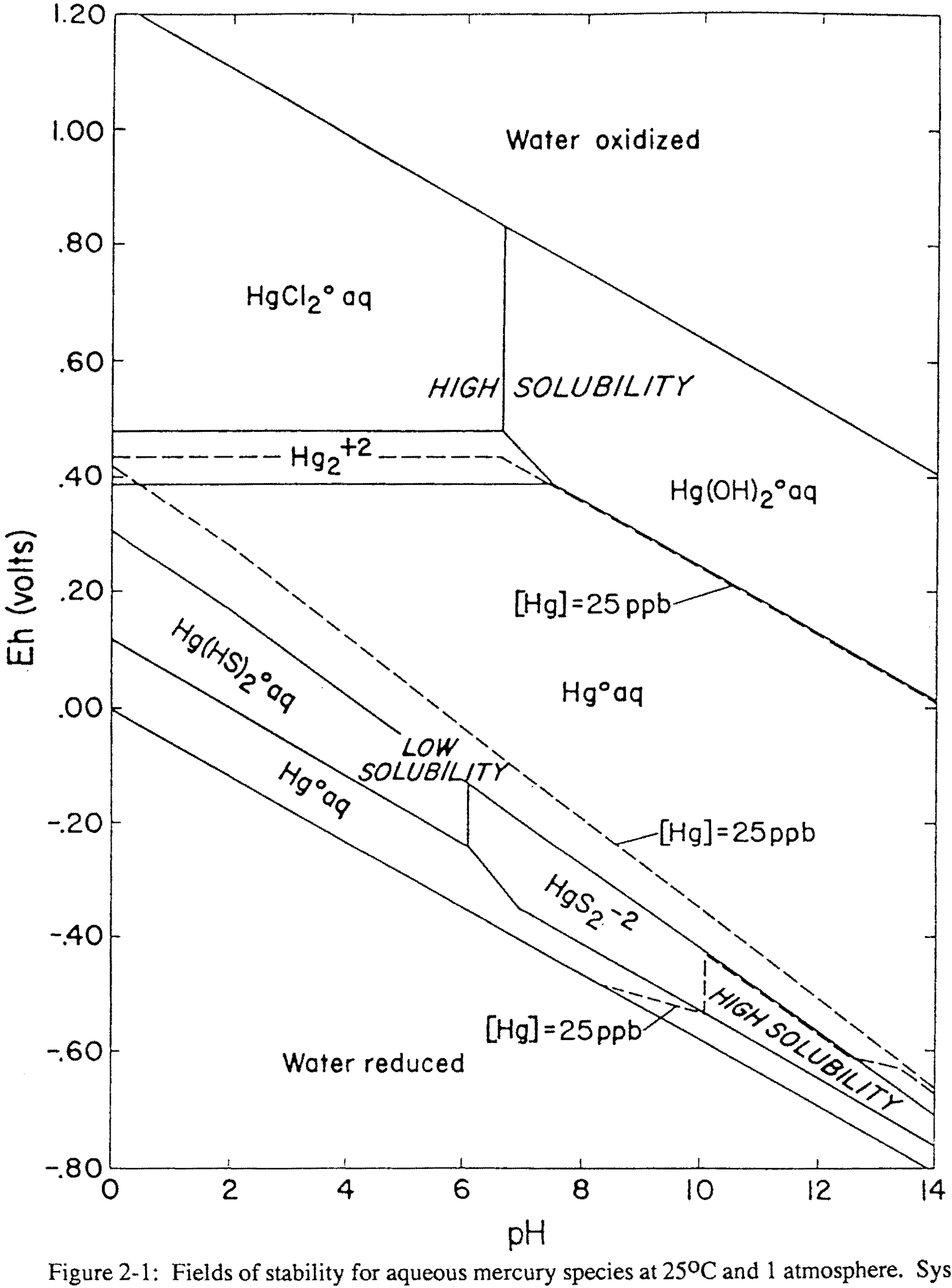


Figure 2-1: Fields of stability for aqueous mercury species at 25°C and 1 atmosphere. System includes water containing 25 ppm Cl^-, total sulfur 96 ppm as sulfate. Dashed line indicates approximate solubility of mercury in this system. (Source: Hem, 1970).

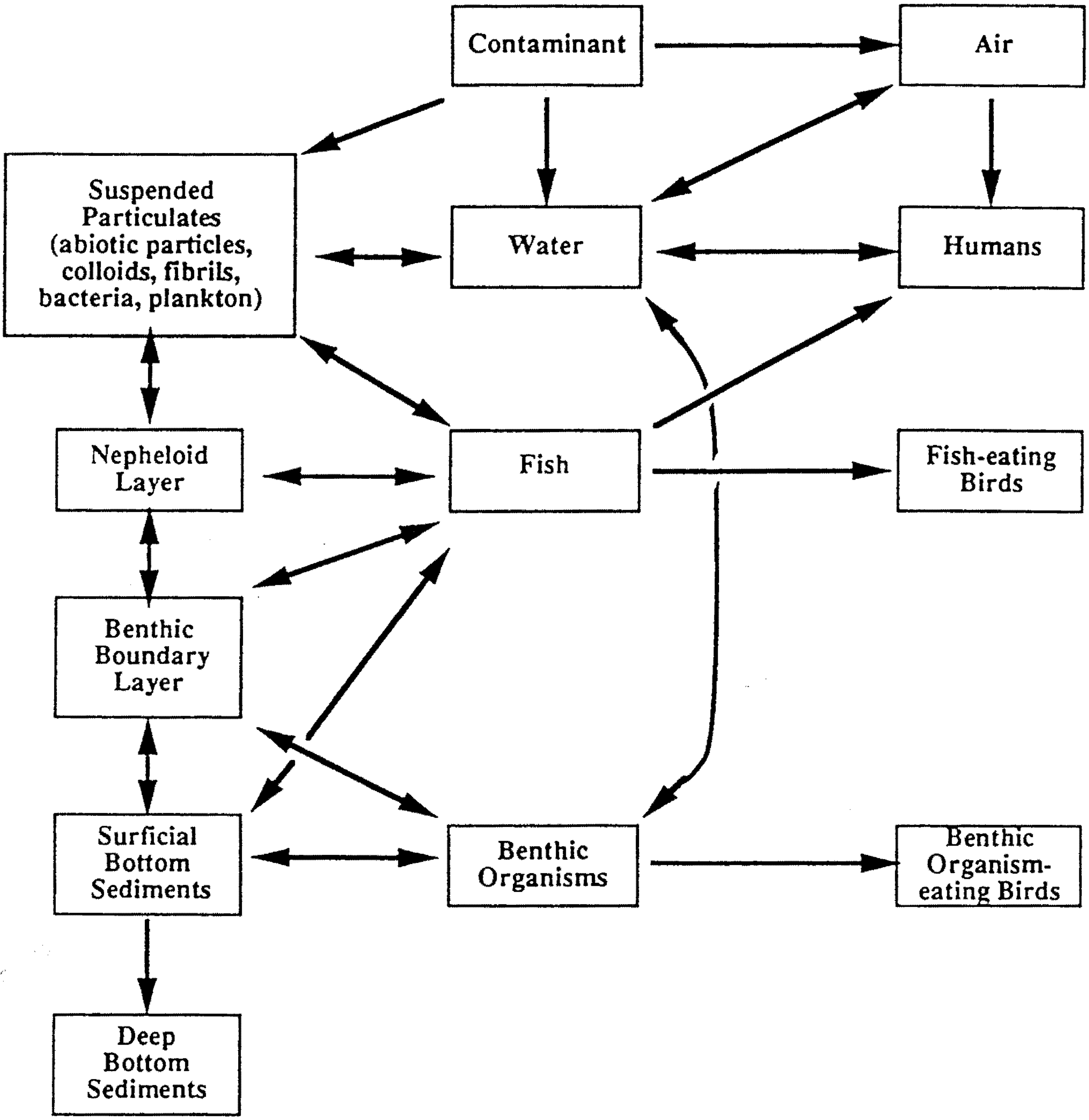


Figure 2-2: Mercury Pathways from Sediments to Fish, Birds, and Humans in Freshwater Systems (Source: Allen, 1986).

2.5.2 Inorganic Chemistry and Equilibria of Mercury

Many sediments exist under conditions where Eh values range from -200 to +400 mV, at pH 7 (Wollast et al., 1975). Under these conditions both aerobic and anaerobic characteristics are displayed, resulting in a mixed chemistry where oxygen and sulfides are not present at eqililibrium. Small changes in redox potential (Eh) affect both the mixed microbiology present as well as the mixed chemistry (Bartlett and Craig, 1981).

At low redox potentials, Hg^{2+} can be reduced to Hg^0. Bacteria can detoxify Hg^{2+} in their environment through biological reduction to Hg^0, which is highly volatile. Oxidation of Hg^0 takes place in aquatic environments when organic substances and oxygen are present. At a Hg concentration of 2 $mg \cdot kg^{-1}$, a redox potential of +80 mV is sufficient to oxidize Hg^0 to Hg^{2+} (Hahne and Kroontje, 1973). Elemental mercury (Hg^0) oxidizes to Hg^{2+}, then mercuric oxide (HgO) forms, and finally hydrolysis results in the formation of relatively soluble mercuric hydroxide [$Hg(OH)_2$]. Above pH 7, the uncharged metal oxide hydrate, $Hg(OH)_2$, is the dominant species of Hg (Lindsay, 1979).

In reducing sediments of low redox potential, Hg^{2+} is immobilized by the sulfide ion S^{2-} forming HgS. Below an Eh of -100 mV, HgS becomes more stable and little is available for methylation (Bartlett and Craig, 1981). Further reduction and decline in pH creates a highly reduced state and increases the solubility, resulting in an excess of free S^{2-} ions present that form soluble polysulfide complexes (HgS_2^{2-} ions) (Fagerstrom and Jernelov, 1972; Lindberg and Hamss, 1974). Between an Eh of -100 and +100, HgS becomes unstable, and CH_3Hg^+ increases as more Hg^{2+} becomes available (Bartlett and Craig, 1981). Above Eh levels of +100, S^{2-} levels are near zero.

Mercuric sulfide (HgS) is almost totally insoluble in water with a Ksp (equilibrium constant) of about 10^{-53} (Helgeson, 1969). This indicates that HgS is formed not only from Hg^{2+} and S^{2-} ions ($Hg^{2+} + S^{2-} \Rightarrow HgS$), but that Hg also may accept the S^{2-} ion from other sulfides like iron sulfides (FeS) and copper sulfides (CuS) (Fagerstrom and Jernelov, 1972). Near a neutral pH, HgS is unstable in soil solutions in equilibrium with atmospheric oxygen. Thus, in alluvium under oxidizing conditions, HgS should not be expected to be a thermodynamically stable mineral (Lindsay, 1979). Its persistence as an insoluble mineral depends upon the kinetic favorability of oxidation and the kinetic favorability of weathering due to its size and structure (Lindsay, 1979). Under oxidizing conditions, the oxidation of sulfides to sulfates (conversion of HgS) takes place by the following reaction; ($HgS + 2O_2 = Hg^{2+} + S0_4^{2-}$).

The formation of complexes of ferric oxides (Fe_2O_3) and manganese oxides (MnO_2) is dependent on the redox potential and oxygen content of the water or sediment. Under reducing conditions, where oxygen concentration is below 0.5 to 1 $mg \cdot kg^{-1}$, iron and manganese are reduced to divalent forms and redissolved in water, releasing Hg^{2+} (Fagerstrom and Jernelov, 1972). An excess of ferrous iron in the surface sediments can bind sulfide as iron sulfide (FeS) and inhibit its usefulness as a Hg-binding agent (Rudd et al., 1983).

2.5.3 Mercury Adsorption by Sediments and Soils

Mercury can bond to both soil inorganic and organic components and tends to accumulate in surface soil horizons. In the top 30 cm of an Oxbow soil, total Hg concentration was 59 $\mu g \cdot kg^{-1}$, as compared to 24 $\mu g \cdot kg^{-1}$ Hg in soil from a depth of 30 to 60 cm (Hogg et al., 1978). The retention of Hg in soil and sediments is due to ionic adsorption by both inorganic and organic fractions (Adriano, 1986). Clay and organic matter particles in soils are negatively charged and can attract the positively charged Hg^{2+} ion (Hannan and Thompson, 1977).

Soil adsorption of Hg depends on the chemical form of Hg present, the structural type, amount, and chemical nature of inorganic and organic soil colloids, soil pH, soil texture, and the type of cations present on the exchange complex (Hogg et al., 1978). The type of clay mineral and soil texture determines the rate and amount of Hg adsorption. Smectite clays have higher adsorptive capacities for Hg than kaolinitic clays.
Clay minerals exhibit maximum adsorption of Hg at pH 7, while organic soils exhibit maximum adsorption at lower pH's (Newton et al., 1976). More than 50% of the total Hg content of some soils is found in particles <0.005 mm in size (Adriano, 1986).

In a Brown Chernozem soil (now called Mollisols), the Hg contents of the sand, silt, and clay fractions were 13, 18, and 69 $\mu g \cdot kg^{-1}$, respectively. In a Gray Luvisol soil (now called Alfisols), the Hg contents of the sand, silt, and clay fractions were 7, 99, and 370 $\mu g \cdot kg^{-1}$, respectively (Dudas and Pawluk, 1976). In coarse-textured soils, the volatilized loss of Hg is greater than in fine-textured soils. Sandy soils amended with 20 ug·Hg per 20 g soil, lost 43% of added mercury in six days; whereas, the clay soil lost only 20% of the applied Hg (Rogers and McFarlane, 1979).

2.5.4 Effect of Chlorides and Iron on Mercury Adsorption

The adsorption of Hg^{2+} to mineral particles and clays tends to decrease with an increase in chloride (Cl^-) concentrations. The Cl^- ion reduces the stability of Hg in the sediments and maintains the organic and inorganic Hg in a chloride complex, unless the pH is high (Reimers and Krenkel, 1974). Chloride concentrations of 10,000 $mg \cdot kg^{-1}$ reduced Hg adsorption by 30 percent on illite, and by 60 percent on montmorillonite (Reimers and Krenkel, 1974). The adsorption of Hg^{2+} by hydrous iron oxide gels is inhibited by chlorides because of the linear configuration of the Hg-Cl complexes which make multidentate bonding difficult (Kinnibergh and Jackson, 1978).

The uptake rate and capacity for inorganic $HgCl_2$ is given in the following order: R-SH (mercaptans) >> illite > montmorillonite > R-NH_2 (amines) > kaolinite > carboxyl groups > fine sand > medium sand >coarse sand (Reimers and Krenkel, 1974). Organic functional groups do not show a Cl^- effect on their adsorption of Hg^{2+} (Reimers and Krenkel, 1974).

Below pH 4, a Cl^- ion concentration of only 1.1 $mg \cdot kg^{-1}$ is sufficient to convert nearly all Hg^{2+} to $HgCl_2$. The result is that precipitation of $Hg(OH)_2$ and adsorption of Hg^{2+} and $HgOH^+$ on inorganic sediment and suspended particles is prevented (Hahne and Kroontje, 1973). At pH 5, a Cl^- ion concentration of 14 $mg \cdot kg^{-1}$ is sufficient for all Hg^{2+} to be in the $HgCl_2^0$ form (Hahne and Kroontje, 1973). From pH's 6 to 9, which are common in lakes and streams, partial mobilization is possible, depending on the concentration of chlorine present (Hahne and Kroontje, 1973). Surface waters of fresh water lakes exhibit Eh potentials near 0.5 V (500 mV), since the redox potentials are only sensitive to very small dissolved oxygen concentrations. Therefore, $Hg(OH)_2$ and $HgCl_2$ are predominate species in most surface waters (Gavis and Ferguson, 1972).

It is common in acid mine drainage waters to have pH's below 4. Chloride concentrations of acid mine drainages can range from 4 to 35 $mg \cdot kg^{-1}$. These concentrations are high enough to mobilize more than 95% of the soluble inorganic Hg^{2+} in the form of $HgCl_2$, at pH 5 (Hahne and Kroontje, 1973). Chloride complexes compete effectively with the hydroxy complexes of Hg^{2+}. In oxygenated water, the solubility of Hg increases as $Hg(0H)_2$ forms in solution. In chloride-rich acidic water, Hg increases as undissociated $HgCl_2$ forms (Gavis and Ferguson, 1972).

The presence of Cl^- and ferric iron (Fe^{3+}) increased the rate of Hg^{2+} release from HgS (Burkstaller et al., 1975). Cinnabar exposed to a combination of 18 mM Fe^{3+} and 54 mM Cl^- for 80 days released Hg to solution at a rate of $>5.0\ mg \cdot L^{-1}$, as compared to a control sample release rate of $0.015\ mg \cdot L^{-1}$ (Burkstaller et al., 1975). These rates were more than one order of magnitude greater than a system without Fe^{3+} and with Cl^-; and two orders of magnitude greater than a system with Fe^{3+} and without Cl^- (Burkstaller et al., 1975). Ferric iron commonly occurs in acid drainage waters from mining areas. This indicates that significant rates of oxidation of cinnabar and release of Hg to solution can occur under conditions prevalent in acid mine drainage waters. In the process, Hg^{2+} released may be readsorbed by HgS or combine with Cl^- removing the anion from solution. Mercuric ions released may also bond to clay- and silt-sized suspended sediment. This supports the contention that Hg^{2+} is transported in water systems in association with sediments (Reimers and Krenkel, 1974).

2.5.5 Mercury Adsorption by Soil Organic Matter (SOM) and Iron and Manganese Oxides

Mercury (II) is strongly bound to soil organic matter (SOM), frequently to amine or thiol groups, and is relatively free of attack by acids, chelates, weak bases, or chlorines (Reimers and Krenkel, 1974). Inorganic sulfides and long chain alkyl thiols (R-SH) are the most effective Hg binding agents (Hannan and Thompson, 1977). Proteins with R-SH groups and the humic acid fraction of SOM in sediments contain favorable binding sites for Hg (Crecelius et al., 1975). Even low humus contents are sufficient to adsorb large amounts of Hg because of an abundance of sites with high bonding energies (Lodenius et al., 1987). Oxidation of sediment may reduce the Hg bonding capacity of the large molecular weight humic materials through SOM decomposition (Gambrell et al., 1980).

Asquith and Oxbow soils with 2.98% organic C at 0-15 cm depth and 0.62% organic C at 15-30 cm depth, had levels of total Hg at 37 and 22 $\mu g \cdot kg^{-1}$, respectively (Hogg et al., 1978). The increased amount of total Hg in the surface horizon is likely due to more cation exchange sites in the organic matter.

The Hg^{2+} ion is also adsorbed by other soil materials, in addition to the aluminosilicate clays and SOM. There is specific adsorption of the Hg^{2+} ion on hydrous iron oxides and on hydrous manganese oxides (Harsh and Doner, 1981). At pH's between 6.5 and 7.0, iron oxides adsorb large quantities of Hg (Burkstaller et al., 1975). These complexes also co-precipitate heavy metals other than Hg. An adsorption selectivity sequence on hydrous iron oxide gels (pH 4.5) was determined as follows: $Pb > Hg = Cu > Zn > Ni > Cd > Co > Sr > Mn$ (Kinnibergh and Jackson, 1978).

In freshwater lakes and streams, amorphous manganese oxides (Mn-oxides) have large adsorption capacities, up to 10% by weight (Lockwood and Chen, 1973). Adsorption of cations on Mn-oxides is attributed to ion exchange on the surface of the precipitate. Mercuric hydroxide [$Hg(OH)_2$] is the main actively adsorbed species (Lockwood and Chen, 1973).

2.5.6 Organic Chemical Bonding of Mercury

Mercury (II) bonds to sulfhydryl groups (-SH) that are attached to carbon atoms within molecules of suspended organic matter. In organic matter, sulfhydryl groups are contained in proteins through their incorporation of the amino acid cysteine [$H_2NCH(COOH)CH_2SH$] (Gavis and Ferguson, 1972). These compounds are capable of inactivating many enzyme systems, particularly those requiring reduced -SH groups for activity (Rath et al., 1986). The Gibbs free energy of formation (ΔG^0) for Hg^{2+} and cysteine at 25°C is about -57 kcal·mol^{-1} (Gavis and Ferguson, 1972). This indicates that Hg^{2+} will bind to organic particles as soon as they are available, and that a large amount of Hg in water is associated with suspended organic sediment (Fagerstrom and Jernelov, 1972).

Mercury also bonds to carbon in organic groups. Mercury combines with one carbon atom to form CH_3Hg^+, and with two carbon atoms to form CH_3HgCH_3. Bacteria synthesize CH_3Hg^+ and CH_3HgCH_3 by obtaining Hg^{2+} in solution. These compounds are thermodynamically unstable in water and, therefore, do not appear in Eh-pH diagrams. These Hg-containing organic compounds are thermodynamically unstable under natural conditions. The Hg-C bond is a weak one with an energy of formation of only 15-19 kcal·mol^{-1}, depending on the organic residue to which Hg is bound (Gavis and Ferguson, 1972).

2.5.7 Methylation of Mercury

The formation processes of organic mercury compounds are not completely understood, although many processes and reactions have been studied. Early research studies isolated several bacteria that contained enzymes which were able to methylate Hg(II). Enzymes, methyl-B_{12}, methyltetrahydrofolate, and S-adenosylmethionine were found to methylate Hg(II).

Some early hypotheses thought methylation of Hg could occur only under anaerobic conditions, but later studies have shown that methylation occurs under both anaerobic and aerobic conditions (D'Itri, 1972). When sediment containing mercury was exposed to the air, the rate of biological methylation increased by 10^3 to 10^4 times the normal methylation rate

(Fagerstrom and Jernelov, 1972). This result can be better understood when the bacteria involved are identified. When bacteria that normally do not methylate under anaerobic conditions are exposed to oxygen, they may use the mercury as a energy source and increased methylation can occur.

Only free Hg^{2+} is considered directly available for methylation (Jackson, 1986). The supply of Hg^{2+} is a function of the following environmental variables: redox potential (Eh), temperature, sulfide and oxygen concentration, nutrient supply, percent SOM, particle size distribution, and the amount of hydrated oxides, chlorines, and other complexing agents which determine the oxidation state, speciation, and solubility of the inorganic Hg (Jackson, 1986; Bartlett and Craig, 1981). The Hg^{2+} ion is methylated by both aerobic and anaerobic bacteria, primarily in aquatic sediments, suspended sediments and particulates in the water column, in the gastrointestinal tracts of fish, and, to a lesser extent, within terrestrial soils (Compeau and Bartha, 1984; Furutani and Rudd, 1980).

Abiotic methylation of mercury has been observed to occur in sediment with high levels of organic material. The ability of dissolved organic material to methylate Hg is not as fast as biotic methylation, yet production of methyl mercury without biological methylation is important to recognize (Miskimmin, 1991).

2.5.8 Rate of Mercury Methylation

The most favorable conditions for methylation are reported to be low redox potentials (anaerobic conditions), low levels of salinity, high amounts of dissolved organic carbon, and low levels of sulfides (Compeau and Bartha, 1984; Miskimmin, 1991).

The rate of methylation is dependent on microbial activity, temperature, pH, nutrient supply, redox potential, and oxygen supply. An increase in temperature of roughly 10°C doubles the rate of methylation (Fagerstrom and Jernelov, 1972). An increased nutrient supply provides a source of energy for microbial activity increasing methylation. Methylation rates were higher in suspended particles and upper layer of sediments, than in deeper bottom sediments (Furutani and Rudd, 1980). Oxygenation of fresh water enhances the availability of Hg for methylation by promoting the decomposition of organic matter and sulfides (Jackson, 1988). Methylation rates in surface sediments increased three-fold with the addition of a nutrient source (Rudd et al., 1983).

Concentrations of CH_3Hg^+ in sediment are usually very low. The percent of Hg in the methyl form averages less than 0.50% in sediment (Mikac et al., 1985). For example, even at a relatively high concentration of 1.40 $mg \cdot kg^{-1}$ total Hg, concentrations of sediment CH_3Hg^+ were only 0.003 $mg \cdot kg^{-1}$ (Mikac et al., 1985). Total Hg in sediments of the Mersey estuary averaged only 0.46% CH_3Hg^+ content. Mikac et al. (1985) found a negative correlation between total Hg of sediment and the percentages of CH_3Hg^+, pointing out that when too much Hg is introduced into an environment, microorganisms are overwhelmed, cannot detoxify Hg (i.e., cannot methylate Hg), and they die.

2.5.9 Effects of pH and Redox Potential on Mercury Methylation

A low pH decreases Hg methylation rates due to an increase in demethylation (Steffan et al., 1988). Acidification in lakes will increase the net CH_3Hg^+ produced in the water column, while decreasing that produced in the anoxic subsurface sediments (Xun et al., 1987). In the water column at a pH near 4.5, methylation was about seven times faster than at pH 8.5 (Xun et al., 1987).

The redox potential at the water-sediment interface affects both the speciation of elements present as well as the type of organisms present. When Hg exists in mercuric sulfides under anoxic conditions, the Hg^{2+} ion becomes available for methylation only when the sulfide ion is oxidized to the sulfate ion, and the Hg^{2+} ions dissociate. The Eh of sediment on lake bottoms exposed to oxygenated water varies near 500 mV, and can extend for several millimeters through an oxidized zone of mud referred to as the oxidized microzone. Summer stagnation causes a decrease in hypolimnetic oxygen resulting in a diminution of the depth of the oxidized microzone (Reid, 1976).

The oxidized microzone may vanish as the Eh of the interface approaches 200 mV. Low redox potentials indicate the presence of reducing substances capable of utilizing any free O_2 brought into solution. From an Eh of -300 to +50 mV, Clostridia are the most common methylating bacteria (Bartlett and Craig, 1981).

2.5.10 Effects of Nutrient Source and Biological Activity on Mercury Methylation

CH_3Hg^+ levels are highest when nutrient supplies and biological productivity are greatest. The decomposition of organic matter stimulates bacterial activity by providing an energy source and thus stimulates Hg methylation (Furutani and Rudd, 1980).

Algal blooms and an abundance of organic matter increased CH_3Hg^+ concentrations, even in areas of low Hg^{2+} concentrations, pointing out a dependence of CH_3Hg^+ production on algal biomass (Jackson, 1986). In Pasqua Lake, Canada, positive correlations were reported between the CH_3Hg^+ content of the water column and the population densities of Microcystis wesenbergi (a planktonic blue-green alga) and Cyclops bicuspidatus thomasi (a planktonic copepod) (Jackson, 1986). As these microbial populations increase, the total Hg and dissolved O_2 concentrations tended to increase. Eutrophic lakes often have a high pH because of high primary productivity. This can result in slower methylation rates than would be normally expected (Xun et al., 1987). In anoxic sediments, there is a decrease in net methylation, due to the binding of Hg^{2+} to free sulfides and to a lesser extent decreased microbial activity.

2.5.11 Effects of Sulfates and Sulfides on Mercury Methylation

Methylation of Hg^{2+} in anoxic environments is due to the suppression of the activity of methanogenic organisms. When sulfates are abundant, actual methanogenesis is suppressed by competition with sulfate reducers, and this specific inhibition of the methanogens instead stimulates methylation by SO_4^{2-}-reducing bacteria. In studies done on the estuarine Berry Creek, sulfide depletion of 0.95 $mg \cdot kg^{-1}$ in dry sediment resulted in an increase in CH_3Hg^+ produced (Berman and Bartha, 1986).

One sulfate-reducing bacterium was identified as a strain of Desulfovibrio desulficans (Compeau and Bartha, 1987). The isolate was unable to methylate Hg, mainly because the added Hg^{2+} ions were precipitated as HgS by the S^{2-}. It is of interest that D. desulficans exhibited increased growth and Hg methylation in the presence of 0.5M NaCl (Compeau and Bartha, 1987). It shows further the dominant role of SO_4^{2-} reducers in Hg methylation. The dominant role is ensured in the aqueous Hg biomethylation process because SO_4^{2-} reduction in marine sediments is responsible for more degradation of organic matter than oxygen respiration and denitrification combined (Compeau and Bartha, 1987).

2.5.12 Effects of Salinity on Mercury Methylation

The presence of soluble salts has a negative effect on Hg methylation. At 0.4% salinity, 260 mg·kg^{-1} of CH_3Hg^+ were synthesized; while at 2.4% salinity, only 120 mg·kg^{-1} of CH_3Hg^+ were synthesized (Compeau and Bartha, 1987). Sulfide concentrations increased with high salinity. At 0.03% salinity, sulfides measured 0.46 mg·kg^{-1}. At 2.4% salinity, sulfides measured 7.1 mg·kg^{-1}, which inhibited the Hg methylation process (Compeau and Bartha, 1987). Thus, high salt concentrations found in marine environments tend to reduce the toxicity of Hg^{2+} (Blum and Bartha, 1980).

2.5.13 Microorganism Adaptation and Mercury Methylation

Microorganisms methylate Hg^{2+} as a means of detoxification when it is present in their food supply (Fagerstrom and Jemelov, 1972). This adaptation results in the development of microbial resistance, and the elimination of Hg^{2+} from the immediate environment through eventual volatilization of Hg^0 (Barkay, 1987).

Aerobic Hg-resistant bacteria detoxify Hg by producing two enzymes, organo-mercurial lyase and mercuric reductase (Tezuka and Takasaki, 1988). Lyase first splits the C-Hg bond of organomercury, and the resulting Hg^{2+} is reduced to metallic Hg^0 by the mercuric reductase and is volatilized (Tezuka and Takasaki, 1988). The bacteria exhibit broad spectrum resistance if they possess both enzymes. Bacteria possessing only mercuric reductase have narrow-spectrum resistance. Broad-spectrum plasmids give both organic and inorganic resistance, while narrow-spectrum plasmids only encode Hg^{2+} resistance (Wang et al., 1987).

Adaptation of bacterial communities to Hg stress are phenotypic and genotypic. Phenotypic adaptations are based on the functions and activities of communities or isolated strains. Mechanisms such as gene transfer, transposition, legitimate and recombination, and DNA rearrangements may promote genotypic adaptation in the environment. Natural bacteria isolated from sediment of Onandaga Lake carried cryptic plasmids and R factors, suggesting that mercury-resistance is common in the indigenous bacterial communities of contaminated sediments (Barkay and Olson, 1986). The highly polluted sediments with Hg concentrations of 6.45 $mg \cdot kg^{-1}$ showed the highest number of Hg-resistant aerobic heterotrophs, which were 0.55% of the total aerobic heterotrophic community (Barkay and Olson, 1986). In Minamata Bay, Japan, sediments with mercury concentrations of 32.4 $mg \cdot kg^{-1}$ had 7.5% (of a total of 1068) bacterial strains able to volatilize Hg^{2+} (Nakamura et al., 1988).

DNA elements, encoding for Hg-resistance that are translocatable, help explain the maintenance and dissemination of Hg-resistant populations (Barkay and Olson, 1986). At concentrations of 100 μM $HgCl_2$, the growth rates and final yields of Aeromonas hydrophila, Pseudomonas spp., Pseudomonas mendocina, and Citrobacter freundi were not reduced (Trevors, 1986).

2.5.14 Demethylation of Mercury

Demethylation is the reduction of CH_3Hg^+ to volatile Hg^0 by Hg-resistant microorganisms. Demethylation in sediments can be accomplished by SO_4^{-2} reducers and methanogens. These can be either anaerobic or aerobic depending on the sediment and location (Oremland et al., 1991).

Mercury resistance is found widely distributed among bacterial genera, including the common flavo-bacterium and Pseudomonas spp. (Olsen et al., 1989). At an Eh from +200 to +300 mV, the aerobic Pseudomonas bacteria are dominant demethylators (Bartlett and Craig, 1981). Microbial demethylation activity in conjunction with methylation influences the equilibrium of CH_3Hg^+

concentrations. Low salinity conditions coupled with low redox potential inhibits demethylation. Conversely, aerobic and high salinity conditions favor demethylation (Compeau and Bartha, 1984; Steffan et al., 1988).

It has been suggested that demethylating organisms may maintain CH_3Hg^+ at a minimum (Spangler et al., 1973a, 1973b). Nevertheless, the evidence showing high CH_3Hg^+ levels in fish suggests that the natural demethylation process does not degrade equivalent quantities of the CH_3Hg^+ produced in the sediments, water column, and fish intestines. At least the rate of demethylation is not sufficient to prevent Hg accumulation in fish and other ecosystem components (D'Itri, 1990).

2.5.15 Bioaccumulation of Methyl Mercury by Plankton and Benthic Invertebrates

The biogeochemistry of CH_3Hg^+ indicates an association with aquatic biota because of its aqueous and lipid solubility and affinity for sulfhydryl groups (Bodaly et al., 1984). The uptake of CH_3Hg^+ by plankton and benthic invertebrates is controlled by the properties of suspended sediment and associated Hg-binding particles, such as humus, sulfides, clays, silts, fine sands, iron hydroxides (FeOOH), and manganese hydroxides (MnOOH) (D'Itri, 1990; Jackson, 1988).

The bioavailability of Hg in the aquatic environment regulates its uptake by plankton. In aerated environments, Hg concentration of the plankton along with the organic C:N ratio of the sediment tends to be the highest (Jackson, 1988). Aeration and current flow accelerate the breakup of Hg-binding substances causing release of Hg^{2+}. Therefore, the Hg content of the lower trophic level phytoplankton is not dependent on CH_3Hg^+ production or distribution, but is determined by existing Hg-binding materials and environmental factors. In contrast, at the upper trophic level, with fish such as pike and largemouth bass (Micropterus salmoides), the production rate and amount of CH_3Hg^+ determines the levels of CH_3Hg^+ present.

In benthic macroinvertebrates, different uptake rates of Hg reflect varying feeding habits between the oligochaetes, nematodes, chronomids, and pelecypods. The oligochaetes ingest Hg-laden bottom sediments, whereas pelecypods, being filter feeders, consume suspended Hg-laden organic particles (Jackson, 1988).

Bioaccumulation of methyl mercury can result in toxic levels of Hg in organisms and is one of the main methods of Hg poisoning of organisms in the environment. A knowledge of how methyl mercury (CH_3Hg^+) complexes with organic groups is important in understanding how mercury becomes toxic to organisms. One of the most studied reactions is the binding of the CH_3Hg^+ to the sulfide groups of cysteine-containing proteins. The S-group on the cysteine readily binds CH_3Hg^+ and completes the charge requirements of the Hg to make it a stable compound. The binding rate of methyl mercury to tissue is faster than the rate of methyl mercury excretion from the tissue. Therefore, methyl mercury bioaccumulation results in toxicity to susceptible organisms in the environment.

2.5.16 Bioaccumulation of Mercury by Fish

Mercury levels of fish are related to lake and watershed size, watershed geology, atmospheric deposition of Hg, lake chemistry, supply of CH_3Hg^+, and size and species of the fish (Phillips et al., 1987; Wren and MacCrimmon, 1986). Bodaly et al. (1984) have hypothesized that reservoir construction increases Hg concentrations in fish. Inorganic Hg activity and the Hg content in fish can be increased if the S^{2-} activity is decreased by lowering pH and/or increasing the redox potential (Bjornberg et al., 1988). An increase in biota Hg accumulation may result at low dissolved oxygen levels, due to an increase in methylation of Hg under anoxic conditions (Bjornberg et al., 1988).

Elevated Hg concentrations have been reported in lakes of low pH (Wren and Stokes, 1988). In Canada, a third of the lakes are acidic and the fish inhabiting them show high Hg contents (Wren and MacCrimmon, 1986). The high Hg levels may be due to an increased production of CH_3Hg^+ due to an increase in biologically available Hg^{2+} (Wren and Stokes, 1988). Lake acidification partially inhibited Hg methylation, and it was hypothesized that the increased CH_3Hg^+ in fish was due to altered gill permeability due to low calcium concentrations or altered partitioning of CH_3Hg^+ between the sediment and water column (Steffan, et al., 1988).

In addition, oligotrophic conditions occur in low pH lakes resulting in greater Hg accumulation in the remaining biota (Wren and Stokes, 1988). Fish in some eutrophic lakes (high bioproduction) have lower total Hg contents, because of the high growth rate of the fish causing a high biological dilution (i.e., the Hg dose is spread throughout a larger biomass).

Total CH_3Hg^+ concentrations often decrease from the sediment up the food chain to fish. The CH_3Hg^+ percent of the total Hg increases from less than 1% in sediment, to 89% of dissolved Hg forms in freshwater systems (Gill and Bruland, 1990), and near 100% in fish (D'Itri, 1990). Total Hg levels in large fish tend to increase with fish size. For example, Hg levels in pike were higher than in pumpkinseed sunfish or perch of a comparable age (Wren and MacCrimmon, 1986).

Methyl mercury has a high affinity for -SH groups and is more soluble in lipids. This allows CH_3Hg^+ to penetrate into cells readily and combine with -SH groups, resulting in high CH_3Hg^+ levels in fish. Wren and MacCrimmon (1986) reported that 80-95% of total Hg in fish muscle is in the organic CH_3Hg^+ form. The percent of Hg in the methyl form in samples of muscle tissue of the fish species, Gobius cobitis, was 94% (Mikac et al., 1985). Dimethyl mercury is more volatile than CH_3Hg^+ and shows no affinity for -SH groups. Many studies have shown low Hg contents in fish which have high concentrations of selenium (Se). Rudd and Turner (1983) showed that in low nutrient enclosures there were rapid increases in fish Hg levels after a decrease in Se levels after 10 to days of exposure. Selenium reduces the Hg uptake by substituting for sulfur in -SH groups in organisms, and thus lowering its affinity for Hg (Wren and Stokes, 1988).

Mercury transferred up the food chain is mainly CH_3Hg^+, a reflection that the biomagnification of CH_3Hg^+ is more likely than that of Hg^{2+} (Chamberlin et al., 1990; Figure 2-3). Biomagnification in fish has been observed to range between 5,000 and 100,000 times the levels in the surrounding water (D'Itri, 1990) and sediments (Phillips et al., 1987).

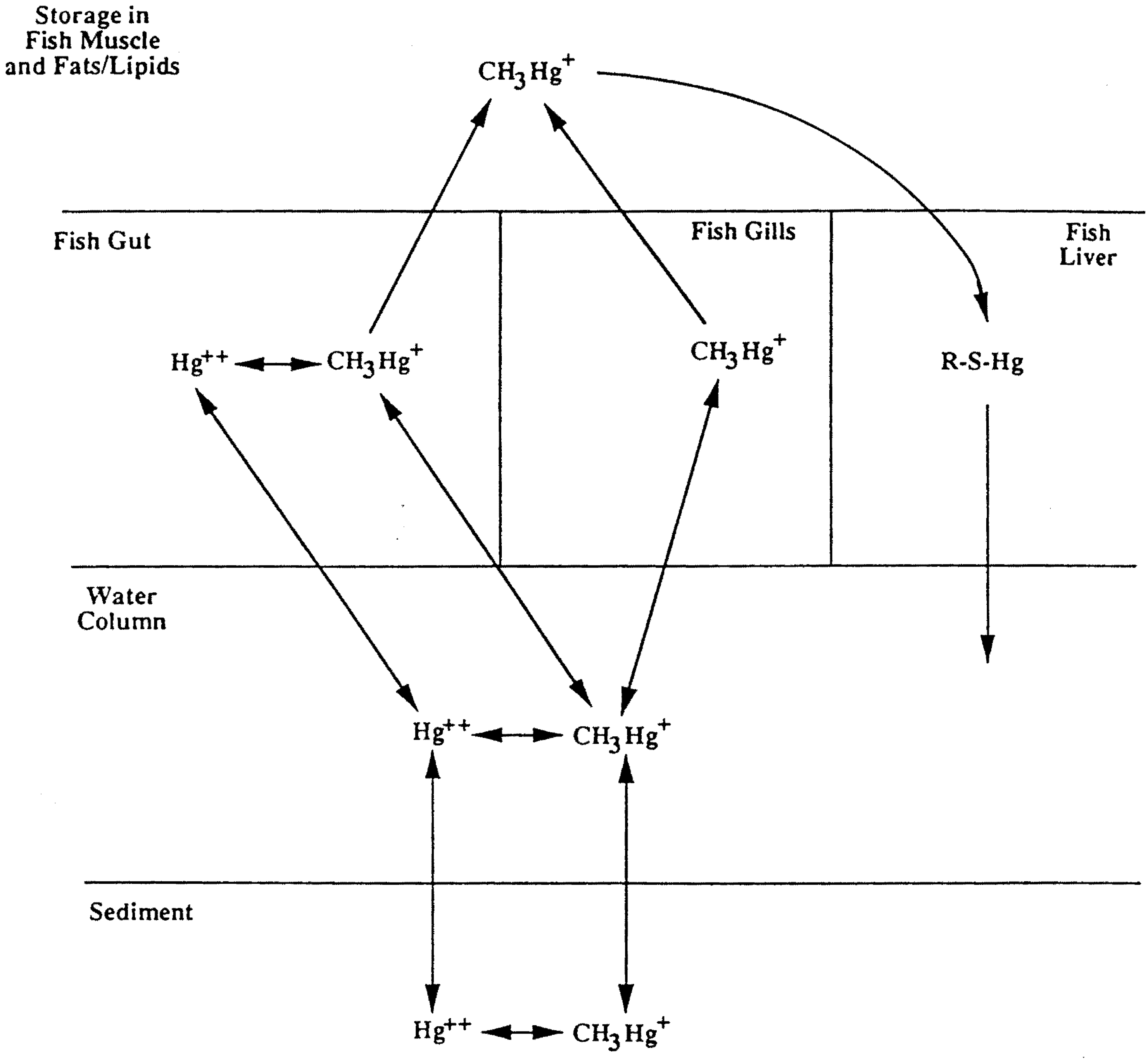


Figure 2-3: Mercury Pathways from Sediments to Water to Fish (Source: Chamberlin et al., 1990).

2.5.17 Uptake of Mercury by Plants

Terrestrial plants rooted in aerated soils have natural barriers limiting the uptake of Hg^{2+} salts and organic Hg complexes. The plants absorb Hg^0 and the alkylmercurials much easier than what they absorb of ionic Hg^{2+} (National Research Council, 1978).

Some plants will preferentially take up Hg from the soil and concentrate it in their leaves. Vegetation growing near cinnabar veins may contain Hg levels of up to 3.5 $mg \cdot kg^{-1}$ in their leaves (USGS, 1970). The growth, death, and decomposition of plant materials can potentially concentrate Hg in topsoil zones. It was hypothesized that Hg migrates into some topsoils from subsoil horizons due to native mercury volatilization or diffusion of CH_3Hg^+ (Mining Waste Study Team, 1988). Grazing animals do not appear to be significantly affected by ingestion of vegetation containing or exposed to low levels of environmental mercury. Mercury does not tend to be passed along to humans consuming meat or milk from animals grazing on vegetation growing in soils with low-to-moderate mercury contents (i.e., less than 500 $mg \cdot kg^{-1}$) (Woodward-Clyde Consultants, 1987).

Leaf absorption of Hg^0 vapor may be accelerated due to rise in soil temperature resulting in increased Hg volatilization of soil Hg (Lindberg et al., 1979). Aerobic soils high in decaying sulfides will release Hg^0 resulting in plant Hg contents ranging from 0.2 to 10.0 $mg \cdot kg^{-1}$. In contrast, reducing soils hold the Hg in insoluble sulfides or organic complexes resulting in plant Hg contents ranging from 0.01 to 0.04 $mg \cdot kg^{-1}$ (National Research Council, 1978).

Plants can provide an additional route for Hg movement within an aquatic system. Submerged, decomposing snakeweed in Lake Powell, Utah contained Hg concentrations of 90 $mg \cdot kg^{-1}$ as compared to 32 $mg \cdot kg^{-1}$ for unflooded snakeweed. Mercury levels of 43 to 283 $mg \cdot kg^{-1}$ can concentrate in lake-transported plant debris. Even in areas of sparse vegetation, flooding of plants and plant debris can result in an enrichment of Hg levels 10^4 times that of surface water (Potter et al., 1975).

Water plants that are used to accumulate Hg include Azolla and duckweed. Azolla, a water weed, converts Hg into the volatile Hg^0 form and is used in Hg contamination cleanups near chlor-alkali factories (Mishra et al., 1987). Duckweed of the Lemnaceae family are small vascular hydrophytic plants that float on stationary or slow-moving water. They have been shown to be very effective at removing Hg from water. With the addition of 5 ppm Hg in a test solution, 4 ppm of Hg were removed by the duckweed after 3 days (Mo et al., 1989). There are two processes of removal; 1) initial rapid removal of Hg by Hg-binding sites located on the duckweed, and 2) transportation of the Hg from the initial binding sites to the duckweed's final target. Hg removal by duckweed was prevented in the presence of Cu (Mo et al., 1989).

3.0 HISTORY OF MINING IN THE LAKE NACIMIENTO WATERSHED

3.1 Introduction

Most of the information in this discussion was obtained from literature published by public agencies between 1918 and 1965 (Bradley, 1918; Bureau of Mines, 1965; Eckel et al., 1941; Franke, 1935). Other relevant sources are listed in the Bibliography section of this report.

3.2 Mining Terms

Most mining in California is by open pit methods. The wastes generated by California mines include the following (Hutchison and Ellison, 1992):

1.) Overburden. This is the soil and rock that is stripped from the top of the ore body. These materials are usually chemically inert and, with the exception of surface runoff trubidity, usually do not present any risk to water quality.

2.) Waste Rock. This material includes nonmineralized and low-grade mineralized rock removed either from above or adjacent to the ore. this material is usually placed in piles close to the mine. The nature and extent of the mineralization, climatic conditions, and buffering capacity of the foundation soil beneath the waste rock pile, determine the potential of the material to impact water quality.

3.) Tailings. These are the uniform, finely ground rock particles from which most of the commercial ore has been extracted in the beneficiation and extraction plant. As with waste rock, the potential for tailings to impact water quality depends on the chemistry of the material and the specific conditions at the tailings disposal site.

4.) Heap Leach Residue. This includes run-of-mine, crushed, and agglomerated ore piles that have been leached by allowing solutions to percolate through the material. Before closure, the ore is rinsed and, if necessary, treated to meet specified residual constituent concentration standards. The potential for water quality impacts from this material depends on site-specific conditions, as well as, as on chemical properties of the ore, reagent types, and the extent of rinsing and/or treatment.

5.) Wastewater. This includes liquid wastes that may be generated at a floatation, acid leach, or solvent extraction facility, from the operation of mechanical equipment, such as boilers, spent leach solutions remaining at the end of the active life of a heap leach facility, runoff from acid generating ore storage areas, and washdown water from recovery plant or maintenance buildings. These wastes can contain elevated concentrations of constituents that represent a threat to water quality, if the liquids are not adequately contained.

Wastewaters are also generated in sand and gravel washing operations. However, these only contain elevated suspended solids and usually can be discharged after temporary detention in settling ponds.

3.3 General Location

The cinnabar deposits of San Luis Obispo County exist in the Santa Lucia Range, of the California Coast Ranges, which lies midway between

San Francisco and Los Angeles. Most of the deposits are located in an area 16 miles long by 4 miles wide in the northwestern portion of San Luis Obispo County (Eckel et al., 1941).

The area of investigation is land in the watershed of Lake Nacimiento. A study of the Hg mines that were located in the Lake Nacimiento watershed was completed. The mines' locations and the key historical facts about the mines are provided.

3.4 Regional Topography

The California Coast Range is a moderately rugged chain of mountains, 2000 to 3500 feet in elevation, which parallels the northwest-trending Pacific Ocean coastline. Land to the west of the range drains into the Pacific Ocean. Land to the east of the range drains into the Salinas River.

A large portion of the Salinas drainage system forms the headwaters of the Nacimiento River, which is fed by several tributaries. The natural flow of water into the Salinas River has been altered by a dam on the eastern end of the Nacimiento River. Construction of the dam resulted in the formation of Lake Nacimiento.

3.5 Geology of the Ore Deposits

The cinnabar deposits most often occur associated with Franciscan Formation rocks and are sometimes injected into Cretaceous or early Tertiary sediments. These geological areas have been uplifted due to tectonic activity in the area, exposing large blocks of older Franciscan rocks, through erosion of younger rocks. The younger faulted rocks crop out along side these blocks. Cinnabar deposits, tend to occur in the contact zone between the Franciscan and younger rocks. The northwest trending fault zones in the area are sites of past hydrothermal activity. The hydrothermal activity has altered the rock in certain areas into silica-carbonate rock or "quicksilver rock", which consists of dense quartz, mixed carbonates and sulfide-rich minerals. One of these sulfide-rich minerals is cinnabar, otherwise known as mercury sulfide (HgS).

A typical deposit of cinnabar consists of brecciated Franciscan rock associated with silica carbonate rock that is interspersed between the fractured breccia. Serpentinite, one constituent of the Franciscan Formation can be found alongside the cinnabar deposits and can even be part of the deposits themselves. The deposits of cinnabar occur mostly as irregular masses and lenses in the breccia. They can range in size from small masses, veins, and veinlets to large sills and dikes with sizes up to 100 feet long and 40 feet wide. Several good examples of vein deposits were found in the Little Bonanza Group, La Libertad, Klau, and Buena Vista Mines.

3.6 Early History

The discovery of cinnabar by non-native Americans in San Luis Obispo county dates back to 1862, when the claim at the Little Bonanza Mine, on the South Fork of Las Tablas Creek, was made. Previous to the discovery of modern mining claims, the native Chumash Indians used cinnabar for its pink color as a pigment for decoration and painting.

3.7 Mercury Mines in the Lake Nacimiento Watershed

Several factors about the mines are considered important, the size of the mining operations at each site, the location of the mine with respect to

Lake Nacimiento, the time period of operation, the quality of ore that was reported, and the method of mining that was performed at each site.

Four main areas of historical mining activity are located in the Lake Nacimiento watershed. The first area is the Klau-Mahoney District, which is located south of Lake Nacimiento along the Klau Branch and the North Fork of Las Tablas Creek. The second area is the Madrone-Cypress Mountain Group, which is further south of Lake Nacimiento than the Klau-Mahoney District and is located near the headwaters of the Las Tablas watershed along the South Fork of Las Tablas Creek. The third area is the Pine Mountain District, which is located west and southwest of Lake Nacimiento near the headwaters of Tobacco Creek. The fourth area is the Bryson District, which is located northwest of Lake Nacimiento in the Sycamore Creek watershed.

A list of the mines in each district follows:

1. **Klau-Mahoney District**
    - Capitola
    - Klau (previously known as the Sunderland, Santa Cruz, Karl, Carson or Sierra Morena)
    - Buena Vista (previously called Mahoney)
    - Santa Monica
    - Willam Tell
2. **Madrone-Cypress Mountain District**
    - Cypress Mountain Group
    - Kismet Group
    - La Libertad
    - Little Bonanza Group

3. **Pine Mountain District**
    - Buckeye
    - Ocean View
    - Pine Mountain
    - Madrone
4. **Bryson District**
    - Botts (Sycamore Creek)

3.7.1 Klau-Mahoney District

The geology of the district consists of Franciscan, Cretaceous, and Tertiary Formations. Most of the rocks along the fault zone have been brecciated from the activity along the Las Tablas fault. The fault strikes N 80° W and parallels Las Tablas Creek. It dips almost vertically, near the Klau Mine. Tertiary rock lies to the north of the fault and Franciscan to the south. South of Las Tablas fault there are two faults which are east trending N 75° W and dip at 40 to 60° W. Both faults are mineralized (i.e., metamorphosed by hydrothermal intrusion) with the southernmost one passing through the Klau and Buena Vista Mines. At the Buena Vista Mine, the fault dips 50-60° and is 1000 feet wide. The zone contains breccia which is mostly shale and is largely kaolinized. Silica carbonate rock surrounds the mine, but is rare in the mine. West of Klau Mine is a sill of serpentinite which has been altered on top and bottom to silica carbonate rock. Eastward the fault disappears under the sandstone and westward it can be traced for several miles.

3.7.1.1 Capitola Mine

Located in Sec 33., T. 26 S., R.10 E., Mount Diablo Baseline and Meridian (M.D.B.M.), the mine is 1/4 mile southeast of the Klau main workings and was a part of the Klau Mine. Located in the same breccia zone as the Klau, the rock at the Capitola contains more pyrite and kaolinite. It was first mined in 1913, and had activity in 1915-1916, and 1918, and intermittently through 1934. The cinnabar in the ore was associated with pyrite and was reported to have 5 lbs Hg/ton ore. Between 100 and 999 flasks (each flask weighs 76 lbs) of quicksilver had been removed from the mine as of 1940. There was a small 1000 lbs ore/day retort on site, but it has been removed. As of 1940, 300 ft of workings (tunnels, shafts, adits, drifts, and stopes) had been completed. There was also another mine located next to the Capitola called the Santa Monica Mine which was most likely an extension of the Capitola.

The mine spoils drain into the Klau Branch of the South Fork of Las Tablas Creek.

3.7.1.2 Klau Mine

Located in Sec. 33., T. 26 S., R. 10 E., M.D.B.M., the Klau (previously known as the Sunderland, Santa Cruz, Karl, Sierra Morena, or Carson Mines), includes the Santa Monica and Capitola Mines as part of the property, was first mined in 1868. In 1902, it was the fourth largest producer in the state and, as of 1940, was the second largest producer of quicksilver in San Luis Obispo County (the Oceanic Mine was the largest in 1940). In 1911, the furnace plant burned down and the mine was idle until 1915. The years of operation were 1868-1878, 1895-1912, 1917-1924, 1927-1940, 1943-1947. The ore was reported to contain 5-30 lbs Hg/ton. The total output from the mine, as of 1965, was more than 24,000 flasks of Hg.

The mine is located on the wide (up to 1000 ft), south-dipping fault zone which has been kaolinized. The fault breccia consists mostly of shale, with some sandstone, chert, and silica carbonate rock. Pyrite and marcasite are prevalent in the rock.

Originally, the mine contained miles of underground workings. These have collapsed resulting in open-pit operations having been used as the more recent method of mining. The ore was processed in a 50-ton rotary furnace until 1918, after which smaller Rossi retorts were used to process the ore. The Rossi retort was designed by Louis Rossi who worked at the Klau Mine in 1927. The retort was widely used because it was inexpensive to construct, had low fuel requirements, and was relatively efficient in quicksilver recovery. The mine was purchased by Klau Mine, Inc. in 1934. A larger ore processing facility was then built, which could handle about 40 tons of ore per day.

Runoff water from the mine drains into the Klau Branch of the South Fork of the Las Tablas Creek. Presently, eroding mine waste piles are located alongside the stream.

3.7.1.3 Buena Vista (Mahoney) Mine

Located in Sec. 33, T 26. S., R. 10 E., M.D.B.M, the Buena Vista (BV) was first mined in 1876 and has been worked in the years 1876, 1899-1903, 1929-1930, 1932-1933, 1935, 1938-1945, 1947-1948, 1953-1955, and 1957-1970. The geology of the mine is similar to the Klau. It is located along the same east trending fault zone and is mainly Franciscan sandstone and shale breccia. Cinnabar occurs in high grade veins, pockets, and disseminations in the sandstone and shale and is reported to be intimately associated with pyrite. Deposits range in size from small pods to as much as 10,000 ton ore bodies. The ore was estimated to contain 5-30 lbs Hg/ton. The original workings of the mine consisted of several thousand feet of tunnels. As of 1940, about 1,800 flasks of Hg had been produced.

Not much information was given for the Buena Vista in the early reports, due to the belief that the mine was not a good future source of quicksilver. However, in 1957, with the assistançe of a contract from the Division of Mining Exploration and Assessment (DMEA), an extensive exploration of the area south of the original mine workings (using 3,504 ft. of rotary drillings in 12 holes at a cost of $5,800), led to the discovery of new deposits of cinnabar. Early mining operations consisted of strip mining. The ore processed in a 30-ton rotary furnace. About 30 tons of ore a day were processed from 1959 to 1970. The total amount of Hg that has been removed from the mine is estimated to be 84,300 flasks, with 8,644 flasks recovered prior to 1959. The mine ceased operation in 1970 following pollution abatement orders from the RWQCB and the closure coincided with the dramatic decline of Hg production in California. No active Hg mining has taken place in California since 1976 (Mining Waste Study Team, 1988).

Water from the mine and its waste tailings piles drains into the North Fork of Las Tablas Creek.

3.7.1.4 William Tell Mine

Located in Sec. 33., T. 26. S., R. 10 E., M.D.B.M, the mine is 1/2 mile west of the Klau Mine It was operated in 1900. The geology is the same as the Klau and located on the same fault zone. Only a small amount, 1 to 9 flasks, were reported to have been removed from the mine. No retort was reported on site. Extensive outcrops of silica-carbonate rock are reported to exist in the area around the mine. The mine drains into the Klau Branch of Las Tablas Creek.

3.7.2 Madrone-Cypress Mountain Group

The Madrone-Cypress Mountain Group is located just northeast of the crest of the Santa Lucia Range, south of the Klau-Mahoney District. The group of the mines follow a northwest trend parallel to the range, and are located near the headwaters of the South Fork of the Las Tablas Creek watershed. The mines are located in a zone of highly sheared and altered Franciscan rock which varies in width from 100 to 1000 feet. The known deposits of cinnabar are located in wide portions of a fault zone and are closely associated with silica-carbonate deposits. North and west of the group are several small rhyolite outcrops which have intruded into the fault zone breccia.

3.7.2.1 Cypress Mountain Group

Located in Sec. 1 and 2, T. 27 S., R. 9 E., M.D.B.M., the mine is due north of Cypress Mountain and near the largest rhyolite exposure in the area. There are several mines in the 167-acre claim which were originally mined from 1870-1875. About 60 flasks of quicksilver were recovered during the active years of 1870-1875. The cinnabar outcrops are located in highly altered serpentinite and are associated with a black clay "alta" and a serpentinite footwall. The mines originally had a 5-ton furnace on site, but it was removed. Mine workings consisted of tunnels and caves. Drainage from the mine enters the South Fork of Las Tablas Creek.

3.7.2.2 Kismet Group

Located in Sec. 7, T. 27 S., R. !0 E., M.D.B.M., the group of three mines is located between the Little Bonanza Group and Cypress Mountain Mines. The mines were active in 1903 with no reported production of quicksilver. They are located on a main fault in the area, contains outcrops of silica carbonate rock, and are located near a rhyolite plug. Drainage from the mine enters a tributary to the South Fork of Las Tablas Creek.

3.7.2.3 La Libertad

Located in Sec. 21, T. 27 S., R. 10 E., M.D.B.M., the La Libertad (previously known as Jacks Mine) was first mined in 1901 and had active production from 1901-1903, 1935, 1947-1948, and 1952. The mine lies on the Madrone-Cypress fault and is located in a zone of Franciscan breccia with small outcrops of silica-carbonate and serpentinite rock. The walls of the cinnabar vein were bordered by black gouge or alta, which ranged in width of a few inches to three feet. Some of the ore was located in the serpentinite with disseminated specks of cinnabar and native mercury. Other ore bodies contained associated pyrite and calcite. Ore contained 7-8 lbs Hg/ton with some ore in the form of boulders of high grade cinnabar. Most of the workings were underground along one main irregular vein. Production prior to 1940 was more than 1,000 flasks, and after 1952 about 1,100 flasks. Ore was processed in a 15-ton rotary furnace in 1952. The drainage enters Jack Creek, which is part of the South Fork of Las Tablas Creek watershed.

3.7.2.4 Little Bonanza Group

Located in Sec. 17, T. 27 S., R. 10 E., M.D.B.M., the group of mines known as the Little Bonanza Group of mines includes the Little Bonanza (originally known as the Josephine), and later, the Modoc, Alice, Alice #2, Ida, Echo, Elizabeth, Winona, the Tamney Group, Mercury #1, Mercury #2, and Mercury #3, and the Mercury.

The Little Bonanza was the first quicksilver mine to be discovered and operated in San Luis Obispo county by non-native Americans. The first year of reported operation was 1862 and other years of operation include 1900, 1902-1905, 1915-1916, 1931-1934, 1938-1939, and 1940. Production from these mines was reported to be more than 1,000 flasks. It was one of the 6 most important mine groups in San Luis Obispo county. The group lies on the Madrone-Cypress fault and consists of brecciated Franciscan which was reported to be silicified altered serpentine rock with chert, chalcedony, and quartz. Other minerals in the gangue are quartz, mixed carbonates, pyrite, marcasite, kaolin, green gouge, and hydrocarbons. The ore was estimated to contain 3-10 lbs Hg/ton. The ore was processed in a retort, now abandoned at the site, and a 15-ton rotary furnace. The method of mining was tunnels and caves, with the largest amount of work done in the Little Bonanza Mine. Past ore processing was done in a Rossi retort. Drainage from the mine enters the South Fork of Las Tablas Creek.

3.7.2.5 Madrone Mine

Located in Sec. 22, T. 27 S., R. 10 E., M.D.B.M., the mine is located 1/2 mile south of the La Libertad. The mine was first worked in 1900 with 10-99 flasks produced. Some activity occurred in 1956-1958. The geology of the area is similar to the Little Bonanza and La Libertad, with brecciated Franciscan rock and outcrops of siliceous gangue. The primary method of mining was tunnels and caves. There were also several areas of topsoil that contained free mercury. Hg loose in the soil may have been the result of a weathered outcrop. The topsoil was panned for Hg, with soil samples having 1.5-2.5 lbs Hg/ton. A retort was on the premises in 1940. Drainage from the mine enters the South Fork of Las Tablas Creek.

3.7.2.6 Mercury Mine

Located in the SW1/4 , NW1/4, Sec. 7, T.27 S., R. 10 E., M.D.B.M., this 55 acre mine is located on the eastern slope of Cypress Mountain and the ore deposit was discovered in 1874. The geology of the area consists of serpentinite and altered Franciscan sandstone. The last report of work at the site was in 1940. No record of any ore production was reported in the literature. Drainage of the mine is the same as the Little Bonanza.

3.7.2.7 Mercury Nos. 1, 2, and 3 Mines

Located in Sec. 17, T. 27 S., R. 10 E., M.D.B.M., these three mines are located adjacent to the Little Bonanza Mine. They were worked in 1934 with no record of quicksilver production. The geology and the mine drainage are similar to that at the Little Bonanza.

3.7.3 Pine Mountain District

Pine Mountain District is located south-southwest of Lake Nacimiento on the eastern side of Pine Mountain. Of the 22 mining claims in this district, only three are in the Lake Nacimiento watershed. The Ocean View, Buckeye, and the Pine Mountain Group are the three mines. The mines are on the east slope of Pine Mountain and are located near the headwaters of Tobacco Creek. The geology of the area is northwest trending, following the Pine Mountain fault (this may be an extension of the Madrone-Cypress fault line). The fault zone extends along the east side of the ridge that is made up of Rocky Butte and Pine Mountain. The east side of the fault zone is made up of Cretaceous shale. The Franciscan Formation makes up the west side of the fault. A cover of Cretaceous rocks overlays the fault zone in areas near the Buckeye and Ocean View Mines. The summits of Rocky Butte and Pine Mountain are made up of rhyolite plugs that have intruded the fault zone. There is a large belt of serpentinite west of Pine Mountain. The geology 1/2 mile north of the Ocean View and Little Almaden Mines consists of silica carbonate rock with cinnabar appearing as siliceous veinlets and disseminations. The richest cinnabar areas are located near the Ocean View, Buckeye, and Pine Mountain Mines. The area has produced about 1,000 flasks of quicksilver. Widespread mineralization of the local rocks is indicated, but full examination of the area has not occurred. The area was discovered in 1870 and operated intermittently through 1903, with some more activity in 1943-1944. The Ocean View was the principal producer of the three mines, with a reported 8-20 lbs Hg/ton ore.

3.7.3.1 Buckeye Mine

Located in Sec. 10 and 11, T. 26 S., R. 8 E., M.D.B.M., the mine is located due east of Pine Mountain and is on the Pine Mountain fault zone. It was actively mined in 1903 with 9 flasks of quicksilver recovered. The geology of the area is the same as the Ocean View with outcrops of silica carbonate rock containing cinnabar in small veinlets and disseminations. The ore dump was reported to contain low grade cinnabar levels. Water from the site drains into the Tobacco Creek watershed.

3.7.3.2 Ocean View Mine

Located in Sec. 3, T. 26 S., R. 8 E., M.D.B.M., the Ocean View Mine is the most northwesterly and the most important Hg producing mine in this district. It is located on the north side of Pine Mountain, close to the intersection of two faults. One fault separates Franciscan rocks on the north from Cretaceous on the south. The other fault is filled by intrusive rhyolite. The mine was first discovered around 1871-1872 and was active from 1871-1903 producing about 1,000 flasks of quicksilver. The ore is in a silica-carbonate rock derived from altered serpentinite. Cinnabar occurs as veins and veinlets with some irregular masses of up to 1 ft in diameter. Mining operations were tunnels and caves. Ore observed in the dump was medium to high grade. An abandoned retort is presently located near the mine. Water from the site drains into the Tobacco Creek watershed.

3.7.3.3 Pine Mountain Group

Located in Sec. 10, T. 26 S., R. 8 E., M.D.B.M., Pine Mountain Group is located a few hundred feet south of Buckeye Mine. Mine operations began in 1871. It was active from 1871-1903 and produced about 100 flasks of quicksilver from underground workings. The geology of the area is the same as the Ocean View and Buckeye Mines. The ore was reported to contain about 8 lbs Hg/ton.

The mines are located near the crest of the Tobacco Creek watershed, so the runoff water flows east and west from the mine. Since there were twenty-two claims in the area, some of the mine claims are likely located in the Tobacco Creek watershed.

3.7.4 Bryson District

The Bryson District is located northwest of Lake Nacimiento. It is northwest of the other known quicksilver deposits in the area. The Bryson District has only one reported mine in the area located east of the Beartrap Flats in the Sycamore Creek watershed. The geology of the area consists of coarse-grained sandstone and bituminous shale and siltstone. All of the rock is of late Cretaceous age. There is a northeast-trending fault that is said to be a tear fault between two major northwest-trending faults on either side of the area of Beartrap Flats.

3.7.4.1 Botts Mine

Located in Sec. 7, T. 24 S., R. 8 E., M.D.B.M., the Botts Mine is located on the south side of Sycamore Creek, which is a tributary to Nacimiento River. The mine first operated in 1939 and the only activity reported was 1939-1940. The geology at the mine site is brecciated sandstone and shale with cinnabar distributed as scales and crusts along the fractures in the breccia. Crystallized pyrite was widespread in the area, but not intimately associated with the cinnabar. Crystalline white calcite was found in the ore piles. The mine had a retort on the premises and a reported production of 10-100 flasks of quicksilver. Mining was done in tunnels and trenches. An abandoned retort is presently located along Sycamore Creek below the mines.

The soil on the hillside near the mine and the stream gravels of Sycamore Creek have grains and nuggets of nearly pure cinnabar. Runoff water drains into Sycamore Creek.

3.8 General Methods of Mercury Ore Mining and Processing

The process of mining and ore processing has not changed much during the years of cinnabar mining in the area. Some of the methods described here will vary in their relative sophistication at various mines. Some of the best descriptions come from a report on the operations of the Oceanic, Klau, and Buena Vista Mines, all located in SanLuis Obispo county, California (Franke, 1935).

The mining operations start with the discovery of a cinnabar-rich ore deposit. Usually the richest ores are found by constructing tunnels and adits into areas where cinnabar deposits are found at the surface. Many indications of cinnabar can occur in the area. Outcrops of silica carbonate rock which represent hydrothermal alteration of the pre-existing rock, indicate that cinnabar deposits are near, especially when Hg levels of downstream sediments contain $>1.0\ \mathrm{mg \cdot kg^{-1}}$ (Pierce et al., 1970).

The presence of fractured rock or fault zone breccia along the contact zone between two shear planes are important geological prospecting clues for deposits. These contact zones are areas where the hydrothermal solutions can find their way to the surface through fractures in the rock.

Serpentinite deposits can also be very helpful in locating cinnabar deposits, since these zones are often directly altered during hydrothermal intrusion and receive cinnabar deposition. Also, serpentinite can be the headwall or footwall of the zone of cinnabar ore. Finally, rhyolite plugs have been observed near deposits of cinnabar, and may be a result of the hydrothermal and tectonic activity in an area.

Once an ore body has been located, the process of following the ore deposit down through the rock begins. This is the most difficult part of the mining operation, since the cinnabar can be deposited in many different forms. Disseminated cinnabar ore deposits may be the most difficult to follow since many times the ore cannot be easily seen. The vein and veinlet form of deposits allow the miners to follow the deposit visually. However, these deposits can twist, turn, dip, and run out in several directions. The sill or dike deposits are easiest to follow, and provide the richest source of ore. The problem of cinnabar mining is the lack of consistent deposits, the inability to determine what is deposited above and below, and the variation of ore quality.

The two most common methods of mining the Hg ore are tunnels and caving, and open pit mining. Tunnel and caving is the method by which tunnels are used to search for and reach the deposits of ore, and caving is used once a deposit is located. Once the cinnabar deposit is reached, the mining operations follow the deposits until it runs out or can no longer be reached safely. The open pit method results in overburden rock removal until a deposit is reached. Then the ore is collected and removed for processing. The ore is processed by crushing, roasting, and retorting (Photos 3-1 and 3-2). Initially, ore taken from a mine is crushed in a jaw-crusher to a size of about 2 inches . This is stored in a large ore bin until it is ready for

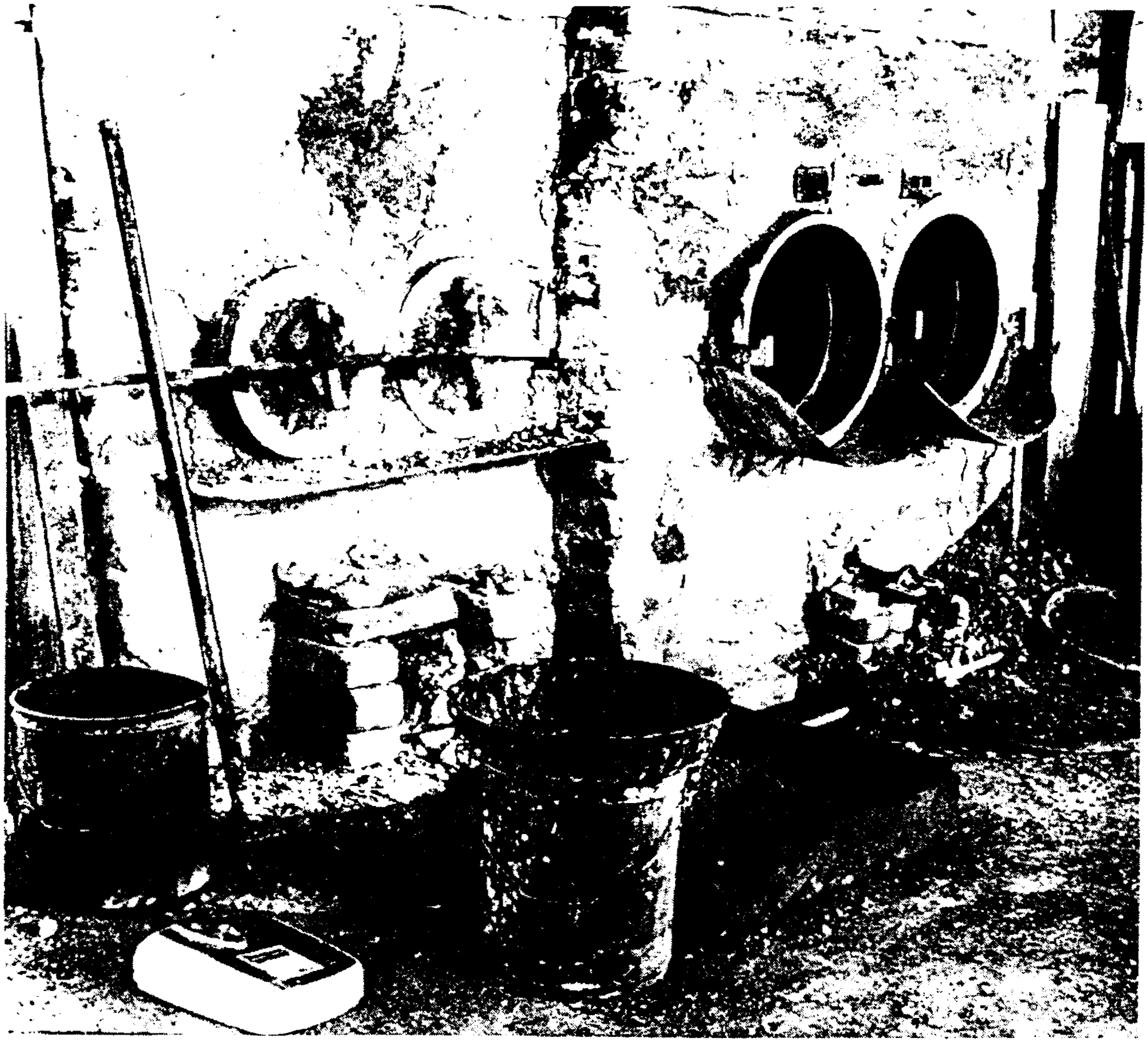


Photo 3-1: Retort furnace from the Oceanic Mine showing the use of natural gas and diesel fuel (Source: Mark Hall-Patton, San Luis Obispo Historical Society Museum; early 1900's, exact date unknown).

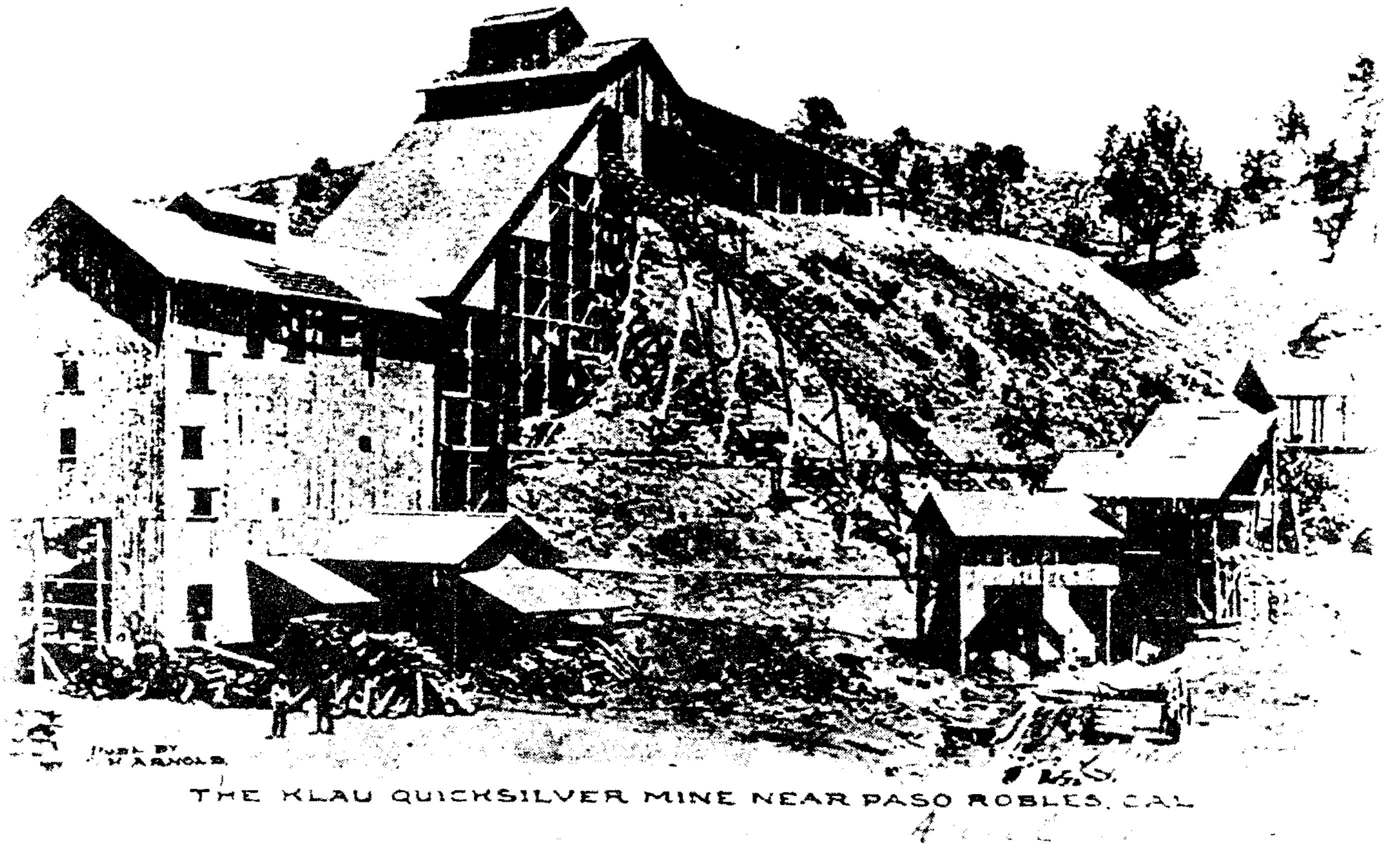


Photo 3-2: Processing buildings from the Klau Mine operations using wood as a fuel source (Source: Mark Hall-Patton, San Luis Obispo Historical Society Museum; 1904-05, exact date unknown).

processing. The ore is usually processed in a large rotary furnace. The rotary furnace size varies with the size of plant operations. Some of the largest rotary furnaces processed up to 75 tons of ore per day. The ore is heated in the rotary furnace to temperatures up to about 1300°F (520°C). which vaporizes the mercury sulfide into Hg^0 and SO_2 gas. The main heating fuel used in recent years was natural gas; wood and diesel fuel was used in the 1800's and early 1900's (Photos 3-1 and 3-2).

The gases and associated dust from the retort furnace is passed through a cyclone condenser, which concentrates the dust and causes it to settle. The dust is then discarded (no mention as to the amount of mercury left in the dust was reported). The gases are passed through a condenser, made up of a system of U-shaped pipes (Photos 3-3 and 3-4). These pipes allow the gases to cool and the Hg vapor subsequently precipitates as elemental mercury, or quicksilver. The condensers are connected to bottom hoppers which are tanks of water that collect the mercury.

The rotary furnace process removed about 60% of the mercury from the ore. In order to recover more Hg, the furnace soot and mercury that collected in the bottom hoppers is removed and put on a large tray, where lime is mixed in, hence the name "calcined wastes". As a general rule of thumb, lime was added to the quicksilver-soot mixture at about a 1:3 (lime:Hg-soot) ratio. This calcined mixture was further homogenized by hoeing the material back and forth over a pan. The remaining soot, after the quicksilver had been removed, was added to the dust collected and sent back into a retort. The retort was heated, and the remaining Hg was removed by vaporization and collected by cooling the vapors in a condenser. The

Photo 3-3: Abandoned processing buildings at the Buena Vista Mine showing the condenser facility in the foreground (12/10/91).

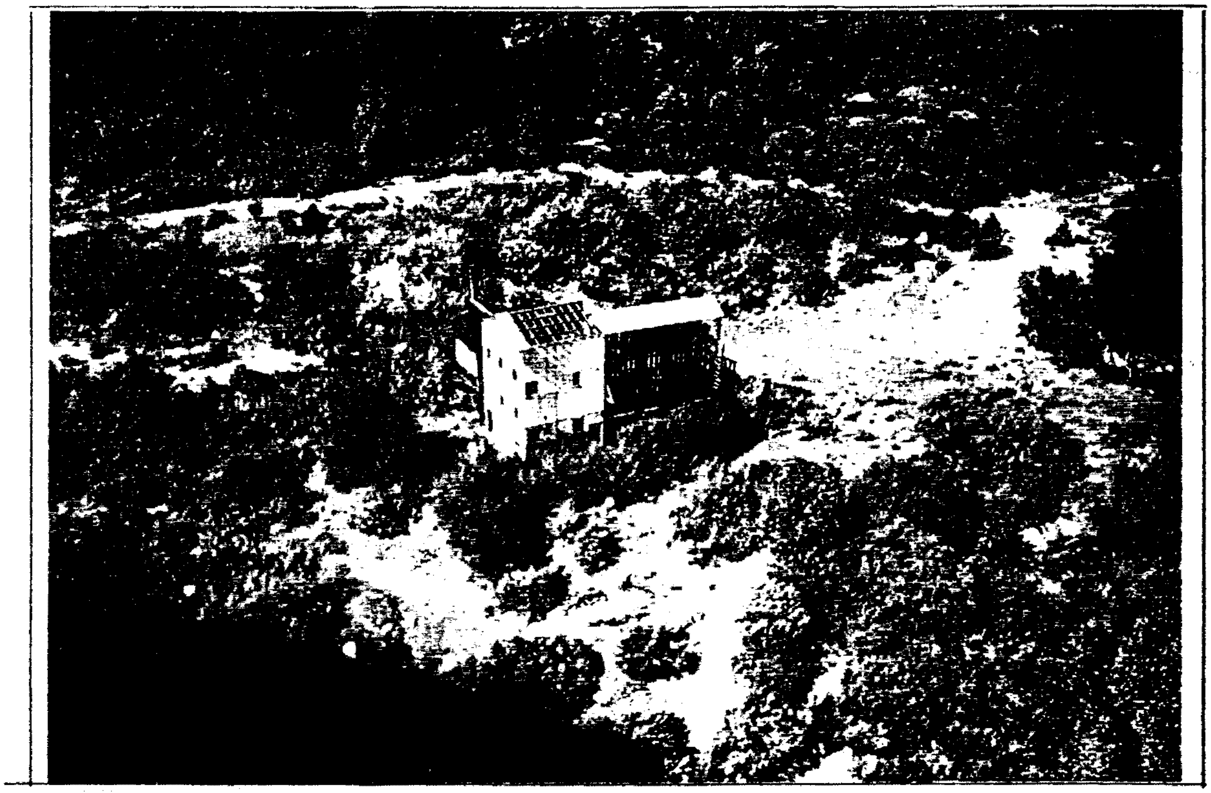


Photo 3-4: Abandoned processing buildings at the Ocean View Mine showing the condenser facility at the right (3/16/92).

working life of most retorts was nine to ten months with continuous use. The Hg-rich bricks that enclosed the retorts were often treated like ore to remove the Hg, when old retorts were dismantled (Franke, 1935).

The estimated mercury recovery from this described method was 90-95%. The remaining 5-10% Hg would be lost in airborne vapors or remain in the retort waste tailings, which were usually dumped near the retort operations.

This reported process varied among the mines in San Luis Obispo. Many of the smaller mines did not have a rotary furnace for processing the ore. Instead, they relied on a smaller retort, which was easy to build and could process small amounts of ore (Photos 3-5 and 3-6). The retort was a set of pans that held the ore and these were heated or roasted to remove the mercury. The retort was heated by wood or diesel fuel that was burned underneath the pans. In older operations, wood was the choice of fuel due to the remote mine location. The efficiency of mercury removal in the ore depended on the type of ore and the size of crushed ore being retorted. The time of retorting the ore varied from several hours to up to a day. No mention of the exact percentage of Hg recovery was given for the retort method, but if the method was done properly it could be up to 90% recovery.

Mercuric sulfide is known to occur in two colors and forms, red (cinnabar), and black (metacinnabar). The transition temperature of red to black is about 345^{o}C. The red form is more thermodynamically stable at ambient temperatures, but it is usually the black that precipitates from aqueous solutions (Hepler and Olofsson, 1974). The calcined waste of the mines is usually gray to black in color and this may be cinnabar transformed into metacinnabar after processing.

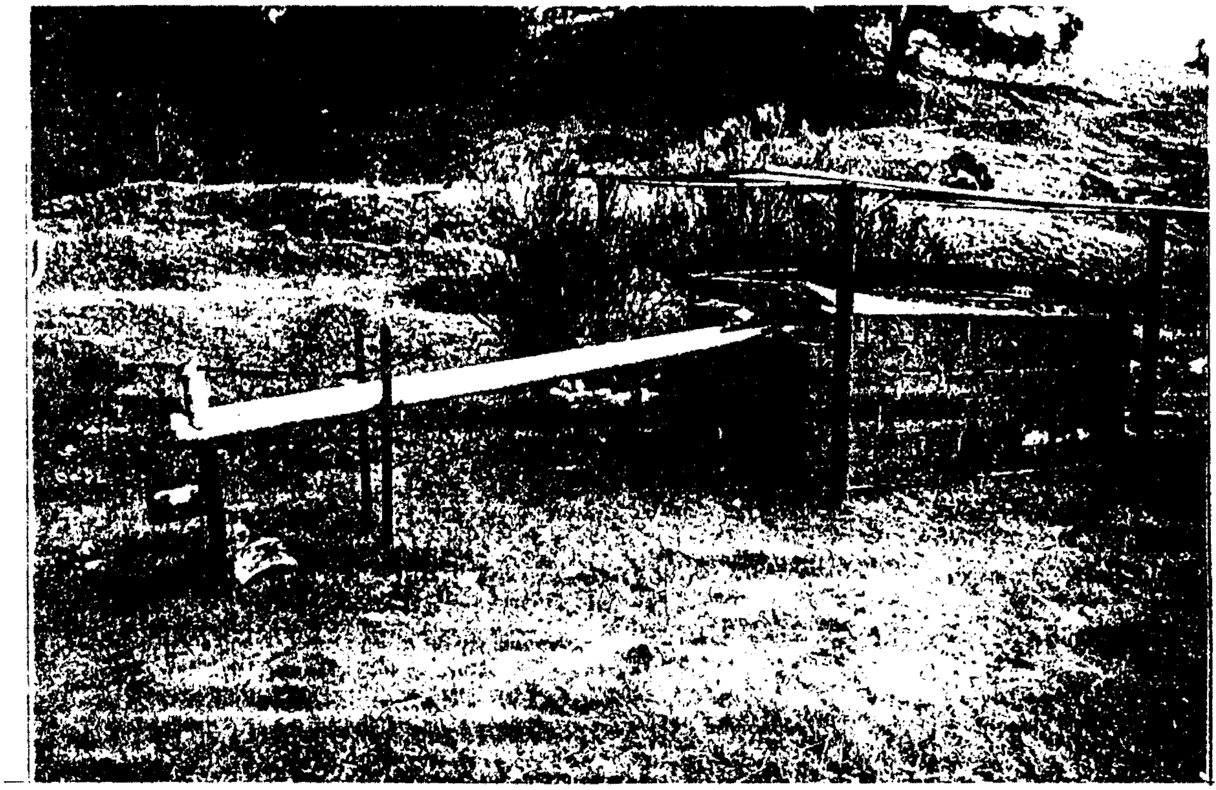


Photo 3-5: Small retort near the William Tell Mine east of the Klau Mine on the Klau Branch of Las Tablas Creek (3/24/93).

Photo 3-6: Small retort near the Botts Mine on Sycamore Creek in Fort Hunter Liggett (1/17/92).

The waste material from the ore processing was usually discarded in piles near the mine workings. These waste dumps contain the dust, processed ore, and water that was used in the mercury removal. If estimated mercury removal was 90-95%, the waste dump ore still contains 5-10% mercury in the form of cinnabar, elemental Hg, and other forms. The average amount of mercury in the processed ore ranged from 5-30 lbs Hg/ton. This means that from 0.25-3.0 lbs Hg/ton still remained in the waste dump materials.

Material that has 0.25 lbs Hg/ton is equal to 125 $mg \cdot kg^{-1}$ Hg and 3 lbs Hg/ton is 1500 $mg \cdot kg^{-1}$ Hg. This estimate of Hg levels is indicative of the levels to expect in waste materials from the more modern mining operations. The older mining operations had less efficient methods of Hg removal, which would result in higher Hg levels expected in the waste retort materials.

4.0 RESULTS AND DISCUSSION

4.1 Mercury Values Relative to Lake Nacimiento Watershed Location

4.1.1 Mercury Occurrence in the Lake Nacimiento Watershed

Several inorganic mercury forms occur naturally and, when combined with anthropogenic materials, some forms can pose severe environmental problems. One natural source of mercury is the mineral cinnabar (HgS), which was extensively mined in the Santa Lucia Range which forms the western divide of the Lake Nacimiento watershed (Eckel et al., 1941). Several abandoned and inactive mercury mines are located in the Lake Nacimiento watershed and are discussed in Section 3. The most recent Hg mining activity occurred in the Las Tablas Creek watershed.

For the purpose of the following discussion, the term "background," as applied to the total Hg levels measured throughout the watershed, is defined as "the total Hg concentration that was found in sediments, soils, or water upstream from identified point sources for Hg pollution."

The Hg levels discussed in Section 2 vary with geographic location and geology of each study area. In many parts of the Lake Nacimiento watershed, the background levels tend to be relatively high since the area has numerous natural geologic Hg deposits and associated mercury mines. The rocks of the Franciscan Formation associated with mineralized zones in California contain a wide range of Hg levels (0.2 to 15,000 $mg \cdot kg^{-1}$) (Bailey et al., 1964). Rocks in the geological formations outside the zone of Hg accumulation have Hg levels which range from <0.001 to 0.05 $mg \cdot kg^{-1}$. Hg levels of <0.001 to 0.09 $mg \cdot kg^{-1}$ have been found in soils in areas that are not affected by mineralized deposits; with Hg levels of 0.1 to 0.77 $mg \cdot kg^{-1}$ in areas of Hg mineralization (Pierce et al., 1970). Stream sediments, in the areas that drain Hg deposits and associated mines, have much higher levels (up to 21.0 mg·kg^{-1}) than the estimated 0.3 mg·kg^{-1} average. Implications of these Hg values will be discussed in greater detail in the subsequent sections of this report.

The following discussion will examine mercury levels in soils, sediments, and water samples collected in different geographic areas within the entire watershed. For this discussion, the Lake Nacimiento watershed has been subdivided into 4 regions; the Upper Nacimiento River watershed north and west of the lake, the Las Tablas Creek watershed, the Snake and Dip Creek watersheds, and Lake Nacimiento itself.

4.2 Upper Nacimiento River Watershed

4.2.1 Sediment

Sediment samples were collected from eleven (11) locations in the Nacimiento River channel upstream of the lake. The Hg levels ranged from <0.001 to 0.052 mg·kg^{-1} (Table 4-1). These values are considered relatively low and are within the range expected from sediments and soils in non-mineralized areas (Pierce et al., 1970).

Sediment samples were collected from twenty one (21) locations in tributaries to the Nacimiento River and upstream of the lake. The Hg levels ranged from <0.001 to 0.896 mg·kg^{-1} (Table 4-1). A relatively high value (0.26 mg·kg^{-1}) was found in a Sycamore Creek sample, taken about 30 feet downstream from an abandoned Hg retort used as part of the Botts Mine operation (Photo 4-1). However, in a sample taken less than one mile downstream from the retort, in sediments from the Sycamore Creek

Table 4-1: Sediment and Soil Data from the Upper Lake Nacimiento Watershed.

SAMPLE NUMBER	SAMPLING DATE	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Nacimiento River sites: upstream from Lake: listed from north to south										
CP1S1	1/18/92	0.017	7.53	21000	38.94	2	85.60	11.80	2.60	Naci. River; Los Padres NF
CP2S1	2/28/92	0.030	7.45	2000	39.50	0	96.80	2.30	0.90	Naci. River; Los Padres NF
CP3S1	2/28/92	0.009	7.58	2400	40.38	3	99.10	0.80	0.10	Naci. River; Los Padres NF
AP4S1	1/18/92	<0.001	6.75	1800	43.32	2	98.60	0.70	0.70	Naci. River; Stony Creek
J1S1	1/17/92	<0.001	7.53	1800	23.55	36	94.10	4.60	1.30	Naci. River; Los Bueyes ford
BP4S1	1/17/92	0.004	6.36	860	33.65	3	95.80	2.90	1.30	Naci. River; The Palisades
BP5S1	1/17/92	<0.001	6.82	400	26.87	7	99.30	0.10	0.60	Naci. River; Steve Creek
BP7S1	1/19/92	<0.001	7.00	7800	29.22	1	95.60	2.50	1.90	Naci. River; The Shut-In
B2S1	1/19/92	<0.001	7.45	740	23.87	18	98.80	0.60	0.60	Naci. River; Turtle Creek
B7S1	3/16/92	0.052	6.27	170	19.73	30	100.00	0.00	0.00	Naci. River; So. Bryson area
B8S1	3/16/92	0.018	6.64	330	22.10	5	100.00	0.00	0.00	Naci. River; Beasley Creek
Tributaries to Nacimiento River: listed from north to south										
AP2S1	1/18/92	0.030	7.36	2300	17.75	14	95.10	3.60	1.30	Slickrock Creek
AP3S1	1/18/92	0.064	6.98	2100	42.44	1	96.20	3.30	0.50	San Miguel Creek
AP1S1	1/18/92	<0.001	6.76	21000	95.59	2	26.70	50.70	22.60	Stony Creek Reservoir
AP5S1	1/18/92	0.004	6.87	270	31.63	25	97.80	0.90	1.30	Stony Creek
AP6S1	1/18/92	0.003	6.86	820	33.83	10	94.60	4.10	1.30	Los Bueyes Reservoir
J2S1	1/18/92	<0.001	7.07	5100	46.64	2	73.90	18.60	7.50	Agua Fria Creek
BP1S1	1/17/92	0.260	7.23	9600	30.26	10	56.00	33.10	10.90	Botts mine; Sycamore Creek
BP2S1	1/17/92	0.009	5.69	15000	80.45	3	53.50	36.50	10.00	Sycamore Creek Reservoir
BP3S1	1/17/92	<0.001	5.07	21000	239.11	1	1.00	35.80	63.20	Sycamore Res'r. spillway
BP6S1	1/17/92	0.016	6.77	2100	29.85	3	91.90	5.50	2.60	El Piojo Creek
B1S1	1/19/92	<0.001	7.09	2200	31.93	2	85.00	10.00	5.00	Sapaque Creek
B3S1	1/19/92	0.002	7.38	2100	26.50	10	77.70	16.60	5.70	Turtle Creek
B4S1	2/28/92	0.003	7.82	3500	24.74	0	96.90	1.00	2.10	Asbury Creek
B5S1	2/28/92	0.024	7.66	1600	35.2	0	54.20	35.20	10.60	Cantinas Creek
B6S1	2/28/92	0.019	7.87	6600	35.07	0	66.60	23.60	9.80	Kavanaugh Creek
PS1S1	3/16/92	0.045	7.05	3400	24.38	13	90.90	6.80	2.30	Little Burnett Creek
PS3S1	3/16/92	0.896	7.44	6100	9.92	20	95.70	2.90	1.40	Ocean View Mine; Tobacco Cr.
PS4S1	3/16/92	0.042	7.23	3900	24.02	30	81.90	14.80	3.30	Tobacco Creek
PS5S1	3/16/92	0.221	7.21	5100	11.12	10	92.00	6.20	1.80	Tobacco Creek
PS2S1	3/16/92	0.052	7.30	3700	26.18	20	97.60	1.60	0.80	Tobacco Creek
PS6S1	3/16/92	0.025	7.24	5200	39.17	0	76.10	18.30	5.60	Unnamed creek, NW Tobacco
Tributaries to Nacimiento Lake: listed from west to east										
LM34S1	2/29/92	0.018	8.08	12000	3.61	0	95.20	1.20	3.60	Town Creek
TRM1S1	2/28/92	0.042	7.92	1200	28.87	10	76.30	15.40	8.30	Oak Shores/Tierra Red. Mt.
A1S1	2/28/92	0.018 (0.015)	7.19	3200	39.65	0	65.20	18.90	15.90	Snake Creek

Reservoir, Hg levels dropped to 0.009 mg·kg^{-1}, indicating a large dilution effect.

The highest Hg value (0.896 mg·kg^{-1}) was found in a sample taken in a tributary to Tobacco Creek, located in the watershed that drains the Ocean View and Buckeye mercury mines in the Pine Mountain District (Eckel et al., 1941). This value is considered relatively high compared to expected values (0.1 to 0.2 mg·kg^{-1}) from sediments and soils derived from Franciscan Formation rocks (Eckel et al., 1941). While sampling in this area, an abandoned ore processing building with a Hg condenser unit was observed near the Ocean View Mine, and reddish, non-vegetated tailings were noticed downhill from the facility (Photo 4-2). The eroding tailings pile is a likely source for the Hg in alluvial sediments that are transported from the area. The Hg levels in Tobacco Creek sediments dropped to 0.052 mg·kg^{-1} just upstream of the confluence with Little Burnett Creek, exhibiting a similar dilution effect as the sediments downstream from the Botts Mine retort facility (located on Sycamore Creek) (Table 4-1).

These data suggest that large dilution effects occur in sediments from drainages from the older, abandoned Hg mine areas in the Upper Lake Nacimiento watershed. The Hg levels of the sediments are not high enough by the time they reach the Nacimiento River to be considered as major Hg sources for the bottom sediments of Lake Nacimiento (see Section 5).

Photo 4-1: Abandoned retort below the Botts Mine on Sycamore Creek in Fort Hunter Liggett (1/17/92).

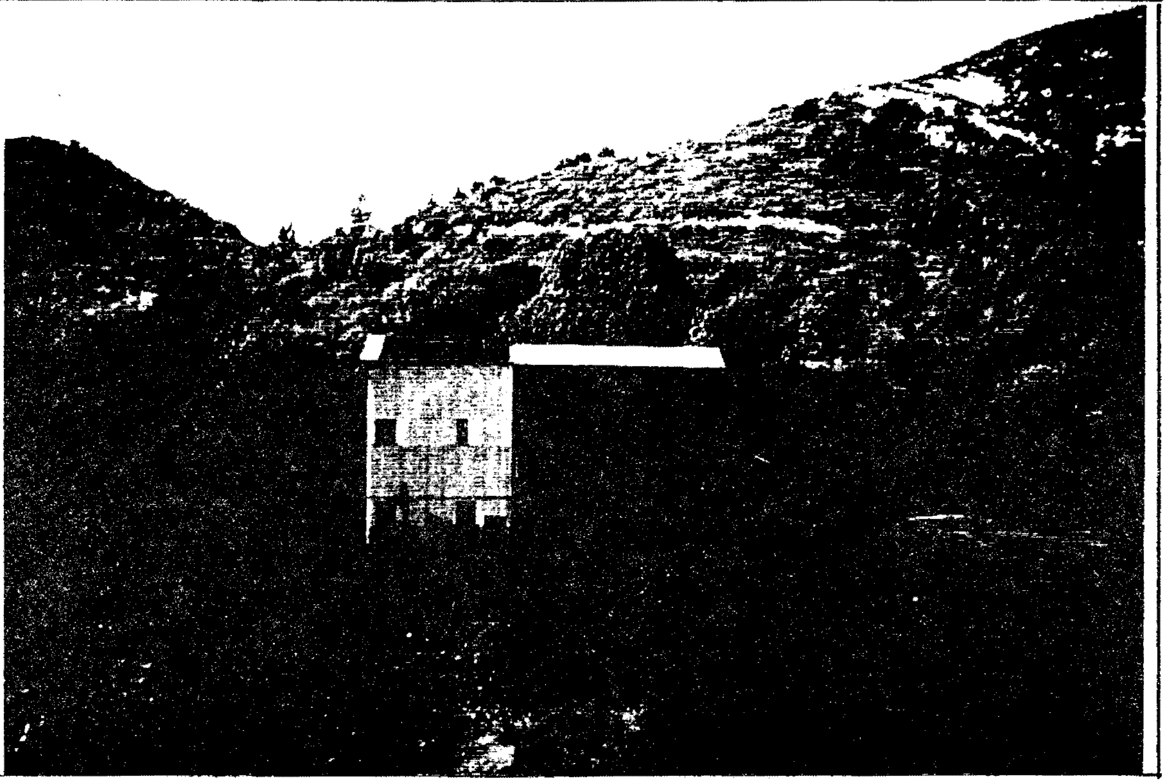


Photo 4-2: Abandoned processing buildings near the Ocean View Mine in the Tobacco Creek and Little Burnett Creek watersheds (3/16/92).

4.3 Las Tablas Creek Watershed

4.3.1 Sediment

The sediment data for the thirty six (36) samples from the Las Tablas Creek watershed will be discussed relative to geographic location. Las Tablas Creek will be subdivided into the Klau Branch and South Fork, the North Fork, Las Tablas Creek below the confluence of the North and South Forks to the Harcourt Reservoir dam, and below the Harcourt Reservoir dam to the lake.

There were seven samples taken in the Klau Branch subwatershed. Six sediment samples have total Hg values ranging from 0.08 to 2.50 $mg \cdot kg^{-1}$ (Table 4-2). The background Hg levels in the Klau Branch are approximately between 0.08 and 0.18 $mg \cdot kg^{-1}$.

However, one of the samples, taken from the dam south of Buena Vista Mine, has a relatively high Hg value of 30.00 $mg \cdot kg^{-1}$ (considered "hazardous waste" by Title 22, California Code of Regulations (CCR), Section 66699). The Buena Vista Mines, Inc. owner claims to have built the dam about 1961 using overburden material from the Buena Vista Mine operations (personal communication, Mr. Harold J. Biaggini; 10/21/92). The dam and half of its reservoir are located on land administered by the U.S. Department of the Interior, Bureau of Land Management (BLM).

BLM personnel from the Toxics Monitoring group of their Bakersfield District Office are presently performing a Preliminary Assessment (P.A.) of the dam under procedures outlined in the "Comprehensive Environmental Response, Compensation, and Liability Act" (CERCLA). BLM's P.A. is expected to rely on data

Table 4-2: Sediment Data from the Klau Branch, South Fork, and North Fork of Las Tablas Creek.

SAMPLE NUMBER	SAMPLING DATE	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Las Tablas Cr.: Klau Branch & South Fork Sediment										
CM10S1	12/17/91	0.16	7.08	7200	26.35	65	78.20	15.50	6.30	4000 ft. SE of Klau Mine
CM11S1	12/17/91	0.18	7.20	20000	119.58	1	55.60	28.40	16.00	Reservoir, So. of BV Mine
CM21S1	5/26/92	30.00*	4.46	7100	3.40	70	39.2	30.8	30.0	Dam, So. of BV mine
DS-11	10/21/92	19.00	4.00	No data	No data	No data	No data	No data	No data	Dam, So. of BV mine
DS-14	10/21/92	27.00*	7.10	No data	No data	No data	No data	No data	No data	Dam, So. of BV mine
CM7S1	12/12/91	1.00	7.10	81000	9.13	50	81.50	7.20	11.30	E. of Carson Drift, Klau
CM8S1	12/12/91	1.00	5.50	1500	549.34	-	37.10	33.80	29.10	So. of Klau Mine tailings
CM2S1	12/10/91	2.50	6.88	5400	46.52	40	82.20	5.90	11.80	W. of Klau Mine tailings
CM15S1	2/29/92	0.08	7.67	4000	32.58	5	72.10	4.50	23.40	So. tributary of Klau Br.
CM18S1	5/26/92	1.10	8.34	7600	7.20	65	89.60	6.60	3.80	So. Fork, Bonanza mines
CM20S1	5/26/92	0.06	7.51	13000	21.60	70	95.70	2.90	1.40	So. Fork, Kismet mine drain.
CM16S1	2/29/92	2.60	7.88	11000	18.29	40	86.70	9.40	3.90	So. Fork, Cypress Mt. Rd. ford
CM17S1	2/29/92	0.36	7.98	4300	4.37	36	99.10	0.40	0.50	So. Fork, below Kismet drain.
LM9S1	12/12/91	0.67	7.24	6300	8.04	58	92.90	4.60	2.50	Mouth of So. Fork, LT Cr.
LM9S2	12/12/91	7.20	7.59	29000	102.70	4	67.30	18.00	14.70	Mouth of So. Fork, LT Cr.
Las Tablas Creek: North Fork Sediment										
A2S1	2/29/92	0.31	7.93	48000	28.51	20	68.10	10.10	21.80	Upstream of BV Mine; No. Fork
CM5S1	12/12/91	26.00*	6.90	6100	22.41	-	38.30	43.50	18.20	BV Mine hillslope
CM4S1	12/12/91	33.00*	6.96	24000	6.80	-	59.00	24.70	16.30	BV Mine tailings
CM3S1	12/12/91	1200*(4400)	3.42	12000	30.02	3	60.10	23.20	16.70	BV Mine Smelter
BV1S1	5/26/92	72.00*	No Data	No Data	No Data	No Data	No Data	No Data	No Data	BV Mine tailings
LM1S1	12/9/91	21.00*	3.38	2500	112.27	20	30.40	57.40	12.10	BV Mine drain.; Klau Rd.
LM3S1	12/9/91	15.00	2.72	2700	83.32	2	79.00	12.20	8.80	BV Mine drain; So. of LT Cr.
LM4S1	12/9/91	14.00	6.70	14000	39.10	32	59.00	19.40	21.60	No. Fk.; 20 ft. up from BV drain
LM5S1	12/9/91	11.00	7.20	8600	764.98	0	27.50	33.70	38.80	Below bridge; NW of BV Mine

NOTE: * = Hg values >20.0 mg/kg are considered as "hazardous waste" by Title 22 CCR, Sec. 66699 guidelines.

generated in this "Clean Lakes Assistance" project, and other on-going RWQCB, Region 3, "mine study" projects (personal communication, Mr. Kent Varvel; 1/27/93; personal communication, Mr. David Schwartzbart; 1/31/93). BLM's P.A. is expected to be completed and be available for public comment by July 30, 1993 (personal communication, Mr. Kent Varvel; 1/27/93).

There were six sediment samples obtained in the South Fork subwatershed. The six samples have total Hg values ranging from 0.06 to 7.20 $mg \cdot kg^{-1}$ (Table 4-2). The background Hg levels in the South Fork are slightly higher than in the Klau Branch and are approximately between 0.06 and 0.36 $mg \cdot kg^{-1}$. The samples from the South Fork contain slightly higher Hg levels likely due to the large number of abandoned Hg mines in the watershed, primarily the Little Bonanza Group of mines near the headwaters of the South Fork (Photo 4-3). The highest value (7.20 $mg \cdot kg^{-1}$) measured in the South Fork alluvial sediments was for a reddish-orange, relatively clay-rich sample taken from a dry depression just upstream of the confluence with the North Fork and downstream of the confluence with the Klau Branch (Photo 4-4).

There were nine sediment samples taken from the North Fork subwatershed. The nine samples have total Hg values ranging from 0.31 to near 4,400.00 $mg \cdot kg^{-1}$ (Table 4-2). The background Hg levels in the North Fork are about 0.31 $mg \cdot kg^{-1}$ for a sample taken upstream from the mines, similar to levels found in the South Fork. There are five sediment samples, all associated with Buena Vista Mine wastes, that have extremely high total Hg concentrations ranging from 21.00 to 4,400 $mg \cdot kg^{-1}$ (>20.00 $mg \cdot kg^{-1}$ is considered hazardous waste by Title 22 CCR, Section 66699). The Hg

Photo 4-3: Abandoned open pit in the Little Bonanza Group near the headwaters of the South Fork of Las Tablas Creek (5/26/92).

Photo 4-4: Sample LM9S2 taken on the South Fork of Las Tablas Creek (12/12/92).

levels downstream of the confluence of the Buena Vista Mine drainage stream and the North Fork of Las Tablas Creek decrease below the levels considered as hazardous waste (i.e., <20.00 mg·kg^{-1}), but they are still relatively high.upstream of the confluence with the North Fork (12/12/91).

There were six sediment samples taken from below the confluence of the North and South Forks of Las Tablas Creek to the Harcourt Reservoir dam (Photo 4-5). These six samples have total Hg values ranging from 1.50 to 5.00 mg·kg^{-1} (Table 4-3). The Hg levels decrease steadily as a function of increasing distance from Buena Vista Mine, until they rise again in the Harcourt Reservoir sediments (Figure 4-1). These data suggest an initial Hg dilution effect in the Las Tablas alluvial sediments followed by a concentrating of total Hg in the relatively clay- and organic carbon-rich bottom sediments in Harcourt Reservoir.

There were five dry sediment samples and two submerged Lake Nacimiento bottom sediment samples taken from the Las Tablas Creek drainage below the Harcourt Reservoir dam (Photo 4-6). The five dry samples have total Hg values ranging from 0.09 to 1.55 mg·kg^{-1} (Table 4-3). An additional sample taken from the Franklin Creek subwatershed had a relatively low total Hg level of 0.04 mg·kg^{-1}. The highest values were found in materials identified as either dry lake sediments or submerged lake bottom sediments. These data suggest a Hg dilution effect of the sediments below Harcourt Reservoir likely due, in part, to the addition of the relatively clean (i.e., low in Hg) sediments from Franklin Creek and, further downstream, from Town Creek where Hg were found to be 0.018 mg·kg^{-1} (Table 4-1).

Photo 4-5: Sampling Las Tablas Creek sediments near Camp Natoma Road. Note the orange colors of the creekbed sediments (12/16/91).

Photo 4-6: Sampling dry lake sediments along Las Tablas Creek and downstream of the Harcourt Reservoir and Franklin Creek (12/16/91).

Table 4-3: Sediment Data from the North/South Forks Confluence of Las Tablas Creek to Lake Nacimiento.

SAMPLE NUMBER	SAMPLING DATE	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Las Tablas Creek: Upstream from Harcourt Dam										
LM14S1	12/17/91	1.80	7.00	11000	4.22	33	95.20	2.60	2.20	No./So. Forks confluence; Davis
LM8S1	12/12/91	1.5 (3.6)	7.26	8600	8.03	45	90.20	6.90	2.90	Above concrete road; Gean
LM20S1	12/17/91	1.40	7.05	4800	32.91	30	96.20	1.80	2.00	LT Cr. meander; Bonnheim
LM6S1	12/10/91	2.00	7.39	6900	35.04	37	92.70	3.50	3.80	LT Cr. rock outcrop; Bonnheim
LM31S1	2/28/92	3.07	7.45	17000	63.86	0	43.80	38.70	17.50	Chimney Rock Rd.; Harcourt
LM12S1	12/13/91	5.00	7.50	22000	79.30	0	24.80	58.90	16.30	So. part of Harcourt Reservoir
Las Tablas Creek: Downstream from Harcourt Dam										
LM10S1	12/13/91	5.10	7.58	45000	52.80	1	30.60	43.70	25.70	Harcourt Reservoir, at dam
LM30S1	2/28/92	1.55	7.8	12000	25.99	5	71.60	19.40	9.00	Harcourt Reservoir spillway
LM11S1	12/13/91	0.09	7.54	45000	34.40	34	85.30	4.60	10.10	Below Franklin Cr. mouth
LM19S1	12/17/91	0.54	6.86	4300	45.58	4	48.00	32.90	19.10	Below Franklin Cr. mouth
LM17S1	12/17/91	1.10	7.00	19000	4.50	45	46.60	45.20	8.20	LT Cr.; Dry lake sediment
LM13S1	12/13/91	0.04	7.10	6700	31.00	30	89.75	2.35	7.90	Franklin Cr.
LK3S1	6/9/92	1.50	6.80	11000	98.7	1	13.00	69.50	17.50	Lake bottom sediment
LK4S1	6/9/92	1.60	6.99	13000	78.9	1	13.00	53.00	34.00	Lake bottom sediment

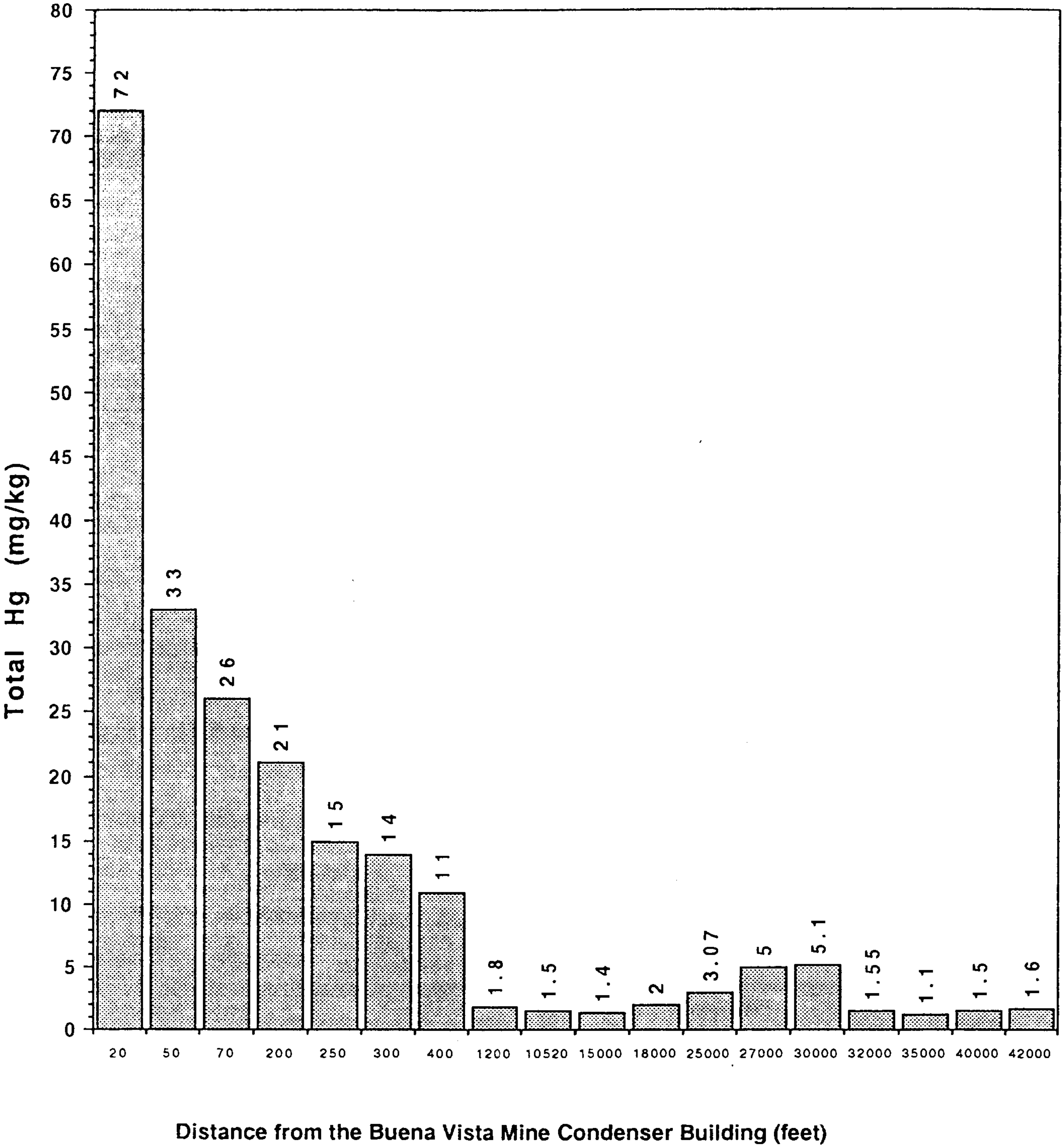


Figure 4-1: Total Hg (mg/kg) in the Las Tablas Creek floodplain system as a function of distance (feet) from the Buena Vista Mine condenser facility.

An augmentation grant study to this Clean Lakes Assistance Program was performed under the direction of Dr. Royden Nakamura of the Cal Poly Biosciences Department in 1993-94. Fish and benthic invertebrates from the Harcourt Reservoir and the Las Tablas watershed were analyzed for total Hg contents. Total Hg concentration data from this augmentation study are included in Section 8 and Appendix 9 for comparison with the sediment and water data and with the Hg level studies of fish tissue in the Las Tablas Arm of Lake Nacimiento (Rasmussen and Starrett, 1987).

Considerable information was available through local newspaper reports, scientific studies, and correspondence regarding the two most productive mercury mines, the Buena Vista (a.k.a. Mahoney) and the Klau, both located in the Las Tablas Creek watershed. Copies of the "Standard Provisions and Reporting Requirements for National Pollutant Discharge Elimination System (NPDES) Permits," and 1993 RWQCB "Cease and Desist Orders," "Waste Discharge Requirements," and "Monitoring and Reporting Program" documents for Buena Vista Mine and the Carson Drift in the Klau Mine are included in Appendix 1.

The largest source of information is the huge file collection held in the San Luis Obispo offices of the Regional Water Quality Control Board (RWQCB), Central Coast Region. Other valuable sources of information include in-house files entitled "Quicksilver" in the Reference section of the San Luis Obispo City-County Library and reports and maps located in the Maps and Documents section of the Cal Poly Kennedy Library.

We searched all relevant collections and conducted personal interviews with the most affected parties in the Lake Nacimiento watershed. The authors are grateful to all of you who shared your experiences and recollections regarding historical accounts and consequences of mercury mining in the Lake Nacimiento watershed. We have tried to document all the important events. We accept full responsibility for any errors or omissions. Interested individuals are referred to the original documents for complete evidence. All the relevent newspaper articles printed in "The Cambrian," the "Sun Bulletin," and the "San Luis Obispo Telegram-Tribune," from 1966 through 1988, that we could find are located in Appendix 2.

A San Luis Obispo County Planning Commission recommendation, in 1966, allowed the "limited processing of mercury ore at the Klau Mine" (SLO Telegram-Tribune, 2/10/66), an extension to the already active Hg ore mining and processing operations at Buena Vista Mine, which coincided with a growing United States involvement in the "Vietnam conflict." This coincidence of events proved important to the accelerated environmental deterioration of the Las Tablas Creek watershed, and, consequently, to Lake Nacimiento's natural resources (especially fish and fish-eating predators).

Hg, and other "strategic metals," prices historically inflate rapidly during times of worldwide unrest and conflict, when international metal sources can become unreliable (Bradley, 1918; Bureau of Mines, 1965; Eckel et al., 1941; Franke, 1935). The rising Hg prices in the early 1960's made mining profitable when the price per flask of Hg exceeded $450.00 (personal communication, Harold J. Biaggini, several dates, most recently, 10/21/92).

World events, combined with the discovery of Hg-rich underground ore deposits on Buena Vista Mine property in 1957, mark a turning point that set the "wheels in motion" for rapid, and largely unregulated, expansion of the mercury mining and processing operations at Buena Vista Mine in the years 1957 through 1970, resulting in gross profits of $25,000,000 and payroll receipts for up to 58 employees (The Cambrian, 7/30/70).

Subsequently, in 1971, the RWQCB issued orders to Buena Vista Mines, Inc. to restrict the runoff of acid mine drainage (AMD) from calcined waste tailings piles into Las Tablas Creek (Morro Bay Sun Bulletin, 2/11/71; SLO Telegram-Tribune, 2/10/71). Shortly after the RWQCB orders were filed, the Buena Vista Mines, Inc. owners shipped a "huge load of mercury" from the mine site via trucks and then on secured Southern Pacific Railroad cars to a bonded warehouse in Sparks, Nevada. The Hg was reported to be worth about $1,300,000 (i.e., about 3,263 flasks at $398.41 per flask weighing a total of 248,000 pounds) (SLO Telegram-Tribune, 2/24/71; personal communication, Harold J. Biaggini, 2/5/93). In 1971, this was the "largest stockpile of mercury owned by anyone except the United States government" (SLO Telegram-Tribune, 2/24/71). The present location of this reported mercury is unknown to us and conflicting rumors persist. Interested parties should contact the Buena Vista Mines, Inc. owners regarding the whereabouts or the potential transference of this mercury stockpile.

The 1966 San Luis Obispo County Planning Commission recommendation to allow Hg processing at Klau Mine was opposed by one local, third-generation landowner (Mr. Raymond "Bunch" Dodd, Sr.) who had observed examples of environmental damage in the immediate vicinity of Buena Vista Mine (i.e., premature rusting of his barbed-wire fences, olfactorially-aggravating yellow fog surrounding the mine processing facilities and the local valley, accelerated sedimentation of Las Tablas Creek, and AMD into Las Tablas Creek). He warned the commission of future environmental degradation of his adjoining property and childhood home located mostly north of the Buena Vista Mine operations (SLO

Telegram-Tribune, 2/10/66; personal communication, Mr. Raymond Dodd, Sr.; several dates, most recently 10/31/92). Nevertheless, Mr. Dodd's objections were countered at the Planning Commission meeting by a Morro Bay attorney named Mr. Charles E. Ogle who was representing Buena Vista Mines, Inc. (SLO Telegram-Tribune, 2/10/66).

Mr. Dodd's 1966 testimony to the Planning Commission has proven to be prophetic. Property damage on Mr. Dodd's land was extensive from 1957 to 1965 (involving deaths of three cattle by sudden live burial under a catastrophic rain-induced debris flow from Buena Vista Mine tailings, rusted fences and gates, loss of 40 acres of vegetation due to acid precipitation, etc.) (see the "Complaint for Injunction, Breach of Contract and for Damages" filed as Case No. 31361 in the San Luis Obispo County Superior Court). The failure of the Buena Vista Mines, Inc. owners to reimburse Mr. Dodd for his damages in a friendly manner lead to the aforementioned lawsuit filed by Mr. and Mrs. Raymond (Evelyn) Dodd against Buena Vista Mines, Inc. in San Luis Obispo County Superior Court (Case No. 31361; initial claim dated August 2, 1965). Mr. and Mrs. Dodd received a favorable judgment on April 16, 1968 and restitution in the amount of $4,357.48 was paid by Buena Vista Mines, Inc. to the Dodds (a partial record of the lawsuit is in Appendix 3; see the full court record on microfiche in the San Luis Obispo County Government Center Law Library). Mr. and Mrs. Raymond (Evelyn) Dodd's only regret was that they decided to have a judge decide their case, rather than to opt for a jury trial (personal communication, Mr. and Mrs. Raymond Dodd, Sr., 10/31/92).

Mr. Dodd's adjoining agricultural lands have sustained continuing environmental damage (from 1956 to the present; personal communication, Mr. Raymond Dodd, Sr., 1/30/93) from Hg-rich vapors from mine processing operations that enriched nearby cropland and rangeland topsoils with Hg (Bigley, 1993) and from accelerated sedimentation, acidification and metals deposition in the Buena Vista Mine drainage that flows across the Dodd's land and to the North Fork of Las Tablas Creek (several personal observations by this study's Project Team as recently as February 24, 1993).

However, since the 1965-68 lawsuit proceedings, Mr. Dodd has decided not to pursue additional legal action against Buena Vista Mines, Inc. because of the time, money, and physical and emotional effort required to conduct a legal proceeding in today's legal justice system (personal communication, Raymond Dodd, Sr., 10/31/92). Instead, the Dodd family members have put their faith in the belief that the appropriate public regulatory agencies (like the RWQCB, Central Coast Region and the California Department of Fish and Game) are acting on behalf of the overall public good in their dealings with Buena Vista Mines, Inc. (personal communication, Mr. and Mrs. Raymond Dodd, Sr., 10/31/92).

However, a general perception of inaction (for whatever reasons) by past and present Regional Water Quality Control Boards and their failure to fully enforce "cease and desist" pollution abatement orders (mainly due to AMD) against Buena Vista Mines, Inc., has resulted in widespread feelings of pessimism and mistrust among several landowners in the Las Tablas watershed, who were interviewed independently by this Project Team and others (Hubbert, 1991; Waller, 1979; personal communication, Mr. Donn Bonnheim, 2/1/93; personal communication, Ms. Donna Harcourt, several dates, most recently, 3/3/93; personal communication, Mr. Raymond Dodd, Sr., several dates, most recently, 1/31/93).

A series of letters are enclosed (Appendix 4); starting in 1979, from a Las Tablas watershed landowner, Ms. Donna M. Harcourt, her father Mr. E.

L. Decker, and Ms. Harcourt's attorney Mr. R. Bruce MacKenzie, along with the response letters by public employees (the RWQCB Executive Director and the California Attorney General). These letters provide a sense of the historical record regarding the effects on local landowners from the pollution originating at the Buena Vista and Klau Mines.

One landowner, who actually conducted his own field sampling operation of Las Tablas Creek water and sediment during the 1970's and 1980's, discontinued his efforts because of his perceived "inaction and lack of interest among RWQCB staff and Board members" for his well-intentioned labors (personal communication, Mr. Donn Bonnheim, 2/1/93).

A past RWQCB Executive Director, Kenneth R. Jones, stated that he observed "up to one foot of orange-colored sludge, originating from the Buena Vista Mine waste tailings, that was deposited in the Las Tablas floodplain channel, up to 5 miles downstream of the mine," following January 19-21, 1969 rainstorms (totaling over 15 inches of rain in 3 days). (precipitation data collected by Louis and Phyllis Bergman, Dover Creek Canyon Road).

Nevertheless, the 1969-1970 Regional Water Quality Control Board and, more recently (in 1988), a RWQCB staff employee felt that "the Buena Vista Mine operation was only a small part of a much larger Hg pollution problem that affected the entire Lake Nacimiento watershed" (personal communication, Kenneth R. Jones, 1/31/93; comments by John Goni, RWQCB employee, to the SLO Telegram-Tribune, 6/2/88; Dirkx, 1988). It was Mr. Jones' belief that there were many small, undocumented mercury prospects, in addition to the larger well known mercury mining operations, located throughout the Lake Nacimiento watershed and that, collectively, these Hg mines were more of a concern than Buena Vista and Klau Mines (personal communication, Kenneth R. Jones, 1/31/93). This belief was still held in 1988 by at least one RWQCB employee (SLO Telegram-Tribune, 6/2/88; Dirkx, 1988).

Based on comments made by the Buena Vista Mines, Inc. owners and some RWQCB Board members at a recent RWQCB meeting held in San Luis Obispo (on Friday, November 13, 1992), several people still share the misconception that Buena Vista and Klau Mines are insignificant contributors of Hg pollution to Las Tablas Creek system and, ultimately, to Lake Nacimiento (see the Agenda and minutes of this 11/13/92 Board meeting).

In fact, as part of our study we have been able to observe, and document by literature search, about 14 major abandoned Hg mine operations in the entire Lake Nacimiento watershed. These mines can, for discussion purposes, be further subdivided and counted as multiple Hg mine claims (based on land ownership maps available in the San Luis Obispo County Assessor's office). We found that the Buena Vista and Klau Mines are the two major Hg mines in the entire watershed and contribute the largest portion of Hg-rich alluvial sediments in the Las Tablas Creek watershed that end up as Lake Nacimiento bottom sediments (see Section 5).

A review of the voluminous files, held in the San Luis Obispo offices of the RWQCB regarding Buena Vista and Klau Mines, emphasizes a common theme that RWQCB staff and Board members were genuinely concerned about citizen complaints and the potential Hg and AMD pollution of natural resources in the Lake Nacimiento watershed (Kenneth R. Jones letter to Mr. E.L. Decker, (Ms. Donna M. Harcourt's father), 4/12/82). However, a past lack of available public monies to conduct a comprehensive study of the total watershed-wide Hg problem, combined with several verbal and written agreements from Buena Vista Mines, Inc. owners that they would make attempts to remediate the AMD problem (Waller, 1979) led some public authorities to believe that "good faith" efforts were being accomplished by the Buena Vista Mines, Inc. owners (e.g., see Appendix 2 for California Attorney General George Deukmejian's letter to Mr. E.L. Decker, 2/24/82).

Based on a complete review of the RWQCB files regarding Buena Vista and Klau Mines, from 1957 to the present, we have come to the belief that past Regional Water Quality Control Boards reached decisions based largely on anecdotal information, rather than on results from comprehensive, rigorous, scientific studies. The RWQCB and, to some extent, the Attorney General's staff appeared to behave out of a perceived fear of implementing and enforcing any actions against Buena Vista Mines, Inc. that might lead to court-ordered pollution abatement obligations by public agencies, including the State Water Resources Control Board (WRCB), regarding the AMD and Hg pollution problems at Buena Vista and Klau Mines (personal communication, Kenneth R. Jones, 1/31/93).

It is our understanding that the Buena Vista Mines, Inc. owners have resisted implementation of effective, engineered pollution abatement measures and long-term remedial actions if these actions resulted in the expenditure of substantial corporation funds (Waller, 1979). In fact, words have been exchanged verbally (personal communication, Harold J. Biaggini, several dates, most recently 10/21/92), and in writing (Ed Biaggini, III letter to RWQCB, 3/20/92, in Appendix 4) that confirm this perception.

4.3.2 Soils

There were fifteen surface soil samples collected in the Las Tablas watershed. The fifteen samples have total Hg values ranging from <0.01 to 7.30 mg·kg^{-1} (Table 4-4). The highest value (7.30 mg·kg^{-1}) was obtained for a topsoil located immediately adjacent to the intersection of Klau Mine Road and Cypress Mountain Road and downhill from the Buena Vista Mine. Other relatively high Hg values found in surface soils near the mine stimulated additional study (Bigley, 1993).

A hillslope transect study was conducted coincidentally with this project. The study examined three soil profiles located immediately north of the Buena Vista Mine. All three soils had the highest Hg values in the topsoil (0.17 to 0.77 mg·kg^{-1}) and decreasing values with depth to the soils' parent materials (<0.01 to 0.09 mg·kg^{-1}). The data suggest an eolian enrichment of Hg in these soils. The most probable eolian sources in the immediate vicinity are past airborne Hg vapors generated at the Buena Vista and Klau Mine processing facilities, dust from roads in the area paved with the mine wastes, and dust from the mine site grading operations (Bigley, 1993). More extensive field sampling and laboratory analysis will have to be completed to determine the full extent of the eolian Hg contribution to soils in the entire Lake Nacimiento watershed. However, in comparison with the alluvial Hg pollution sources, the eolian pollution problem is considered minor.

The second highest value (2.40 mg·kg^{-1}) was determined for an overburden soil sample deposited about 40 feet downhill from an eroded Cypress Mountain roadbank onto a rangeland pasture (Photo 4-7). We later determined that the road material was obtained from the Buena Vista Mine Hg retort wastes sometime in the 1960's. It was common knowledge in this

Table 4-4: Surface Soils Data from the Las Tablas Creek Watershed.

SAMPLE NUMBER	SAMPLING DATE	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Surface soils in Las Tablas Creek Watershed										
CM14S1	2/29/92	1.01	7.61	54000	37.27	1	22.80	29.10		**NE of BV Mine; Dodd**
CM6S1	12/12/91	2.50	7.21	8200	8.46	2	27.60	32.40	40.00	**Near BV Mine**
LM2S1	12/9/91	7.30	6.43	33000	20.20	10	47.00	39.50	13.50	**Near BV Mine**
LM7S1	12/10/91	1.30	7.00	70000	34.06	-	44.60	35.00	20.40	**Near BV Mine**
LM40S1	5/7/92	0.50	6.19	No data	19.60	1	24.20	29.40	46.40	**No. of BV mine; Dodd**
LM41S1	5/16/92	0.50	6.67	No data	19.60	1	18.00	26.00	56.00	**No. of BV mine; Dodd**
LM42S1	5/7/92	0.17	7.13	52000	22.80	1	12.00	24.00	64.00	**No. of BV mine; Dodd**
LM33S1	2/28/92	2.72	4.02	7400	9.25	7	73.60	17.50	8.90	**Cypress Mt. Rd.; Davis**
CM9S1	12/13/92	0.64	7.29	11000	14.88	5	61.20	21.90	16.90	**Roadcut; So. of Klau Mine**
LM15S1	12/17/91	0.64	6.75	38000	14.54	20	59.60	29.40	11.00	**Camp Natoma Rd.**
LM16S1	12/17/91	0.11	6.74	19000	14.70	50	59.70	27.40	12.90	**Camp Natoma Rd.**
LM23S1	12/19/91	0.01	7.02	18000	117.78	1	17.70	42.20	40.10	**Bonnheim reservoir**
LM22S1	12/18/91	0.01	7.37	32000	38.31	3	18.20	36.70	45.10	**Hillside reservoir; Gean**
LM24S1	12/19/91	<0.01	7.09	35000	28.25	1	21.20	28.50	50.30	**Chimney Rk. Rd., Bonnheim**
LM32S1	2/28/92	0.01	7.79	1200	12.32	1	78.30	17.10	4.60	**Chimney Rk. Rd., Bonnheim**

area for the San Luis Obispo County Engineering Dept. road maintenance crews to use these readily available mercury waste materials on both county-maintained and private roads within about a 10-mile radius of many of the region's mines, especially Buena Vista and Klau (Woodward-Clyde Consultants, 1987; personal communication, Harold J. Biaggini, 3/14/92; letter from Louis Bergman to Harold J. Biaggini, 4/30/92; letter from SLO Co. Counsel to T. J. Rice, 5/28/92; letter from SLO Co. Engineering to T. J. Rice, 6/8/92; three letters in Appendix 4). Analyses of additional road materials from the Las Tablas watershed will be discussed in the next portion of this report.

4.3.3 Road Materials

When we recognized the possible Hg source contribution to Lake Nacimiento sediments from eroding road materials, particularly in the Las Tablas watershed, an additional study was undertaken with a supplemental financial contribution from the State Water Resources Control Board (Bigley, 1993).

There were nine road samples collected in the Las Tablas watershed. The nine samples have total Hg values ranging from 0.05 to 46.00 $mg \cdot kg^{-1}$ (Table 4-5). Three of the samples had total Hg values (>20.00 $mg \cdot kg^{-1}$) that define them as hazardous wastes by Title 22 CCR, Section 66699. The road materials with the highest Hg levels are located on Cypress Mountain Road from the Klau Mine area north to the intersection of Cypress Mountain Road and Chimney Rock Road. The common color of the most Hg-rich road materials is reddish-brown to orange (Photo 4-8) due mainly to the presence of hemetite and goethite which are weathering products of pyrite and other Fe-bearing minerals (Mining Waste Study Team, 1988).

Photo 4-7: Sediment deposited onto Marion Davis' pasture land; derived from eroded Cypress Mountain Road materials (2/28/92).

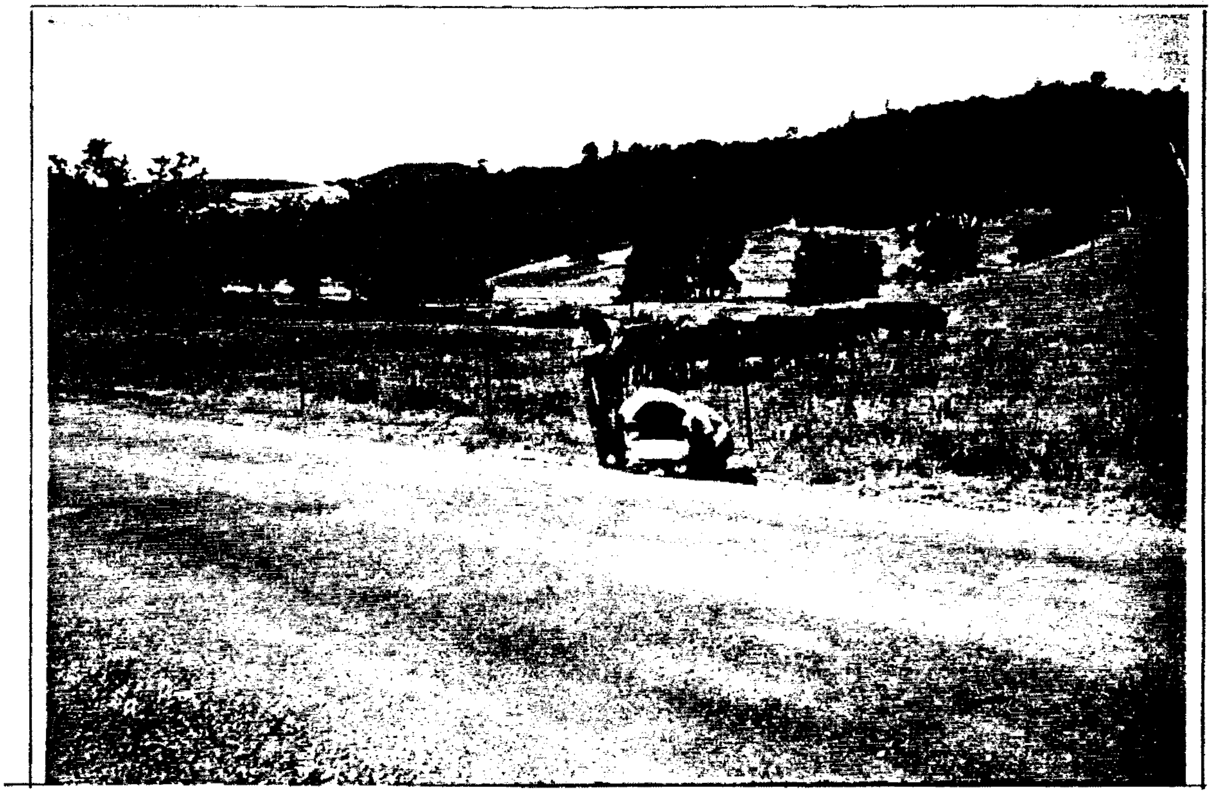


Photo 4-8: Sampling Cypress Mountain Road materials near the Gean Ranch and parallel to Las Tablas Creek (6/18/92).

Table 4-5: Roads and Soil Profiles from the Las Tablas Creek Watershed.

SAMPLE NUMBER	SAMPLING DATE	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Road Samples in Las Tablas Watershed										
RD1S1	6/18/92	34.00*	3.23	No data	4.3	15	57.0	25.0	18.0	Cypress Mt. Rd. (Las Tablas)
LM33S1	2/28/92	2.72	4.02	7400	9.3	7	74.00	17.50	9.0	Cypress Mt. Rd.; Davis
RD2S1	6/18/92	17.00	3.22	No data	6.6	10	67.0	23.0	10.0	Cypress Mt. Rd. (Las Tablas)
RD3S1	6/18/92	14.00	3.34	No data	8.0	22	64.0	22.0	14.0	Cypress Mt. Rd. (Las Tablas)
RD4S1	6/18/92	46.00*	3.35	No data	5.5	17	73.0	17.0	10.0	Cypress Mt. Rd. (Las Tablas)
RD5S1	6/18/92	15.00	3.84	No data	4.0	45	89.0	8.0	3.0	Cypress Mt. Rd. (Las Tablas)
RD6S1	6/18/92	26.00*	3.30	No data	6.4	26	74.0	17.0	9.0	Cypress Mt. Rd. (Las Tablas)
RD7S1	6/18/92	0.05	7.38	No data	4.8	25	79.0	14.0	7.0	Chimney Rock Rd.
RD8S1	6/18/92	2.70	7.82	No data	4.8	35	86.0	9.0	5.0	Cypress Mt. Rd. (So. Fork)
Soils on Transect in N. Fork Las Tablas Watershed										
LM40S1	5/7/92	0.77	6.19	No data	19.6	1	24.2	29.4	46.4	Las Tablas Creek (Dodd)
LM40S2	5/7/92	0.06	6.84	22000	22.4	1	21.5	27.6	50.9	Las Tablas Creek (Dodd)
LM40S3	5/7/92	0.05	7.22	48000	16.9	15	38.0	24.1	37.9	Las Tablas Creek (Dodd)
LM41S1	5/16/92	0.50	6.67	No Data	19.6	1	18.0	26.0	56.0	Las Tablas Creek (Dodd)
LM41S2	5/16/92	0.20	7.03	No Data	20.7	1	12.0	24.0	64.0	Las Tablas Creek (Dodd)
LM41S3	5/16/92	0.00	6.93	No Data	22.2	1	13.0	21.0	66.0	Las Tablas Creek (Dodd)
LM41S4	5/16/92	0.00	7.40	No Data	23.5	1	12.0	24.0	64.0	Las Tablas Creek (Dodd)
LM42S1	5/7/92	0.17	7.13	52000	22.8	2	23.9	28.7	47.4	Las Tablas Creek (Dodd)
LM42S2	5/7/92	0.09	7.85	35000	34.8	9	25.0	29.5	45.5	Las Tablas Creek (Dodd)
LM42S3	5/7/92	0.09	8.17	No Data	No Data	No data	No data	No dat	No data	Las Tablas Creek (Dodd)

NOTE: * = Hg values >20.0 mg/kg are considered as "hazardous waste" by Title 22 CCR, Sec. 66699 guidelines.

Potholes in these roads hold pools of orange colored water after rainstorms. The material becomes very dense and compacted following a period of wetting and drying, most likely due to the bridging of mineral grains by Fe-oxide crystals, which are common weathering by-products. Iron-cemented hardpans called ironstone, Ortstein, or placic horizons, with mineralogies similar to these road materials, have been studied throughout the world (Fanning and Fanning, 1990).

San Luis Obispo County Engineering Dept. personnel on this project's Technical Advisory Committee stated that more study will be necessary to assess the extent of the Hg levels in the area's roads and that it would be expensive to pave the Hg-contaminated road materials (Greene, 1992).

The lowest value ($0.05\ \mathrm{mg \cdot kg^{-1}}$) was obtained for a sample taken below a culvert on Chimney Rock Road. The road was thought to be previously paved with Hg wastes (personal communication, Allen Ramage, 5/14/92). The present low Hg value suggests that covering the mercury wastes with material low in Hg (like decomposed granite) and sealing the road surface with asphalt will effectively reduce Hg pollution from roads in this watershed (Bigley, 1993).

4.3.4 Water

There were thirty (30) water samples collected in the Las Tablas watershed. The thirty samples have total Hg values ranging from <0.01 to $0.94\ \mu\mathrm{g \cdot L^{-1}}$ (Tables 4-6 and 4-7). The highest total Hg value ($0.94\ \mu\mathrm{g \cdot L^{-1}}$) was determined for a creek water sample collected about 80 feet below

Table 4-6: Las Tablas Creek Water Data for the Klau Branch, South Fork, and North Fork.

SAMPLE NUMBER	SAMPLING DATE	SAMPLING DEPTH (ft)	TOTAL Hg (ug/L)	pH	TURBIDITY (NTU)	TEMP. (oC)	GENERAL LOCATION (See Maps: Appendix 5)
Las Tablas Creek: Klau Branch and South Fork							
CM10W1	12/17/91	0 to 4	<0.01	6.40	26.50	1.50	4000 ft. SE Klau Mine
CM11W1	12/17/91	0 to 6	<0.01	6.70	51.30	9.50	Reservoir, So. of BV Mine
CM12W1	12/19/91	0 to 6	<0.01	6.40	5.79	11.90	Klau Mine Reservoir
CM7W1	12/13/91	0 to 6	0.34	2.40	ND	12.00	E. of Carson Drift, Klau Mine
CM8W1	12/12/91	0 to 6	<0.01	5.10	10.10	6.50	So. of Klau Mine tailings
CM2W1	12/10/91	0 to 12	0.15	6.10	0.52	12.00	So. of old Klau Mine retort
LM9W1	12/12/91	0 to 6	<0.01 (0.5)	7.20	2.48	2.50	Mouth of So. Fork, LT Cr.
Las Tablas Creek: North Fork							
CM13W1	12/19/91	0 to 6	<0.01	7.20	7.63	7.50	1000 ft. above BV mine
LM4W1	12/9/91	0 to 6	<0.01	6.50	67.20	9.00	100 ft. above BV mine
CM1W1	12/10/91	0 to 1	0.21	6.40	40.7	15.00	BV Mine pipe from shaft
LM29W1	12/19/91	0 to 1	<0.01	4.50	1.23	19.00	BV Mine retort spoil drain
LM29W2	12/19/91	0 to 5	<0.01	4.50	17.40	14.00	BV Mine retort spoil drain
LM1W1	12/9/91	0 to 5	0.75	3.72	12.70	9.00	BV Mine drain, no. of road
LM3W1	12/9/91	0 to 2	0.41	2.95	6.60	9.00	BV Mine drain, So. of LT Cr.
LM5W1	12/9/91	0 to 4	0.94	7.20	61.90	8.50	Below bridge, NW, BV Mine

Table 4-7: Las Tablas Water Data from the North/South Forks Confluence to Lake Nacimiento.

SAMPLE NUMBER	SAMPLING DATE	SAMPLING DEPTH (ft)	TOTAL Hg (ug/L)	pH	TURBIDITY (NTU)	TEMP. (oC)	GENERAL LOCATION (See Maps: Appendix 5)
Las Tablas Creek: Upstream from Harcourt Dam							
LM28W1	12/19/91	0 to 12	<0.01	7.20	4.97	9.00	LT Creek meander; Davis
LM8W1	12/12/91	0 to 4	<0.01 (0.70)	6.60	5.05	4.00	LT Cr. above concrete rd.; Gean
LM21W1	12/18/91	0 to 5	<0.01	6.70	1.01	12.50	LT Cr. below concrete rd.; Gean
LM23W1	12/19/91	0 to 6	<0.01	7.40	5.29	5.00	Bonnheim reservoir
LM20W1	12/17/91	0 to 6	0.58	6.25	19.90	10.00	LT Cr. meander; Bonnheim
LM6W1	12/10/91	0 to 12	<0.01	6.20	1.84	9.00	LT Cr. rock outcrop; Bonnheim
LM25W1	12/19/91	0 to 6	0.11 (<0.01)	7.10	16.30	5.00	LT Cr. above Harcourt reservoir
LM25W1	12/19/91	0 to 6	0.11 (<0.01)	7.10	16.30	5.00	Above Harcoutrt reservoir
LM12W1	12/13/91	0 to 6	0.11	6.90	17.20	10.50	So. end of Harcourt reservoir
Las Tablas Creek: Downstream from Harcourt Dam							
LM10W1	12/13/91	0 to 6	<0.01	6.60	29.10	7.00	Harcourt reservoir; at dam
LM26W1	12/19/91	0 to 6	<0.01	7.20	1.09	9.00	Below Harcourt reservoir
LM27W1	12/19/91	0 to 6	<0.01	7.20	2.77	6.50	Below Harcourt reservoir
LM11W1	12/13/91	0 to 3	<0.01	6.75	4.58	11.50	Below Franklin Cr. mouth
LM18W1	12/17/91	0 to 12	<0.01	6.40	1.95	11.50	Below Franklin Cr. mouth
LM19W1	12/17/91	0 to 36	0.02	6.90	2.01	11.50	Below Franklin Cr. mouth
LM13W1	12/13/91	0 to 6	<0.01	7.10	6.62	8.00	Franklin Cr.

a Cypress Mountain Road bridge that is located about 400 feet downstream of the confluence of the Buena Vista Mine drainage stream and the North Fork of Las Tablas Creek. An adjacent sediment sample had a total Hg level of 11.00 $mg \cdot kg^{-1}$ (Table 4-2).

A relatively high total Hg value (0.34 $\mu g \cdot L^{-1}$) and the lowest pH (2.40) was determined for a water sample collected in a small pool at the entrance to Carson Drift in the Klau Mine complex.

A relatively high total Hg value (0.58 $\mu g \cdot L^{-1}$) was obtained for a sample collected in a pool that contained about 9 $ft.^3$ of water located on the Bonnheim property in the Las Tablas Creek watershed. An adjacent sediment sample had a total Hg concentration of 1.4 $mg \cdot kg^{-1}$ (Table 4-3). In all cases, the water samples contained significantly lower Hg concentrations than associated sediment samples. These data support earlier studies that show Hg is concentrated in the sediments of aqueous systems with relatively low Hg levels in the water column (D'Itri, 1990).

A soluble Hg concentration of >0.20 $mg \cdot L^{-1}$ is defined as "hazardous waste" by Title 22 CCR, Section 66699. These data show that all the water samples collected in the Las Tablas watershed are <0.20 $mg \cdot L^{-1}$.

These sediment and water data also suggest that future environmental monitoring studies for Hg pollution must require analysis of both water <u>and</u> sediment samples to get a complete interpretation of the full pollution effects on downstream reservoir and lake organism. Past pollution monitoring efforts at the Buena Vista and Klau Mines only required water samples to be analyzed for total Hg levels. Therefore, the Las Tablas area mine drainage waters were recently found to be in compliance with water quality guidelines (Earth Systems Environmental, 1990), in spite of pollution of Las Tablas Creek and Lake Nacimiento by sediment-borne Hg.

4.3.5 Fractionation Study of Soils and Sediments

A fractionation study was carried out on two soil samples and four alluvial sediment samples. The samples were fractionated into sand, silt, and clay subfractions by a combination of sieving and differential settling in a Calgon-water suspension. The total Hg levels were then measured for each of the subfractions. The data are presented in Table 4-8.

The sample taken from under the Buena Vista Mine smelter (CM3S1) has an extremely high Hg content in the clay fraction, a relatively high Hg level in the clay fraction and a very low Hg level in the silt fraction. The data confirm our field observation of some sand-sized cinnabar and elemental Hg found in this sample. The low Hg content in the silt fraction is difficult to explain and more research would have to be done to reach any final conclusions. The two soil samples (CM6S1, CM9S1) show that most of the Hg is associated with the silt and clay fractions. The data suggest that very little, if any, sand-sized cinnabar is found in these soils. The Hg found in these soils located near the Buena Vista and Klau mines was likely added as eolian dust from the nearby roads and Hg waste tailings and may have been added from Hg vapors present when the Hg ore processing activities were operational in the 1960's.

Two of the alluvial sediment samples (LM9S2, LM12S1) taken downstream from the Hg mines show that most of the Hg is present in the silt and clay fractions. The presence of Hg in these smaller particle sizes suggests that there is a general decrease in particle size of cinnabar as a function of increasing distance from the mines which would hasten the weathering of cinnabar and the release of Hg^{2+}. The Hg^{2+} may be adsorbed on the surfaces of the aluminosilicate and Fe-oxide clays and silts which are transported downstream as suspended sediment. The Hg-contaminated

Table 4-8: Soils and Sediment Fractionation Data from the Las Tablas Creek Watershed.

SAMPLE NUMBER	Fraction Type	TOTAL Hg (dry basis) (mg/kg)	GENERAL LOCATION (See Map)
CM3S1	Sand	263.25	BV Mine Smelter
CM3S1	Silt	0.92	BV Mine Smelter
CM3S1	Clay	27581.39	BV Mine Smelter
CM6S1	Sand	0.20	Soil; Near BV Mine
CM6S1	Silt	1.78	Soil; Near BV Mine
CM6S1	Clay	15.48	Soil; Near BV Mine
CM9S1	Sand	0.12	Soil; So. of Klau Mine
CM9S1	Silt	0.59	Soil; So. of Klau Mine
CM9S1	Clay	0.26	Soil; So. of Klau Mine
LM5S1	Sand	0.96	Below bridge, NW, BV Mine
LM5S1	Silt	no data	Below bridge, NW, BV Mine
LM5S1	Clay	0.08	Below bridge, NW, BV Mine
LM9S2	Sand	4.42	Mouth of So. Fork, LT Cr.
LM9S2	Silt	12.64	Mouth of So. Fork, LT Cr.
LM9S2	Clay	17.04	Mouth of So. Fork, LT Cr.
LM12S1	Sand	0.85	Harcourt Reservoir
LM12S1	Silt	11.81	Harcourt Reservoir
LM12S1	Clay	92.14	Harcourt Reservoir

sediments (LM9S2) then settle in the floodplain channel of Las Tablas Creek as flood waters recede. When water flow is excessive, the suspended sediments continue to move downstream and will eventually settle in the bottom sediments of Harcourt Reservoir (LM12S1), and when the reservoir overflows through its spillway, into Lake Nacimiento bottom sediments.

4.3.6 Mercury Pathway Flux Experiments

The original plan to use fifteen total soil and fifteen total water samples to determine the mercury flux between soil and water was reduced to five soil/sediment and five water samples. The effects of algae on mercury flux on the five water samples were not investigated separately.

To study the movement of mercury from soil to water, five field-collected samples of relatively high mercury content were exposed to clean water. After exposure for time intervals of one day, one week and one month the water was analyzed to determine the soil to water mercury flux. The procedure consisted of combining 20 grams of mercury contaminated soil and 200 mL of Type II water in a 250 mL Erlenmeyer flask, sealing the flask with a parafilm wrapped rubber stopper and placing the sample on a mechanical shaker. After shaking for the specified time of 1 day, 1 week or 1 month, the flask was removed from the shaker and the contents allowed to settle. A 50 mL aliquot was withdrawn and filtered through Whatman No. 42 filter paper. The flask and remaining sample were returned to the shaker. The filtrate was analyzed for mercury using the standard procedure for water samples.

The results of these experiments are shown in Table 4-9. The soil was not sterilized so the flux noted may be due to a combination of chemical and biological factors which could operate at very different rates. The amount

Table 4-9: Lake Nacimiento Mercury Equilibrium and Kinetics Study

Clean Sediment in Contaminated Water

Sediment sample number	Total Hg (mg/kg)	Time (days)	Sample Origin (all from Fort Hunter Liggett)
AP1S1	0.157	1	Stony Creek Reservoir
AP1S1	0.131	7	Stony Creek Reservoir
AP1S1	0.584	30	Stony Creek Reservoir
AP4S1	0.08	1	Nacimienmto R.-Stony Cr.
AP4S1	0.274	7	Nacimienmto R.-Stony Cr.
AP4S1	0.065	30	Nacimienmto R.-Stony Cr.
BP3S1	1.349	1	Sycamore Cr. Reservoir spillway
BP3S1	1.284	7	Sycamore Cr. Reservoir spillway
BP3S1	0.596	30	Sycamore Cr. Reservoir spillway
J1S1	0.047	1	Nacimiento R.-Los Bueyes ford
J1S1	0.06	7	Nacimiento R.-Los Bueyes ford
J1S1	0.016	30	Nacimiento R.-Los Bueyes ford
J2S1	0.185	1	Agua Fria Creek
J2S1	1.146	7	Agua Fria Creek
J2S1	0.324	30	Agua Fria Creek

Clean Water/Contaminated Sediment

Water sample number	Total Hg (ug/L)	Time (days)	Sample Origin
LM3S1	0.110	1	BV Mine drain above No. Fork Las Tablas Cr.
LM3S1	0.000	7	BV Mine drain above No. Fork Las Tablas Cr.
LM3S1	0.417	30	BV Mine drain above No. Fork Las Tablas Cr.
LM4S1	0.000	1	No. Fork Las Tablas Cr. above BV Mine drain
LM4S1	0.000	7	No. Fork Las Tablas Cr. above BV Mine drain
LM4S1	0.140	30	No. Fork Las Tablas Cr. above BV Mine drain
LM10S1	1.060	1	Harcourt reservoir near dam
LM10S1	0.000	7	Harcourt reservoir near dam
LM10S1	0.000	30	Harcourt reservoir near dam
LM12S1	0.000	1	Harcourt reservoir
LM12S1	0.000	7	Harcourt reservoir
LM12S1	2.140	30	Harcourt reservoir
CM3S1	6.960	1	BV Mine mercury retort/condensor
CM3S1	15.760	7	BV Mine mercury retort/condensor
CM3S1	7.850	30	BV Mine mercury retort/condensor

and kinetics of flux of mercury from soil to water shows pronounced differences for different kinds of soil. Sediment from Las Tablas Creek (Samples LM3S1 and LM4S1) and the silt-rich sediment sample from Harcourt Reservoir (Sample LM12S1) showed the highest release after one month of exposure which implies that a significant transfer of mercury to water would occur only after prolonged exposure of water to these soils in a nonflow situation. In marked contrast the relatively quick release from the Harcourt Reservoir sediment (Sample LM10S1) shows this site may be a source of mercury in water during runoff. The sample sampled near the Buena Vista Mine ore processing buildings (Sample CM3S1) showed a continual release of mercury at relatively high level throughout the experiment which signifies an ongoing release of mercury from soil to water from these Hg-rich materials.

In a second set of experiments five field-collected soil samples which were essentially mercury-free were exposed to water containing 0.5 ppm mercury. After exposure intervals of one day, one week and one month the soils were washed with cold water until the wash was mercury free. The soils were then analyzed to see if they had accumulated mercury. The procedure consisted of combining 20 grams of mercury-free soil and 200 mL of Type II water spiked with 0.5 ppm mercury in a 250 mL Erlenmeyer flask. The flask was sealed with a parafilm wrapped rubber stopper and placed on a mechanical shaker. After the specified time of one day, one week or one month a 20 mL aliquot representative of the flask contents was withdrawn. The aliquot sample was filtered through a Whatman No. 42 filter and the soil on the filter washed three times with cold water. The filtrate from the third wash was analyzed for mercury content. If mercury was detected in the filtrate, washing was repeated until the filtrate was mercury free. After the final washing the soil was dried, weighed and analyzed for mercury content using the standard procedure for soil samples.

The results of these experiments are also shown in Table 4-9. The soil used in these studies was not sterilized so the results may be influenced by both chemical and biological factors. Differences in soils gave a pronounced difference in the rate and amount of mercury flux from water to soil. The silt-rich soil (Sample AP1S1) showed a slow accumulation of mercury through the study. It appears that silt may be a slow but significant sink for mercury from contaminated water. All three sandy soils (AP4S1, J1S1, J2S1) gave accumulation that peaked at one week then decreased. This indicates some interaction with the mercury of contaminated water but sand is not a permanent mercury sink. The clay soil (Sample BP3S1) showed a rapid uptake of mercury from the water and then a gradual release indicating that clay may be a significant mercury sink during short term exposure to contaminated runoff, but release the mercury back into the water after the exposure.

4.3.7 Mercury Forms and Processes in Las Tablas Creek Watershed

Mercury likely exists in many different forms and in various size fractions in the Las Tablas Creek floodplain. The following discussion will aid in the identification of these many possible Hg forms and their potential for alluvial transportation downstream to Lake Nacimiento.

Acid mine drainage waters have pH's below 4 and more than 95% of the soluble inorganic Hg^{2+} is in the form of $HgCl_2$, at pH 5 (Hahne and Kroontje, 1973). This is the case with drainage waters from portions of both Klau and Buena Vista Mines (Table 4-2). Therefore, it is possible that one Hg form in the mine drainages that enter Las Tablas Creek is $HgCl_2$.

Ferric iron (Fe^{3+}) commonly occurs in acid drainage waters from mining areas and this is certainly the case with Buena Vista and Klau mines (Photo 4-9). Significant rates of oxidation of cinnabar and release of Hg^{2+} to solution can occur under conditions prevalent in acid mine drainage waters (Photo 4-10).

An excess of ferrous iron (Fe^{2+}) in surface alluvial sediments can bind sulfide as iron sulfide (FeS) and inhibit its usefulness as a Hg-binding agent (Rudd et al., 1983). This may be a mechanism by which some Las Tablas Creek Hg-laden sediments from Buena Vista and Klau mines remain in the HgS form until Fe levels decrease downstream from the mines.

Mercuric sulfide (HgS) is almost totally insoluble in water with a Ksp (equilibrium constant) of about 10^{-53} (Helgeson, 1969). This indicates that HgS is formed not only from free Hg^{2+} and free S^{2-} ions in solution ($Hg^{2+} + S^{2-} \Rightarrow HgS$), but that Hg^{2+} also may accept the S^{2-} ion from other sulfides like iron sulfides (FeS) and copper sulfides (CuS) (Fagerstrom and Jernelov, 1972). With the high iron sulfide levels (mainly from the minerals pyrite and marcasite) reported in the Buena Vista Mine tailings and ore deposits (Eckel et al., 1941), it is possible that some Hg^{2+} reacts with the iron sulfides present to form HgS.

Near a pH of 7, HgS is unstable in soil solutions which are in equilibrium with atmospheric oxygen. Thus, in alluvium under oxidizing conditions, HgS should be expected to be a thermodynamically unstable mineral (Lindsay, 1979). This would suggest that any HgS transported downstream from the Hg mines in the Las Tablas Creek becomes more unstable and capable of decomposing into Hg^{2+} as the pH increases from 3.5 near the mines to about pH 7 within two miles downstream from Buena

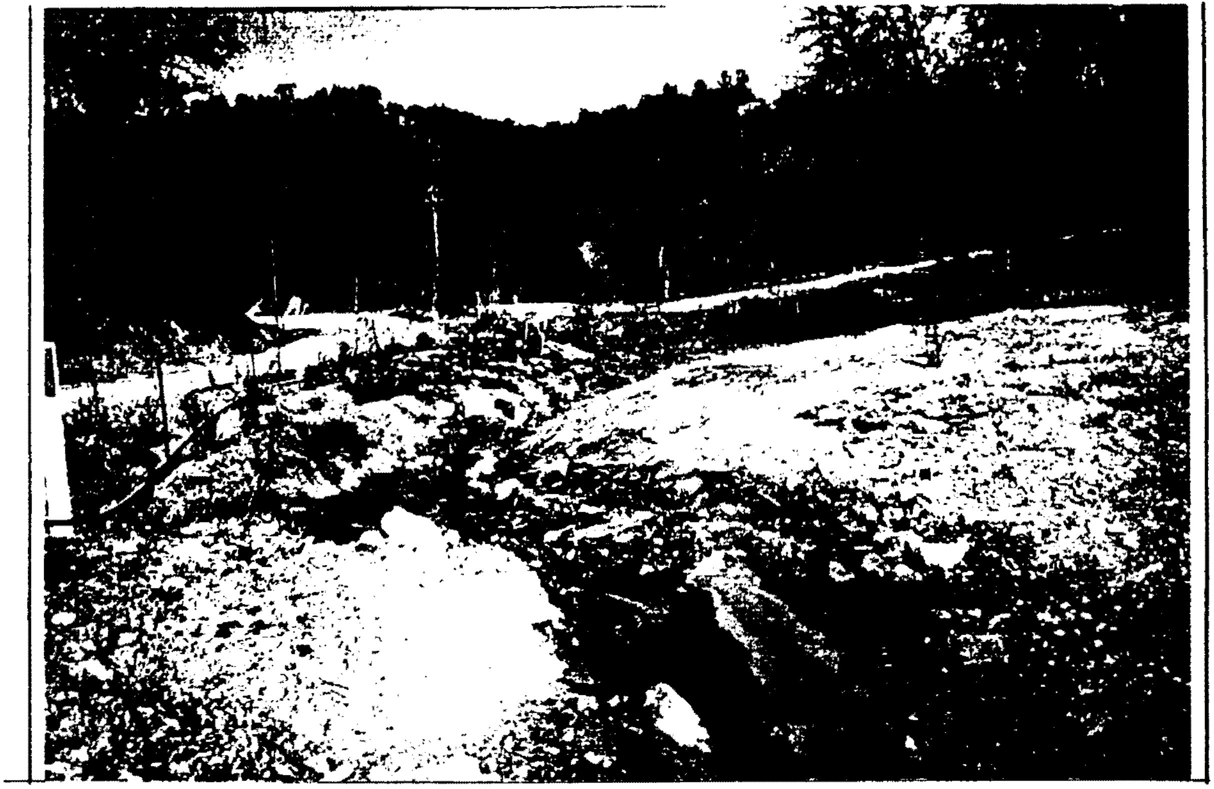


Photo 4-9: Fe-rich, acidic waters draining from the mining wastes at the Buena Vista Mine (1/25/92).

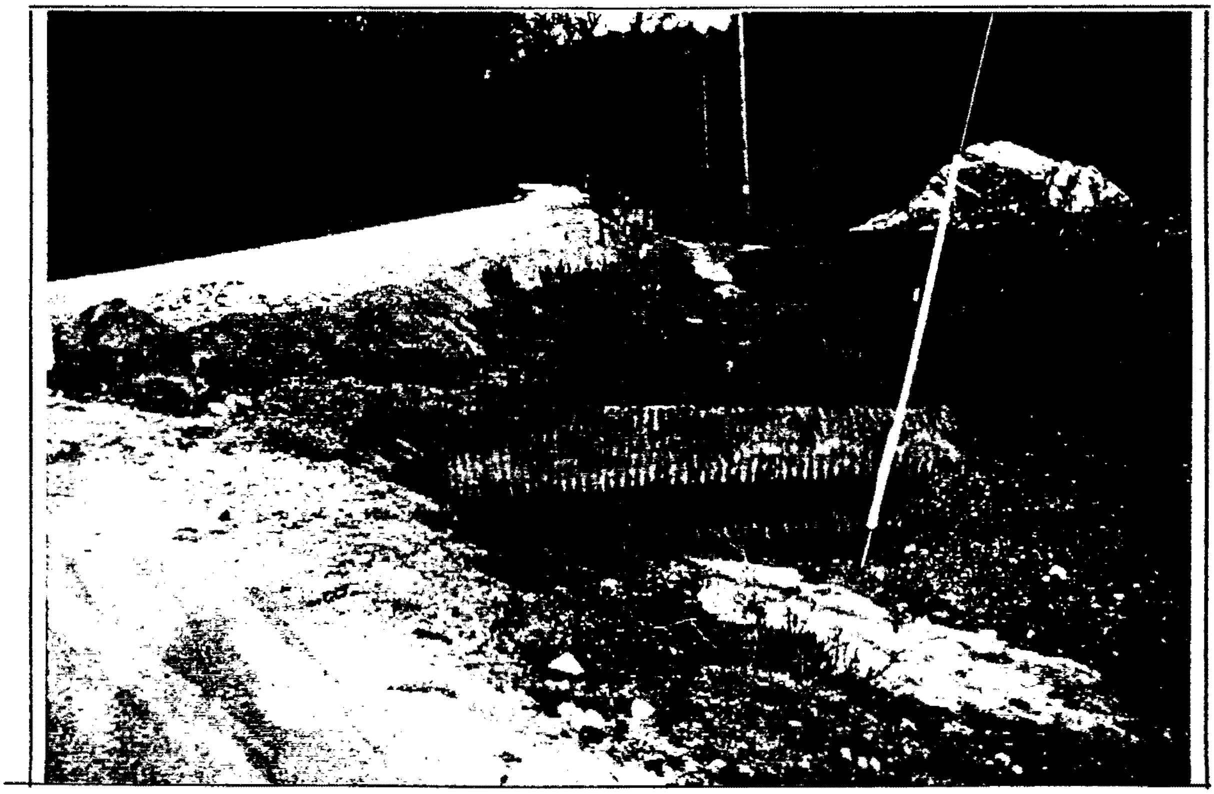


Photo 4-10: Culvert corroded by AMD below Buena Vista Mine at the Klau Mine-Cypress Mountain Road intersection (2/29/92).

Vista Mine. However, the recrystallization of HgS may occur in Harcourt Reservoir and Lake Nacimiento between sediments high in FeS or sulfide.

Grains of HgS can exist in the clay and silt fractions of the sediment, as well as coarse-grained fractions. The distribution of Hg in the alluvial sediment deposited as HgS from eroded mine spoils in Napa County, California, was mostly found in the very fine sand, find sand, and silt fractions (Harsh and Doner, 1981). Reported values of 49% total Hg were found in the silt size, and 38.9% in the fine and very sand fractions (Harsh and Doner, 1981). We observed sand-sized grains of cinnabar as far as three miles downstream from Buena Vista Mine in the Las Tablas Creek stream channel. It would seem likely that the particle size of the cinnabar grains generally decreases as they are transported downstream from the mines and other source areas. The subsequent particle size decrease of the cinnabar grains would result in a coincident surface area increase, resulting in a more rapid HgS decomposition and release of Hg^{2+}.

There is specific adsorption of the Hg^{2+} ion on hydrous iron oxides and on hydrous manganese oxides (Harsh and Doner, 1981; Jackson, 1989). At pH's between 6.5 and 7.0, iron oxides adsorb large quantities of Hg (Burkstaller et al., 1975). This may be a mechanism by which Las Tablas Creek Hg^{2+} released from weathering HgS-rich sediments originating in Buena Vista and Klau mines adsorb on hydrous iron oxides and is transported downstream from the mines. This would help to explain the relatively high Hg levels that we found in reddish-orange (Fe-rich) sediments (sample LM9S2: 7.20 $mg \cdot kg^{-1}$) in Las Tablas Creek downstream from Klau and Buena Vista mines when compared with relatively low total Hg levels in adjacent brown or gray colored sediments (sample LM9S1: 0.67 $mg \cdot kg^{-1}$) (Photo 4-4; Table 4-3).

Mercury(II) bonds to sulfhydryl groups (-SH) that are attached to carbon atoms within molecules of suspended organic matter (Gavis and Ferguson, 1972). In alluvial sediments near mercury source areas, Hg^{2+} that is sorbed to soil constituent surfaces or loosely bound to soil organic matter may exist in significant quantities (Harsh and Doner, 1981). Hg^{2+} will bind to organic particles as soon as they are available, and therefore a large amount of Hg in water is associated with suspended organic sediment (Fagerstrom and Jernelov, 1972). This adsorption process would indicate that there is Hg^{2+} bonded to organic-rich alluvial and lacustrine sediments in Las Tablas Creek, Harcourt Reservoir, and Lake Nacimiento.

The organic C content in alluvial sediments is often similar to the organic C content of the surrounding surface soils within the adjacent watershed. The range of organic C was 0.3 to 5.5%, with a mean of 1.9 ± 1.1% in 58 small (0.2 to 4,000 km^2 in area) reservoirs (Ritchie, 1989). Organic C is potentially eroded with surface soils, and is transported as alluvial sediment. The total Hg concentration of the sediments increased with increasing carbon/nitrogen (C/N) ratios of organic matter (Smith and Loring, 1981). In sediments of the Everglades, the concentration of Hg in the clayey sediment is positively correlated to the organic content of the sediment (Lindberg and Harriss, 1984). Therefore, it is important to reduce any erosion of Hg-contaminated topsoils in the immediate vicinity of mercury mines in the Las Tablas watershed in order to reduce the total Hg loading of this creek system. This can best be accomplished by maintaining a vegetative soil cover.

The Hg^{2+} ion adsorbed to organic-rich sediment can be released into solution and be methylated to CH_3Hg^+ by both aerobic and anaerobic bacteria, primarily in aquatic sediments, suspended sediments, and particulates in the water column, in the gastrointestinal tracts of fish, and, to a lesser extent, within terrestrial soils (Compeau and Bartha, 1984; Furutani and Rudd, 1980). This is likely a mechanism by which CH_3Hg^+ bioaccumulates in fish in both Harcourt Reservoir and Lake Nacimiento. The biological study supervised by Nakamura adds information to support this belief (see Section 8).

Methylation of Hg^{2+} in anoxic environments is due to the suppression of the activity of methanogenic organisms. When sulfates are abundant, actual methanogenesis is suppressed by competition with sulfate reducers, and this specific inhibition of the methanogens instead stimulates methylation by SO_4^{2-}-reducing bacteria. In studies done on the estuarine Berry Creek, sulfide depletion of 0.95 $mg \cdot kg^{-1}$ in dry sediment resulted in an increase in CH_3Hg^+ produced (Berman and Bartha, 1986). When reduction occurs in sediment, the sulfide ion (S^{2-}) immobilizes Hg^{2+} and forms insoluble HgS. The redox potential of the upper layer of sediment is an important governing this process. If the redox potential is not low enough to keep sulfur in the S^{2-} state, oxidation and formation of mercuric sulfate ($HgSO_4$) takes place (Lindsay, 1979). The $HgSO_4$ dissociates in water releasing Hg^{2+} ions which then become available for methylation by bacteria. It would seem likely that as Hg-laden sediments are transported further downstream from the more sulfate- and sulfide-rich sediments near Klau and Buena Vista mines, resulting in decreased sulfate and sulfide levels, that Hg^{2+} is more susceptible to methylation (from Hg^{2+} to CH_3Hg^+). This process would further result in CH_3Hg^+ bioaccumulation in fish in both Harcourt Reservoir and Lake Nacimiento.

4.4 Snake and Dip Creek Watersheds

4.4.1 Sediment

Sediment samples were collected from two (2) locations in these creeks that drain directly into Lake Nacimiento River. The Hg levels ranged from 0.015 to 0.018 $mg \cdot kg^{-1}$ (Table 4-1). These values are considered relatively low and are within the range expected from sediments and soils in non-mineralized areas (Pierce et al., 1970).

4.5 Lake Nacimiento Water and Sediments

Earlier reports indicate that Hg enters lake bottom sediments close to a point source of pollution (Mikac et al., 1984). In studies of Lake Erie, bottom sediment total Hg levels were shown to range from 0.0005-0.0124 $mg \cdot kg^{-1}$, with higher concentrations found near known point sources of Hg pollution. In a lake such as the Nacimiento reservoir, transport and re-distribution of Hg would likely be relative to mercury source areas in the watershed, lake sediment characteristics, lake water levels, and prevailing water currents in the lake.

The following discussion will examine Hg levels within four different areas of the watershed: 1) the upper Nacimiento River Arm west and north of Las Tablas Creek; 2) the Las Tablas Creek Arm; 3) Lake Nacimiento east of Las Tablas Creek and west of Dip Creek; and 4) Lake Nacimiento east of the mouth of Dip Creek to the dam.

4.5.1 Upper Nacimiento River Arm West and North of Las Tablas Creek

A recent study of sediments in this portion of the lake showed total Hg levels ranging from 0.04 to 0.16 $mg \cdot kg^{-1}$ (Hubbert, 1991). Our values (0.01 - 0.04 $mg \cdot kg^{-1}$) fall within this range and compare well with the Hg values we found in Nacimiento River samples about 1 mile upstream of our westernmost lake site (Table 4-10).

Our sediments had somewhat lower Hg levels because we sampled in June, 1992 at Pebblestone Shut-In which is several miles upstream from the Las Tablas Creek watershed, the primary mercury source region in the entire watershed, and about 2 miles west of Hubbert's most westerly site. His westernmost sample site was less than 0.5 mile west of the Las Tablas Creek mouth because he could not gain boat access to the far western part of the lake during the months of October and November, 1990, when the lake water level was about 6.6% capacity (23,100 A.F.) due to the preceding 5-year drought. In contrast, when we sampled lake sediments on June 15, 1992, the lake water level was at about 26.9% capacity (94,150 A.F.) (personal communication, Sharon Graves, KSBY-TV; 1/28/93).

4.5.2 Las Tablas Creek Arm

Total Hg levels would be expected to be highest in lake sediments closest to a Hg pollution source and located in submerged stream channels where clay and organic carbon levels are high. Relatively high Hg values (1.5 and 1.6 $mg \cdot kg^{-1}$) in the sediments of the Las Tablas Creek Arm of the lake indicate that Las Tablas Creek is the major transport system for mercury-laden sediments to the lake (Table 4-10). A previous study of Hg levels in Lake Nacimiento bottom sediments from the Las Tablas Arm show a range of 0.168-0.990 $mg \cdot kg^{-1}$ (Hubbert, 1991).

Table 4-10: Lake Nacimiento Bottom Sediment Data

SAMPLE NUMBER	SAMPLING DATE	SAMPLING DEPTH (ft)	TOTAL Hg (mg/kg)	pH	TOTAL ORG. CARBON (mg/kg)	MOISTURE CONTENT %	CO. FRAGS. %	SAND %	SILT %	CLAY %	GENERAL LOCATION (See Maps: Appendix 5)
Lake Nacimiento Bottom Sediment Samples											
LK1S1	6/9/92	10	0.01	7.18	790	23.7	25	94.5	3.5	2.0	Pebblestone Shut-In
LK2S1	6/9/92	28	0.04	6.71	6300	91.2	1	38.0	50.0	12.0	Oak Shores area
LK3S1	6/9/92	10	1.50	6.80	11000	98.7	1	13.0	69.5	17.5	Las Tablas Creek Arm
LK4S1	6/9/92	33	1.60	6.99	13000	78.9	1	13.0	53.0	34.0	Las Tablas Creek Arm
LK5S1	6/9/92	57	0.08	6.65	14000	104.9	1	16.0	53.0	31.0	Mile 19 (Las Tablas Creek Arm)
LK6S1	6/9/92	4	0.02	6.77	660	39.1	4	73.0	19.0	8.0	Dip Creek shore
LK7S1	6/9/92	3	0.18	5.70	9000	72.0	1	36.0	33.0	31.0	Mile 17 (Dip Creek)
LK8S1	6/9/92	32	0.08	5.68	5900	60.0	1	23.0	45.0	32.0	Snake Creek Arm; Heritage Ranch
LK11S1	6/23/92	3	0.07	7.36	No Data	41.7	2	51.0	36.0	13.0	Dip Creek mouth
LK12S1	6/23/92	70	0.13	7.01	No Data	204.0	0	9.0	35.0	56.0	Snake Creek mouth

In the earlier study, there were no positive correlations found among sediment properties and total Hg levels in the Las Tablas lake sediment samples (Hubbert, 1991). One sample had a relatively high Hg content (0.990 $mg \cdot kg^{-1}$) and a high sand content (51.9%). A likely explanation was that the sample contained sand-sized cinnabar grains that were transported miles downstream from the Hg source areas by strong creek currents following high intensity storm events. A Napa, California study of Hg-contaminated riverwash polluted by Hg mining waste found that more than 90% of the Hg recovered in alluvium was in the >4.0 $g \cdot cm^{-3}$ fraction (indicating the presence of cinnabar, which has a specific gravity of about 8.0 $g \cdot cm^{-3}$) (Harsh and Doner, 1981).

Hubbert's Hg values are slightly lower than the values we obtained because he sampled in the Las Tablas Creek Arm during the months of October and November, 1990, when the southernmost lake sediments, closer to mine sources, could not be reached by boat because of extremely low water levels.

4.5.3 Lake Nacimiento East of Las Tablas Creek and West of Dip Creek

Total Hg levels were found to increase in lake bottom sediments immediately east of the confluence of Las Tablas Creek and the submerged Nacimiento River channel. Hg levels ranged from 0.045 to 1.200 $mg \cdot kg^{-1}$ (Hubbert, 1991). Our Hg value (0.080 $mg \cdot kg^{-1}$) falls within the range that Hubbert found, but his values were consistently higher than ours (Table 4-10). The likely reason that he found higher Hg levels was again because he collected samples during shallower lake water levels and was able to consistently collect bottom sediments high in clay and organic carbon in the submerged Nacimiento River channel.

Comparison of Hg data from our studies suggests that the best times to sample Hg enriched lake sediments is at the lowest possible lake water level when clayey organic-rich sediments can be consistently obtained using dredge sampling equipment.

The relatively high sediment Hg levels immediately east of the Las Tablas Creek mouth further support our conclusion that Las Tablas Creek watershed is the major source of mercury to the lake. Once the Hg-contaminated sediments enter the lake they are likely re-distributed downstream (i.e., north and then east) following normal water currents in the lake and historic flow patterns of the Nacimiento River.

4.5.4 Lake Nacimiento East of the Mouth of Dip Creek to the Dam Total Hg levels were found to generally decrease in lake bottom sediments as one moves east in the lake from the mouth of Dip Creek to the Nacimiento Lake dam. Hg levels were found to range from 0.053 to 0.620 $mg \cdot kg^{-1}$ (Hubbert, 1991). Our Hg concentrations ranged from 0.02 to 0.18 $mg \cdot kg^{-1}$ and also tended to be slightly lower than Hubbert's because they were sampled outside of the immediate submerged river channel in coarser sediments that were lower in organic carbon (Table 4-10). The data further suggest a general decrease in Hg levels of the lake sediments from the mouth of Dip Creek to the dam. Additional sampling locations, undistributed sediment core samples and laboratory analysis would be needed to fully document this preliminary conclusion.

We noticed that it was impossible to collect bottom sediment samples at several lake locations using the Eckman Dredge sampler. The main reasons are either a hard rock bottom with a lack of sediment or coarse-textured nature (i.e., high gravel and sand contents) of the sediment which will not stay in the sampler as it is raised from the lake bottom.

In addition to our observations, the Monterey County Flood Control District reported that in the 1970's, SCUBA divers noted underwater rock ledges that were relatively clean of sediment near the Nacimiento Water Company wells just offshore of the Oak Shores development (Envicom, 1984). These observations suggest that most of the fine textured lake bottom sediments (which would likely be the highest in Hg content) are located in deep submerged channels of the old Nacimiento River and are also deposited in the several tributary arms that directly enter the lake, mostly from the south.

4.5.5 Lake Water

There were ten (10) surface water and thirteen (13) bottom water samples collected in Lake Nacimiento. The total Hg levels ranged from <0.001 to 0.868 $\mu g \cdot L^{-1}$ (Table 4-11). The highest Hg values in both surface and bottom water samples were collected in the Las Tablas Creek Arm of the lake. These water data follow the trends seen in the sediment data (Table 4-11).

A sediment sample collected near the bottom water sample with the highest total Hg value (0.868 $\mu g \cdot L^{-1}$) had a total Hg value of 0.80 $mg \cdot kg^{-1}$, about 100 times the total Hg concentration of the water (Tables 4-10 and 4-11). In all cases, the water samples contained significantly lower Hg concentrations than associated lake bottom sediment samples. This observation is consistent with other studies that indicate that Hg is quickly removed from solution and is immobilized in sediments or organisms, when

Table 4-11: Lake Nacimiento Surface and Bottom Water Data.

SAMPLE NUMBER	SAMPLING DATE	SAMPLING DEPTH (ft)	TOTAL Hg (ug/L)	pH	TURBIDITY (NTU)	TEMP. (oC)	GENERAL LOCATION (See Maps: Appendix 5)
Surface Lake Water Samples listed by location, from West to East							
LK1W1	6/9/92	0 to 1	0.020	7.35	4.67	25.5	Pebblestone Shut-In
LK2W1	6/9/92	0 to 1	<0.001	7.50	6.31	25.0	So. of Oak Shores
LK3W1	6/9/92	0 to 1	0.020	6.83	6.01	26.0	So. Las Tablas Creek arm
LK4W1	6/9/92	0 to 1	0.776	6.92	4.72	26.0	No. Las Tablas Creek arm
LK5W1	6/9/92	0 to 1	0.817	6.84	5.17	25.0	Las Tablas Creek mouth
LK6W1	6/9/92	0 to 1	0.020	6.94	15.40	28.0	Dip Creek west shore
LK7W1	6/9/92	0 to 1	<0.001	6.82	3.63	26.0	No. of Lake Milepost 17
LK8W1	6/9/92	0 to 1	<0.001	7.08	6.25	26.0	W. of Snake Creek marina
LK9W1	6/9/92	0 to 1	<0.001	6.84	4.04	26.0	NW of Lake Milepost 15
LK10W1	6/9/92	0 to 1	0.061	7.31	3.42	26.0	600 ft. west of Lake dam
Subsurface Lake Water Samples listed by location, from West to East							
LK1W2	6/9/92	9 to 10	<0.001	7.48	9.37	23.5	Pebblestone Shut-In
LK2W2	6/9/92	27 to 28	0.051	7.42	9.37	23.8	So. of Oak Shores
LK3W2	6/9/92	9 to 10	0.102	6.83	9.60	23.0	So. Las Tablas Creek arm
LK4W2	6/9/92	32 to 33	0.143	6.74	36.90	23.0	No. Las Tablas Creek arm
LK5W2	6/9/92	56 to 57	0.868	6.66	30.50	23.0	Las Tablas Creek mouth
LK6W2	6/9/92	3 to 4	0.184	7.00	11.70	28.0	Dip Creek west shore
LK11W2	6/2392	2 to 3	<0.001	6.85	7.74	19.0	Dip Creek mouth
LK7W2	6/9/92	18 to 19	0.020	6.82	38.90	23.0	No. of Lake Milepost 17
LK8W2	6/9/92	31 to 32	0.102	6.76	27.10	23.0	W. of Snake Creek marina
LK12W2	6/23/92	69 to 70	0.200	6.50	29.20	24.0	Snake Creek mouth
LK9W2	6/9/92	39 to 40	<0.001	6.92	5.27	26.0	NW of Lake Milepost 15
LK13W2	6/23/92	84 to 85	<0.001	7.45	14.20	11.0	W. of resort marina
LK10W2	6/9/92	119 to 120	0.194	6.84	19.40	23.0	600 ft. west of Lake dam

it is found above very low background concentrations, which rarely exceed 0.1 $mg \cdot L^{-1}$ (Chamberlin et al., 1990; Gavis and Ferguson, 1972).

The following discussion will focus on the implications of these reported sediment and water data to the environmental quality of Lake Nacimiento.

4.5.6 Factors Influencing the Forms and Occurrence of Mercury in Lake Nacimiento Sediments and Water

When mercury reaches lake bottom sediments, it may be held by the following binding mechanisms: 1) sorption on hydrated ferric oxide, 2) surface sorption and/or ion exchange with aluminosilicate clays like montmorillonite, and 3) sorption and/or complexation with organic matter, especially sulfur-containing material (D'Itri, 1990). The distribution of Hg has been shown to be strongly correlated with organic carbon, clay, iron, phosphorous, and sulfur contents of particulate matter in Lake Ontario and with organic carbon, iron, and sulfur in Lake Huron (Thomas 1972, 1973). A positive correlation of Hg levels with total organic carbon and clay contents was found in a recent study of Lake Nacimiento bottom sediments (Hubbert, 1991).

The pH of all our sediment and water samples (5.68 to 7.50) was higher than the acid pH's (3.5 to 4.5) measured immediately downstream of Buena Vista and Klau mines. As pH values rise, the cation exchange capacities (CEC) of soils and sediments generally increase. It has been shown that the maximum adsorption of Hg^{2+} by clay minerals occurs near pH 7 (Newton et al., 1976). This would indicate a relatively high adsorptive capacity for Hg^{2+} by Lake Nacimiento clayey sediments relative to pH.

Bodaly et al. (1984) have hypothesized that reservoir construction increases Hg concentrations in fish. Inundated terrestrial soils provide new Hg sources, increase retention of inflowing material, and increase microbial activities due to decomposition of flooded terrestrial organic matter (Bodaly et al., 1984).

Completion of the Lake Nacimiento dam in 1957 resulted in the flooding of mostly terrestrial alluvial sediment. Any pre-existing Hg-bearing river sediment that was covered by the lake was potentially able to be biologically methylated and, therefore, serve as a source of CH_3Hg^+ that could be bioaccumulated by aquatic organisms. Also, any post-1957 sediment input to the lake has likely increased Hg levels in the lake bottom sediment. There are no known pre-1957 Hg concentration data for river sediments or aquatic organisms in the Lake Nacimiento watershed. Therefore, it can be concluded that the present Hg-bearing sediment in Lake Nacimiento is a combination of sediment and soils flooded by the reservoir water as of 1957, together with bed material and suspended sediment that entered the lake waters after construction of the dam.

Inorganic Hg activity, and the Hg content in fish, can be increased if the sulfide activity is decreased by lowering pH and/or increasing the redox potential (Bjornberg et al., 1988). An increase in biota Hg accumulation may result at low dissolved oxygen levels, due to an increase in methylation of Hg under anoxic conditions (Bjornberg et al., 1988). Hg^{2+} methylation will occur when available Hg^{2+} is released due to current flow and aeration causing the decomposition of HgS (cinnabar) (Berman and Bartha, 1986). Hg^{2+} release will also take place when organic matter decomposition releases exchangeable Hg^{2+} during periods of aeration when lake levels drop exposing organic-rich sediments to the air. The

Hg^{2+} may later be available for methylation when the lake levels again rise. The annual rise and fall of Lake Nacimiento water levels would be expected to result in the release of Hg^{2+} during the late summer months, followed by Hg methylation in the late Spring when the water levels peak and temperatures begin to increase.

It would be too costly to determine all the potential "hot spots" for CH_3Hg^+ production, due the many environmental variables involved. However, our data and the scientific literature suggest that clayey sediments high in organic carbon and located downstream from Hg source areas are the most probable areas to investigate as "hot spots". This would be in the Las Tablas Creek Arm of Lake Nacimiento and in the lake immediately east of Las Tablas Creek mouth.

The concentration of dissolved Hg in the Oaks Arm of Clear Lake, which receives Hg-rich sediment from the Sulphur Bank Hg Mine, is generally below 0.013 $\mu g \cdot L^{-1}$ (Chamberlin et al., 1990; Walker, 1988). Yet fish are known to accumulate as much as 1.9 $mg \cdot kg^{-1}$ fish tissue (Mining Waste Study Team, 1988). Fish samples collected in the Las Tablas Creek Arm by the California Department of Fish and Game have shown relatively high Hg levels (up to 1.8 $mg \cdot kg^{-1}$ fish tissue) in the filets of largemouth bass sampled (Rasmussen and Starrett, 1987). This would suggest relatively high CH_3Hg^+ contents available for bioaccumulation in this part of the lake.

Interestingly, the fish in both Clear Lake and Lake Nacimiento have comparable Hg levels in their tissues and the Hg levels in the water columns are similar at both lakes. However, Hg levels in the sediments in the Oaks Arm of Clear Lake are over 50 times higher (up to 100 $mg \cdot kg^{-1}$; Chamberlin et al., 1990) than the Hg levels in the sediments in the Las

Tablas Arm of Lake Nacimiento (1.6 mg·kg^{-1}; Table 4-9). A substantial body of evidence supports the contention that aquatic organisms directly accumulate large CH_3Hg^+ concentrations primarily from the extremely small quantities in the water column (D'Itri, 1990). These facts have important implications regarding strategies to reduce the Hg levels in the fish of Lake Nacimiento (see a more thorough discussion in Sections 6 and 7 of this report).

A mercury speciation study of California lake surface waters, including Lake Nacimiento sampled on April 8, 1987, found that 80% of the total mercury (10.0 mg·kg^{-1}) in the Las Tablas Creek Arm and 76% of the total mercury (5.0 mg·kg^{-1}) in the Snake Creek Arm was dissolved organo-Hg forms, mostly CH_3Hg^+ (Gill and Bruland, 1990). The methylation of Hg^{2+} in the lake bottom sediments and suspended particulates in the water column leads to Hg bioaccumulation by fish in Lake Nacimiento. Because of its relative stability in biological systems, CH_3Hg^+ is more slowly metabolized and eliminated by fish than the inorganic forms of Hg (Chamberlin et al., 1990; D'Itri, 1990).

Prevention of additional Hg loading from streams entering the lake appears to be the best method to decrease Hg levels in the lake sediments and in water column and, subsequently, in the lake fish population (Chamberlin et al., 1990; Gavis and Ferguson, 1972; Rudd et al., 1983).

5.0 MERCURY LOADING MODEL FOR LAKE NACIMIENTO

5.1 Research Strategy

The watershed that contributes sediment and mercury (Hg) into Nacimiento Lake is complex in landform and geology. The number of sediment samples that could be taken from different portions of the watershed was limited by budgetary constraints, and in some cases by ease of access. A sampling strategy was developed that spread the sampling over a broad region of the watershed, and over a range of geologic conditions, but three contributory drainages (Los Burros, Pozo Hondo, and Salmon Creeks in Hunter Liggett Military Reservation) were not sampled due to inaccessibility. However, Nacimiento River channel sediments immediately downstream of the confluences with these drainages were sampled. The task was then to extrapolate the data from sampled drainages to those that were unsampled, in order to best calculate the total Hg yield to the lake.

The extrapolation of information between sampled and unsampled areas required first that some correlation of geologic and geographic conditions be made. It was therefore critical to understand those conditions commonly associated with Hg mineralization in, and close to, the watershed.

5.2 Parameters Controlling Mercury Mineralization

Study of relevant geologic maps (Chipping, 1987; Dibble, ; Durham, 1968; Seiders, 1982; Seiders, 1989) and reports (Eckel et. al., 1941) shows that certain geologic features are often associated with Hg and co-associated silica-carbonate mineralization. These features were used to indicate the possible occurrence of undiscovered Hg deposits within the watershed, or the likely extension of mineralization beyond known mining areas.

The key features appear to be a combination of more than one of the following features:

1) association with the Nacimiento Fault;
2) association with the boundary between Cretaceous "Great Valley Sequence" sandstones and shales, and the slightly older (Cretaceous/Jurassic) Franciscan Formation melanges;
3) close spatial association to serpentinite slabs; and
4) close spatial association to Tertiary or Quaternary volcanics.

There are exceptions. The Dutra-Polar Star mine/claim complex, which lies outside and to the west of the watershed, is entirely within the Franciscan Formation, and apparently far from volcanics or the Nacimiento Fault. The Botts Mine on Sycamore Creek is entirely within Cretaceous sediments, and on a NE-trending fault. Both of these occurrences are, however, on faults.

Hg is usually mobilized in association with hydrothermal activity, often co-associated with emplacement of the sulfides of other metals and with volcanic activity. Thus possible movement pathways for such fluids, and the proximity of an igneous body or other source of heat would be prospecting targets for cinnabar. The main mining districts lie across the axis of the Santa Lucia Range in a broad zone that is about 20 miles long and about 5 miles wide, elongated along a northwest axis that parallels the crest of the Santa Lucia Mountains (Eckel et. al., 1941). The deposits occur in sheared and brecciated fault zones that show evidence of east-west tensional extension and possibly east-west directed right lateral shear. These faults are well documented (Eckel et. al., 1941: Plate 78).

Tertiary rhyolites are mapped throughout the area, and are the most probable source of heat and metallic mobilization, although it is possible that the thermal events simply concentrated Hg that was first introduced to the area during the original subduction process that created the Franciscan Formation. Of less certainty is the role of Quaternary basalts mapped in the center of the Burnett Peak Quadrangle (Seiders, 1989). These may have generated enough heat to either reactivate original Hg in the Franciscan Formation, or Hg deposited in the Tertiary.

Hg claims are conspicuously absent in nearly all of the watershed to the east of the Nacimiento Fault, where either "Great Valley Sequence" (Cretaceous) or Tertiary rocks are found, and the implication is that either these rocks did not fracture to allow the Hg to enter, or that the rocks were not present when the mineralization took place. The introduction of Hg to early Tertiary rocks at the Buena Vista and Klau Mines, which is east of the Nacimiento Fault but in rock that is faulted parallel to the Nacimiento system, tends to suggest that "Great Valley Sequence" and some Tertiary strata were present during the introduction of the Hg, and that the absence of Hg elsewhere in similar rocks is due to lack of fracturing.

The Botts Mine on Sycamore Creek is also entirely within Cretaceous sediments, but is on or close to a NE-trending fault that might have provided a pathway for mineralizing fluids.

The role of serpentinite in the Hg mineralization is uncertain. Serpentinites are considered to be hydrothermally altered ultramafic igneous rocks, but the alteration is thought to take place under different conditions that the generally epithermal regimes associated with cinnabar concentration. Serpentinites associated with Hg mines could either be fortuitous, or similar to that of the "Great Valley Sequence" sandstones, such that Hg-bearing fluid flow was controlled by the position and orientation of dike-like masses of serpentinite.

The geologic parameters for known mine districts are listed in Tables 5-1 and 5-2. On the basis of Tables 5-1 and 5-2, the following generalities can be made. Hg mines are usually within four miles of serpentinite bodies, and more frequently within one mile of a serpentinite body. They are up to eight miles from igneous bodies, but usually within a mile. They are usually within a mile of the boundary between the Franciscan Formation and other units, but can be up to 3.5 miles distant.

5.3 Extrapolation of Information to Unsampled Watershed

The first step was to find a correlation, if any existed, between the geologic parameters discussed in the previous section with Hg values in sampled sediments. The process required the assignment of an artificial 'value' to each geologic parameter, with the assumption that a real correlation with Hg and that "value" would show a tendency toward a linear correlation when the "value" and Hg concentrations had a linear regression applied. The "value" numeration was adjusted to provide the highest R-value on the regression, and then the "value" was applied to all unsampled subwatersheds in the system.

The following geologic parameters and assigned values were used :

(1) Proximity to igneous rock or thermal source: 1(far) to 5(close);

(2) Proximity to fault line: 0(not on fault) or 2(on fault);

(3) Proximity to serpentinite: 0(no serpentinite in watershed), 1(melanges of Franciscan Formation in watershed), or 2(serpentinite body in watershed); and

(4) Mine proximity: 0(no mine/claim in watershed) or 1(mine/claim present).

Table 5-1: Geologic parameters for known mercury mines in the Lake Nacimiento watershed.

DISTRICT MINE SITE(S)	ON FAULT; FAULT STRIKE	DISTANCE TO SERPENTINITE	PROXIMITY TO IGNEOUS ROCK	PROXIMITY TO GVS/FRANCISCAN or TERTIARY/FRANCISCAN
Botts	Possibly northeast[1]	4.0 miles	4.0 miles[2]	3.5 miles[3]
Bonanza Group	Yes; northwest	0.0-1.0 mile	1.0 mile	0.25 mile
Buckeye, Ocean View, & Pine Mt.	Yes; northwest	0.25 mile	0.0 mile	0.0 mile
Buena Vista, Capitola, & Klau	Yes; west-northwest & northeast	0.0-0.5 mile	3.0 miles	0.0 mile
Cypress Mt.	Yes; northwest	1.0 mile	0.0 mile	0.75 mile
Kismet	Yes; northwest	0.5 mile	0.0 mile	0.75 mile

NOTES:

1. There is no agreement between geologic maps by Seiders, 1989 and Dibblee, relative to the local geologic structure, but field observations during our study did indicate some shearing was present.
2. This distance is measured from a small Quaternary basalt. All others are measured from Early Tertiary volcanics of much larger volume.
3. The mine lies within Great Valley Sequence rocks, rather than the Franciscan Rocks.

Table 5-2: Geologic parameters for known mercury mines near the Lake Nacimiento watershed.

DISTRICT MINE SITE(S)	ON FAULT; FAULT STRIKE	DISTANCE TO SERPENTINITE	PROXIMITY TO IGNEOUS ROCK	PROXIMITY TO GVS/FRANCISCAN or TERTIARY/FRANCISCAN
Cambria	Yes; northwest	0.0 mile	1.5 mile	0.0 mile
Doty, Quien Sabe	Yes; northwest	0.0 mile	0.5 mile	0.75 mile
Dutra	Unknown	1.0 mile	8.0 miles[1]	None in vicinity
Fitzhugh	Yes; northwest	1.0 mile	0.0 mile	0.0 mile
Hamilton, Warren	Yes; northwest	0.0 mile	0.0 mile	1.0 mile
Keystone	Yes; northwest	0.5 mile	0.0 mile	1.0 mile
Lil. Almaden	Yes; northwest	0.25 mile	0.0 mile	0.0 mile
Oceanic	Yes; northwest	1.0 mile	1.0 mile	0.0 mile
Pole Star	Unknown	3.0 miles	6.0 miles[1]	1.0 mile[2]
Vulture	Yes; northwest	0.75 mile	0.0 mile	0.25 mile
Wittenberg	Yes; northwest	0.25 mile	1.0 mile	0.0 mile

NOTES:

1. This distance is measured from a small Quaternary basalt. All others are measured from Early Tertiary volcanics of much larger volume.
2. This is the distance to a large block of sandstone that could have acted as an impermeable barrier, similar to the Great Valley Sequence.

The highest possible total for all of the parameter values is 10, the lowest 1. These values were calculated for all subwatersheds in the basin for which Hg values were obtained, graphed and then the regression equation was found. In Figure 5-1, data from Las Tablas Creek were not used as the concentrations were orders of magnitude higher than those found elsewhere, and statistically overwhelmed the data set (i.e., Las Tablas data skewed the analysis even when a relatively low value of 0.2 ppm was used, but measured Hg levels are much higher). The model was first tested using Las Tablas Creek values, to verify if it produced predicted Hg values similar to those that were measured in some of the other subwatersheds, but it overestimated those values.

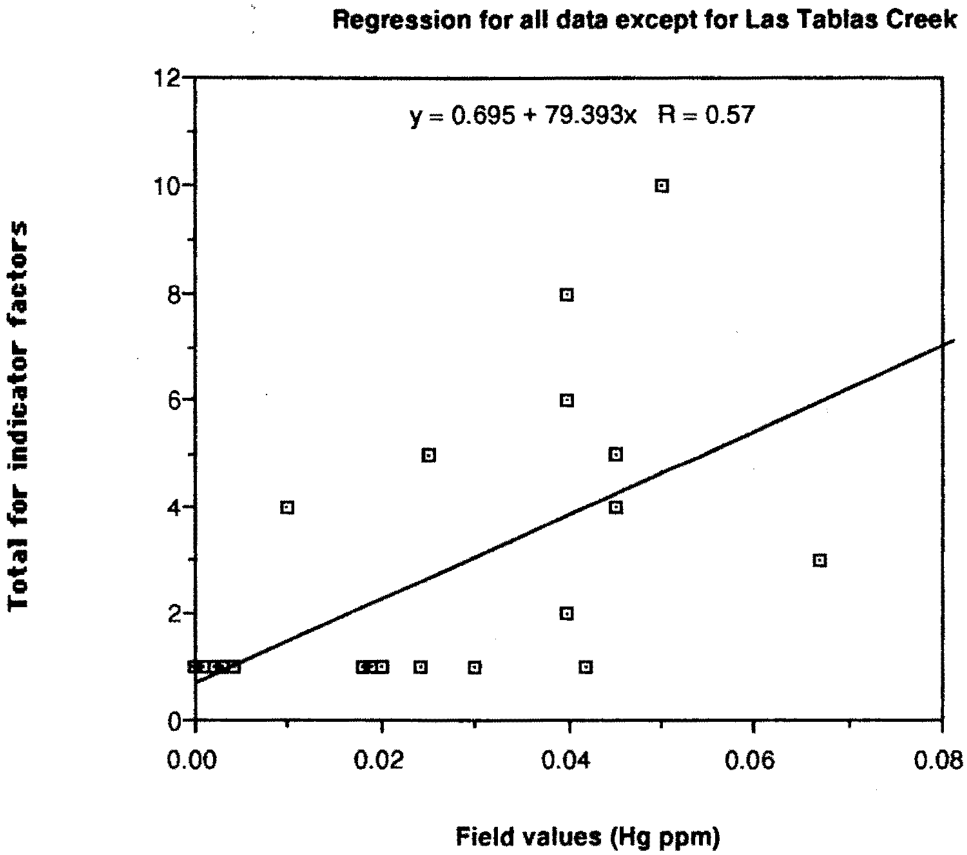


Figure 5-1: Total Hg values (ppm) for field collected samples compared to the "values" predicted from the indicator factors.

Removal of the Las Tablas Creek data produced a much better match.

As a result of the correlation between the predicted value and the observed values, which can be described only as "fair" rather than "good", attempts were made to alter the allocated values contributing to the indicator total, but this was unsuccessful. In general, changing the relative values of these factors would push another sampling point into outlier status, and there was no lowering of the R-value for the correlation.

This regression curve:

"(total indicator value) = 0.695 + 79.393 (calculated Hg content of sediments)"

was applied to the entire assemblage of subwatersheds in the basin, so that values of Hg in sediment would be estimated from the indicator value of each subwatershed. This also enabled estimated values from the model to be compared to field values in the relatively small number of subwatersheds the average model error is then measured. Excluding Las Tablas Creek data (at 0.2 ppm), the average error was 0.00014 ppm for the 25 sites (Spreadsheet 1 in manila folder). If Las Tablas Creek is included at a value of 0.2 ppm, the average error increases to 0.01384 ppm (Spreadsheet 2 in manila folder), and if the Las Tablas Creek data is included at 2.0 ppm, the average error increases to 0.2067 ppm. Thus the model appears sensitive enough to apply to the basin as a whole. Error distribution values are compared to field measured values in Tables 5-2 and 5-3.

It can be seen that the typical error is less than 100%. On first inspection, a 100% error seems very large, but it represents errors that hold the value at essentially the same order of magnitude. For example, a field value of 0.02 ppm would yield a predicted value of 0.04 ppm if the error was to the lake a positive 100%. In view of the large variation of values that

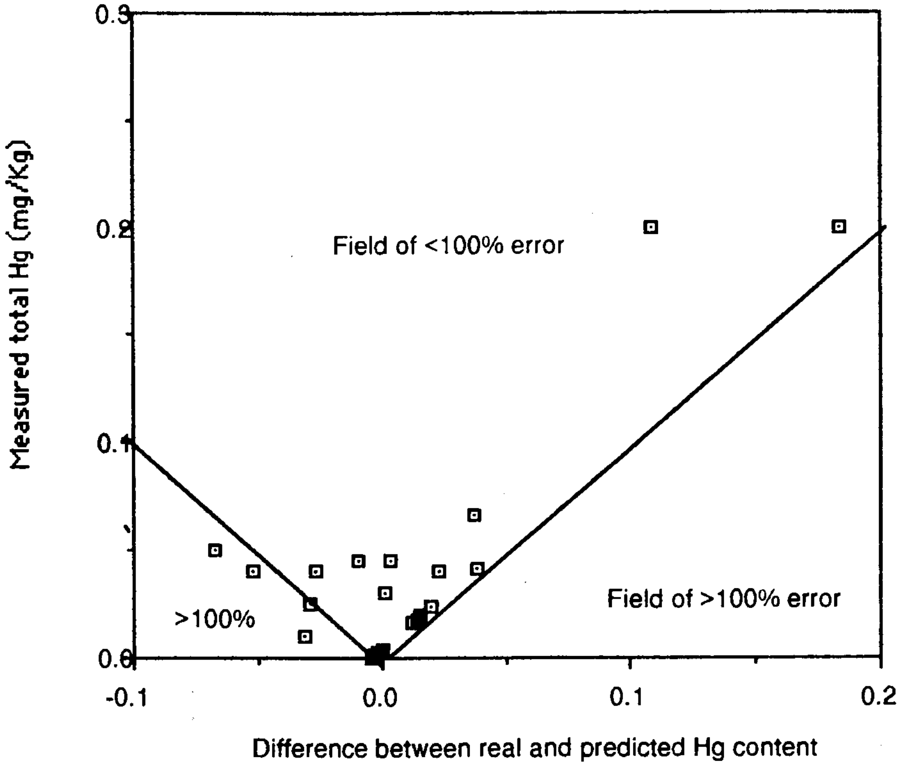


Figure 5-2: Comparison of prediction error to total Hg value for field collected samples (Las Tablas data at 0.20 mg/kg)

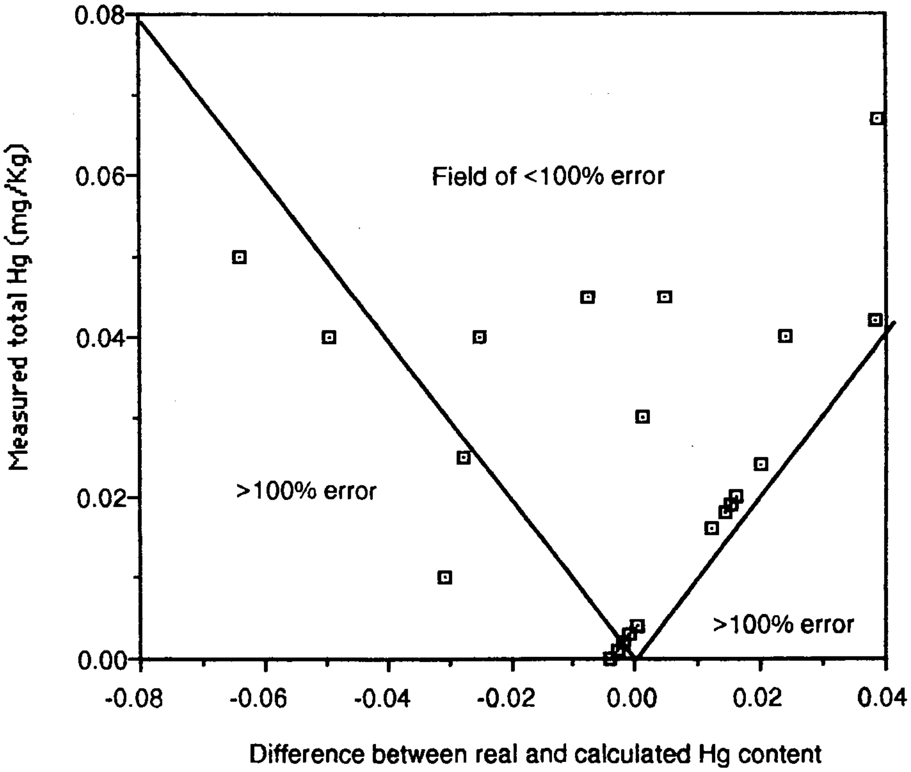


Figure 5-3: Comparison of prediction error to total Hg value for field collected samples (Las Tablas data excluded).

might be expected from a series of field samples in the same area, as illustrated by sampling in the Las Tablas Watershed, it is felt that this error amount is reasonable. Note also that the errors are essentially evenly distributed between positive and negative values. Thus generated errors should be expected to cancel each other out, so that gross Hg loadings to the lake should be estimated with some accuracy.

Once the expected Hg content of sediments has been calculated, the actual Hg loading to the lake can be estimated from the total sediment input

5.4 Sediment Production Calculation For Each Subwatershed

There are no sediment production studies for the Nacimiento watershed, but studies have been done elsewhere in the Coast Ranges and Transverse Ranges. These studies have been applied to the Nacimiento watershed, with the understanding that any figures generated would be an approximation. Better evaluations could be made through application of the Universal Soil Loss Equation (SCS, 1976) to the watershed, but this requires detailed analysis of soil condition, vegetative cover, slope and other factors that could not be accommodated in this study's budget. On the other hand, the variation in sediment production is extreme in those watersheds that have been measured, and in many cases it would be difficult to predict accurately the sediment production of any given year using data from previous years. Factors such as fire and high intensity storms play a major role in sediment production, and these could not be evaluated in this study.

5.5 Sediment Data Sources

The sediment discharge was measured in Santa Rita Creek, just south and west of Templeton, and in Upper Arroyo Grande Creek, both in San

Luis Obispo County (Knott, 1976). The sediment production ranged from less than 1 ton/mi.^{2} in a dry year to thousands of tons/mi.^{2} in a wet year.

The 1943-1972 average sediment yield for Santa Rita Creek was 1,800 tons/mi.^{2} at a gaging station sampling 2.95 mi.^{2}, and 1,100 tons/mi.^{2} at a station sampling 18.2 mi.^{2} (Table 8 in Knott, 1976). The report shows that Arroyo Grande Creek above Phoenix Creek yielded an average of 1,200 tons/mi.^{2} for a watershed of 13.5 mi.^{2} over the years 1943-1972 (Table 7 in Knott, 1976). Lopez Creek, near Arroyo Grande Creek, yielded a much smaller 380 tons/mi.^{2} for a watershed area of 21.6 mi.^{2} over the same time period.

The sedimentation of Williams Reservoir in Santa Clara County was studied (Ritter and Brown, 1972). Using calculations partly derived from work on nearby creeks, sediment production averages of 900-970 tons/mi.^{2}/year were estimated.

Erosion and resultant sediment yields in the Transverse Ranges of southern California were studied (Scott and Williams, 1974; 1978). The sediment production figures were given in yd.^{3}/mi.^{2} (cubic yards per square mile), but analysis of the study data show that sediment yield varies inversely and exponentially with watershed area. Yields of up to 25,000 tons/mi.^{2} were encountered in very small (~0.3 mi.^{2}) watersheds that presumably are both steep with unstable soils; like much of the land in the Lake Nacimiento watershed. Watersheds of about 1 mi.^{2} yield 5,000 tons/year, while 50 mi.^{2} watersheds yield about 1,900 tons/mi.^{2} (Scott and Williams, 1974; 1978).

The sediment load in the Ventura River also within the southern California Transverse Ranges was studied (Hill and McConaughy, 1988). The 188 mi.^{2} watershed yielded an average 5,660 tons/mi.^{2} sediment yield over a 1969-1981 sampling period. Annual yield calculations varied from a low of 25 tons/mi.^{2} to a high in the great 1969 storm year of 35,800 tons/mi.^{2}.

The rather different watershed basins of the Trinity, Eel, Mad, and Van Duzen Rivers were studied (Hawley and Jones, 1969). These watersheds are in very steep, erosive terrain that produce some of the highest sediment yields in the nation. Sediment yields of 7,800 tons/mi.^{2} were found in the lower Eel River, 6,900 tons/mi.^{2} from the Van Duzen River, and 3,820 tons/mi.^{2} in the Mad River. These data are for suspended sediment yields, and presumably total (bedload plus suspended) sediment loads are considerably higher. The headwaters of the Trinity River had 160 tons/mi.^{2} and 780 tons/mi.^{2} from the area between the cities of Hoopa and Helena, California.

5.6 Application of Sediment Production to the Nacimiento Watershed

The value of 1,000 tons/mi.^{2} (about 1.56 tons/acre) was chosen as a relatively conservative sediment yield value for the entire Nacimiento Watershed basin. The figure was applied to the entire watershed, for although slope steepness was greater on the west side of the river, rocks are generally softer and more erodible on the east side of the river. With a watershed area of about 82 mi.^{2} (about 52,480 acres), sediment yield data from nearby watersheds would suggest a typical year's production of about 1,000 tons/mi.^{2}.

The Transverse Range data suggests a higher value should be used, but those watersheds coincide with some of the fastest geologic uplift rates in the country, and with easily eroded, relatively young rocks (Hill and McConaughy, 1988; Scott and Williams, 1974; 1978). Therefore, the

Transverse Range data have not been applied to this study, except as an upper limit for comparison purposes. Similarly the very steep Klamath Mountain watersheds are exceptional in their sediment production, although some areas underlain by more resistant rocks have lower values (Hawley and Jones, 1969).

The sediment production of 1,000 tons. mi.^{2} must be adjusted for watershed area when the sediment production of each subwatershed is calculated. Langbein and Schumm (1958) showed that sediment production varied inversely with the 0.15 power of the drainage area (x), such that $\left(\frac{x}{5.25}\right)^{0.15}$.

These numbers have been emplaced into this model to adjust for sediment production area, raising the production from small subwatersheds and diminishing the production from large subwatersheds. There is an inherent risk in this method, as unsampled watersheds were not subdivided for areal measurement purposes to the same degree as watersheds which were actually sampled, leading to a possible bias toward underestimation of sediment production from unsampled watersheds. The spreadsheet-derived sediment production figures, using a watershed area correction, were about 10% smaller than production figures without the Langbein-Schumm correction.

5.7 Subwatershed and Total Watershed Mercury Loadings

The calculated Hg loadings, derived from the prediction model described above, are assumed to be present in all sediment derived from each subwatershed. There is no way to know if Hg concentrations would, in fact, rise in a linear manner relative to sediment production, but this simplistic assumption is used. The sediment production is then converted to a loading value for Hg in terms of pounds of Hg per year. The data from Las Tablas Creek was not entered from the model, but was entered at the observed values of 0.2, 1.0, and 2.0 ppm, in order to ascertain the relative importance of production from the watershed. This was done because the predictive model for Hg concentrations does not accurately predict the very high Hg values that isolate this subwatershed from the rest. The spreadsheet indicates that with an assumed loading from Las Tablas Creek of 0.2 ppm, the total loading from Las Tablas Creek would constitute about 25.8% of the entire watershed's contribution to the lake. If Las Tablas Creek sediment had 1.0 ppm or 2.0 ppm Hg, the contributions would be about 63.3% or 77.5% of the total annual lake Hg contribution, respectively. These values are subject to the qualitative criticism discussed below.

5.8 Hydrologic Parameters Influencing Mercury Contribution from the Las Tablas Arm, and Unknown Factors Relative to Mercury Loading Predictions

5.8.1 Mercury in Sediments Available for Transportation to the Lake

The sediment flux through the Las Tablas Creek watershed, above the level of the lake itself, is controlled by several variables. The most obvious variable, discussed at length in other sections of this report, is the continued flux from the old Hg mines, including their waste dumps, processing facilities, and workings. Both very fine, molecular size Hg is present with coarse silt, sand, and gravel-size grains of cinnabar. Thus some of the Hg can be expected to be transported in the fines fraction, but a significant amount would occur also in the coarser sediment fraction.

The soils in vicinity of the Buena Vista Mine are contaminated with Hg that is presumed to have been vapor-deposited from smelter gasses (see Section 4.3.2 and Appendix 3). This Hg must be assumed to exist at the quasi-molecular level, likely adsorbed to individual soil mineral and organic particles, and thus could be transported easily in flowing water. The issue of these Hg-contaminated soils has also been addressed in Section 4.3.2 of this report.

Below Buena Vista and Klau Mines, Hg-contaminated materials are primarily found in Las Tablas Creek sediments. It is presumed that coarser materials containing Hg are to be found throughout the sediment between the mines and Lake Nacimiento, and thus may be re-exposed, remobilized, and will continue to flow to the lake even if the mine facilities and surrounding hills cease to be a source of Hg pollution. Annual Hg loadings will depend on the proportion of this sediment stockpile that reaches the lake in any given year. It is possible that a high level flood event (100-year storm or larger) could scour a very significant portion of this sediment from the Las Tablas Creek floodplain, although much sediment would be redeposited in the floodplain channel as waters recede. Fine sediments would move more efficiently, so that a very large percentage of the Hg-contaminated fines (silts and clays) will likely reach Lake Nacimiento.

5.8.2 Harcourt Reservoir as a Sediment Sink

Harcourt Reservoir is a significant Hg-contaminated sediment sink. High Hg levels in the fine sediments of the reservoir indicate that contaminated fines are stored on the lake bottom. This storage may be 100% efficient for small storm events that do not cause the reservoir to spill, and which are followed by a long period in which sediments could settle to the bottom of the lake. Lake bottom sediments are anaerobic, and therefore conversion to methylated forms of Hg would be possible and is likely occurring. In the event of a series of high intensity rainstorms and subsequent flooding, Hg-contaminated sediments spill from Harcourt Reservoir at the same rate that they enter the reservoir from upper Las Tablas Creek. Residence time for the suspended sediments would be longer than for a stretch of the river channel of equal length, but would still be short enough to enable most fines to move with the flowing water over the spillway. In addition, the high turbulence associated with a high intensity storm may stir up much of the fine Hg-contaminated sediment on the lake bottom, so that some of the stored Hg would be re-released for passage to Lake Nacimiento. Coarse sediment bedload would tend to be trapped within Harcourt Reservoir, and a well defined debris fan has been observed to be building into the upstream end of the reservoir. This deposition is burying previously deposited fines at the south end of the reservoir, and as the reservoir progressively fills with sediment it will develop an increasingly coarser sediment bottom that will eventually seal the fines from further downstream transport. In the worst case scenario, any failure of the Harcourt Dam would potentially release all of its trapped sediment to Lake Nacimiento.

5.8.3 Remobilization of Fines from the Upper Las Tablas Arm at Low Lake Stage

The level of Lake Nacimiento is seldom allowed to reach maximum stage causing Harcourt Reservoir and Lake Nacimiento waters to merge. Sediment-rich waters from Las Tablas Creek will deposit their fine suspended sediment load in the still waters of the lake. Whenever the lake is at a low level, but receives high level floodwaters via the Las Tablas Creek Arm, previously exposed old lake floor sediments will be re-transported further north into the Las Tablas Arm and eventually into the main lake channel.

5.9 Dependence of the Annual Mercury Loading Model on Balance of Sinks and Sources, and Some Model Limitations

The sediment flux entering the lake is controlled by the pattern of erosion at the mine areas, the pattern of erosion of Hg-contaminated soils primarily near Buena Vista and Klau Mines, the pattern of sediment remobilization in the Las Tablas floodplain upstream of Harcourt Dam, the Harcourt Reservoir water level when a flood event passes through the reservoir, the stage of infill of Harcourt Reservoir, the level of Lake Nacimiento, and the erosion of lake sediments between Harcourt Reservoir and Lake Nacimiento.

The highest total Hg levels downstream of the Buena Vista and Klau Mines are associated with sediment fines in the lake, and the total sediment in the Las Tablas Creek alluvium (Tables 4-2 and 4-3). Sediment yield calculations assume a mixture of bedload and suspended sediment load in lake contributions, and we have applied total Hg levels of 0.2, 1.0, and 2.0 ppm to the entire sediment load. The amount of field-gathered data does not allow for this high degree of sophistication in the model, but it appears valid to state that the application of the maximum measured value of 2.0 ppm to the entire sediment flux would likely result in an overestimation of the Hg contribution from Las Tablas Creek to Lake Nacimiento. Conversely, application of the total Hg value of 0.2 ppm will underestimate the contribution. Therefore, the estimated Hg contribution value of about 77.5%

from Las Tablas Creek to the lake is probably too high, and the 25.8% value appears too low. The real Hg contribution value lies somewhere in the range 25.8% to 77.5% and can only be made more precise by continued sediment and water sampling and research study.

Nevertheless, it can be safely stated that the Las Tablas Creek watershed is the primary Hg source contributor for over one-half (50%) of the total Hg load to Lake Nacimiento. The Hg pollution source control measures to be discussed in Section 6 of this report will, therefore, focus on the measures that could be successfully implemented at Buena Vista and Klau Mines, the two main "point sources" for Hg sediment and water pollution located in the Las Tablas watershed.

6.0 SOURCE CONTROL REMEDIATION MEASURES

6.1 Overview

Two routes for Hg conveyance from the watershed sources to Lake Nacimiento were investigated: 1) fluvial transport, and 2) eolian transport. The estimate developed for the average annual Hg transport rate via each route indicated total estimated contributions of about twenty one (21) pounds of mercury per year (Section 5) from fluvial transport. The estimated Hg contribution from eolian transport to the lake was assumed to be negligible; although local eolian contributions to topsoils immediately adjacent to Hg mines can be significant (Bigley, 1993). Consequently, effective source control measures should focus on reducing rates of fluvial transport of Hg-bearing suspended sediments to Lake Nacimiento. The focus of this discussion of source control remediation measures will be two inactive Hg mines, the Buena Vista and Klau, which have been identified as "problem" mines (Mining Waste Study Team, 1988) and which we have identified as the primary source pollution locations in the entire watershed.

6.2 Statement of Problem at Buena Vista and Klau Mines

Since the mid-1960's, pollution abatement recommendations and requirements have been made by California Department of Fish and Game and the State Water Resources Control Board (WRCB) to Buena Vista Mines, Inc. owners (Mining Waste Study Team, 1988; Waller, 1979). Numerous reports, memoranda, letters, and miscellaneous correspondence pertaining to the Buena Vista and Klau Mines are available for in-office examination in the San Luis Obispo offices of the Regional Water Quality Control Board (RWQCB) (see Section 4). For the most part, the remediation measures taken by Buena Vista Mines, Inc. have never been adequately designed and/or engineered to achieve appropriate and complete implementation of the RWQCB's requirements (Waller, 1979).

Pollutant soures have not been comprehensively assessed, but several problems still exist today. A thorough description, reflecting conditions in December 1992, of Buena Vista Mine and a nearby dam on the Klau Branch of Las Tablas Creek is found in Appendix 6. The Buena Vista Mine tailings pile has been covered with locally available soil material low in Hg, but the cover is permeable and water continues to leach through it to the underlying acidic and Hg-rich waste materials (Figure 6-1). In February and March, 1992 following several rainstorms, we observed several locations near the interface between the cover and the tailings pile where seepage had occurred. Evidence of this phenomenon is the reddish color (Fe-rich) left at the soil surface at the lower end of the waste piles following rainstorms in February and March, 1992 (Photo 6-1). The underlying waste tailings appears to act as an aquitard, presumably due to their slowly permeable nature, and water that percolates through the cover perches above the waste and moves laterally until it eventually seeps out at some position downslope.

The waste material in the immediate vicinity (i.e., within about 100 feet) of the inactive Buena Vista Mine condenser facility contains numerous beads of elemental Hg ("quicksilver") intermixed with the sediment and soil. Soil materials sampled near the condenser facility and in the mine waste stream sediments are considered hazardous waste according to Title 22 CAC, Sec. 66699 because their Hg levels exceed 20.0 $\mathrm{mg \cdot kg^{-1}}$ (Table 4-2).

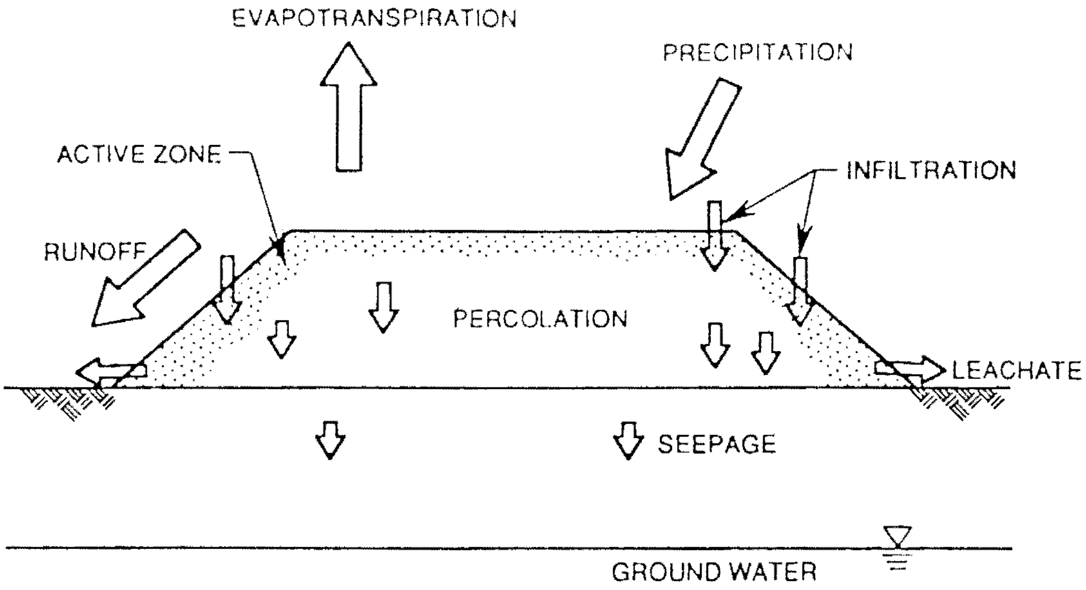


Figure 6-1: Generalized Hydrologic Cycle for a Typical Mine Waste Pile (Source: Hutchison and Ellison, 1992).

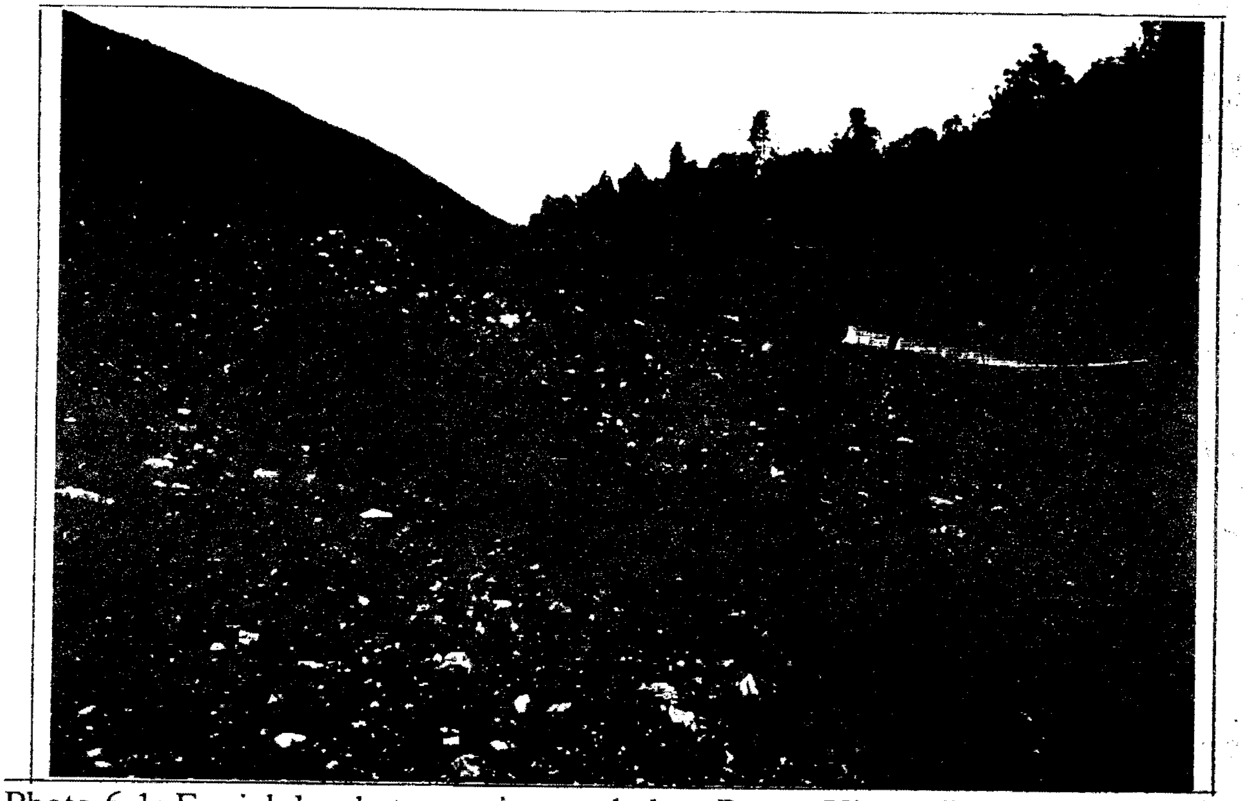


Photo 6-1: Fe-rich leachate seeping out below Buena Vista Mine tailings pile (2/29/92).

In February and March, 1992, we observed these Hg-rich sediments being transported by runoff waters into the concrete drainage ditch that runs downhill parallel to Cypress Mountain Road (Photo 6-2 and 6-3). On February 15, 1992, employees of Buena Vista Mines, Inc. attempted to build a small earthen diversion dam above the concrete drain in order to contain the eroding sediments, but the dam quickly eroded.

The Hg-laden, acidic, suspended sediments eventually flowed into the waste stream drainage below (i.e., to the north of) the buried Buena Vista Mine tailings piles and into the North Fork of Las Tablas Creek, to be eventually transported downstream and deposited as bottom sediments in Las Tablas Creek, Harcourt Reservoir, and Lake Nacimiento.

As recently as October, 1992, the Buena Vista Mines, Inc. owner again applied soil materials, taken primarily from the ridge area south of the mine, as a cover for the waste stream sediments and seepage areas below the tailings pile. This action is being taken in an attempt to "neutralize" the water and sediments' acidity in the waste stream and to provide a cosmetic cover (personal communication, Mr. Harold J. Biaggini; 10/21/92).

The problem with this measure of covering the most Hg-contaminated materials with uncompacted fill is that the sediments continue to erode and be transported to the North Fork of Las Tablas Creek. The extra cover material that is added to the waste materials is in itself suspect relative to its natural Hg, S, and Fe contents (our data suggest relatively high Hg and Fe levels in most topsoils surrounding Buena Vista Mine) (Table 4-4).

Photo 6-2: Fe-and Hg-rich sediment and water below Buena Vista Mine processing buildings (2/29/92).

Photo 6-3: Erosion gully that carried Fe- and Hg-rich sediment and waters down concrete ditch at Buena Vista Mine (2/29/92).

The Fe-oxides in the cover material can serve as an adsorbent for the Hg^{2+} released from the weathering of cinnabar (HgS). Also, the added sediment cover material is not adequately compacted or vegetated and, therefore, erodes with the first major rainstorms, adding to the total sediment load of the North Fork of Las Tablas Creek.

Erosion of nearly all the cover material (placed on material below the waste pile in October, 1992) and associated Hg-contaminated sediments into the North Fork of Las Tablas Creek had occurred by late January, 1993 due to heavy rainstorms in late December, 1992 and January, 1993 (19.73 in. of rain was recorded from January 7-18, 1993; Figure 6-2; Bergman, 1993). The erosion from Buena Vista Mine results in the relatively high suspended sediment loads observed in the North Fork of Las Tablas Creek from the Buena Vista Mine drainage to below the confluence with the South Fork of Las Tablas Creek on Marion Davis' property in January, 1993 and, earlier in this study, following heavy precipitation in February, 1992 (11.8 in. of rain from February 8-15, 1992; Figure 6-3; Bergman, 1992) (Photos 6-4 and 6-5).

Klau Mine wastes have not been comprehensively assessed, but some of the pollution problems were noticed by the project team members. The waste tailings piles to the south of the Klau Mine "Glory Hole" pit are very steep and continue to erode directly into the Klau Branch of Las Tablas Creek (Photos 6-6, 6-7, 6-8, and 6-9). These steep slopes and pit could be regraded, terraced, and stabilized with some artificial or vegetative cover to eliminate contaminated sediment loading of the creek system (see later recommended measures). As an alternative measure, the waste materials along the creek banks and subject to erosion could be completely removed.

The reservoir dam, constructed by the Buena Vista Mines, Inc. owner in 1961-62 on the Klau Branch of Las Tablas Creek, is mostly non-vegetated

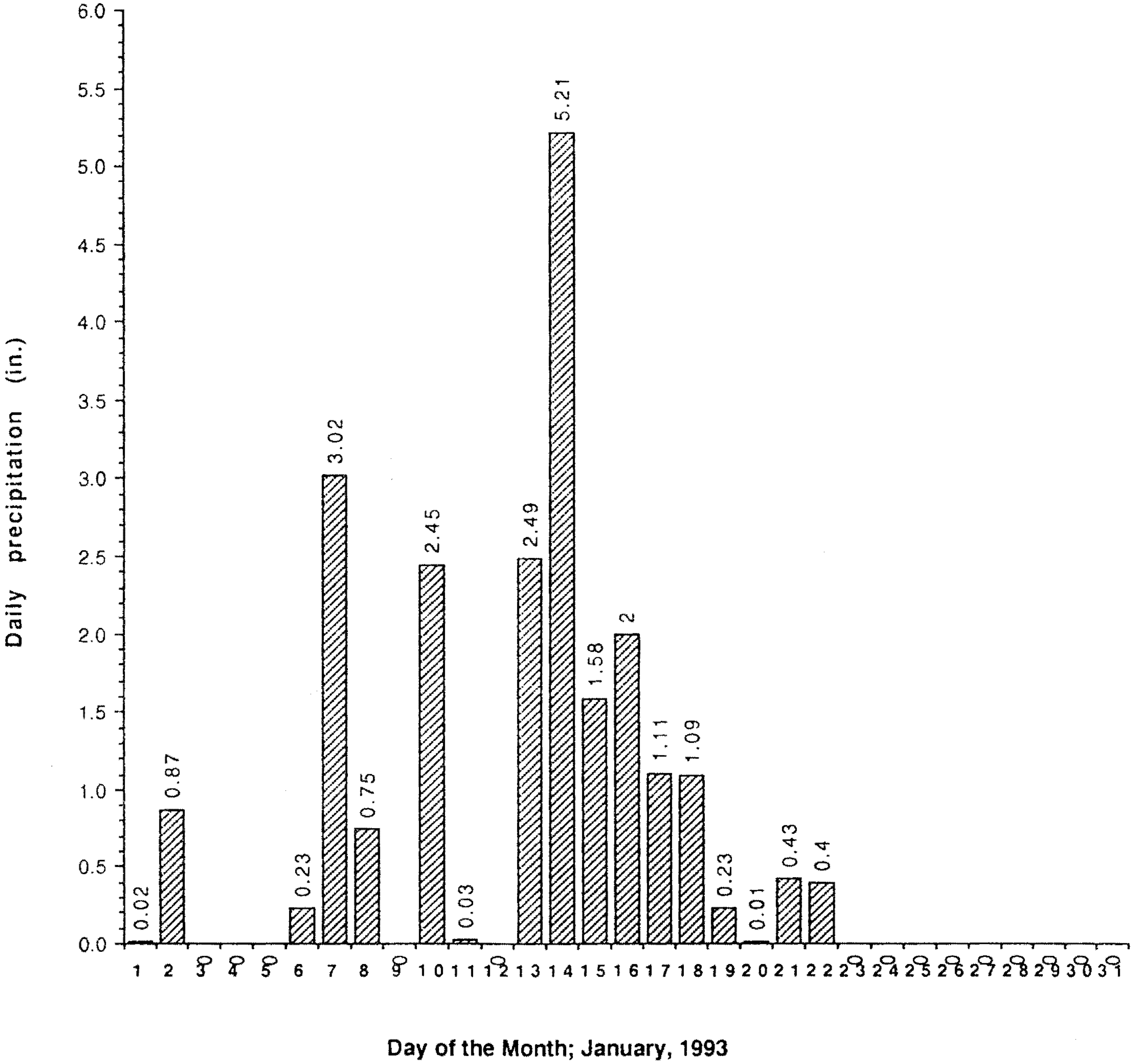


Figure 6-2: Daily precipitation (in.) for January, 1993 recorded at Dover Canyon, San Luis Obispo County, CA.

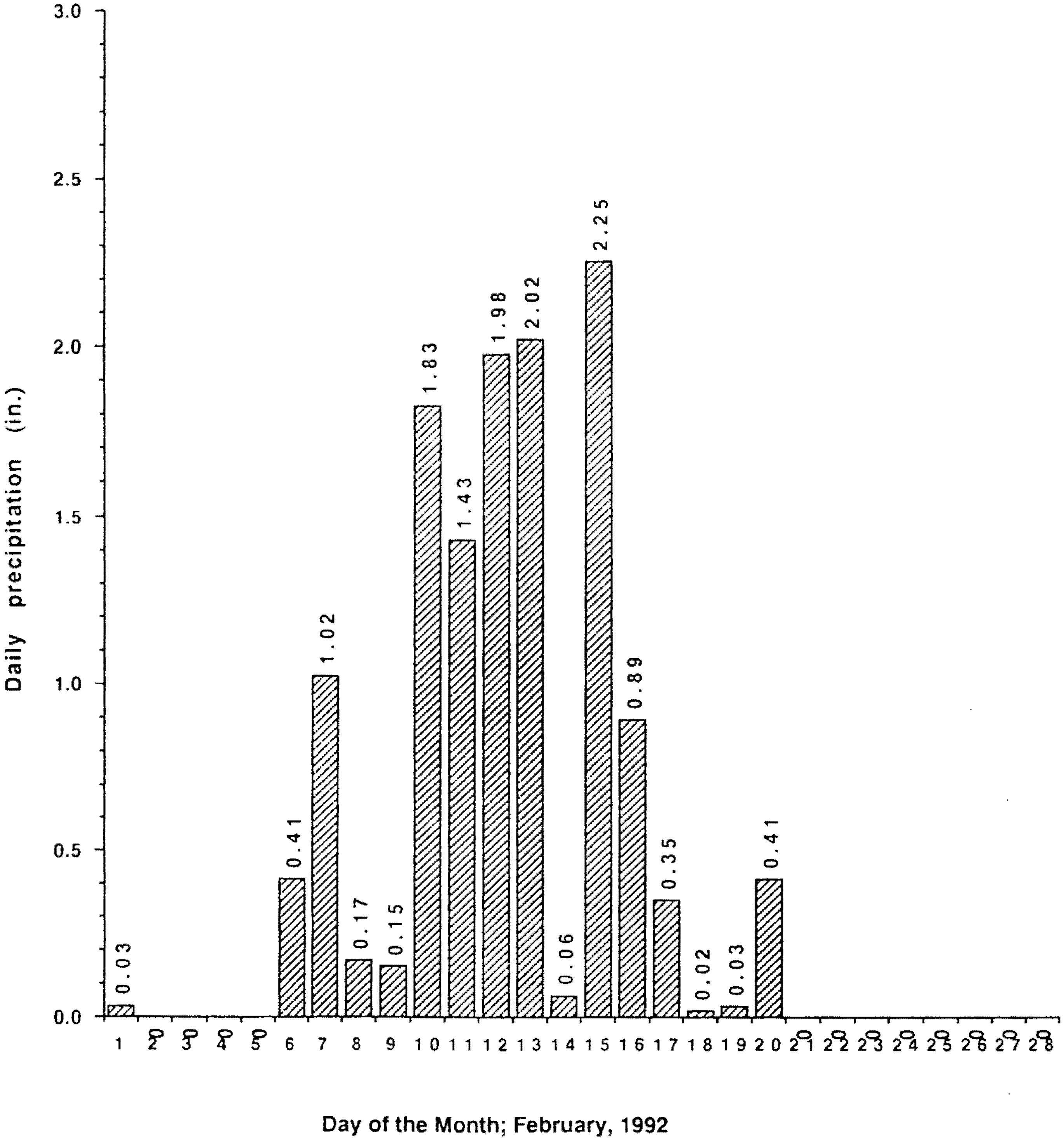


Figure 6-3: Daily precipitation (in.) for February, 1992 recorded at Dover Canyon, San Luis Obispo County, CA.

Photo 6-4: Las Tablas Creek just below confluence of the North and South Forks on Marion Davis' land (2/28/92).

Photo 6-5: Aerial view of Las Tablas Creek and the confluence of the North and South Forks on Marion Davis' land (3/16/92).

Photo 6-6: Klau Mine pit with a small pool of acid water following 20 inches of cumulative precipitation (2/14/92)

Photo 6-7: Klau Mine pit with acid waters that are draining down the access road to the Klau Branch of Las Tablas Creek (2/24/93)

Photo 6-8: The west access road to Klau Mine pit showing a drainage stream to the Klau Branch of Las Tablas Creek (2/24/93).

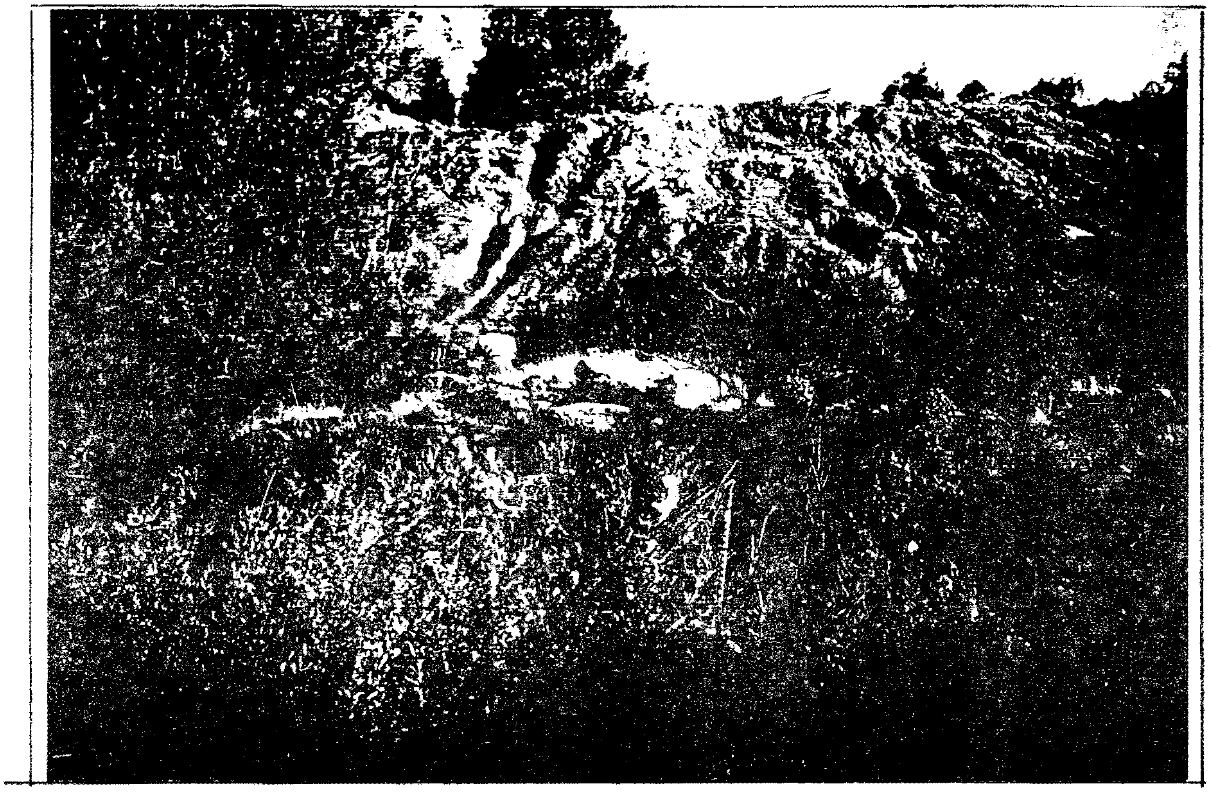


Photo 6-9: Klau Mine tailings pile eroding directly into the Klau Branch of Las Tablas Creek (10/31/92).

Photo 6-10: Klau Mine tailings pile eroding directly into the Klau Branch of Las Tablas Creek (2/24/93).

and very steep. The dam materials are considered "hazardous waste" according to Title 22 CAC, Sec. 66699 because their Hg levels >20.0 mg·kg^{-1} (Table 4-2; Sample CM21S1). As a result, the dam's downstream face continues to erode directly into the Klau Branch of Las Tablas Creek (Photos 6-11 and 6-12). The dam could be stabilized with some artificial or vegetative cover to reduce sediment loading of the creek system or it should be removed (see later recommendations and Appendix 6).

In order to reduce Hg loadings to Lake Nacimiento, and to reduce subsequent continued contamination of fish and wildlife, water discharging from the mines and mine wastes should ideally be eliminated and Hg-laden sediments should be kept at the source areas and be restricted from reaching the Las Tablas Creek system and, eventually, Lake Nacimiento. Generally, it is necessary to keep storm water runoff velocities low, to protect the mines and mine waste areas from storm water runoff and accelerated sediment erosion, and to retain contaminated sediment at each mine site or actively eroding geologic Hg source area.

6.3 General Considerations for Active and Abandoned Mines

Three strategies can be employed to prevent Hg mining wastes from polluting the environment (Mining Waste Study Team, 1988). The first, the preventive approach, is designed to prevent the pollution from ever forming. Where this can be achieved, it is the most desirable and generally the most inexpensive approach. Once the pollution has formed the next most desirable strategy is to prevent it from contacting either ground or surface waters. This is termed the segregative approach. If neither of these methods can be used the last resort is to treat the pollution before it is discharged to

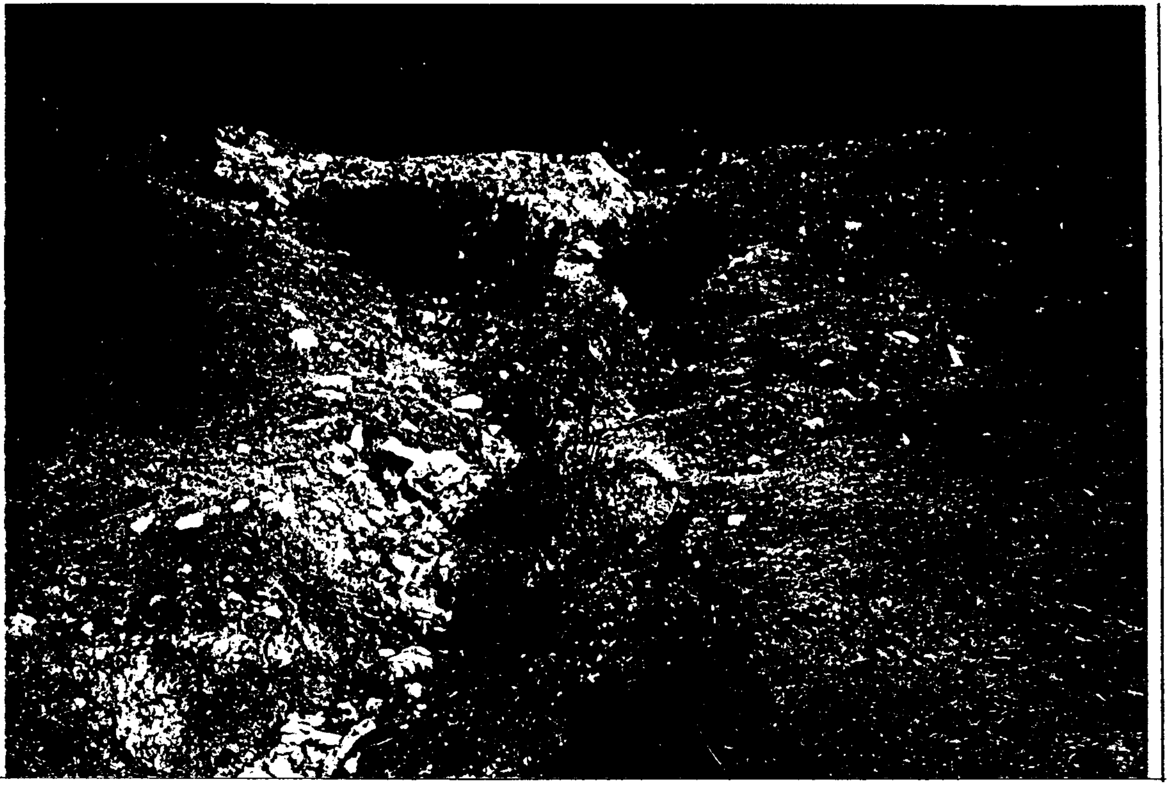


Photo 6-11: Erosion gully on the downstream face of the dam south of Buena Vista Mine; Klau Branch of Las Tablas Creek (10/7/92).

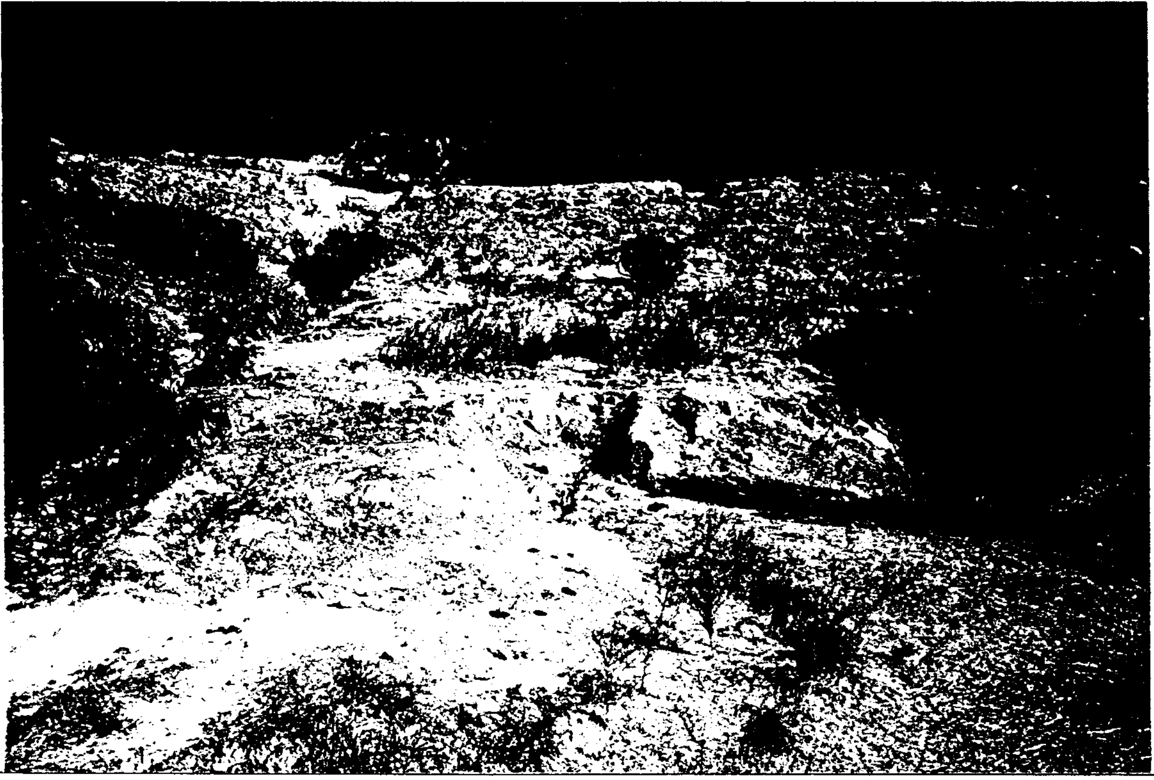


Photo 6-12: Eroded downstream face of the dam south of Buena Vista Mine on the Klau Branch of Las Tablas Creek (10/7/92).

the environment. Generally, the mitigative approach is the least desirable and most expensive strategy (Mining Waste Study Team, 1988).

Several measures have been proposed to reduce Hg and acid mine drainage (AMD) contamination in both terrestrial and aquatic ecosystems (Hutchison and Ellison, 1992; Mining Waste Study Team, 1988). Mitigative water treatment methods must be used if preventive and segregative measures are not successful in controlling the generation and/or release of Hg-contaminated and AMD effluents into the environment (Mining Waste Study Team, 1988).

In general, mitigative treatment methods are expensive due to continual operating costs, in addition to the initial investment. Process selection usually involves a trade-off between cost and effectiveness of pollution abatement. In general, it can be noted that Hg contamination, due to the weathering of cinnabar deposits and the historic mining exposing these deposits, is now so widespread that "complete" cleanup would be impractical in the entire Lake Nacimiento watershed or even in the whole length of the Las Tablas Creek riparian zone (Mining Waste Study Team, 1988). Therefore, a prioritization must be accomplished, based on the Hg Loading Model described in Section 5, in order to recommend and implement remediation measures at the watershed locations that continue to potentially contribute Hg-rich pollutants to waterways that drain to Lake Nacimiento. The main contributing point source locations identified in this study are Buena Vista Mine, the dam on the Klau Branch of Las Tablas Creek, and Klau Mine. The Harcourt Reservoir contains relatively Hg-rich sediments and these sediments flow past the spillway to the Las Tablas Arm of the lake during periods of high water flow. Indeed, the Harcourt

Reservoir is just above the southernmost part of the Las Tablas Arm of Lake Nacimiento when the lake is at maximum capacity.

A knowledge of the principal mechanisms involved in the mobilization, transport, and retardation of Hg from mine waste will aid in any pollution control program and can be summarized as follows (Mine Waste Study Team, 1988):

1). mechanisms facilitating Hg mobilization:
   - a) the acid oxidation of cinnabar (HgS) to Hg^{2+} and S^{2-};
   - b) anaerobic bacterial formation of methyl mercury (CH_3Hg^+) from Hg^{2+};
   - c) the reduction of Hg^{2+} to metallic mercury (Hg^0) by organic nutrients with or without mediation by organic nutrients and/or microorganisms.

2). mechanisms facilitating transport of Hg:
   - a) dissolution of native mercury (Hg^0) in water and volatilization of Hg^0 by advective or convective transport in aqueous or vapor phases;
   - b) transport of volatile methyl mercury (CH_3Hg^+) compounds, in a reducing environment;
   - c) particulate transport of cinnabar (HgS), elemental mercury (Hg^0), and sorbed mercury (Hg^{2+}) on suspended clay and organic particles.

3). mechanisms facilitating Hg retardation:
   - a) inorganic and organic complexation of Hg; and
   - b) reduction of Hg^{2+} to cinnabar in the presence of S.

Due to the Hg contamination that already exists in the Lake Nacimiento watershed, preventative, segregative, and mitigative approaches may be inapplicable at several locations and remediation measures mshould be undertaken.

Specific remediation measures that will be considered include:

1. PHYSICAL REMEDIATION METHODS
   - A. cut back slopes to reduce erosion and prevent slope failures on tailings piles;
   - B. vegetate bare soil surfaces to reduce erosion;
   - C. riprap streambanks to protect them from eroding and undercutting;
   - D. mine seals placement;
   - E. grout the mine wastes;
   - F. cap the mine wastes with soil-cement;
   - G. cover the mine wastes with a flexible geotextile cap;
   - H. cover the mine wastes with a concrete blanket;
   - I. cover the mine wastes with a webbed geotextile;
   - J. solidify the mine wastes;
   - K. vitrify the mine wastes;
   - L. excavate and dispose of the mine wastes;
   - M. sediment trap construction and maintenance; and
   - N. wetlands establishment.
2. CHEMICAL REMEDIATION METHODS
   - A. acid mine drainage neutralization;
   - B. bactericides; inhibition of S oxidation;
   - C. oxidation processes;
   - D. reduction processes; and
   - E. ion exchange methods.
3. BIOLOGICAL REMEDIATION METHODS
   - A. biological oxidation.

Each of these measures will be examined to evaluate its potential application at the Buena Vista and Klau Mines, as well as at other Hg source areas in the Lake Nacimiento watershed, in terms of the estimated decrease of Hg loading to Lake Nacimiento. All cost estimates will need to be adjusted to present-day dollars by any future implementation contractors with the use of the Engineering News Record construction cost index or comparable technical and cost guides.

Based on consultations with RWQCB Staff, it was decided that unit costs for each remediation measure shall be reported but that the total costs would need to be completed by professional engineers and licensed contractors as part of any future implementation projects.

Where possible, California-based contractors or manufacturers experienced or specializing in a specific technology were contacted for unit cost estimates. If actual "as built" costs are available for successful analogous projects, such costs should be used to alter appropriate adjustment for project scale and time. Future contractors or manufacturers giving estimates should be informed of (or should be required to document as part of their tasks) special conditions at each mine site, such as potential toxic metal levels (in addition to Hg), steep unstable slopes, important soil chemical and physical properties, and the proximity to Lake Nacimiento. In some cases, a range of cost estimates should be provided by the contractors where alternative remediation measures have conflicting monetary figures.

It is not likely that any one strategy or remediation measure would be used alone but rather each would be implemented in conjunction with some other measures. For example, cutting back a steep waste tailings slope would be implemented in conjunction with riprapping of the streambank at the base of the tailings pile. In addition, revegetation of the slope should be accomplished in topsoils that are adequately positioned, fertilized, and irrigated to allow for optimal vegetative growth. Plant materials adapted to the site conditions should be utilized. The topsoil would overlie an impermeable geotextile cap that would prevent leaching of precipitation or irrigation water to the underlying tailings, and, therefore, prevent generation of AMD. This foregoing example is just one generalized scenario of successful implementation of a combined (i.e., integrated or holistic) remediation strategy. Other potentially successful combinations of measures will be presented in later discussions.

6.3.1 Physical Remediation Methods

Physical remediation methods generally involve reduction of Hg loading to the lake by catchment dam construction and maintenance, slope stabilization, erosion control practices, and wetlands establishment. Erosion control measures should be implemented in the watershed to prevent any organic sediment, nutrient enrichment, and heavy metal loadings of lake and river waters.

Erosion control reduces lake eutrophication by limiting phosphate and nitrate levels in water which reduces CH_3Hg^+ concentrations in water and sediments (Jackson, 1986). Stabilization of soils at abandoned and inactive mine sites through revegetation, surface mulching, and slope contouring are favorable physical remediation measures that result in a reduction of both sediment and toxic metal loadings to receiving waters.

Because of the tendency of Hg to collect in topsoil zones and be taken up by some plants, and for CH_3Hg^+ and other Hg-organic compounds to form in anaerobic zones in the presence of bacteria, plant feeding and stream bottom animals are most likely to rapidly assimilate and concentrate CH_3Hg^+ compounds, as are predators that feed on plant eaters and bottom feeders. If there is evidence that such biological concentration (i.e., bioaccumulation and/or biomagnification) is occurring in the vicinity of abandoned and inactive Hg mines, prohibitions may be required in the hunting of game and the consumption of fish in the contaminated area, as is already suggested for Lake Nacimiento (California Department of Fish and Game Regulations, 1993).

Each of the physical remediation methods will be examined in greater detail in the following discussions.

6.3.1.1 Cut Back Slopes

Based on a slope stability analysis using Bishop's Method of Slices, Harrington (1988) determined that steep slopes on nonvegetated mine waste piles, like those found at Buena Vista and Klau Mines, have a relatively stable slopes during dry weather conditions but that slope stability is sensitive to observed groundwater table changes.

The estimated factors of safety ranged from 1.385 to 1.343. All slope failure planes appear to intersect the face of the slope at the toe of the slope face (Harrington, 1988). During wet conditions with high soil moisture levels, the safety factors for the slope drop below 1.0 for failure planes associated with surficial failures. Improved stability during wet conditions could be obtained by reducing or cutting back the slope angle to <32° (about 64% slope). Another study recommended reducing slope angles of coal mining waste piles to less than 32° (Veder, 1979).

In addition to improving slope stability, cutting back and rounding of the slopes is also necessary for successful revegetation efforts. Stair-stepping (i.e., terracing) of the slopes with 8-10 ft. benches is desirable to obtain luxuriant establishment of vegetation (Chamberlin et al., 1990).

In an application more like that anticipated at the Buena Vista and Klau Mines, the Homestake Mining Company (1982) used a design slope of 2.5H:1V (i.e., about 36% (20°) slope) for reclaimed waste rock slopes associated with the McLaughlin Project located in the southeast corner of Lake County, California. Their revegetation efforts on slopes of about 40% were successful (Chamberlin et al., 1990).

The analysis below assumes a reduction or cutback in the slope to about 30° (2.5H:1V or about 58%) or about 20° (2.5H: IV or about 36%) along the entire length of the steep mine wastes at the Buena Vista Mine site. These slope modifications have been found to result in successful revegetation efforts on tailings piles of the Sulphur Bank Mine that had historically eroded into Clear Lake, Lake County, California causing Hg contamination of fish in the lake (personal communication, C. E. Chamberlin, 1/18/93; Chamberlin et al., 1990).

The excavated Hg-rich material could be removed from steep slope faces and deposited in abandoned mine tunnels or adits. To the extent possible, each abandoned and inactive mine site should be reconstructed to hold Hg-contaminated soils and sediments within the site and avoid expensive off-site disposal and transportation costs.

Because the soil surface would be disturbed in any initial restoration phase, there is the potential for increased erosion. To mitigate this risk, the construction work should be carried out during the dry season (i.e., April through October). In addition, geotextile barriers and sediment traps should be erected at the base of potentially erodible slopes. Other erosion control measures used during restoration activities at environmentally sensitive sites (which would include Buena Vista and Klau Mines as well as the Bonanza

Mine Group located on the South Fork of Las Tablas Creek) should be implemented (California Dept. of Forestry, 1985).

The estimated volume of material to be excavated in order to achieve this slope reduction is specific to each mine site and such detail is beyond the scope of this study. Detailed engineering plans should be prepared before final project implementation at any of the mine sites in the Lake Nacimiento watershed (Appendix 6).

Given the success of the revegetation efforts at the Homestake Mining Company gold mine site (at Lower Lake, Lake County, California) using a cutback to 20° (about 36%), a slope cutback to 20° is considered to be the most reliable option (Homestake Mining Co., 1983). Estimated heavy equipment and labor costs assume a unit cost of \$3.00 to \$4.00/yd^3 of soil material (Chamberlin et al., 1990).

The impact of the slope reduction on Hg discharges from any mine site can be estimated using the Universal Soil Loss Equation (USLE) model (SCS, 1976). Using the Sulphur Bank Mine as an example, the major effect of any slope reduction was to reduce the slopes of the tailings piles from an average of about 58% (30°) to about 36% (20°) (Chamberlin et al., 1990). In part, this is offset by an increase in the slope length, the L factor in USLE, from about 37m to 53m and an increase in the area of the waste slope by about 50%. The rainfall erosion index, R, and the soil erodibility factor, K, are assumed to be unchanged. In combination with no other measures, the cropping management factor, C, and the pollution control practice factor, P, would also be unchanged so that simply reducing the slope to 20°, in the absence of a revegetation effort, would probably not produce more than a 10% reduction in Hg loadings caused by so-called "gully and rill" fluvial erosion (Chamberlin et al., 1990; SCS, 1976).

6.3.1.2 Revegetation

Vegetation, primarily woody plants, helps to prevent mass movement (particularly shallow sliding or surficial failures), rill erosion, and sheet erosion (Chamberlin et al., 1990). The major ways vegetation can reduce erosion are: 1) interception of rainfall by absorbing the energy of the raindrops and reducing runoff; 2) decreasing surface water velocities; 3) physical restraint of soil movement; 4) improvement of soil aggregation, increased porosity and water permeability caused by plant roots and surface plant residue; 5) increased beneficial biological activity in the soil; and 6) transpiration of water by plants, which decreases soil moisture levels (during the dry season and during winter dry spells) resulting in increased soil water storage capacities (Schwab et al., 1981).

For revegetation efforts to be successful, adaptable plant species must be selected and the slopes must be stabilized according to specifications discussed above. It is recommended that native plant species rather than non-indigenous species be used in the revegetation efforts. Although introduced species may rapidly increase short-term productivity and topsoil cover as compared with native stands of vegetation, native vegetation have been proven to be superior with respect to long-term stability and productivity.

The measure used by the Homestake Mining Company for revegetation of mine tailings at their McLaughlin facility located at the junction of Lake, Napa, and Yolo counties is to first cut back the slopes of their tailings piles to a 2.5H:1V (20° or about 36%) slope (Homestake Mining Company, 1983). Native planting stock was acquired from local producers who obtain their supplies from the project area ensuring plant stock adapted for survival under the prevailing conditions. A year-long lead time is necessary to collect and propagate seed and cuttings from around the site. Seeding of local grasses normally takes place in early October to take advantage of winter rains. Tree and shrub species are planted either in October or in early spring when the soil is trafficable.

Prior to planting or seeding, a soil testing program should be implemented to determine potential nutrient deficiencies as well as the soils' overall chemical and physical properties. Analyses should include: 1) pH; 2) available and total nitrogen; 3) available phosphorus; 4) available potassium; 5) available calcium, magnesium, and sulfur; 6) electrical conductivity; 7) organic matter content; 8) particle size distribution (USDA textural class); 9) exchange acidity; and 10) depending on the soil pH, selected micronutrients such as "plant available" Fe, Mn, Cu, and Zn. Fertilizers, agricultural minerals, and other soil amendments should be added at the rates indicated by the soil tests (Follett et al., 1981).

Since many of the waste rock, overburden piles, tailings piles, and Cypress Mountain Road materials in the Lake Nacimiento watershed have low soil pH's (i.e., 2 to 5), it may be necessary to neutralize soil acidity by adding limestone (or other alkaline soil amendments) to the soil to raise the pH which would reduce the solubility of metal (Cu, Fe, Mn, Ni and Zn) ions and reduce their potential for increased solubility and plant toxicity (Smith, 1985). Each soils' "exchange acidity" data can be used to calculate the soil lime requirement (i.e., the amount of alkaline soil amendment needed to raise the soil pH to a desired level and expressed in pounds of calcium carbonate per acre) (Soil Science Dept. Faculty, 1990; Follett et al., 1981).

There is a possibility of bioaccumulation of Hg in the food chain. The Hg uptake by plants depends upon site and soil conditions in addition to total Hg concentrations (National Research Council, 1978). The total Hg in the soil is not always a reasonable indicator of the bioavailable Hg. Bioavailable Hg is usually a small portion of total Hg. Hg levels in plants in mercury mining areas do not appear to be strongly related to the Hg content of soils, reflecting that Hg strongly bonds to soil components, such as humus and aluminosilicate clays (Mining Waste Study Team, 1988).

The main objective of any revegetation effort is to stabilize the Hg-contaminated material and other non-vegetated areas within the mine sites in order to reduce fluvial transport of Hg-contaminated suspended sediment. Cost estimates for surface preparation (not including excavation) and revegetation using native grasses and woody vegetation have been previously reported for 2 abandoned mine sites (Sulphur Bank mercury mine and Homestake gold mine, both in Lake County, CA) and for a Redwood ecosystem rehabilitation post-logging project (Chamberlin et al., 1990). Any cost estimates for revegetation of the waste piles at Buena Vista and Klau Mines must take into account comparable factors. The unit costs are estimated to be $1,200/acre(A) for hydroseeding, $1,000/A for surface preparation (including grading, fertilizer, soil amendments, etc.), and $2,850/A for plants, mainly native shrubs.

Using the USLE to estimate the impact of revegetation on Hg discharges from a mine site, the major effect would be to reduce the cropping management factor, C, from 1.0 down to about 0.01 to 0.04, thereby reducing discharges by 96% to 99% compared to non-vegetated material (SCS, 1976; Chamberlin et al., 1990). However, if the toes of any waste material slopes remains susceptible to undercutting by stream erosion, the effectiveness of revegetation efforts along the upslope portions would be reduced substantially due to potential future slope failure.

6.3.1.3 Riprap

Riprap is used to protect erodible materials and structures from mainly water erosion. Riprap structures are commonly constructed by placing progressively larger blocks and pieces of rock on a bed of filter cloth or fine gravel. The filter cloth is composed of a variety of synthetic materials whose primary purpose is to permit the passage of water while preventing the transport of sand- and silt-sized particles (Chamberlin et al., 1990). A 6- to 8-inch layer of quarry stone is placed on top of the filter cloth. On top of this large armor cover, more stone is placed.

The final riprap is a dense, uniform mass of durable angular stone with no apparent pockets or voids. Riprap could be used to stabilize the most unstable banks of Las Tablas Creek as well as the banks of large gullies on steep, barren slopes within the mine sites. The slopes will need to be initially free of vegetation and graded to a smooth, uniform grade. The riprap should extend from the floodplain channel to the elevation comparable to the 100-year floodplain or to the highest point where the streambank remains unvegetated and subject to erosion (Chamberlin et al., 1990).

Blodgett and McConaughy (1986) identified the nature and causes of riprap failure. The major factors contributing to failure were:

1. design D_{50} was too small or actual stream velocities were larger than expected;
2. the riprap material was poorly graded with too large a size variation;
3. the material was poorly placed;
4. the slope was too steep; and
5. no filter blanket/geotextile was used.

They reviewed many common design methodologies. The final designs to be utilized should follow their recommendations in general and the California Department of Transportation (CalTrans) procedure for streambank protection specifically.

The riprap would be made up of well-graded stone with a specific gravity of 2.6 to 2.8. Assuming a design water level of 3 ft based on a 5 mi fetch, the design velocity would be 14 ft/sec. Given that velocity, a specific gravity of 2.65 and a slope of 20° (about 36%), then the D_{50} for the riprap should be about 1.25 ft (Blodgett and McConaughy, 1986; Building Construction Cost Data, 1988; Chamberlin et al., 1990). The D_{85}/D_{50} should be less than 1.5 and the depth of cover should be ≥ 2.5 ft. For example, to cover 1,300 ft of creek bank over a width of 40 ft to a depth of 2.5 ft would require 4,800 yd^3 of rock.

The unit cost for a streambank riprap project would be about $100/linear ft (Chamberlin et al., 1990; Water Resources Administration, 1984). In combination with slope reduction and revegetation, the riprap would reduce Hg loadings from mine site gullies and contaminated creek banks by 96% to 99%.

6.3.1.4 Mine Seals Placement

Effluent drainage from abandoned and inactive Hg mines is best treated by sealing adits and tunnels with concrete plugs and allowing the workings to flood. This method has proven to be at least partially effective in reducing AMD discharge volumes from the Carson Drift, Klau Mine, but some seeps of AMD still occur (personal communication, David Schwartzbart, RWQCB, 1/31/93). Flooding of Hg-rich materials will prevent ventilation and establish reducing conditions that results in the chemical stabilization of cinnabar and reduces the release of Hg^{2+} to the environment.

In any abandoned or inactive Hg mine, the goal should be to inhibit oxidation of cinnabar to Hg^0 or Hg^{2+}; thereby preventing potential volatile or aqueous transport of mercury. All efforts should be made to provide an anaerobic environment to encourage the reduction of Hg to cinnabar, or at least prevent cinnabar oxidation, while at the same time trapping mobile mercury in organic-rich soil zones (Mining Waste Study Team, 1988).

An important segregative method for underground mines is the use of mine seals. This approach can be effective, especially where the entries are adits (horizontal tunnels driven into hills or mountains).

The principal difficulty with this method is that once the entries are sealed and the mine floods, the polluted waters, can continue to escape through other, previously unknown entries or through discontinuities caused by internal rock faults and fractures (Mining Waste Study Team, 1988).

This is likely the case at the Carson Drift, Klau Mine, where AMD has been significantly reduced but not completely eliminated, apparently due to seepage of AMD through rock fractures (personal communication, David Schwartzbart, RWQCB, 1/31/93; RWQCB meeting agenda, 9/11/92; Photos 6-13 and 6-14). Effective sealing of all of potential AMD seepage pathways is technically difficult and may be expensive (Photo 6-15).

6.3.1.5 Capping Techniques and Liners

Typical Hg mine waste, calcined retort ore and mill tailings, should be graded and covered with soil, and water flow through such material should be minimized or prevented (Figure 6-4). Properly engineered barriers or liners should be incorporated, where feasible. Such barriers must function

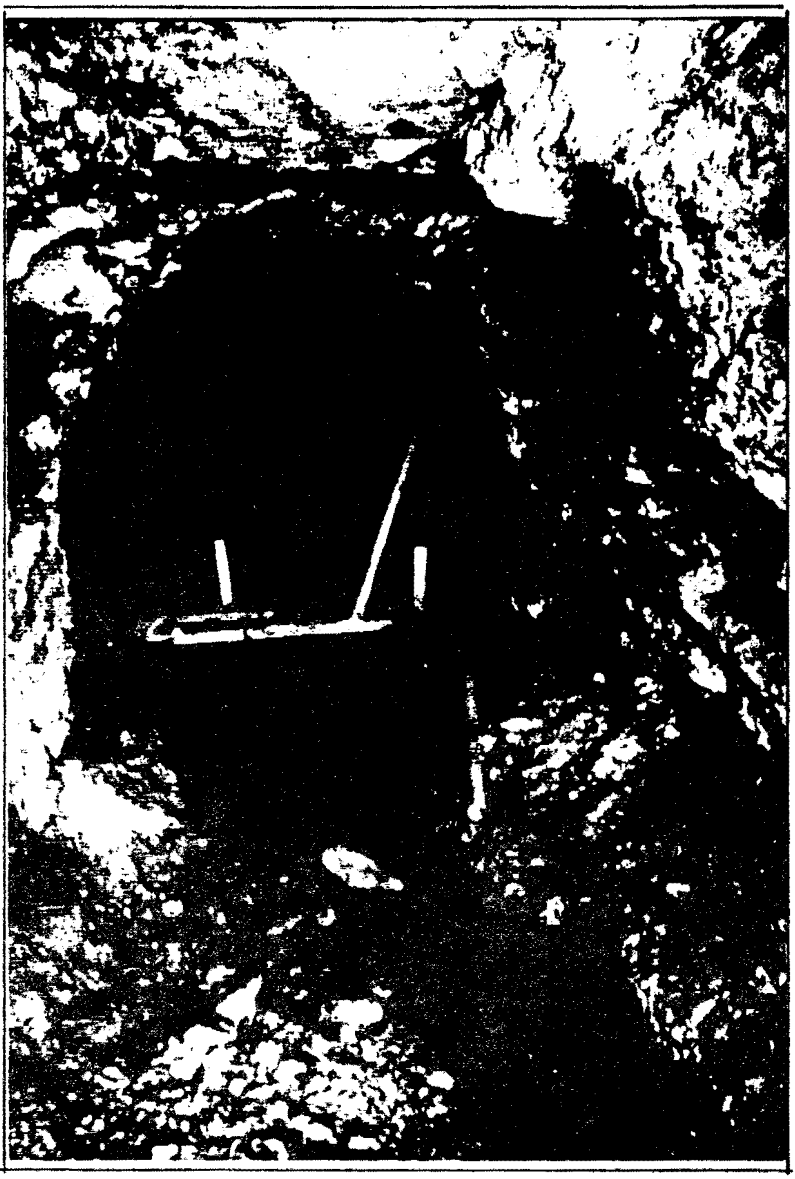


Photo 6-13: Drainage stream from the Carson Drift, Klau Mine, several months after the last seasonal rains (6/15/92).

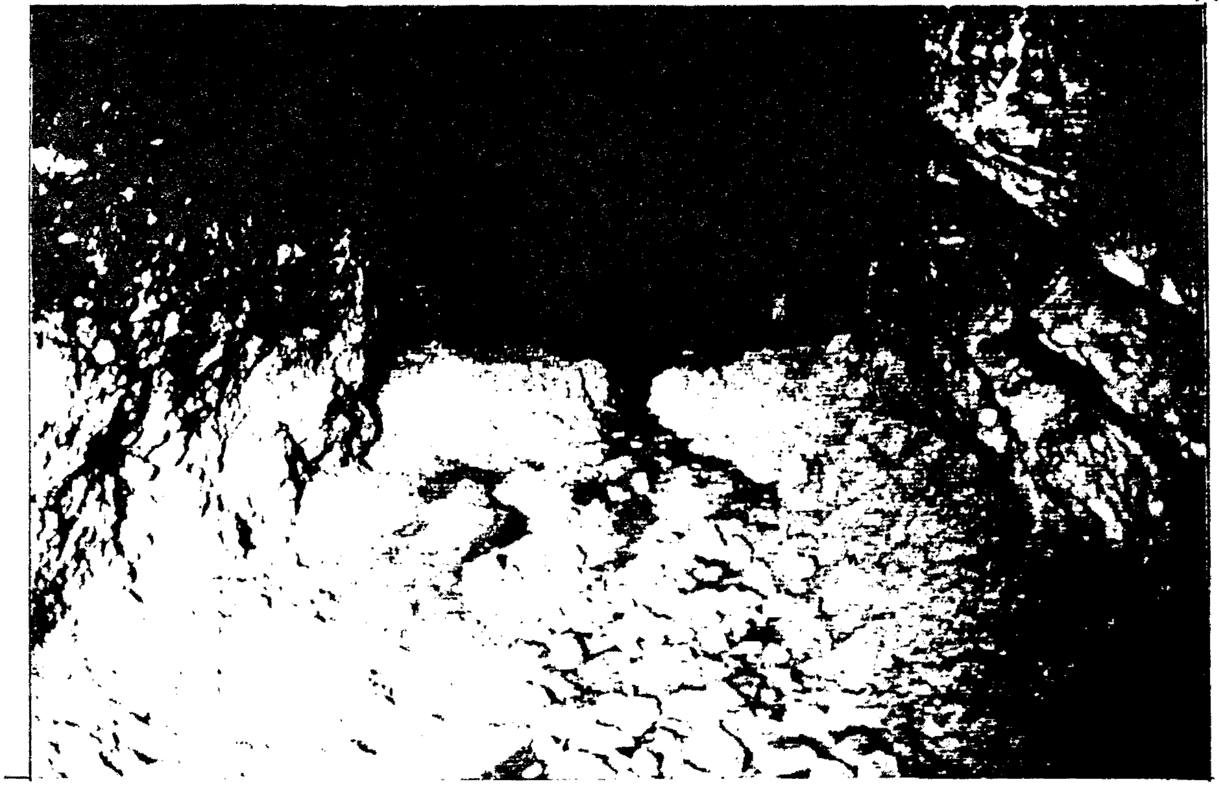


Photo 6-14: Carson Drift, Klau Mine, drainage stream after over 40 inches of cumulative seasonal precipitation (2/24/93).

Photo 6-15: Acid mine drainage from the Carson Drift, Klau Mine into the Klau Branch of Las Tablas Creek (2/24/93).

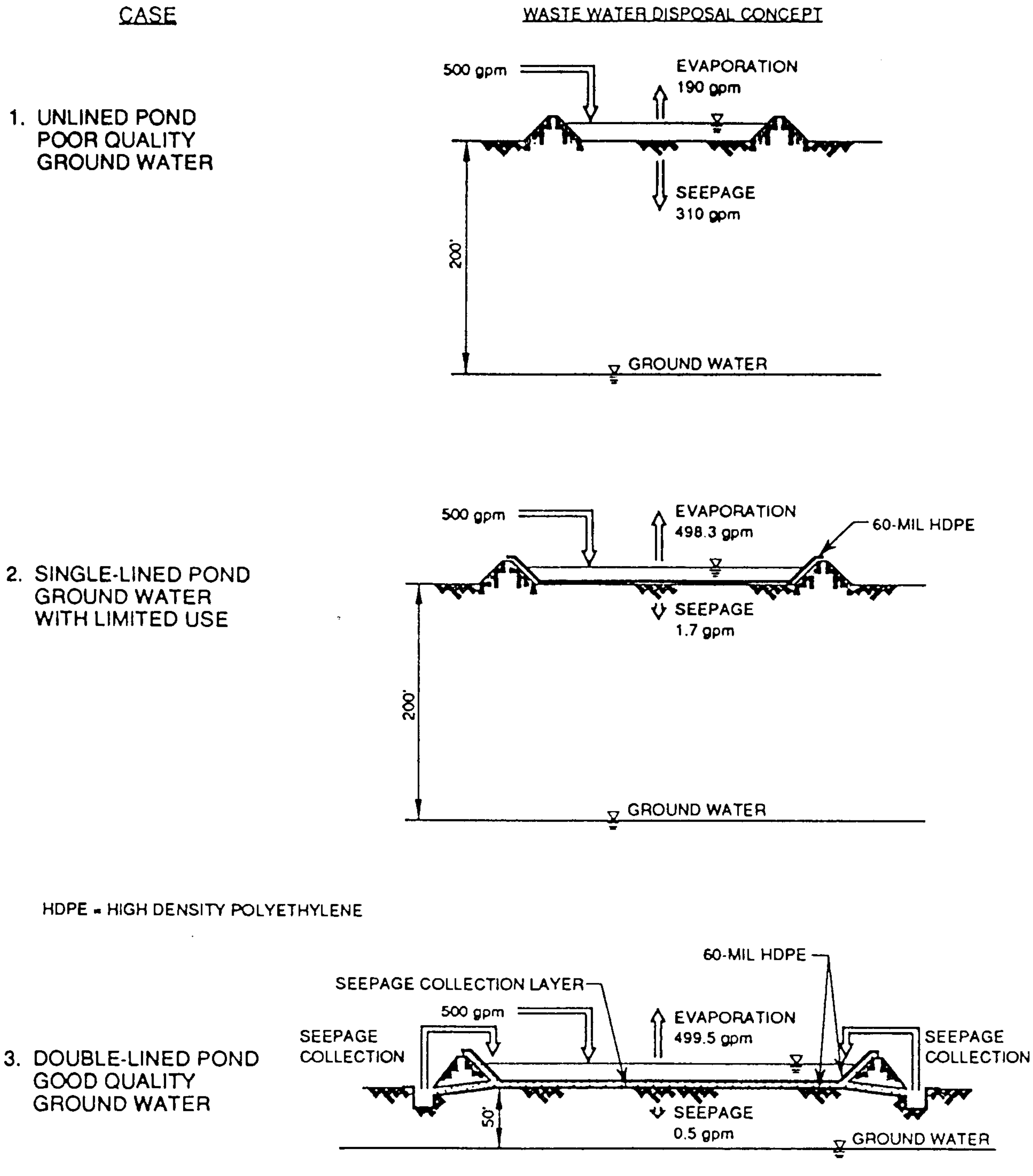


Figure 6-4: Wastewater Pond Concepts used in Containment Assessments (Source: Hutchison and Ellison, 1992).

properly over very long periods of time, because Hg will persist for decades (Hutchison and Ellison, 1992; Mining Waste Study Team, 1988). The purpose for using engineered barriers and covering the waste with fertile topsoil is to prevent particulate leaching and retain downward migrating dissolved or volatile Hg in the soil zone.

Although a properly engineered liner will greatly reduce leakage from a Hg waste piles, there is some concern about the long term viability of liners (Hutchison and Ellison, 1992: Mining Waste Study Team, 1988). The integrity of most commercially available liners deteriorates with age, which could lead to the discharge of large quantities of polluted water decades after a liner was installed. Therefore, leachate collection and removal systems should be integrated into the overall design plan. Although the phenomena that cause deterioration are not always well understood, it is known that exposure to heat and sun over long periods of time will break down synthetic liners, and excessive drying will crack clay liners.

There remains some controversy over the relative merits of synthetic versus clay liners. At the present time there are incomplete scientific answers to questions related to this controversy. In view of the importance of liners in the strategy for regulating mining wastes, more research is needed to address these uncertainties regarding the effectiveness of liners (Mining Waste Study Team, 1988).

Tailings impoundments, properly sealed with clay liners which will remain water saturated after rehabilitation, together with the addition of a thick alkaline soil cover will be adequate in most cases (Figure 6-5; Table 6-1). If feasible, mine waste should be disposed of underground below the

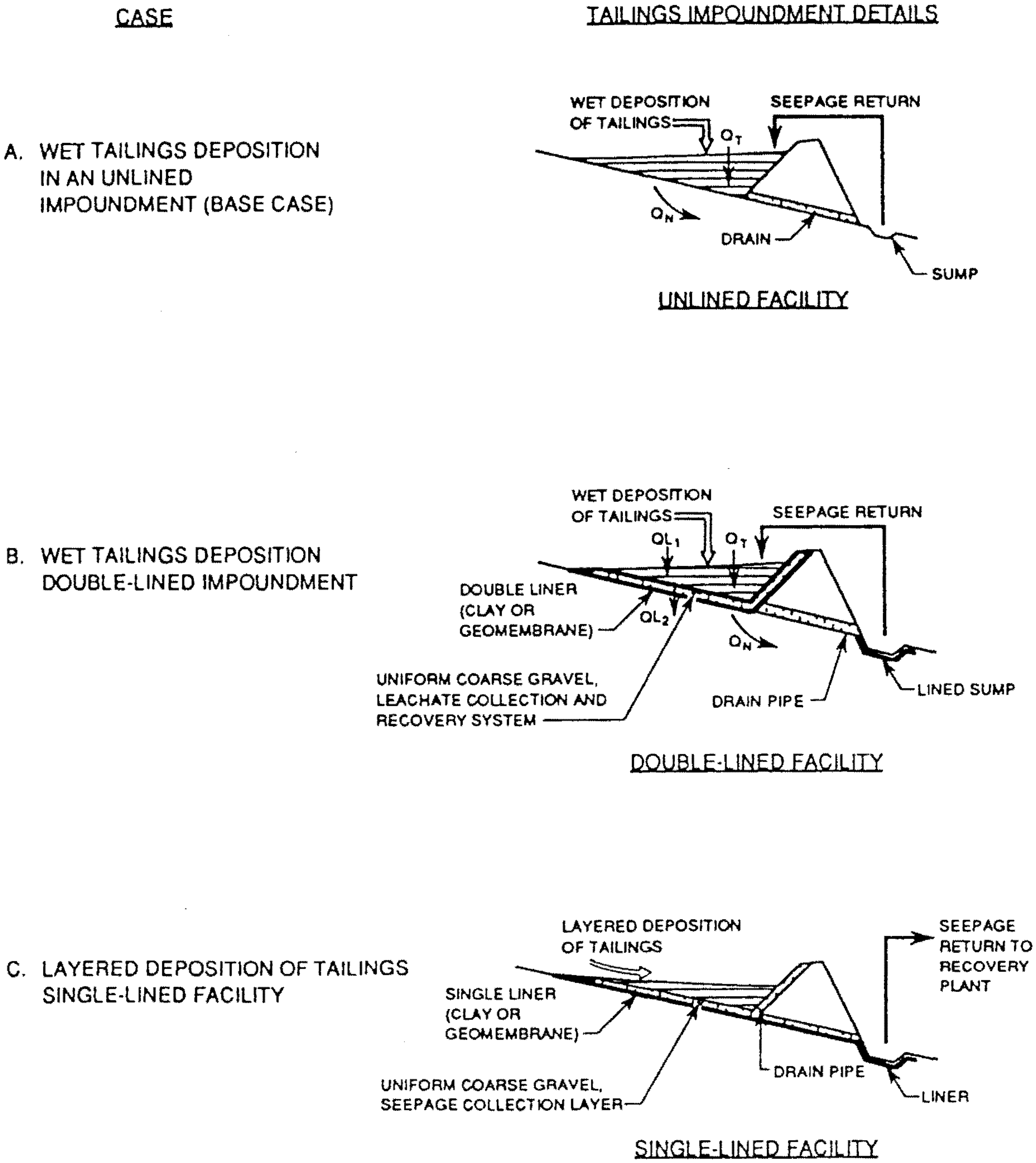


Figure 6-5: Impoundment Concepts used in Containment Assessments (Source: Hutchison and Ellison, 1992).

Table 6-1: Current Prescriptive Waste Containment Requirements: State of California (Source: Hutchison and Ellison, 1992).

WASTE GROUP	WASTE MANAGEMENT UNIT	GEOLOGIC SETTING	LINER(S) HYDRAULIC CONDUCTIVITY (cm/sec)	LEACHATE COLLECTION AND REMOVAL SYSTEM
A	Waste Pile	Natural geologic material(2) or single clay liner(3)	$\leq 1 \times 10^{-7}$	Required
	Surface Impoundment or Tailings Pond	Not applicable	Double liner system, both liners $\leq 1 \times 10^{-7}$ Outer liner: clay Inner liner: clay or geomembrane	Required(4)
B	Waste Pile	Natural geologic material(2) or single clay liner(3)	$\leq 1 \times 10^{-6}$	Required
	Surface Impoundment or Tailings Pond	Not applicable	Double liner system, both liners $\leq 1 \times 10^{-6}$ Outer liner: clay or natural material $\leq 1 \times 10^{-6}$ Inner liner: clay or geomembrane, or single replaceable clay liner(5)	Required(4)
C	Waste Pile, Surface Impoundment, or Tailings Pond	Not applicable	Not applicable	Not applicable

(1) California Code of Regulations, Title 23, Division 3, *Chapter 15*, Article 7.

(2) Geologic material must be of sufficient thickness to prevent vertical movement of fluid, including waste and leachate, from the waste management unit to the waters of the State so long as such wastes pose a threat to water quality.

(3) Geomembrane liner may be used for short-term containment (see Subsection 2572 [f][1] of this article).

(4) Liner and leachate collection and removal system for tailings pond must be able to withstand the ultimate weight of wastes.

(5) Single clay liner ($\leq 1 \times 1^{-6}$ cm/sec) for surface impoundment, to be removed before the last 25 percent (minimum 1 foot thickness) of liner is penetrated by fluid, including waste and leachate.

water table, or if an open pit operation is contemplated, be returned to the open pit with the most cinnabar-rich waste placed at the bottom (Mining Waste Study Team, 1988). Any excess waste should be disposed of so that erosion or mineral oxidation is inhibited.

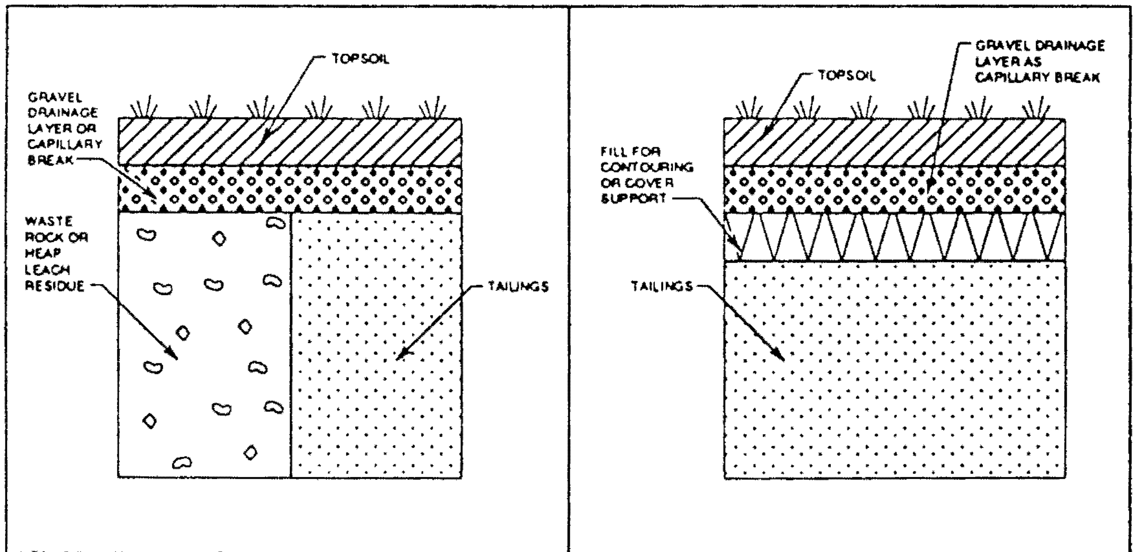
If the mine wastes contains abundant pyrite, which is the case at both Buena Vista and Klau Mines, then the waste should be inhumed below the water table, with added alkaline material if acid is already being produced. Under these conditions, an alkaline anoxic environment will be sustained in which cinnabar will tend to remain stable and the solubility of Hg will be decreased (Mining Waste Study Team, 1988).

The principal weapon in the mining waste regulator's arsenal is to require the use of a liner beneath tailings and other wastes (Hutchison and Ellison, 1992). The liner, whether a synthetic material or a layer of clay, acts as a barrier to prevent leakage of liquid effluent from the facility. What is believed to be the most effective, but is also the most expensive, type of liner is the "double liner". This consists of either two synthetic liners separated by a permeable bed or a clay base overlain by a permeable bed and covered with a synthetic liner (Table 6-2; Figures 6-6 and 6-7). The permeable bed serves as a leachate collection system. Occasionally, a “triple liner” system has been employed with a groundwater de-watering system integrated into the overall design (personal communication, David Schwartzbart; 3/20/93).

Table 6-2: Design Guidelines for Cover Elements (Source: Hutchison and Ellison, 1992).

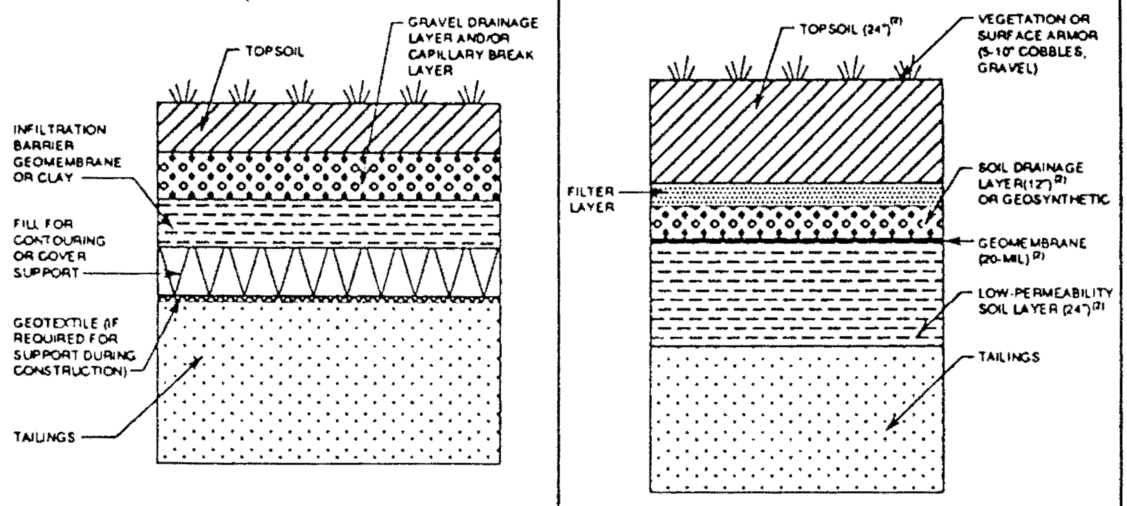
LAYER	PURPOSES OF LAYER	LAYER ALTERNATIVES	TYPICAL THICKNESS	GENERAL REQUIREMENTS[(1)]
TOP LAYER	Minimize Waste Dispersion by Surface Water or Wind Transport.	Granular In Situ Mine Waste	Variable	• Slopes can vary from a minimum of 1-1/2 percent to the angle of repose of the material. • Slopes and material should be stable and provide durable protection against erosion. • Surface contouring to prevent surface runoff concentration in local areas or ponding of water.
		Vegetation	Not Applicable	• Slopes can vary from a minimum of 1-1/2 percent to 50 percent. • Slopes and vegetation should be stable and provide durable protection against erosion. • Vegetation should be: - Persistent. - Drought resistant. - Adaptable to local conditions. - Shallow-rooted.
		Surface Armor	1/2- to 5 feet	• Slopes can vary from 1-1/2 percent to the angle of repose of the waste pile. • 1-inch nominal gravel up to boulders approximately 3 to 4 feet in diameter. • Size and thickness of armoring layer should be based on rainfall intensity and slope.
	Support Vegetation.	Soil	6 to 24 inches	• Slopes can vary from a minimum of 1-1/2 percent to 50 percent. • Required thickness will depend on the vegetation type, end use of reclaimed area, and suitability of the underlying mine waste to partially support vegetative growth.
DRAINAGE LAYER	Minimize Percolation and Damage to Infiltration Barrier. Prevent Upward Capillary Rise of Liquids From the Underlying Waste.	Sand or Gravel	12 to 24 inches	• Slopes range from 1-1/2 percent to a maximum controlled by stability considerations. • Adequate capacity to handle at least five times the anticipated infiltration rate through the layer above. • The layer should include a gravel toe drain or equivalent to direct drainage flows away from the waste management unit. • In some instances, it may be necessary to place a soil filter or geotextile over the drainage layer to prevent clogging by fines.
		Geotextile Geogrid Geonet	Variable (30 to 150 mils)	• Performance should be equivalent to the overlying sand or gravel layer.
INFILTRATION BARRIER LAYER	Minimize Percolation Into the Waste.	Geomembrane	20 to 60 mils	• Slopes range from 1-1/2 percent to a maximum controlled by stability considerations.
		Soil With a Low Hydraulic Conductivity	12 to 36 inches	• Hydraulic conductivity ranging from 10^{-5} cm/sec to 10^{-7} cm/sec depending on site-specific needs. • Should be located below the frost zone.
SPECIAL LAYER	Minimize Damage to Infiltration Barrier.	Biotic Barrier	12 to 24 inches	• Large materials, such as coarse gravel, cobbles, etc.
	Support Cover and Promote Drainage.	Foundation Layers	Minimum 24 inches and up to tens of feet, as required for control of drainage and contouring of surface.	• Frequently can be constructed from mine waste such as centrifuged coarse tailings fractions, spent ore, or waste rock. • These layers may require compaction to assure adequate support of overlying cover layers.

(1) The maximum slope ranges have been increased over those specified by EPA (1989). These flatter minimum slopes have been selected because of the large areas of mine waste management units and because tailings beach angles are frequently in the range of 1-1/2 percent. The steeper maximum slopes have been selected to accommodate the steep slopes typically associated with mine waste piles. Practice has shown that mine waste management units can be successfully closed with this larger slope range.



(E) Multilayered Soil Cover and Revegetation

(F) Surface Recontouring Plus a Multilayered Soil Cover and Revegetation



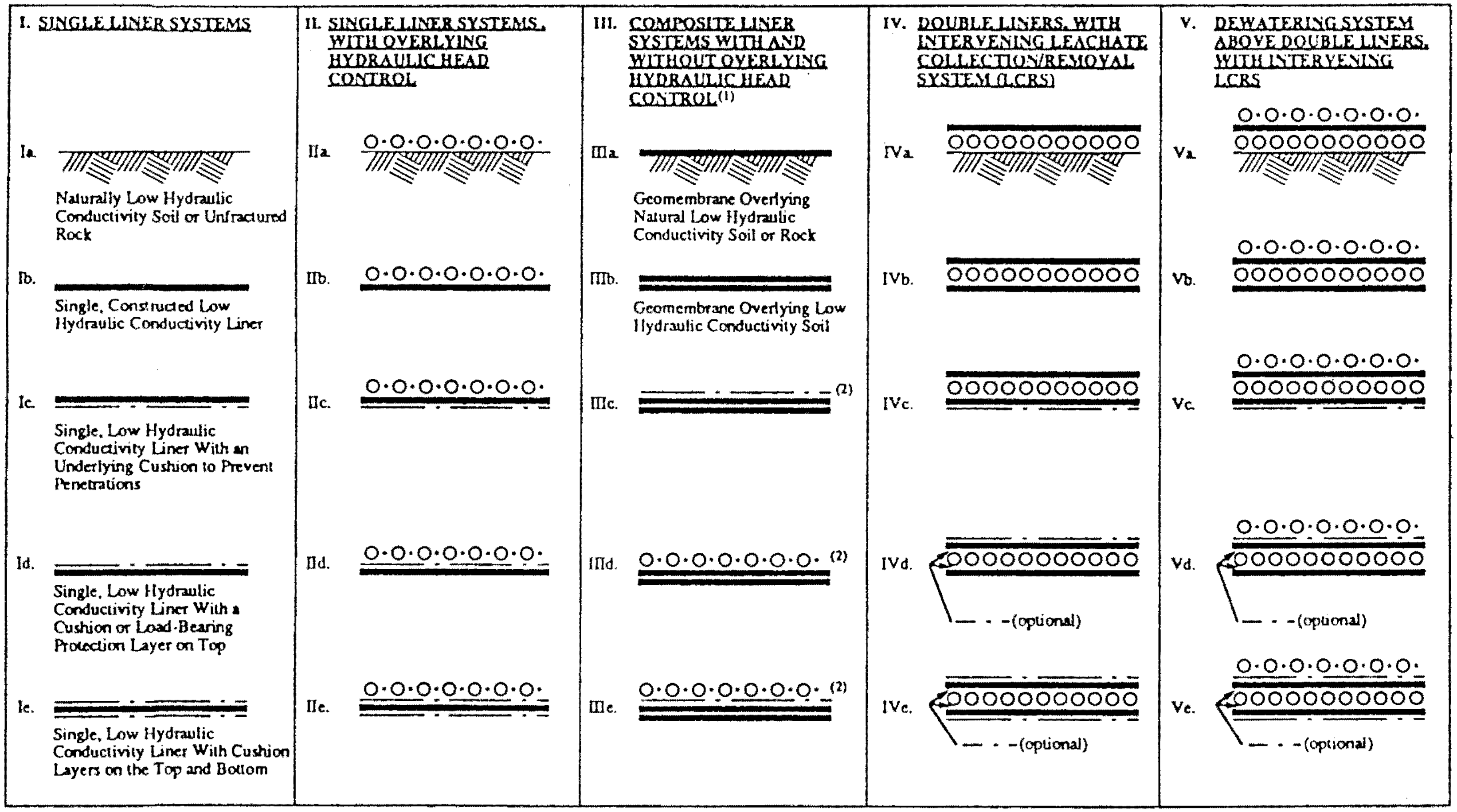
(G) Surface Recontouring Plus a Multilayered Cover Incorporating Infiltration Barrier

(H) EPA Recommended Cover for Hazardous Wastes (1)

(1) EPA (1989).

(2) Minimum Thickness

Figure 6-6: Typical Mine Waste Management Unit Covers (Source: Hutchison and Ellison, 1992).



LEGEND:

- ▨ Natural Low Hydraulic Conductivity Soil or Rock
- ▬ Low Hydraulic Conductivity Liner
- — - — Cushion or Load-Bearing Protection Layer
- O·O·O·O Hydraulic Head Control Layer
- OOOOO Leachate Collection and Removal System (LCRS)

Figure 6-7: Types of Liner Systems Potentially Applicable to Mine Wastes (Source: Hutchison and Ellison, 1992).

[1] The most common composite liner system involves a geomembrane overlying a low hydraulic conductivity soil.

[2] These composites also include a geomembrane overlying natural low hydraulic conductivity soil or rock.

6.3.1.5.1 Grouting

Grouting is the injection of gelling and solidifying agents under pressure into the ground. Grouting is frequently used to reduce the permeability of a mass of material thereby reducing mass movement. Cement and water is the most widely used grout mixture although clay, clay and cement, asphalt, and various chemical solutions are also utilized (Bowen, 1981). It is recommended that a sodium silicate derivative chemical grout be used for any acidic fine-grained soil types encountered at a mine site (Chamberlin et al., 1990; Pressure Grout Company, South San Francisco, CA). Sodium silicate solution is generally considered nontoxic and noncorrosive. Sodium silicate is commercially available as an aqueous solution. It has many industrial uses including adhesives, catalysts, deflocculants, and bleaches (Karol, 1983). Most silicate formulations are considered permanent although strength varies with grain size of the soil being grouted. There is some risk of failure over a 5 to 10 year period. Grouting is not effective underwater. Riprapping to protect the toe of the slope would be necessary (Chamberlin et al., 1990).

For a grouting project at any abandoned and inactive mercury mine in the Lake Nacimiento watershed, slopes would need to be stabilized by cutting back as described above, grout would then be injected to form a four to six inch blanket of grouted soil near the surface. Estimated unit costs are \$1.50/ft^2 (Chamberlin et al., 1990; Pressure Grout Company, South San Francisco, CA). The area to be grouted varies depending on site specific conditions at each source area. In combination with slope reduction and riprap, grouting would reduce Hg loadings for most mine sites by >90%.

6.3.1.5.2 Soil-Cement Cap

Capping of the mine wastes with a soil-cement serves a similar purpose as grouting in that it reduces the permeability of a mass of material and associated mass movement. This alternative would require the removal of existing vegetation, filling of cracked ground, and application of a soil-cement surface barrier. An estimated unit cost is $725,000/A (Environmental Protection Agency, 1986). In combination with slope reduction and riprap, soil-cement caps would reduce Hg loadings from a mine site by >90%.

6.3.1.6 Geotextile Caps

A variety of commercially available geotextile materials are marketed as alternatives to soil-based cover materials. These include flexible membranes, concrete blankets, and webbed/cellular materials. At the Buena Vista and Klau Mines, the use of this and other remediation and abatement approaches should be preceded by a complete site characterization considering many factors (Table 6-3; and Appendix 6).

Grading operations will likely be necessary in some portions of each of the mine sites because of the steepness of some of the actively eroding slopes.

6.3.1.6.1 Flexible Geotextile Membranes

Flexible membranes must be resistant to tearing and should be placed over a smooth buffer of soil. Damage to membranes may be caused by exposure to sunlight, burrowing animals, and deep plant roots. Therefore, trees that have deep, strong tap roots should not be used in any revegetation efforts.

For erosion control using a geotextile material, a blanket of the geotextile is laid down on the slope then covered with a three to six inch bedding layer followed by a layer of riprap or revetment (Chamberlin et al., 1990; Philips Fibers Corporation, Sacramento, CA). Estimated unit costs are of \$2.00/yd^2 for the geotextile and \$48.00/yd^2 for the revetment (Chamberlin et al., 1990; Philips Fibers Corporation, Sacramento, CA; Building Construction Cost Data, 1988).

6.3.1.6.2 Concrete Blankets

Concrete blankets are constructed of water permeable, double layer, woven fabric forms which are pumped full of fine aggregate concrete (Chamberlin et al., 1990; Nicolon Corp., Norcross, GA) Site preparation consists of removing rocks, brush, roots and large soil clods from the mine site. The fabric forms are anchored into a trench approximately two feet deep by one foot wide at the top of the slope. The fabric form panels are put into position and rolled down the slope, adjacent panels are sewn or zipped together. The fabric is then pumped full of concrete to produce a 4-inch thick cap. Estimated unit costs are \$0.50/ft^2 for the fabric forms, \$60.00/yd^3 for the concrete, and \$17.00/yd^3 for labor (Chamberlin et al., 1990; Nicolon Corp., Norcross, GA).

The manufacturer of concrete blankets (Nicolon Corporation, Norcross, Ga.) claims that the blanket would perform on slopes of 45° or steeper so that no slope reduction would be necessary. No independent confirmation of this claim has been made (Chamberlin et al., 1990).

Table 6-3: Site-Specific Factors to Consider in Liner System Design (Source: Hutchison and Ellison, 1992).

Potential Waste Material Toxicity

- Chemical Properties of the Waste
- Physical or Chemical Changes Resulting from Mining or Ore Extraction
- Net Acid Generation Potential
- Soluble Constituents for Anticipated Environmental Conditions
- Special Treatment or Neutralization Procedures Utilized
- Total Resulting Mass of Soluble Constituents Which Could Be Mobilized Under Site Conditions

General Water Resource Values at the Site

- Adequate Quality for Beneficial Use
- Sufficient Quantity for Beneficial Use
- Existing or Identified Beneficial Uses
- Probable Locations of Future Beneficial Uses

Leachate Availability to the Environment

- Waste Material Characteristics
    - Hydraulic Conductivity Based on Direct Measurement, Laboratory Tests, or Grain Size and Density
    - Moisture Retention Capacity
- Thickness of the Waste
- Site Climatic Conditions
- Provisions at Closure to Restrict Infiltration

Site Factors

- Topography
- Geology, Including Predictability of Uniformity and/or the Potential for Discontinuities
- Unsaturated Zone Thickness, Continuity, Hydraulic Conductivity and Natural Water Content
- Potential Migration Time for Seepage to Ground Water
- Effects of Climatic Conditions on Long Term Unsaturated Zone Migration Characteristics
- Constituent Attenuation Potential

Waste Unit Management Practices

- Facility Type
- Waste Placement Method
- Protection of Liner Systems From Environmental or Physical Damage
- Controls on the Hydraulic Head
- Risk Reduction Practices, Such as Placement of Underdrains, Sub-Aerial Depositions, Limited Time of Operations
- Non-Liner Barriers, Such as Cutoff Walls
- Installation of Special Early Warning Monitoring Systems

6.3.1.6.3 Webbed Geotextiles

Webbed geotextile material consists of a cellular grid of high density polyethylene (Chamberlin et al., 1990; Soil Stabilization Products Co., Merced, CA). Installation consists of anchoring the unexpanded material with ground stakes to the top of a slope. Each section of material is then expanded and then anchored to the toe of the slope with ground stakes. Clean fill material is then dropped into the webbed material with a backhoe. The fill can then be hydroseeded with grasses. Estimated costs to cover soils to a depth of 4 in. include unit costs of \$0.79/ft^2 for geotextile, \$0.60/yd^2 for labor, \$14.70 yd^3 for topsoil, and \$1,200/A for hydroseeding (Soil Stabilization Products Co., Merced, CA) .

6.3.1.7 In-Situ Methods

The prior alternatives basically cover the mine wastes with vegetation, fabric, or other material to form a barrier between the wastes and water. In contrast, solidification and vitrification fix the wastes in place by converting them to a solid that is not susceptible to erosion or leaching.

6.3.1.7.1 Solidification

Solidification of the mine waste piles will convert the tailings into a chemically inert stable mass and eliminate pollution from mine wastes to any drainage channel. Solidification is achieved by excavating the wastes and then mixing or blending of the waste with crystallizing, polymerizing, or gelling agents. The estimated unit cost is \$50.00/yd^3 (Chamberlin et al., 1990; McLaughlin Enterprises Inc., Claremont, CA).

6.3.1.7.2 Vitrification

Mine wastes may be solidified by the application of sufficient heat to cause vitrification (Smith, 1985). Heat can be generated by passing an electric current through the ground. At sufficient temperatures soil or rock components will melt, organic components will decompose, and metallic components will fuse or vaporize. One major disadvantage of this method For Hg-bearing wastes is the potential volatilization of Hg vapors and consequent air pollution during the initial heating process. Therefore, the materials would need to be placed in a closed system chamber. When cooled the fused mass will solidify into a crystalline solid. Estimated unit costs are \$100.00 to \$250.00/yd^3 (Chamberlin et al., 1990; Smith, 1985). Both of these *in situ* techniques would effectively eliminate >99% of the Hg discharges from the mine site by fluvial or eolian transport.

6.3.1.8 Excavation and Disposal

Complete excavation of the mine wastes from each abandoned and inactive mine in the watershed would significantly reduce the sources of Hg contamination to the lake. Disposal of the waste at an approved hazardous waste disposal site would be necessary in some cases due to the high levels of Hg in the material; especially Cypress Mountain Road materials from Klau Mine north to Chimney Rock Road intersection (Bigley, 1993), the calcined retort wastes at Buena Vista and Klau Mines, and the dam material for the Klau Branch reservoir.

Costs for this alternative assume that the wastes would be brought to the Chemical Waste Management, Inc. Kettleman Hills facility near Kettleman City, California. Estimated unit costs include \$3.00/yd^3 for excavation, \$12.50 to \$25.00/yd^3 (i.e., assuming 16 yd^3/load, 2-4 hrs/load, and $100/hr for hazardous materials transport) for trucking from the mine sites to the Kettleman Hills facility and disposal at the Kettleman Kills facility at an additional unit cost of $120/yd^3 (Chamberlin et al., 1990; Chemical Waste Management, Newark, CA; Jackson Equipment Co., Middletown, CA; Dutra Trucking, Arcata, CA).

These costs do not include the necessary restoration costs for the area uncovered by the removal of the wastes. However, one can readily calculate the enormous total costs of implementing this remediation measure.

6.3.1.9 Sediment Trap Construction and Maintenance

In the event that Hg already contaminates stream sediments, as is the case in the Las Tablas Creek floodplain, the use of dams and sediment basins (traps), in which fine suspended sediments and bed material sediments will settle, may provide the best form of containment. The Harcourt Reservoir dam on Las Tablas Creek was constructed in the 1950's. It is used as a source of water for cattle, as a source of irrigation water for adjoining agricultural lands, and for private recreational fishing. It is a state registered dam and receives annual inspections from the California Division of Safety of Dams.

The Harcourt Reservoir has served the function of trapping Hg-rich suspended and bedload sediments, even though it was not initially intended to be used as a sediment retention area for Hg-contaminated sediments (personal communication, Ms. Donna M. Harcourt, 1/31/93; Table 4-3; Figure 4-1).

Sediments can be removed from mine drainage and tailings pond effluents in large, quiescent clarification ponds. Sediments settle by gravity.

The detention time of the system should be at least several hours to allow finer particles to settle. Ultrafine and colloidal material can be removed by aggregation with chemical flocculants, such as the organic polymers widely used in mineral processing clarification processes (Mining Waste Study Team, 1988).

Dams or sediment traps can be built on streams and rivers just downstream from a Hg point source. We recommend that a study be undertaken to locate another potential sediment retention reservoir site closer to Buena Vista and Klau Mines. The main reason for locating a site upstream of the Harcourt Reservoir is because the reservoir periodically almost becomes part of the Las Tablas Arm of Lake Nacimiento when the lake is at full capacity (most recently in Spring, 1983, and approaching maximum level in March, 1993). At these times of maximum lake water levels, the potential for movement of Hg-laden sediments from Harcourt Reservoir out to the Las Tablas Arm and then to other parts of the lake is enhanced. Additionally, the Harcourt Reservoir is rapidly filling with sediment (Photos 6-16 and 6-17) and an engineered study should be undertaken to determine its sediment-bearing capacity so that Hg-rich suspended sediments do not continue to be transported over its spillway during periods of high water flow (as we observed during late February, 1992, and from early January, 1993 through March, 1993 following periods of high precipitation totals in the upper Las Tablas Creek watershed).

Depending on dam size and location, some downstream sedimentation of Hg-rich sediments can be reduced. The physical mixing of lake sediments can potentially dilute sediment Hg concentrations by mixing "hot spots" of high Hg concentrations with nearby sediments lower in Hg content (Rudd et al., 1983).

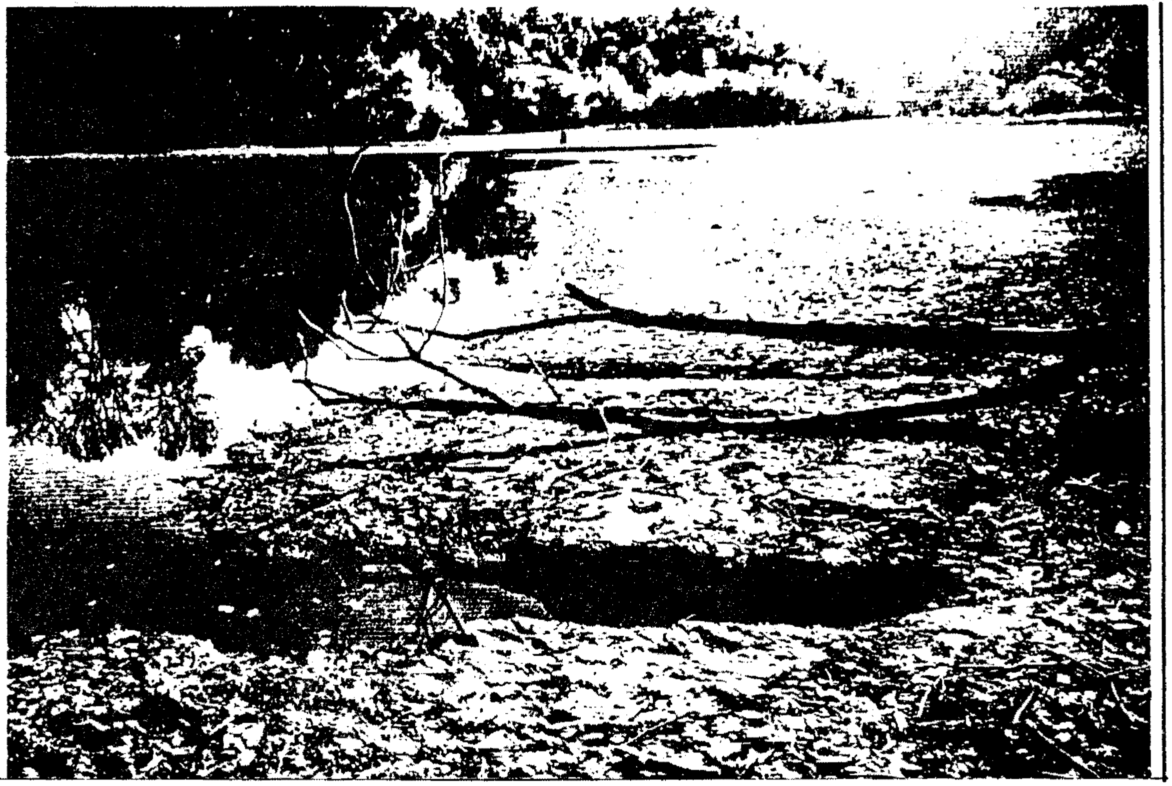


Photo 6-16: View of the central and southern parts of the Harcourt Reservoir at relatively low water levels (12/13/91).

Photo 6-17: View to the north toward the Harcourt Reservoir, rapidly filling with sediment-rich water (2/14/92).

Another dam of concern is located in the Klau Branch of Las Tablas Creek just upstream of the Klau Mine. It was constructed in 1961-62. It first filled with water during the 1962-63 rainy season.

It has been used as a source of water for cattle. It has been witnessed that the Buena Vista Mines, Inc. owners also periodically used water from the reservoir until about 1970 in order to spray-irrigate the hot calcined retort waste in an attempt to mitigate the evolution of noxious sulfurous odors in the vicinity of the tailings piles (personal communication, Mr. Raymond Dodd, 10/31/92).

If any reservoir spillway becomes plugged with logs and other debris during periods of high runoff, the water may flow over an earthen dam at the lowest point along the crest of the dam. Since the flow is concentrated, the water velocity is often sufficient to erode the crest of the dam and thus increase the overflow rate. Catastrophic dam failures can result. This potential failure can be temporarily prevented by maintaining a clear spillway.

The spillways at both the Klau Branch reservoir and the Harcourt Reservoir are cut almost completely to native bedrock and if they are maintained so as to remove all large "debris plugs" they should function well and reduce the potential for breaching of the dams' faces during periods of high water.

However, because of the high salt contents, and perhaps due to metal toxicities in the Klau Branch dam material, little or no vegetation covers its surface. There are portions of the face that are being actively eroded and contaminate downstream portions of the Klau Branch and South Forks of Las Tablas Creek with AMD and heavy metals (Photos 6-18 and 6-19). If

Photo 6-18: Reservoir and poorly vegetated dam south of the Buena Vista Mine, Klau Branch of Las Tablas Creek (5/26/92).

Photo 6-19: Large gully on the downstream face of the dam south of the Buena Vista Mine, Klau Branch, Las Tablas Creek (2/24/93).

the dam and reservoir are to remain competent, some integrated grading, riprapping, and revegetation effort should be carried out as soon as possible to avoid catastrophic failure of this Klau Branch dam.

Otherwise, a decision should be made to slowly drain the reservoir and remove the dam material and reservoir sediments if they are also found to be Hg-contaminated. The material could be placed in the abandoned tunnels and adits at Buena Vista Mine or they could be placed over the ridge to the north in the depressional area above the inactive Buena Vista processing buildings (see Appendix 6).

The lower part of the spillway channel which carries the overflow for the Klau Branch reservoir cuts through soft unconsolidated sediments and will require armoring or riprapping to reduce further downstream transport of Hg-laden alluvial sediments. The channel below the dam could be armored using riprap ($D_{50} = 0.5$ ft with $D_{85}/D_{50} \leq 1.5$ to a depth of 1.0 ft), with an estimated channel protection unit cost would be $\$48.00/yd^2$.

6.3.1.10 Wetlands Establishment

The treatment of AMD by chemical means has recently been estimated to cost the mining industry over one million dollars a day (Kleinmann, 1987). Attempts to find an inexpensive means of treating this waste have resulted in increased interest in the use of integrated biological, chemical, and physical treatment processes, particularly that of wetlands technology, which is not only less expensive than many chemical processing technologies, but requires the addition of few or no chemicals (Mining Waste Study Team, 1988).

Wetlands can be effective in treating AMD flows, with pH's as low as 3, because the vegetation in the ponds removes metals from acid waters by adsorption, uptake, and filtration. A major advantage of the use of wetlands is the relatively low cost.

Wetlands technology may not be suitable for all Hg mine sites in the Lake Nacimiento watershed because of unsuitable environmental conditions, mainly a lack of a reliable water supply. Wetlands require continuous flow, and they have little tolerance for variations in the flow rate (Mining Waste Study Team, 1988). The water depth also is critical for marsh-type wetlands dominated by Typha (cattails) in that the treatment efficiency is greatest in shallow (2-4 inch) waters.

Nevertheless, the considerable benefits of wetlands technology for AMD control, the principal benefit being its affordable nature, warrants their application to suitable locations.

The use of artificial wetlands as a technique for the control of AMD has been widely adapted for coal mines in Appalachia, where over 100 such systems are in operation (Kleinmann, 1985; Girts and Kleinmann, 1986). A survey conducted by the U.S. Bureau of Mines (USBM) indicates that a typical wetland site consists of three ponds, treats 20-30 gallons of AMD per minute, and contains a total area allocated on the basis of 600 ft^2/gpm (Kleinmann, 1987). Drainage from the mines is heavily laden with acid, iron, manganese, and sulfate. Heavy metal concentrations typical of AMD at the Buena and Klau Mines are not typical of coal mine drainage waters, and heavy metal effects were not a consideration in any of the mine studies cited (Mining Waste Study Team, 1988). The cost of establishing a wetland in Appalachia in the early 1980's was given as less than \$1.00/ft^2, and the subsequent maintenance costs are very small (Girts and Kleinmann, 1986).

The overall environment of wetlands systems is complex. The vegetation zone is dominated by species of Sphagnum (moss), Typha (cattails), Equisetum (horsetails), and sedge, which remove metals from acid waters via absorption, uptake, and filtration. Iron- and manganese-oxidizing bacteria are active in the upper water depths, as are sulfate-reducing bacteria in the lower, anoxic depths (Kleinmann, 1987).

Earlier studies focused on the use of Sphagnum to improve the water quality of AMD. Sphagnum recurvans have been shown to tolerate iron concentrations up to 500 $mg \cdot L^{-1}$ for up to four weeks in the laboratory. However, tolerance levels in the field are considerably lower (<150 $mg \cdot L^{-1}$) due to the less than ideal conditions in the field (Kleinmann, 1985). Typha, however, have been more successful with respect to their ability to survive in AMD, and thus are more commonly used at present (Kleinmann and Erickson, 1986).

Many of the wetland systems adapted to AMD operate at pH's near 3. Metal removal is most pronounced in shallow wetlands (two to four inches deep) that are dominated by Typha (Kleinmann, 1987). Most of the systems treat approximately 80 gallons per minute and have a detention time of 10 days (with a range from 4 hours to 75 days) (Girts and Kleinmann, 1986).

Acid removal has been shown to be efficient in systems constructed over a layer of limestone; however, this feature is not essential. In these past studies, Fe was the metal of most concern and was shown to be removed at efficiencies of 34 to 99 percent with 50 percent of the wetlands reducing the Fe concentration in water to less than 3,000 $\mu g \cdot L^{-1}$ (Kleinmann, 1987). All systems in use prior to 1987 were partially successful, and some completely eliminate the need for further chemical water treatment of applied AMD prior to downstream discharge to receiving waters (Kleinmann, 1987).

The development of artificial wetlands for the treatment of AMD is not problem-free. As mentioned earlier, wetlands require continuous water flow, with very little variation in flow tolerated, particularly by Sphagnum. Water depth is also critical for marsh-type wetlands dominated by Typha in that treatment efficiency is inconsistent in water that is greater than 2 feet deep and is very consistent in water that is 2 to 4 inches deep. In a survey of 20 wetlands constructed prior to 1986 in Pennsylvania, Typha survival was 100 percent, whereas Sphagnum survival was marginal. In addition to vegetation mortality, problems included breached banks, proper water depth regulation, sedimentation at the inlet, sedimentation at the outlet, muskrats and other burrowing animals, washouts, and channelization within the wetlands. Limestone and/or fertilizer additions were required at several of the wetlands to maintain optimal vegetative growth (Girts and Kleinmann, 1986).

The USBM is currently investigating the applicability of wetland systems for the treatment of AMD with elevated concentrations of heavy metals such as copper (Kleinmann, 1988). In addition to problems associated with heavy metals, treatment of AMD in the Lake Nacimiento watershed is further complicated by the seasonally dry environmental conditions. Vegetation capable of surviving periods of no flow or even periods of drying will have to be examined. Thus, it is necessary to identify suitable vegetation for these harsh conditions.

More general questions pertaining to the efficiency of metal removal by wetlands, and to design parameters that will effectively regulate flow rates and water depth need to be answered. If adaptable to Lake Nacimiento watershed conditions, wetland systems may be applicable as an inexpensive means of treating drainage from abandoned, inactive, and active mine operations.

The successful application of artificial wetlands to treat AMD typical of Buena Vista and Klau Mines is more tenuous than that of Appalachian mines in that high concentrations of heavy metals, including As, Cd, Cr, Cu, Hg, Ni, and Zn, and are associated with the drainage waters (Kleinmann, 1988). Many of these metals are toxic to plants at levels far lower than those typical of AMD found at Buena Vista and Klau Mines. The ability of wetland species to survive under these conditions would have to be investigated and poses another excellent research study topic for the on-going "Mining Study" being conducted by the Central Coast RWQCB staff.

An additional problem, which may make this approach to AMD clean up infeasible, is that wetlands are attractive areas for birds and other wildlife. The high concentrations of heavy metals (notably Hg, Ni, and Cr) associated with AMD at some mines like Buena Vista and Klau, may prove toxic to the vegetation used in wetlands establishment. Finally, because wetlands are attractive to migrating birds, the impact of toxic marshlands on migrating bird populations can be detrimental. Special steps would have to be taken to prevent fauna from entering these wetlands.

Biologists from the California Department of Fish and Game should be consulted before any full scale implementation of wetlands technology is undertaken at the abandoned and inactive Hg mines in the Lake Nacimiento watershed, so that approval can be given regarding the long term viability of this technology in light of the concerns regarding wildlife.

6.3.2 Chemical Remediation Methods

Most successful chemical treatment methods have one objective of maintaining the pH of water and sediments near neutral (i.e., 6.5 to 7.5). The pH will in turn regulate the solubilities of potentially toxic heavy metals like As, Cd, Cr, Cu, Hg, Ni and Zn. These metals are most soluble in acid pH's and therefore result in greater environmental degradation in acid environments.

The redox potential (i.e., the Eh; measured in mV or V) is the other important chemical property that determines the metal species that is likely to be present and, therefore, its relative solubility (Garrels and Christ, 1966). Generally, the higher the redox potential, the more aerobic (i.e., more air and more gaseous oxygen) the environmental surroundings. Many metals are, therefore, oxidized with an increase in Eh and the oxides of most metals are less soluble and, subsequently pose less of an environmental hazard. This is not true for all metals and the so-called "Eh-pH phase diagrams" that are readily available in the chemical literature can be consulted to help one determine which form of the metal is to be expected based on the ambient pH and Eh levels of any ecosystem (Garrels and Christ, 1965; Lindsay, 1979).

Many studies that attempt to measure the spatial variabilities of pH and Eh in the inherently complex sediment and soil environments indicate that micro-environments exist in natural systems in which there are large pH variations (as much as 2 units) and even greater differences in Eh (up to hundreds of millivolts) over relatively short distances (Fanning and Fanning, 1989). However, some level of "dynamic equilibrium" will be established over time which allows earth scientists the ability to generalize about Eh-pH condition differences between such diverse environments as "oxidized" hillslope soils and "reduced" lake bottom sediments (Garrels and Christ, 1965).

Chemical remediation methods discussed below include such diverse methods as treatment of reservoirs by adding sulfides to stabilize Hg, increasing water pH by liming with neutralizing agents, and adding selenium (Se) and manganese (Mn) to complex and immobilize Hg.

6.3.2.1 Acid Mine Drainage Neutralization

The production of acid mine drainage (AMD) is accomplished by a multi-staged, oxidative process (Table 6.4; Hutchison and Ellison, 1992; Mining Waste Study Team, 1988). An understanding of the necessary reactants in each step of the total AMD process is fundamental to inhibiting the overall process from occurring.

The most common mitigative measure currently used, or considered as a viable economic alternative to other control measures, is neutralization of excess acid (Holland et al., 1968; Bialas and Middleton, 1977). This measure is appropriate for acid mine drainage (AMD) treatment at active and inactive mines, where each component of a mine may generate AMD (Table 6.5). Neutralization of acid has the secondary beneficial effect of stabilizing soluble heavy metals (Hg, Cr, Ni, etc.) by precipitating them as insoluble hydroxides or oxides.

A major disadvantage of this acid neutralization approach is the treatment process must be continued for as long as the acidic effluents are produced, which in the case of AMD can be decades. Furthermore, the process generates large quantities of heavy metal-laden sludge that pose a difficult disposal problem. In fact, the volume of sludge can often exceed the volume of the original waste primarily due to the addition of neutralizing materials.

A change from an acidic to alkaline pH by adding neutralizing materials might lower concentrations of CH_3Hg^+ in the water column. This reduction of CH_3Hg^+ in the water column may result in lower Hg accumulation by fish species which accumulate Hg through the process of filtering Hg-rich waters through their gills (D'Itri, 1990). Hg concentrations in fish are generally greater in lakes with acid pH levels than in less acidic lakes (D'Itri, 1990).

Table 6.4: Multi-Staged Process of Pyritic Sulfide Oxidation(1) (Source: Hutchison and Ellison, 1992).

REACTIONS

1. $2FeS_2 + 7\,O_2 + 2H_2O = 2Fe^{2+} + 4SO_4^{2-} + 4H^+$
2. $4Fe^{2+} + 10\,H_2O + O_2 = 4Fe(OH)_3 + 8H^+$
3. $2Fe^{2+} + O_2 + 2H^+ = 2Fe^{3+} + H_2O$
4. $FeS_2 + 14\,Fe^{3+} + 8\,H_2O = 15\,Fe^{2+} + 2\,SO_4^{2-} + 16\,H^+$

STAGED PYRITIC SULFIDE OXIDATION

STAGE 1

Reaction 1 proceeds both abiotically and by direct bacterial oxidation.
Reaction 2 proceeds abiotically and slows as pH falls.

Chemical Conditions: pH above approximately 4.5, high sulfate and low iron concentrations, little or no acidity.

STAGE 2

Reaction 1 proceeds both abiotically and by direct bacterial oxidation.
Reaction 2 proceeds at a rate determined primarily by the activity of T. ferro-oxidans.

Chemical Conditions: Approximate pH range of 2.5 to 4.5, high sulfate levels, acidity, total iron increasing, and a low Fe^{3+}/Fe^{2+} ratio.

STAGE 3

Reaction 3 proceeds at a rate totally determined by activity of T. ferro-oxidans.
Reaction 4 proceeds at a rate primarily determined by rate of Reaction 3.

Chemical Conditions: pH below approximately 2.5, high sulfate levels, acidity, total iron and high Fe^{3+}/Fe^{2+} ratio.

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(1) Reference: Kleinmann et al., 1981.

Table 6.5: Potential Sources of Samples for Acid Generation Prediction(1) (Source: Hutchison and Ellison, 1992).

MINE COMPONENT FOR WHICH ARD TESTING MAY BE REQUIRED	SOURCES OF SAMPLES FOR ACID GENERATION PREDICTION
Pit Walls	Drill Core and Cuttings Underground Exploration Passages Trenches Pit Walls (Existing Mines Only)
Rock Surrounding Underground Workings	Drill Core Underground Exploration Adits Mining Faces and Walls (Existing Mines Only) Excavated Waste Rock (Existing Mines Only)
Waste Rock and Overburden Piles	Drill Core Underground Exploration Adits Waste Rock Piles (Existing Mines Only)
Ore Stockpiles	Drill Core Underground Exploration Adits Ore Stockpile (Existing Mines Only)
Tailings From Milling Operations	Residue From Bench Scale Metallurgical or Pilot Plant Tests Tailings Impoundment (Existing Mines Only)
Spent Ore From Heap Leach Operations	Residue From Laboratory Column or Pilot Scale Heap Leach Metallurgical Tests Heap Leach Residues (Existing Mines Only)

(1) Adapted from B. C. AMD Task Force, 1989.

It may not be feasible to continue to operate an effluent treatment plant after mine closure because of the problems of staffing and maintaining supplies of chemicals, particularly in geographically isolated regions (Mining Waste Study Team, 1988). Finally, mitigative techniques often themselves generate wastes (e.g., the metal hydroxide sludges from lime neutralization of acids) which require responsible disposal .

Disposal of AMD sludge often presents an environmental problem of magnitude nearly equal to that of the original AMD. Successful segregation of this sludge in sludge ponds and lagoons, or in abandoned underground mine workings, is possible, but the sludge volumes can be enormous. Although a substantial amount of research has done on improvement of AMD sludge thickening, (Kostenbader and Haines, 1970), conventional AMD neutralization plants will typically produce sludges of 0.5 to 4.0 percent solids (Bosman, 1974) whose volume is equal, on the average, to approximately 10 percent of the AMD flow (Bosman, 1983). Volumes as high as 33 and 50 percent have been reported in the United States (Holland et al., 1968) and South Africa (Bosman, 1983), respectively.

Hydrated lime is the most common alkaline material employed (Bosman, 1983; Hill, 1969), although other process variations use quicklime, sodium hydroxide, sodium carbonate, limestone, dolomite, phosphate rock, magnesium oxide and other alkaline materials (Heunisch, 1987; Hill and Wilmoth, 1971; Browning, 1970; Schiller and Khalafalla, 1984; Smith, 1977). In addition to being the least expensive choices, lime and limestone also are superior at yielding relatively denser sludges than most of the other chemical choices. This is because of the co-precipitation of calcium carbonate with the otherwise poorly settling metal hydroxides and oxides.

For example, lime neutralization of acidic iron sulfate AMD yields:
$2Ca(OH)_2 + Fe^{3+} + H^+ + 2SO_4^{2-} \Longrightarrow Fe(OH)_3 + H_2O + 2Ca^{2+} + 2SO_4^{2-}$.

Calcium sulfate, or gypsum, also can precipitate from some AMD waters whose sulfate levels are many magnitudes greater than their carbonate levels, but otherwise the significantly smaller solubility product of $CaCO_3$ relative to $CaSO_4$ (i.e., approx. 10^{-9} vs. 10^{-5}) generally favors $CaCO_3$ as the principal precipitated calcium salt. This chemical process of gypsum formation is likely occurring immediately below the Buena Vista Mine waste discharge stream below the buried tailings piles located near the intersection of Klau Mine and Cypress Mountain Roads (Photo 6-20).

The ponds, lagoons, and mine workings that are used for sludge disposal oftentimes are permeable to water and can result in sludge AMD leachate escape to the surrounding environment (Figures 6-8 and 6-9). Dissolved metals and sulfate in the leachate can adversely impact nearby ground and surface water quality. Precipitation of metals by sulfates appears to be occurring at Klau and Buena Vista Mines (Photo 6-21).

6.3.2.2 Bactericides

The most popular bactericides used to reduce AMD have been anionic detergents (Mining Waste Study Team, 1988). These detergents have been applied in dilute solutions and in slow-release formulations to coal waste piles and to the underground workings of abandoned coal mines. In these coal mine applications, AMD was substantially reduced following these treatments. As of 1988, the effectiveness of bactericides for treating AMD in California had yet to be demonstrated. However, experiments using the bactericides are straightforward and relatively inexpensive. Thus, a recent

Photo 6-20: Salt precipitation, likely sulfates, in the drainage stream of the Buena Vista Mine (6/15/92).

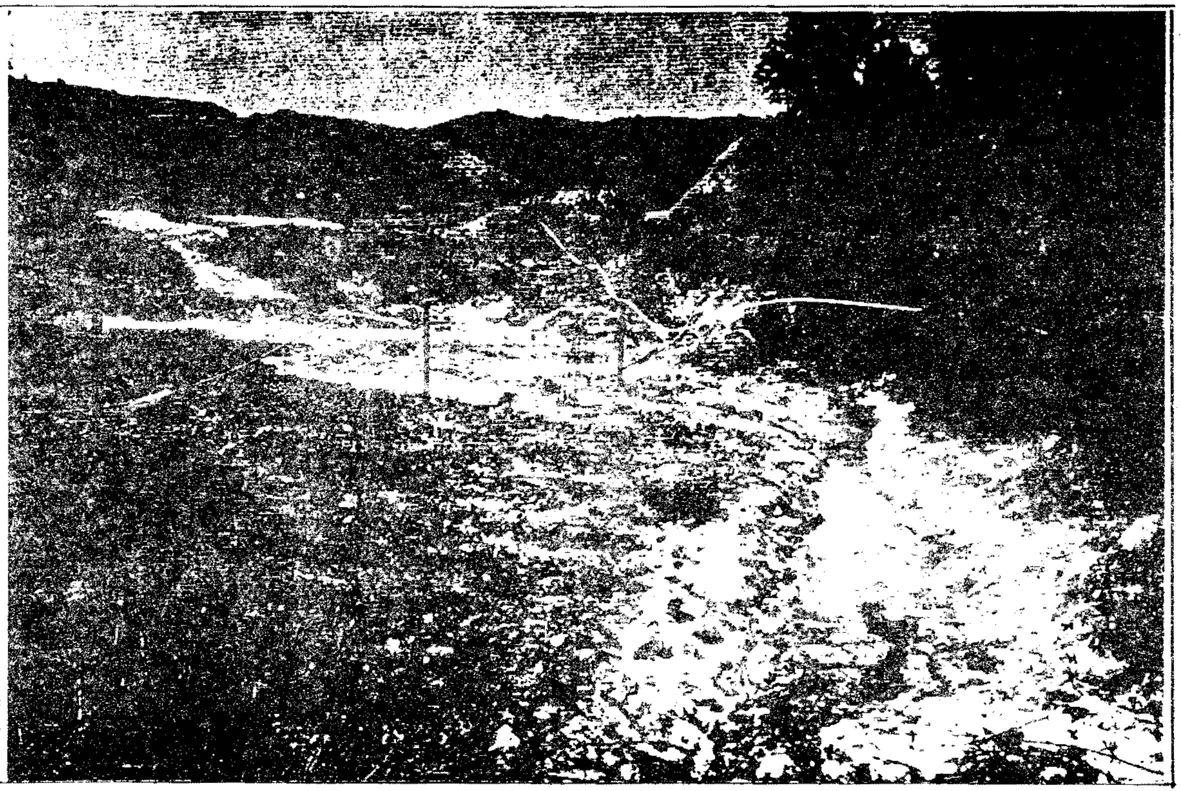


Photo 6-21: Salt precipitation, likely some metal sulfates, in the drainage stream of the Buena Vista Mine (6/15/92).

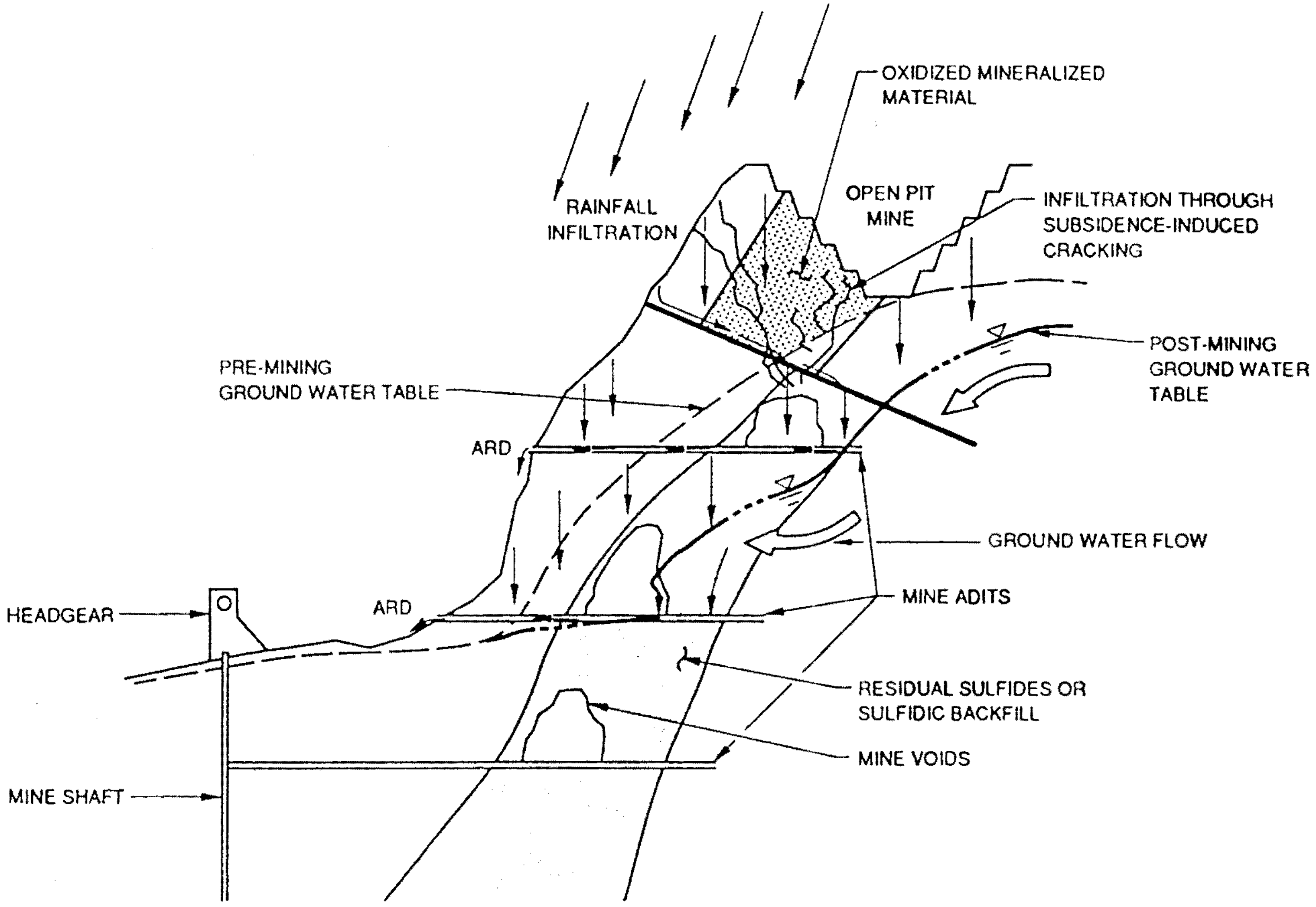


Figure 6-8: Conceptual Illustration of the AMD Process in an Abandoned Underground Mine (Source: Hutchison and Ellison, 1992).

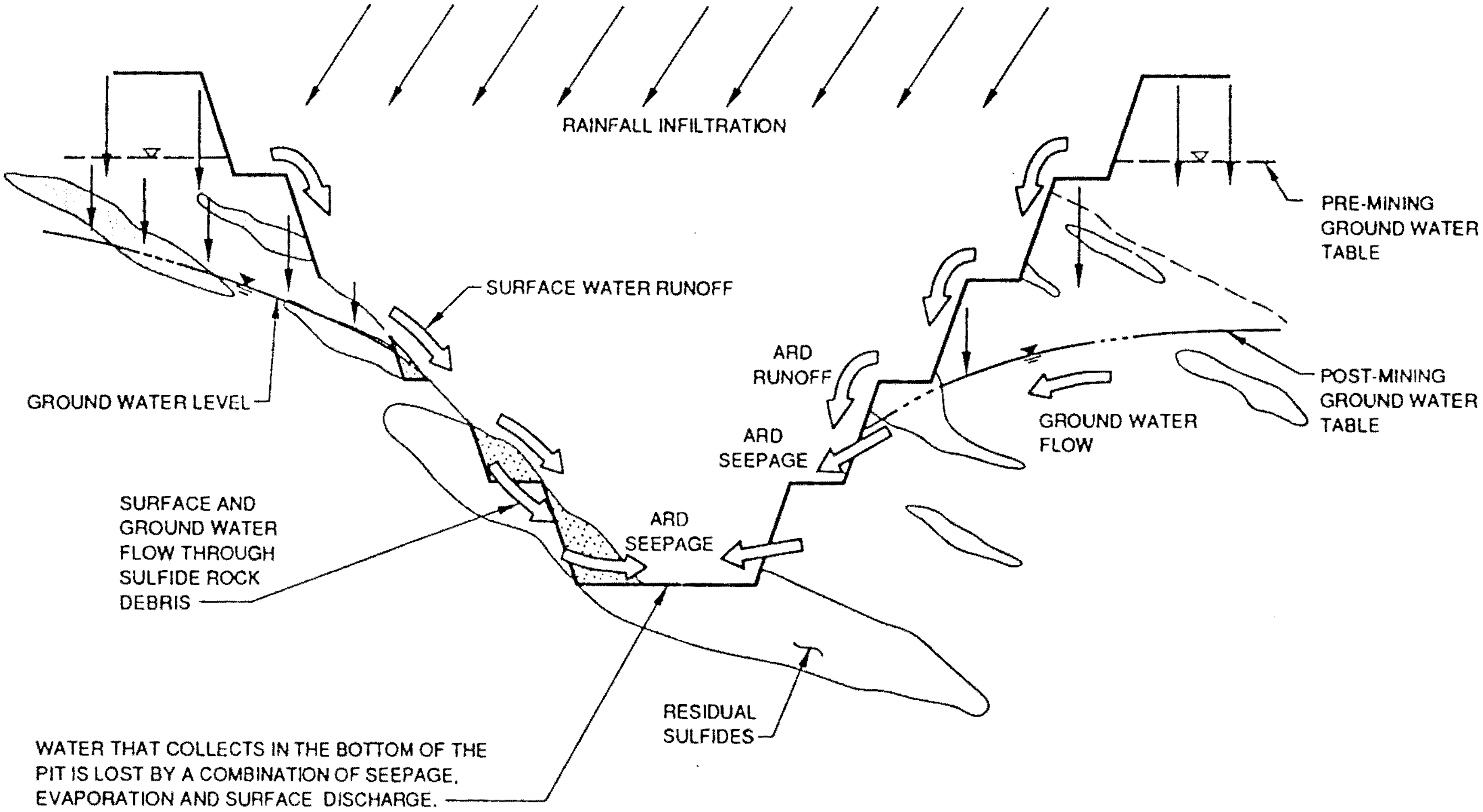


Figure 6-9: Conceptual Illustration of the AMD Process in an Abandoned Open Pit Mine (Source: Hutchison and Ellison, 1992).

study recommends that work in this area be initiated as soon as possible to determine whether this technology can be employed to alleviate some of the severe AMD problems in California (Mining Waste Study Team, 1988).

6.3.2.3 Oxidation Processes

Oxidation of certain transition metal species, such as Fe and Mn, will promote their precipitation from solution as insoluble oxides or hydroxides. This is because the more highly charged cations are more readily hydrolyzed than the less highly charged cations, and hence precipitate at relatively low pH (Mining Waste Study Team, 1988). The oxidation of Fe downstream of the waste runoff waters from Klau and Buena Vista mines normally appears as orange to red colored sediments and staining of rock and mineral surfaces in the Las Tablas Creek floodplain channel (Photos 6-22 and 6-23).

Chlorine, peroxide, permanganate, ozone and sulfur dioxide-activated oxygen are all effective oxidants for Fe (II) and Mn(II) in acidic solutions (Crabtree and Schaefer, 1966; Beller et al., 1970; Streeter, 1970; Cole et al., 1977; Sato et al., 1984), and hence could be used to treat AMD with minimum need for neutralization. Chlorine is already being used as an alternative to neutralization for removing iron from AMD at some Appalachian coal mines (Crabtree and Schaefer, 1966).

Additions of Mn-oxides and -oxyhydroxides would tightly bind and immobilize available Hg. At Lake San Antonio, north of Lake Nacimiento, total Hg levels in transplanted freshwater clams were low (0.023 to 0.016 $mg \cdot kg^{-1}$) when levels of Mn were high, with levels recorded at 14.81 and 2.14 $mg \cdot kg^{-1}$ (Stevens, 1988). The presence of MnOOH in oxidizing environments has been shown to inhibit the Hg uptake by benthic invertebrates by strongly binding the available Hg (Jackson, 1988).

Photo 6-22: Orange, Fe-rich sediments in the Klau Branch, Las Tablas Creek below Klau Mine (1/25/92).

Photo 6-23: Orange, Fe-rich sediments in the North Fork, Las Tablas Creek below Buena Vista Mine (6/15/92).

Selenium (Se) has also been suggested as a Hg ameliorating agent. The rate of accumulation of Hg by fish and other aquatic biota in an enclosed water system was reduced by a factor of two when Se at 100 $\mu g \cdot L^{-1}$ was added (Rudd and Turner, 1983). However, careful studies of the potential toxicities of all selenium species should be studied before its use as an ameliorating agent.

6.3.2.4 Reduction Processes

In principle, AMD could be treated by chemical, electrochemical, or biological reduction processes, which would reverse the oxidation reactions that form AMD, and result in precipitation of metals as relatively insoluble sulfide minerals. Although sulfate is unstable under reducing conditions, very high overpotentials generally are required to reduce sulfate to sulfide-containing species. Thus chemical and electrochemical reduction is technically infeasible under field conditions. Bacterial reduction of sulfate to sulfide with concurrent precipitation of heavy metals has been investigated. Contaminated sediments should be protected from weathering and buried in an anoxic S-rich environment (Berman and Bartha, 1986).

The bacteria require organic carbon substrates, but inexpensive sources such as sewage or sewage sludge may be adequate (Sissler et al., 1977; Tuttle et al., 1969a, 1969b). The technical and economic feasibility of this approach is uncertain at present, particularly for abandoned Hg mines. This method may be a potential research topic for the "Mine Study" presently underway by the RWQCB staff in San Luis Obispo. One advantage of this method may be the potential beneficial disposal of sludge from sewage treatment facilities in local municipalities like Atascadero and Paso Robles.

The addition of sulfides to lake and reservoir waters has been suggested as one way to complex and immobilize Hg. However, sulfides probably would not be effective since they would only immobilize Hg in deep anoxic sediments which do not pose a problem (Mining Waste Study Team, 1988). Also, sulfides may be biochemically oxidized when reservoir levels drop resulting in acidification which would then tend to stimulate Hg methylation (Rudd et al., 1983) and may have potential detrimental effects on aquatic organisms due to the production of AMD.

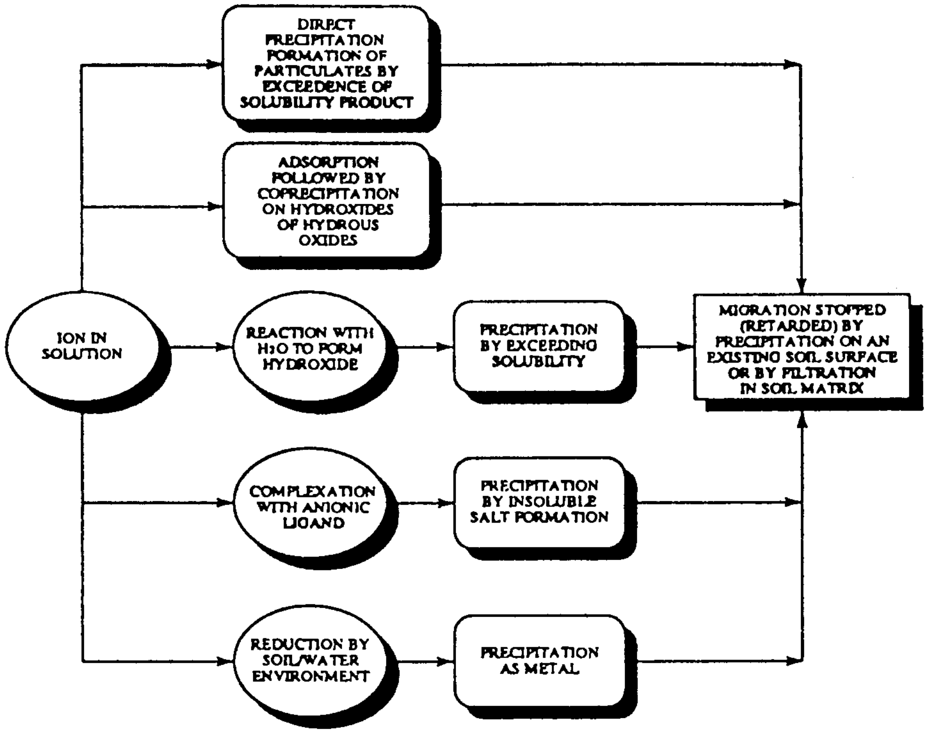
An important concept relative to remediation of mining wastes relates to "attenuation." Simply, the concept assumes that initial toxicity levels of a substance will decrease to relatively lower, nontoxic levels as a result of successful implementation of some remediation or pollution abatement measure(s) or as a function of dilution during natural transport away from a contaminated site (Figure 6-10; Hutchison and Ellison, 1992; Mining Waste Study Team, 1988).

6.3.2.5 Ion Exchange Methods

Ions in mine waters, such as Fe^{2+}, Cd^{2+}, and SO_4^{2-}, can be removed by exchange with cationic or anionic functional groups immobilized on porous polystyrene resin beads. The resin is generally used as packed columns or fluidized beds. Exhausted resin is regenerated by elution with concentrated acid or alkali, which reverses the exchange reaction. The resulting brine can pose a disposal problem. Columns are susceptible to plugging by fines and other solids in the effluent.

At present, ion exchange may be too expensive for treatment of mine waste waters, although past studies suggest that this technology may be feasible now (Pollio and Kunin, 1967; Rose, 1970; Zabban et al., 1972).

(A) PRECIPITATION



(B) TOXICITY REDUCTION

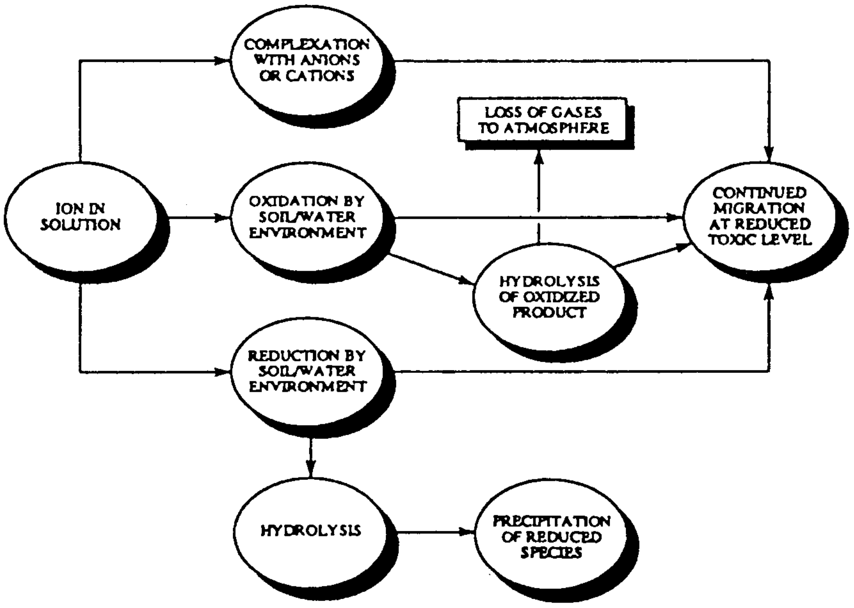


Figure 6-10: Illustrations of Chemical Attenuation Mechanisms (Source: Hutchison and Ellison, 1992).

Activated carbon systems, which are very effective at adsorption and removal of organics from solutions, are in the developmental stage for hazardous waste stream metal removal after metal chelation with organic supplements (Bhattacharyya and Cheng, 1987). The technology may also prove feasible for removal of metals from AMD and may be another research topic to be explored by the RWQCB staff involved in the "mine study".

6.3.3 Biological Remediation Methods

When biological methods are used, remediation methods should address CH_3Hg^+ production in the whole system and not just in the bottom sediments. This points out the importance of CH_3Hg^+ production in the suspended particulates. Aquatic plants like Azolla have been used to accumulate and volatilize Hg. Use of plants presents a disposal problem for fast growing water plants that concentrate with Hg.

6.3.3.1 Biological Oxidation

Acidophilic bacteria can catalyze the otherwise slow oxidation of Fe(II) at low pH, although natural or supplemental aeration is still required. Various processes and reactors, including rotating biological contactors, sequenced batch reactors, and biofilters, have been proposed for the treatment of mine wastewater (Lacey and Lawson, 1970; Lazaroff et al., 1982; Mandl, 1984; Myerson, 1981; Nordstrom, 1982; Olem and Unz, 1977, 1980; Theis et al., 1982). The economic feasibility of biological oxidation processes is presently uncertain.

6.4 Summary

Table 6-6 summarizes the individual physical remediation measures that have been discussed, their objectives, and their unit costs. The effectiveness of the various measures will be compared in the next section where combinations of measures are discussed.

6.4.1 Source Control Remediation Measure Combinations

Some of the measures discussed above would be effective in isolation. For example, solidification and vitrification, and the excavation, transportation, and disposal alternatives would not require the implementation of other operations for them to significantly reduce the Hg loading in the Las Tablas Arm of Lake Nacimiento from the Hg mines, especially Buena Vista and Klau. All of the other measures would need to be implemented in conjunction with others to be fully effective.

Some requirements and limitations on combining source control remediation measures include:

1.) Riprapping the streambanks and large drainage gullies on the mine sites would be necessary components of all measures in order to protect against erosion. In the absence of such protection, streambanks would gradually fail and active gullies would continue to enlarge.

2.) Cutting back the steepest slopes from their current conditions to 20° (about 36%) would be a necessary preparatory step prior to revegetation, grouting, or capping with a soil-cement, a flexible geotextile with revetment, or a webbed geotextile with soil cover. The manufacturer of concrete blankets claims that the blanket

Table 6-6: Cost Estimates for Individual Physical Remediation Measures

Control Measure	Objective	Est. Unit Costs ($)
A. Cut Back Slopes	Eliminate surficial failures & reduce erosion.	\$3 to 4/yd^3 soil
B. Revegetation	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$1,200/A: hydroseeding \$1,000/A: surface prep. \$2,850/A: plant matter
C. Riprap streambanks and gullies.	Prevent undercutting and fluvial erosion.	\$2/yd^2: filter blanket \$48/yd^2: revetment
D. Mine Seals	Reduce erosion and AMD.	Not determined.
E. Grouting	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$1.50/ft^2
F. Capping with Soil-Cement	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$725,000/A
G. Capping with Flexible Geotextile	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$2/yd^2: flex. geotextile \$48/yd^2: revetment
H. Capping with concrete blanket.	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$0.50/ft^2: fabric forms \$60/yd^3: concrete \$17/yd^3: labor
I. Capping with Webbed Geotextile	Reduce erosion & stabilize slopes. Reduce fluvial transport.	\$0.79/yd^2: geotextile \$0.60/yd^2: labor \$14.70/yd^3: topsoil \$1,200/A: hydroseeding
J. Solidify all wastes	Eliminate erosion.	\$50/yd^3
K. Vitrify all wastes	Eliminate erosion.	\$100-250/yd^3
L. Excavate, Transport, and Dispose of All Wastes	Remove contaminated material.	\$3/yd^3: excavation \$12-25/yd^3: transport \$120/yd^3: disposal
M. Sediment Traps	Capture fluvial sediment.	Not determined; (site specific).
N. Wetlands	Capture sediment and reduce AMD.	Not determined; (site specific).

would perform on slopes of 45° (i.e., 100%) or steeper so that no slope reduction may be necessary for this measure to be effective (Nicolon Corp., Norcross, GA).

3.) Solidification, vitrification, or excavation and disposal of the wastes would additionally only require maintenance of a spillway channels at the Klau Branch reservoir and at the Harcourt Reservoir or drainage gullies that flow at the base of Buena Vista, Klau, Bonanza Group, and Ocean View Hg mines.

The major difference in the effectiveness of the various combinations of measures is simply the site variations among the specific areas involved. Assuming that the streambanks and drainage gullies are riprapped and the steep slopes are modified as required to inhibit accelerated erosion, the anticipated reduction in Hg loading is approximately equal among the measures whether achieved by revegetation, grouting, or capping with a soil-cement, a flexible geotextile with revetment, a concrete blanket, or a webbed geotextile with soil cover.

If Hg loading contributions from any mine site are approximately 90% from eroding gullies and 10% from collapsing streambanks, then applying revegetation, grouting, or capping with a soil-cement, a flexible geotextile with revetment, a concrete blanket, or a webbed geotextile with soil cover would produce approximately a 88% (i.e., 90% [0.96 to 0.99] = 88%) reduction. Applying the same techniques to the eroding gullies and also to the non-vegetated sections of collapsing streambanks would produce a Hg loading reduction of about 98%.

The combinations of source control remediation measures discussed above do not consider heavy metal pollution and AMD generated below the soil surface. Further characterization of the groundwater conditions and subsurface physical and chemical conditions at the Buena Vista and Klau Mines and at other abandoned mines needs to be completed and analyzed before effective remediation measures can be developed that solve the subsurface pollution problems.

For each combination of source control remediation measures, the revegetation practices applied in conjunction with slope reduction to 20° (about 36%), riprapping of streambanks and/or active gullies, and maintenance of the spillways at the Klau Branch reservoir and at Harcourt Reservoir will likely provide the lowest cost alternative. Variation in the total costs will reflect the range of cost estimates for riprapping and cutting back the steepest, most erodible slopes. Revegetation costs are considered relatively low in comparison to all other measures except for the spillway maintenance (Chamberlin et al., 1990). Given the proper selection of vegetation and engineered soil surface preparation, vegetation becomes self-maintaining after an initial establishment period, assuming that the plant species selected are self-propagating, drought tolerant species with low nutrient requirements.

7.0 POLLUTION ABATEMENT MEASURES

7.1 Overview

The Hg loading in the Las Tablas Arm (see Section 5) assumes that the upper lake bottom sediments store essentially all of the Hg in that portion of the lake, although the storage in the water column makes up the mobile fraction. The data show approximately 2.8 x 10^{-4} to 5.3 x 10^{-4} kg of Hg/m^3 sediment are stored in the upper lake sediments, while the water column stores about 1.0 x 10^{-7} to 7.0 x 10^{-7} kg of Hg/m^3 water. Under present conditions, annual Hg inputs from the Las Tablas Creek watershed range from near zero during extreme drought years to a range of about 4.2 x 10^3 to 7.95 x 10^3 kg of Hg/yr, depending on precipitation and erosion losses. A substantial amount of resuspension and redeposition of Hg-contaminated sediments likely occurs in Lake Nacimiento as well, due primarily to the seasonal inflows to the lake and water level fluctuations.

Control of Hg-laden sediment loads from the Hg mines to the lake was examined as a direct means for improving water quality. However, the Hg already stored in the upper sediments of the lake may continue to cause bioaccumulation by fish and wildlife species for many decades, or even centuries. Therefore, in-lake pollution abatement measures have also been developed and evaluated.

A wide range of control options have been considered:

A. Do nothing;

B. Implement a source control program on the mine sites but do nothing in the lake (see Section 6 for full discussion);

C. Dredge and treat or remove contaminated Lake Nacimiento and/or Harcourt Reservoir sediments;

D. Cover Hg-laden lake sediments *in situ.*; and

E. Establish a bounty system to reduce human consumption of the most Hg-contaminated fish.

The relationship between Hg levels in the lake sediments and in the fish populations was discussed in Sections 2 and 4 of this report. Each of the pollution control options and potential combinations are examined and evaluated with respect to our present state of knowledge relative to Hg pollution and toxicity and the effectiveness of each option in reducing the detrimental environmental effects of Hg pollution of the lake and its watershed. Since the Harcourt Reservoir is the most effective sediment trap for Hg-laden sediments in the Las Tablas watershed, we have considered abatement measures for it as well.

7.2 Abatement Options

7.2.1 Do Nothing

The primary question to ask is "What would happen to Hg levels in the Lake Nacimiento surface sediments and fish populations if no action were taken?"

In Swedish lakes contaminated primarily from industrial discharges of Hg as the mercuric ion (Hg^{2+}), Jernelov et al. (1975) estimated that:

*approximately 10-15 years are required for systems to return to equilibrium following sudden changes in inputs;

*approximately 7 years (1 fish generation turnover time) would be required for a system to recover if all Hg were suddenly removed; and *approximately 10-100 years would be required for recovery if no new Hg inputs entered the system if an internal source from sediment deposits was present.

The English-Wabigoon river system in Canada became contaminated with Hg as the result of the discharge of 9,000 to 11,000 kg of Hg from 1962 to 1969. Since 1970, the discharge has been controlled and reduced to 1% of earlier uncontrolled levels. Following the significant decrease of these discharges, sediment profiles showed that Hg concentrations peak several centimeters below the sediment water interface. Surface sediment Hg concentrations decreased due to later deposition of cleaner sediments (Rudd et al. 1980). Armstrong and Scott (1979) had reported that Hg concentrations in fish continued to decline despite continued high Hg concentrations in deeper sediments. Despite these reductions, Hg concentrations in fish remain about 10 times the legal limit for human consumption (Allan, 1986).

In the English-Wabigoon river system following the removal of the industrial point source discharge, the immediate decline in Hg levels in short-lived organisms like crayfish was quite rapid (i.e., over a 80% decrease in 10 years). But the subsequent decline (after 10 years) was much slower, implying that a mass balance equilibrium was being reached in the lake system (Allan, 1986).

Allan (1986) and Jernelov et al. (1975) both argued that recovery rates would be expected to be higher in systems with high productivities (i.e., nutrient-rich waters), low hydraulic residence times, high sedimentation rates of alluvium low in Hg, a neutral to alkaline pH, and anoxic (i.e., anaerobic, low Eh) sediments.

The highest Hg levels in the entire Lake Nacimiento watershed are found in the alluvial sediments of Las Tablas Creek and in lake sediments in the Las Tablas Arm of Lake Nacimiento (Hubbert, 1991; Table 4-9 this report). Total Hg levels in the Las Tablas Creek watershed range from over 4,000 $mg \cdot kg^{-1}$ in sediments next to the Buena Vista Mine condenser to about 5.0 $mg \cdot kg^{-1}$ in Harcourt Reservoir sediments, and then decrease to about 1.5 to 2.0 $mg \cdot kg^{-1}$ in Las Tablas Arm sediments (Tables 4-2 and 4-3; Figure 4-1).

If all of the Hg stored in the lake was suspended in the water column and well-mixed, it would become available for removal by hydraulic transport into other areas of the lake. Under these conditions (i.e., from the perspective of removing the Hg from Harcourt Reservoir and from the Las Tablas Arm of the lake), the nominal hydraulic residence time (HRT) could be used to estimate the half-life (or $t_{1/2}$) of Hg in the Las Tablas Arm of the lake (Chamberlin et al., 1990), where:

$$t_{1/2} = \ln(2) \cdot \mathrm{HRT} \qquad \text{(Eq. 1)}$$

For an HRT range from 5 to 19 yrs, $t_{1/2}$ would extend from 3.5 to 13.2 yrs. Since it would require 3.32 half-lives for the Hg level to decrease by 90%, from 12 to 44 years would be required for levels to decline by that amount. This provides an extreme lower limit on the recovery time. The true half-life is certainly much larger (Chamberlin et al., 1990).

The best estimate of the rate of recovery of the Las Tablas Arm if no action were taken is based on the observed Hg levels in the lake sediment (Hubbert, 1991; Table 4-9 this report). Using least squares linear regression on ln(C) vs. Z, each curve has been described by an exponential function of depth:

$$C_Z = C_0 \cdot e^{kZ}; \qquad \text{(Eq. 2)}$$

where: C_Z = Hg level at sediment depth, Z ($mg \cdot kg^{-1}$);
C_0 = Hg level at Z = 0.0cm ($mg \cdot kg^{-1}$);
k = exponential coefficient (1/cm); and
Z = depth (cm).

All of these estimated parameters were shown to be statistically significantly different from 0.0 at a 5% significance level using data from the Oaks Arm of Clear Lake, Lake County, California which is contaminated by Hg-laden sediments originating from the Sulphur Bank Hg mine (Chamberlin et al., 1990). The same interpretation can be reached using data reported in this report for the Las Tablas Arm of Lake Nacimiento. Using the sedimentation rate (V_S) of 0.6 cm/yr, the $t_{1/2}$ for the surface sediment Hg level in the Las Tablas Arm of Lake Nacimiento can be estimated:

$$t_{1/2} = \ln(2) / V_S \cdot k \qquad \text{(Eq. 3).}$$

In other words, the Hg levels at the Lake Nacimiento sediment surface would decrease by 50% in the period $t_{1/2}$. These half-life estimates range from 34 to 61 years which correspond to estimates of 113 to 219 years for surface sediment Hg levels to decrease by 90%. We do not have the data from Lake Nacimiento sediment cores like those collected in the Sulphur Bank Hg mine study (Chamberlin et al., 1990). However, the general theoretical model developed by Chamberlin et al., 1990 can be applied in a general way to Hubbert's (1991) and our bottom sediment data collected in Lake Nacimiento.

When the same analysis was carried out using data for the top 10 cm of Clear Lake sediment, the surface concentration estimates are higher and the $t_{1/2}$ estimates for core No. 8.0 is almost 300% greater than the comparable values for the data as a whole (Chamberlin et al., 1990). The estimated time for surface sediment Hg levels to decrease by 90% would range from 190 to more than 300 years in the Oaks Arm of Clear Lake (Chamberlin et al., 1990). We may expect comparable natural Hg level attenuations in the sediments of Las Tablas Arm of Lake Nacimiento.

7.2.2 Source Control Only

To assess the impact of implementing source controls in the absence of in-lake abatement projects on lake recovery time, assume that the average annual Hg loadings from the Buena Vista and Klau mine sites will be reduced by about 95% (e.g., reducing all Hg tailings slopes to 20° (about 36%), revegetating the non-vegetated mine sites, and by riprapping the most severely eroding banks along Las Tablas Creek). This could reduce the loading by about 85 to 95%.

The impact of this substantial reduction of loadings on the Hg levels in the water column and surface lake sediments would depend strongly on the extent of the recycling of Hg-rich sediments within the Las Tablas Creek Arm. Since the surface sediments throughout the entire Las Tablas Creek Arm are highly susceptible to erosion and transport, such recycling is probable (Hakanson, 1982).

The recycling rate can be estimated from the following:

$$L_{sb} = L_{SBM} + (Q_t \cdot C_t) - (Q_o \cdot C_w) - L_a \qquad \text{(Eq. 4)}$$

$$\Delta S_s = \Delta t \cdot V_s \cdot A_{OA} \cdot \text{B.D.} \cdot (1 - p_w) \cdot C_s \qquad \text{(Eq. 5)}$$

$$\Delta S_s = \Delta t\,(+ L_s + L_{\Pi}) \qquad \text{(Eq. 6)}$$

where:

ΔS_s = change in storage during time interval in sediments (kg)
Δt = duration of time interval (yr)
L_{SBM} = Hg input from Buena Vista (or Klau) Mine site (kg/yr)
Q_t = Las Tablas Creek streamflow into the lake arm (m^3/yr)
C_t = Hg concentration in Las Tablas Creek as it enters lake (kg/m^3)
L_{sb} = flux from water column to sediment blanket (kg/yr)
L_a = flux from water column to air (kg/yr)
Q_o = flow due to currents from the Las Tablas Arm into the main Lake Nacimiento channel (m^3/yr)
C_w = Hg concentration in Las Tablas Arm water column (kg/m^3)
L_s = net flux from sediment blanket into sediments (kg/yr)
L_{Π} = recycling flux from sediments back to sediments (kg/yr)
V_s = sedimentation rate = 0.6 (cm/yr)
A_{OA} = area of Las Tablas Arm = 2.4×10^6 (m^2) = 600 A.
B.D. = bulk density of surface sediment = 1.07 g/m^3 (wet wt.)
p_w = water content of surface sediment = 0.84 = 84%
C_s = Hg content of surface lake sediment (upper 0-10 cm)
C_s = 1.0 to 2.0 mg $Hg \cdot kg^{-1}$ sediment (dry wt).

The foregoing estimate of the current magnitude of Hg recycling is obtained using the three equations which compare the net losses to the upper sediments to the Hg accumulation rate estimated from the sedimentation rate (Chamberlin et al., 1990).

Our estimates are very gross and more lake sediment depth sampling would be necessary to confirm these values (Chamberlin et al., 1990). ΔS_S can be determined from Eq. 5 (i.e., 0.49 to 0.99 kg/yr). Since the net loss to the upper sediments (L_{sb}) as determined by equation Eq. 4 is -8.23 to -118.6 kg/yr, then the recycling contribution (L_{Π}) can be estimated from equation Eq. 6 to be about -355.05 to -357.6 kg/yr. These negative values indicate a net gain of Hg to the water column each year, as well as net movement of Hg from the surface lake bottom sediments to the water column and sediment transport downstream toward the main channel of Lake Nacimiento. Indeed, the Hg concentration data indicate movement of some Hg-rich sediments out of the Las Tablas Arm to the north and then east along the main channel of Lake Nacimiento (Hubbert, 1991; Table 4-9 this report).

Reducing the Hg levels in the surface lake sediment, by whatever method(s), would have additional effects on the Hg levels in the water column and on the recycling rate itself. The magnitude of the effects is uncertain but, qualitatively, an accelerated rate of lake recovery should be produced; as compared to the "No Action" alternative.

The same Hg recycling procedure described above for the Las Tablas Arm could be applied to the Harcourt Reservoir if more intensive, undisturbed sediment core sampling is accomplished.

7.2.3 Dredging

Unless major obstructions exist, dredging can remove accumulated sediments, increase lake depth, and simultaneously remove contaminants incorporated in the sediments. In Lake Nacimiento, dredging might be used to remove the surface sediments (ca. 1 m deep) from the entire lake, the

Harcourt Reservoir, or from only the most contaminated area of the lake, i.e. the Las Tablas Arm. The Las Tablas Arm includes most of the lake sediment with Hg levels in excess of 1.0 $mg \cdot kg^{-1}$ (Hubbert, 1991; Table 4-9).

The sediment removal could be carried out by mechanical, hydraulic, or special purpose dredges. Mechanical dredges remove the dredged materials by means of buckets of various design. Hydraulic dredges lift dredged materials by means of pumps. The type of dredging that could be accomplished at Lake Nacimiento or at Harcourt Reservoir would depend on the size limitations of the dredging equipment (some areas of the lake that might require dredging may be too small to accommodate some types of dredges) and the ability to transport machinery overland to the site.

Since the Las Tablas Arm is at all points less than 100 ft deep (at maximum lake water levels), no extreme mechanical difficulties should be experienced. However, access by transportation equipment may be difficult at low lake water level due to a lack of paved roads. Access to the Harcourt Reservoir is good and the water levels rarely exceed 25-30 ft.

A clamshell dredge can place lake sediments onto small barges which can then be transported to a disposal site or decanting basin. A hydraulic dredge can be disassembled for transport and then reassembled at the lake. The equipment available for hydraulic dredging includes centrifugal pumping systems and portable hydraulic pipeline dredges. Hydraulic dredging serves the same purpose as mechanical dredging, but requires a nearby location to use as a dump site for the dredged materials. Sediments can be pumped large distances using floating or submerged pipelines with booster pumps every few miles. Cook et al. (1986) describe a class of special purpose dredges specifically designed for removing fine-grained, contaminated sediment.

The process of finding a disposal site for dredged sediments may be difficult. The easiest solution would be to use a disposal site close to the lake, but this choice cannot be considered if the sediment is Hg-contaminated. If the sediment is deemed hazardous, transportation to an approved site (like Chemical Waste Mgt., Inc. Kettleman Hills, CA facility) may be required.

Dredged sediments from Harcourt Reservoir and, at least, a portion of Lake Nacimiento may be deposited back at the mine sites, especially Buena Vista and Klau. Assuming that the ultimate sediment bulk density in the Klau Mine pit is the same as the value in Harcourt Reservoir, the volume of the Klau Mine pit and the Buena Vista Mine adits and tunnels would likely provide sufficient storage for the sediment that would be generated by dredging the Harcourt Reservoir, but may not provide enough storage for the sediment that would be generated from dredging the Las Tablas Arm or the entire lake. A detailed engineering evaluation of the total available storage volume at the mines and potential groundwater contamination caused by wastes should be undertaken before implementation of a dredging effort.

The dredged effluent produced during the dewatering process may require treatment. Regulations regarding the disposal of hazardous material may also make it necessary to either build a hazardous waste landfill at the site or to transport the filtered sediments to an approved disposal site. Costs for dewatering treatment and construction of a hazardous waste handling disposal site have not been evaluated. Our sediment data, and Hg concentration data collected from an earlier study (Hubbert, 1991) suggest that even the most contaminated sediments in the Las Tablas Arm and in the Harcourt Reservoir are not considered as "hazardous waste" (Table 4-3).

Activities associated with dredging can produce serious environmental problems. Dredging causes disturbance and increased turbidity during dredge operation. This can have grave consequences if sediments are hazardous and if toxic materials embedded in the silts and sediments are released into the overlying water column. To some extent these problems can be reduced by the use of silt curtains as shown in Figure 7-1 which would contain the resuspended material within the immediate area of the disturbance. Silt curtains are essentially a skirt constructed of a continuous sheet of plastic buoyed at the surface and weighted at the bottom so that it hangs perpendicular to the water surface. Based on laboratory studies, Feick et al. (1972) estimate that about 10% of the Hg removed by dredging ends up suspended in the water column and that total recoverable Hg levels in the water column might approach 100 to 1,000 $\mu g \cdot L^{-1}$.

A variety of tests should be performed to assess the potential hazards of dredging. These consist of a combination of elutriate tests and dredged sediment bioassays. If a disposal area nearby is being considered, a knowledge of the physical, chemical, and biological characteristics of the site will be necessary. The costs of the tests or studies would have to be added to the dredging cost.

Several mitigation alternatives may be proposed at Lake Nacimiento which utilize dredging processes to reduce contamination of fish and wildlife due to Hg-polluted sediments. One assumption inherent in the use of this technology is that dredging the sediments may reduce the levels of Hg in the sediments to background levels. The cost of these projects has been

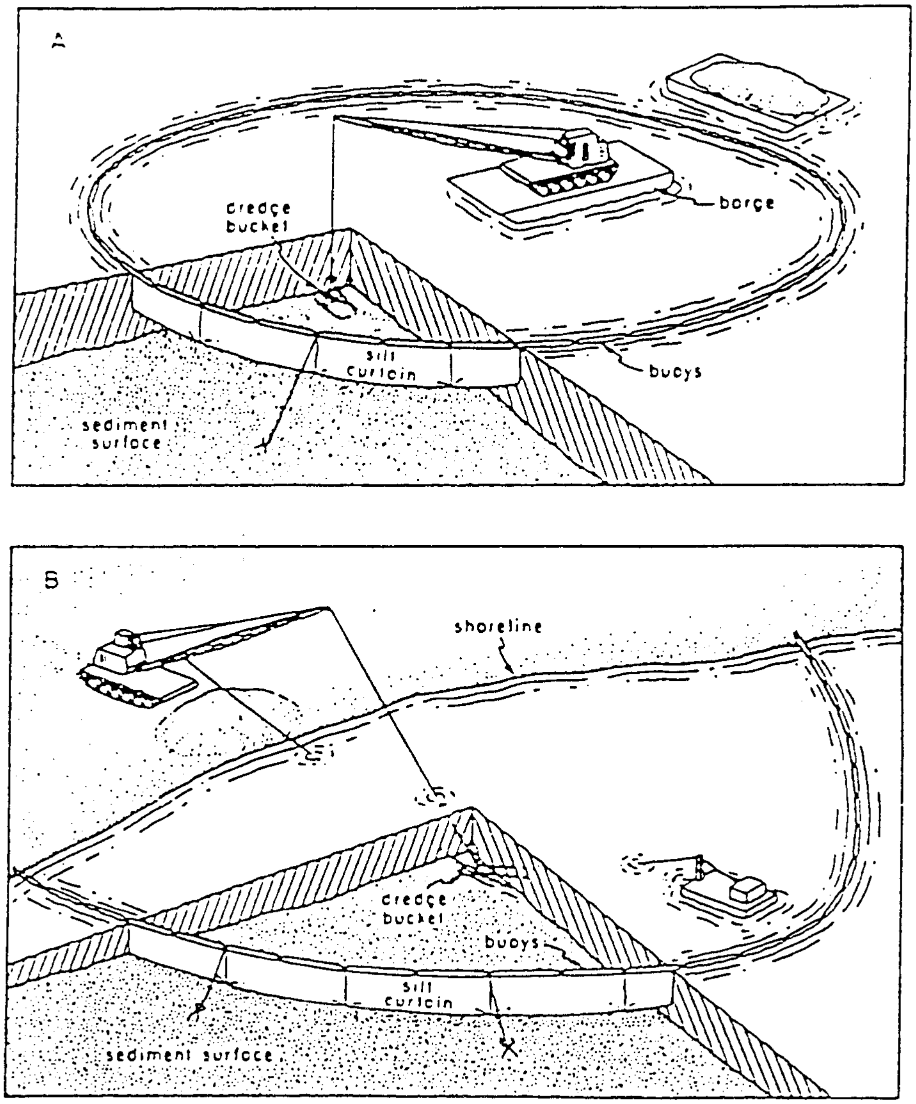


Figure 7-1: (A) Silt-Curtain Encirclement of an Open Water Grab Dredge Operation; (B) Silt-Curtain Isolation of an Open Water Bucket Dredge Operation (Source: Hutchison and Ellison, 1992, after Cook et al., 1986).

estimated on the basis of mobilization and demobilization cost for the dredge of $35,000 per job and a unit dredging cost of $2.00 to $5.00 per yd^3 removed (Chamberlin et al., 1990; California Dredging Company, Martinez, CA, 1988; U.S. Army Corps of Engineers, 1988; Building Construction Cost Data, 1988).

If dredging were chosen as a viable abatement option, the resulting project costs could be estimated by determining the total sediment volume to be removed, the dredged sediment disposal costs, and the initial set-up costs of the dredging equipment.

The reduction in Hg levels in the fish population would strongly depend on the extent and duration of the contamination of the water column by the resuspended sediments. Following the period of resuspension which might last about 30 days (Snodgrass, 1986), the Hg levels in the upper sediments should be about equal to the low background in the sediments below 1 m depth, assuming dredging of the entire lake is implemented.

If only the most heavily contaminated part of the lake, the Las Tablas Arm, were dredged the Hg in the surface sediments of the remainder of the lake east of the Las Tablas Arm would still be susceptible to resuspension and deposition so that the Hg level in lake sediments east of the Las Tablas Arm will still be a potential Hg source for addition to the water and fish.

7.2.4 Covering Lake Sediments

The Hg levels in the water column could be reduced without removing the Hg-contaminated sediments by overlaying the sediments with sand and gravel (Bongers and Khattak, 1972), locally available clean sediments (Rudd et al., 1980; Rudd and Turner, 1983), or clays such as bentonite. These measures are somewhat attractive in that they control Hg levels in both the water column and at the sediment-water interface (Chamberlin et al., 1990).

In the water column and surface sediments, resuspended sediments would bind Hg and reduce its bioavailabillty. At the sediment surface, increased deposition of clean, organic-poor material would dilute concentrations of both Hg and organic carbon, the latter being a source of bacterial food and energy. Both of these factors can control rates of microbial Hg methylation (Furtani and Rudd, 1980; Rudd et al., 1983).

Rudd and Turner (1983) found that immediately after sediment additions, the decreased light penetration reduced daily rates of productivity by about a factor of 2. These reductions in primary productivity are thought to have a small negative effect on rates of Hg bioaccumulation. They also found that the addition of organic-poor sediment substantially reduced bioaccumulation of Hg by the zooplankton, crayfish, clams, and pearl dace. Zooplankton concentrations were reduced to 20%, while Hg concentrations of crayfish, clams, and pearl dace were reduced from 10 to 15%. Movement of Hg into pearl dace muscle was reduced even further to 5% of the control population. Hg concentrations per gram of periphyton were lowered by 50 to 75% with the addition of organic-poor, suspended sediments. Sediments were effective at reducing the rate of Hg bioaccumulation by binding the Hg to fine particulates, making it less available for methylation or bioaccumulation. The addition of sediment had no effect on the rate of loss of Hg from the water column. However, there was a significant increase in the percentage of Hg on fine particulate material with a corresponding decrease in the quantity of Hg in organism tissues.

Rudd and Turner (1983) also followed the bioaccumulation of Hg and Se in the presence and absence of organic-poor sediment, throughout various members of the food chain. In the absence of sediment, it was determined that Hg was bioaccumulated 8 to 16 times faster than when it was either suspended in the water or present on the bottom.

Rudd et al. (1983) have concluded that measures such as harrowing of lake sediments to dilute sediment Hg concentrations or a single application of clean clay on the lake surface would only result in short-term improvements. Continued erosion and desorption of Hg from surface sediments of upstream stretches of river, followed by deposition onto the new clean clay of the surface sediments of the lakes would re-elevate the Hg concentration of the surficial sediment. This is one possible scenario if the Las Tablas Arm sediments were covered, and no upstream source control measures were implemented at or near the Hg mine sites.

Rudd et al. (1983) also suggest that further reduction in Hg loading to the system would improve the situation, as the rates of Hg methylation in lake water and surface sediments are very responsive to changes in Hg concentrations. Unlike dredging of lake sediments, the removal of contaminated upstream river sediments would be desirable as a means of reducing continuing Hg input.

As a cautionary note, Rudd et al. (1983) address several concerns which they feel are needed to be resolved before employing this method as an amelioration (abatement) procedure. These considerations include the need: 1) to determine the acceptable concentrations of resuspended sediment required to reduce Hg levels in biota to acceptable levels; 2) to assess the relative importance of Hg bioaccumulation in fish from surface sediments and the water column; 3) to determine the ameliorating efficiencies of various sediments; and 4) to determine the effects of suspended sediment on primary productivity and fish growth rates.

7.2.4.1 Application of Clean Sand to Cover All or Part of the Lake Nacimiento Sediments

The principal cost in covering the Lake Nacimiento in whole or in part with sand is the acquisition and transport of the sand itself. A convenient and relatively inexpensive measure would be to dredge clean sands from one area of the watershed and deposit them onto the lake "Hg hot spots" to a specified depth. In short term laboratory studies by Jernelov (1970), 10 cm of clean sands placed over Hg contaminated sediments was sufficient to reduce Hg levels in the fish to background levels.

A conservative (upper bound) estimate for the required depth of coverage can be obtained using a numerical model of the vertical transport of Hg from the contaminated sediments into the water column (Chamberlin et al., 1990). The model is a one-dimensional multi-phase contaminant transport model which can be used to simulate the movement of Hg from lake sediments into the water column. Detailed development of the model is presented in Chamberlin et al., 1990, Appendix D. Previous studies indicate that after 5 years a sand cover depth of 30 cm (about 1 ft) would be sufficient to reduce water column Hg levels by 90% (Chamberlin et al., 1990). More study at Lake Nacimiento would be necessary to determine the optimum depth of coverage.

Possible source areas for the sand cover materials are bed material sediments upstream of the lake near the Nacimiento River headwaters on Los Padres National Forest land and on the Hunter Liggett Military Reservation. These materials may be desirable since they ultimately would naturally enter the lake.

The most effective and simplest application procedure would be to discharge the sand material at the water surface of the Las Tablas Arm so that it would spread out and settle onto the existing Hg-contaminated sediments at the terminal settling velocity of very fine to medium sands (0.3 to 10.0 cm/sec). At a water column depth of 50 ft (about 1,525 cm), the total fall time through the water column would be 2.5 minutes to 1.4 hours. If this operation were contained within a silt curtain as shown in Figure 7-1, the depth of coverage could be regulated and the region of disturbance limited.

The cost of these projects has been estimated on the basis of mobilization and demobilization cost for the dredge of $35,000 per job and a unit cost of $4 to $7 per yd^3 for dredging the clean sands, transporting the sands to the Las Tablas Arm, and spreading them (Chamberlin et al., 1990; Calilornia Dredging Co., Martinez, CA, 1988; U.S. Army Corps of Engineers, 1988; Building Construction Cost Data, 1988).

If covering Hg-contaminated lake sediments with clean sands was chosen as a viable abatement option, the resulting total project costs could be estimated by determining the total sediment area to be covered, the costs of obtaining the sand, the transportation costs of the sand, and the initial set-up costs of the necessary equipment.

Even given the measures described above, it is not possible to apply the clean sands such that a continuous layer of uniform depth would be produced. Some areas might be covered by 50 cm of sand while other areas might not be covered at all. Given sufficient attention to heavy coverage of the area of highest contamination, i.e. the most heavily contaminated part of the Las Tablas Arm, it should be possible to obtain a 80 to 90% reduction in the average surface sediment Hg level (Chamberlin et al., 1990).

7.2.4.2 Application of Bentonite Clay to Cover All or Part of Lake Nacimiento Sediments

Instead of sand, clay material could also be used to cover lake sediments. Wyoming-type bentonite clay is used extensively to impede the movement of water through earthen structures, and to retard or stop similar movement through cracks and fissures in rock or concrete structures (Chamberlin et al., 1990). In studies done by Robins and Nelson (1977), bentonite clay was effective in sealing phosphorous-laden sediments from pond waters. It has been used successfully at hazardous waste sites to form slurry walls and compacted clay liners for containing wastes.

The explanation of its water impedance property lies in two characteristics of bentonite. One is that the clay tends to disperse into extremely small particles which fill the interstices of sediment or soil with a very dense soil mass. Secondly, because of the charge distribution on the clay particles the bentonite tends to absorb water up to a point where a gelatinous mass forms. Without vigorous agitation the gelatinous mass takes up no more water and becomes an impervious layer.

The bentonite clay may be placed to form an unbroken blanket between the sediments and the water (Chamberlin et al., 1990; American Colloid Company, Arlington Heights, IL., 1988). This blanket is formed by dispersing the clay into water, thus forming a gel or slurry which is then pumped into the lake bottom. The slurry is made by mixing one half pound of clay per gallon of lake water in a mechanical mixer which can be mounted on a boat or barge. This type of application of clay requires at least one pound of clay per square foot of lake bottom. A continuous layer of bentonite is difficult to assure with this method of application, and the gelatinous clay layer may be easily disturbed by currents.

Possible negative environmental impacts from the use of bentonite clay to cover lake sediments are potential fish kills caused by increased turbidity during the application of the clay slurry.

The cost of these projects has been estimated on the basis of $49/ton for the bentonite clay, $60/ton for shipping the clay, and a unit cost of $17.54/yd^3 for mixing and application (Chamberlin et al., 1990; American Colloid Company, Arlington Heights, IL., 1988; Building Construction Cost Data, 1988).

If covering Hg-contaminated lake sediments with bentonite clay was chosen as a viable abatement option, the resulting total project costs could be estimated by determining the total sediment area to be covered, the purchase costs of the clay, the transportation costs of the clay, and the initial set-up costs of the necessary equipment.

Even given careful application of the clay layer, it is not possible to produce a continuous, uniform layer. But given sufficient attention to heavy coverage of the area of highest contamination, i.e. the most heavily contaminated part of Las Tablas Arm, it should be possible to obtain a 80 to 90% reduction in the average surface sediment Hg level (Chamberlin et al., 1990).

7.2.5 Bounty System for Fish

Since the oldest and largest fish in most lakes like Lake Nacimiento are the most heavily contaminated with Hg, mechanisms that would reduce or eliminate the taking and eating of these fish would substantially reduce the health risk to consumers of these fish (Chamberlin et al., 1990; D'Itri, 1990). The current mechanism is a health advisory issued by the California Department of Health that recommends limiting the consumption of fish taken. Based on several visits to Lake Nacimiento, it does not appear that this advisory is well publicized or well known. Other possible mechanisms would include establishing an upper size limit in addition to the current lower size limit for taking fish from the lake or possibly offering a bounty on fish larger than a specified size.

The second option would not only reduce the consumption of the most contaminated fish but would actually remove them from the lake. These fish might also provide a source of samples for a continuing monitoring program on fish Hg levels. The cost of such measures depends on the number of such fish taken each year from the lake. For example, a bounty for largemouth bass >12 in. and white bass >12 in. may effectively eliminate the consumption of fish from Lake Nacimiento exceeding the 1.0 ppm FDA action limit if the bounty were sufficient to attract all such fish.

Based on estimated proportions of largemouth bass and white bass reported by size class to exceed the 12 in. limit proposed above and on the total take of largemouth and white bass, bounties would be required on about 47% of the catch for these species. Assuming about 340,000 anglers/yr, 4 angler-hr/angler-day, and a average catch of 1.23 fish/hr, then the total annual catch from the lake is about 1,700,000 fish/yr. Largemouth and white bass make up less than 2% of the typical catch so that about 33,000 fish/yr might be taken of which about 63% would exceed the proposed size limits. Therefore, bounties would be paid on a gross estimate of 21,000 fish/yr.

How large would the bounty need to be to attract almost all such fish? In the absence of a defined economic indifference curve, assume that a bounty of $20.00/fish would be sufficient. Based on the levels of Hg observed in the fish acquired, the size limits could be adjusted as necessary and the amount of the bounty could be similarly adjusted to attract the target fish. Given these general assumptions, then the total annual cost for bounties on 21,000 fish/yr would be $420,000. To support this payment rate indefinitely would require an investment of about $4,000,000 assuming a 10% rate of return.

This measure may effectively reduce or eliminate the exposure of humans to fish with Hg levels above the FDA limit but may not reduce human consumption of fish with Hg levels above the lower 0.5 ppm NAS (National Academy of Sciences) limit.

8.0 SURVEY OF TOTAL MERCURY ACCUMULATION IN THE AQUATIC BIOTA OF THE LAS TABLAS CREEK WATERSHED AND ADJACENT AREAS IN LAKE NACIMIENTO

8.1. Introduction

The purpose of this study was to assess possible mercury contamination in certain components of the biotic community of the Las Tablas creek drainage. This effort was adjunct to a larger investigation on the sources of mercury contamination from the soil and sediments in the Lake Nacimiento watershed (discussed in earlier sections of this report). The scope of this study was restricted to aquatic organisms in the Las Tablas Creek drainage in order to insure a more robust data set than that based on a diluted superficial survey covering <u>all</u> creek drainages and the lake proper. The survey was restricted to aquatic organisms because of practical and legal difficulties associated with sampling terrestrial animals such as raccoons, ospreys and other water fowl within a restricted time frame.

It should be emphasized that mercury contamination in biotic communities is generally most acute in aquatic and marine ecosystems (NRC, 1978). While initial efforts were made to also sample invertebrate animals, it quickly became apparent that the fauna was depauperate in most sections and thus a wide diversity of organisms were not readily available. While some samples of crayfish were obtained, these originated outside Las Tablas Creek proper. Crayfish were also not observed in Harcourt Reservoir. Nonetheless these few individuals were assayed for comparison with fish samples sympatric with the crayfish. Thus most of the samples are of fish, historically the primary target organisms in mercury contamination assessments because of their relatively high trophic position and close connection to the human population as an economically important food resource and an source of widespread recreation activity.

8.2. Materials and Methods

Fish surveyed in this study were collected through a variety of methods including hook and line fishing, baited traps, electrofishing, lift nets and small seines. Samples were obtained throughout the warmer months of the year when fish are more active and accessible. All fish were identified to species then weighed and measured to the nearest gram and 0.1 centimeter. Approximate 5 gram samples of muscle tissue was taken from the region above the left pectoral fin in all fish. Occasional samples of liver tissues were taken for comparative purposes. Tissue samples were frozen in capped glass vials for pre-assay storage. Samples were partitioned into two groups each destined for mercury assay at two independent biochemical laboratories. These were FGL Environmental Chemists (Santa Paula, CA) and the California Department of Fish and Game (CDFG) Water Quality Laboratory (Rancho Cordova, CA). This split-sample format was instituted to simply insure consistency in any observable trends from independent sources rather than for purposes of any kind of inter-laboratory protocol critique. The two laboratories followed different protocols and methods for mercury assessment resulting in the data reported either in mg per kilogram or micrograms per gram. These data are presented here in terms of parts per million (ppm) wet weight and related to the international and state standard of 0.50 ppm.

Early analyses of the data revealed within sample skewed distributions which resulted in logarithmic transformations and geometric means in addition to the commonly used arithmetic means in mercury studies. Inspection of CDFG and FGL data indicate generally lower assay values from the CDFG laboratory. This and the fact that the two laboratories utilized different protocols and methodologies warranted the independent treatment of both data sets even though no significant statistical differences were found ($P = 0.42$ to 0.36) when logarithmically transformed data were compared (Table 8.1). The statistical comparison of the two data sets (arithmetic mean values) are summarized in Table 8.2.

Unless otherwise noted, most of the data displayed in this report are based on arithmetic means despite the skewedness of the within sample data. This decision was made to facilitate comparisons with other investigations, most of which are based on arithmetic means. The results from all samples were related to specific locations in a roughly linear transect running from the lake area immediately adjacent to the mouth of Las Tablas Creek, on up through the creek proper towards its origins near the Klau mining area and extending to the Buena Vista mine and Ramage area. The sampling sites chosen are listed as Entrance (Mouth), Down River, Harcourt Reservoir, Ramage Reservoir, and Buena Vista Reservoir and are indicated (as circled areas) on the expanded topographic maps in Appendix 5 and referenced in the GIS system database component of this study. Additionally two other localities were sampled for the purposes of a general comparison with an off-site area. These are the Nacimiento River Fork and Marina Forks locations. The levels of mercury found in the fish communities are also compared by location species, trophic level (position in the food web), predominant microhabitat (e.g., benthic, upper water column) and size.

Table 8.1. Statistical comparison of overall tissue mercury assays from CGFG and FGL laboratories based on logarithmically transformed data.

ANOVA test		DF	SS	MS	F	P
FGL Lab	Location	4	21.079	5.27	11.63	0.00
	Error	33	14.958	0.453		
	Total	37	36.037			
CDFG Lab	Location	6	19.31	3.218	19.22	0.00
	Error	74	12.392	0.167		
	Total	80	31.702			

Table 8.2. Comparison of overall mercury levels by sample location and laboratory based on logarithmically transformed data.

LAB	SAMPLE LOCATION	N	MEAN (Log n)	MEAN (ppm)	ST. DEV. (Log n)
FGL Lab	Ramage Reservoir	4	-2.3383	0.096	0.6581
	Harcourt Reservoir	11(1)	-0.2562	0.774	0.9016
	Down River	11	-0.6177	0.539	0.5242
	Entrance	10	-0.4938	0.61	0.5534
	Buena Vista Reservoir	2	1.355	3.876	0.1626
CDFG Lab	Ramage Reservoir	4	-2.462	0.085	0.3702
	Harcourt Reservoir	10	-0.3817	0.683	0.3228
	Down River	7	-0.7343	0.4798	0.3141
	Entrance	11	-0.4532	0.6356	0.4359
	Buena Vista Reservoir	3	0.4307	1.538	0.2303
	Nacimiento River Fork	27	-0.5398	0.5829	0.3515
	Marina Forks	19	-0.8995	0.4068	0.5391

8.3. Biological Study Results

A total of 120 fish representing 10 species were captured and sampled for biochemical assay for total tissue mercury. The total data set is displayed by location and laboratory in Figure 8.1. In addition a small sample of 5 crayfish (Pacificastacus spp.) were assayed. These data are summarized on Table 8.3 according to the particular laboratory conducting the assay. For the FGL laboratory, ranges of mercury from 35 fish samples were 6.4 to <0.01 ppm with arithmetic and geometric means of 0.75 and 0.52 ppm, respectively (Figure 8.2). The parallel CDFG laboratory data (Figure 8.2) based on 81 samples show a range of 2.0 to 0.03 ppm and an arithmetic mean of 0.60.

Using the larger data set (CDFG lab), the higher values are associated with top-predators in the aquatic food web, with one exception. These predators are the largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieu) and the white bass (Morone chrysops) which had geometric mean levels of 0.7559, 0.7258 and 0.7450 ppm, respectively.

Similar high values were obtained for the threadfin shad (Dorosoma petenense). Other species with higher levels (i.e., >0.50 ppm) include the common carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), and the green sunfish (Lepomis cyanellus) with means of 0.6633, 0.5350, 0.6700 ppm, respectively. Marginal values were obtained for the blue-gill sunfish (Lepomis macrochirus) with 0.4013 ppm while lower values were registered for Sacramento suckers (Catostomus occidentalis), brown bullhead (Ictalurus nebulosus) and crayfish with values of 0.3733, 0.1900 and 0.0733 ppm, respectively.

The FGL results are very similar to the CDFG data set and summarized on Table 8.3. These indicate overall high readings for all top predators (largemouth bass, smallmouth bass, white bass) with 10 out of 11

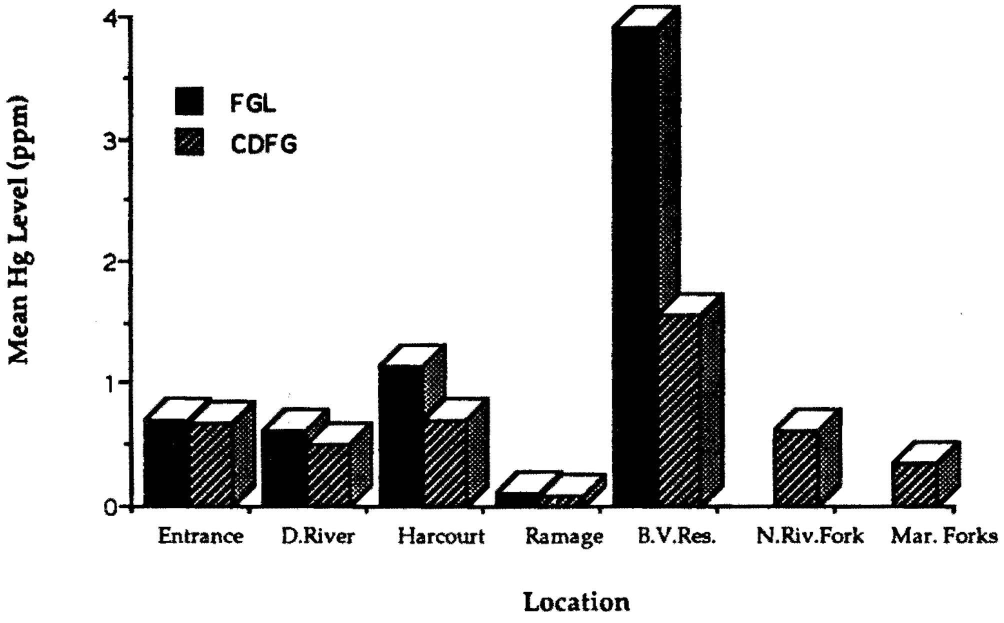


Figure 8.1. Combined species tissue mercury concentrations by location based on arithmetic mean values from the FGL and CDFG laboratories.

Table 8.3. Total tissue mercury concentrations by species and laboratory based on arithmetic mean values.

Species	N	Mean (ppm)	Median	Standard Deviation	Minimum	Maximum
M. chrysops	6	0.745	0.745	0.296	0.280	1.200
I. nebulosus	2	0.1900	0.1900	0.0707	0.1400	0.2400
I. punctatus	2	0.5350	0.5350	0.0919	0.4700	0.6000
L. macrochirus	16	0.4013	0.3350	0.1732	0.2000	0.7400
L. cyanellus	2	0.6700	0.6700	0.0141	0.6600	0.6800
M. salmoides	27	0.7559	0.6600	0.3762	0.2600	2.0000
M. dolomieui	12	0.7258	0.7200	0.1771	0.4000	1.1000
C. occidentalis	6	0.3733	0.3350	0.0784	0.3000	0.5000
C. carpio	3	0.6633	0.6500	0.1007	0.5700	0.7700
D. petenense	2	0.795	0.795	0.573	0.390	1.200
Pacifasticus sp.	2	0.055	0.05500	0.00707	0.05000	0.06000

Species	N	Mean (ppm)	Median	Standard Deviation	Minimum	Maximum
M. chrysops	2	0.985	0.985	0.1061	0.910	1.060
I. nebulosus	6	1.2100	0.1900	2.55	0.0000	6.4000
I. punctatus	3	0.6330	0.6000	0.1528	0.5000	0.8000
L. macrochirus	8	0.465	0.4500	0.1295	0.2600	0.6000
L. cyanellus	2	0.8500	0.8500	0.495	0.5000	1.2000
M. salmoides	9	1.491	0.8000	1.446	0.2000	4.3600
M. dolomieui	2	0.735	0.7350	0.0354	0.7100	0.7600
C. occidentalis	1	0.6	0.6000	*	0.6000	0.6000
C. carpio	2	0.38	0.3800	0.0707	0.3300	0.4300
D. petenense	1	1.57	1.57	*	1.570	1.570
I. catus	1	1.21	0.19	*	1.210	1.210
Pacifasticus sp.	2	0.055	0.05500	0.00707	0.05000	0.06000

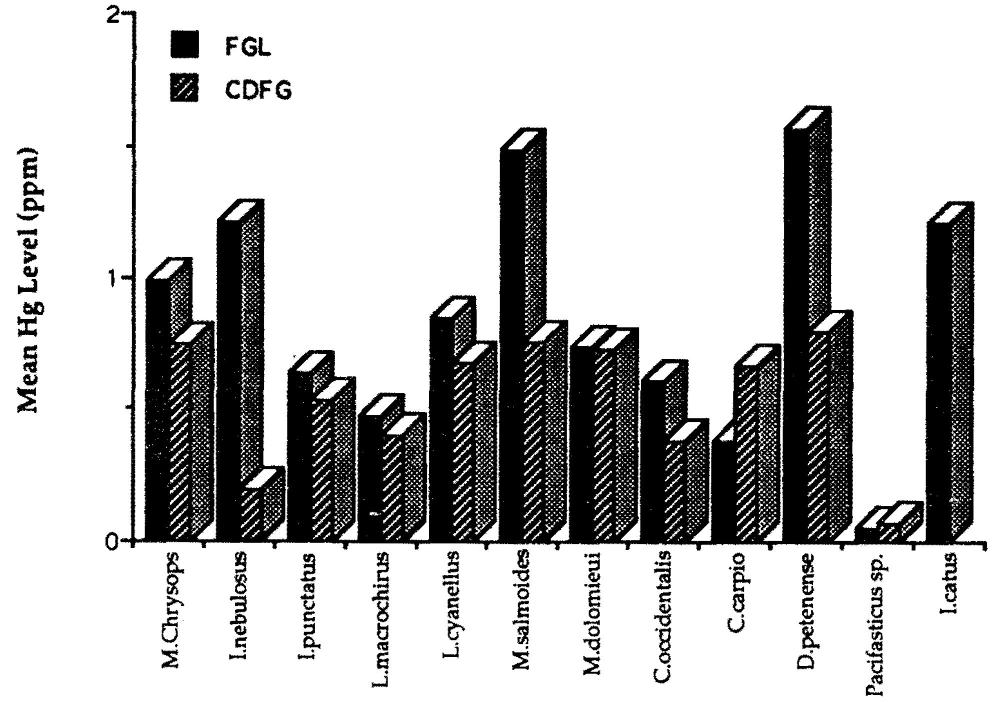


Figure 8.2. Tissue mercury concentration by species based onarithmetic mean values from the CDFG and FGL laboratories.

samples with values 0.50 ppm or higher. In this case, the mercury concentrations for these major predators are 1.491, 0.735 and 0.985 ppm for the same sequence of species. A single threadfin shad specimen yielded a level of 1.57 ppm. The highest concentrations in this data set were found for an individual brown bullhead with a reading of 6.4 ppm, while 3 other specimens had concentrations ranging from 0.17 to 0.20 ppm. The remaining white catfish (I. catus) and channel catfish and two-thirds of the sunfishes (green sunfish, blue gill) displayed values equal to or in excess of the 0.5 ppm level. The two carp in this data set had levels below the 0.5 ppm standard. Similar to the CDFG laboratory results, the crayfish assayed in this set recorded a low of <0.01 ppm total Hg concentration.

Comparisons between sampling localities and total mean values (i.e., all species combined) of mercury in fish taken from all stations (Table 8.4, Figure 8.2), show concentration above the 0.50 ppm standard with the exception of the Ramage sampling site (0.0900 ppm). The highest values in the CDFG data were found in the Buena Vista reservoir and the Harcourt reservoir with overall concentrations levels of 1.5670 ppm and 0.7130 ppm, respectively. The comparison of FGL data at four locations shows high concentrations in Buena Vista reservoir (3.9200), Harcourt reservoir (0.774 ppm), the Entrance of Las Tablas station (0.6100ppm) and the Down-River station (0.7740 ppm). In contrast, the Ramage Reservoir location had a mean concentration level of only 0.096 ppm.

Comparisons of the transformed CDFG data by microhabitat and trophic position (Table 8.5, Figure 8.3) show top predators (largemouth, smallmouth and white bass) with the highest mean concentrations (0.689 ppm) while the benthic and herbivorous species had mean mercury concentrations less than 0.500 ppm standard set by EPA (0.0290, 0.0415 ppm,

Table 8.4. Total tissue mercury levels by sample location and laboratory based on arithmetic mean values (NOTE: Upper data from CDFG Lab and Lower data from FGL Lab).

Sample Site	N	Mean (ppm)	Median	Standard Deviation	Minimum	Maximum
Entrance	11	0.6918	0.68	0.2985	0.300	1.200
Down River	7	0.4971	0.5400	0.1198	0.2400	0.6000
Harcourt Reservoir	10	0.7130	0.6700	0.2089	0.3400	1.0000
Ramage Reservoir	4	0.09	0.0800	0.0356	0.0600	0.1400
Buena Vista Reservoir	3	1.5670	1.4000	0.379	1.3000	2.0000
Nacimiento River Fork	27	0.6152	0.6500	0.1906	0.2600	1.0000
Marina Forks	19	0.35	0.3500	0.2815	0.2000	1.1000

Sample Site	N	Mean (ppm)	Median	Standard Deviation	Minimum	Maximum
Entrance	10	0.701	0.655	0.4	0.290	1.570
Down River	11	0.6045	0.6000	0.2895	0.2000	1.2300
Harcourt Reservoir	12	1.1420	0.6000	1.712	0.0000	6.4000
Ramage Reservoir	4	0.1125	0.1150	0.0665	0.0500	0.1700
Buena Vista Reservoir	2	3.9200	3.9200	0.622	3.4800	4.3600

Table 8.5. Total tissue mercury concentrations by feeding habit and size based on arithmetic mean data.

			ANOVA	test		
LAB		DF	SS	MS	F	P
FGL Lab	Feed Habit	2	6.143	3.071	3.6	0.038
	Error	35	29.895	0.854		
	Total	37	36.037			
CDFG Lab	Feed Habit	2	10.00	5.00	17.97	0.00
	Error	78	21.701	0.278		
	Total	80	31.702			
	Level	N	Mean (Log n)	Mean (ppm)	St. Dev. (Log n)	
FGL Lab	Benthic	14	-1.0037	0.366	1.229	
	Phytovore	11	-0.5897	0.554	0.519	
	Predator	13	-0.0504	0.951	0.7928	
CDFG Lab	Benthic	16	-1.238	0.290	0.8079	
	Phytovore	20	-0.8784	0.415	0.4938	
	Predator	45	-0.373	0.689	0.4067	

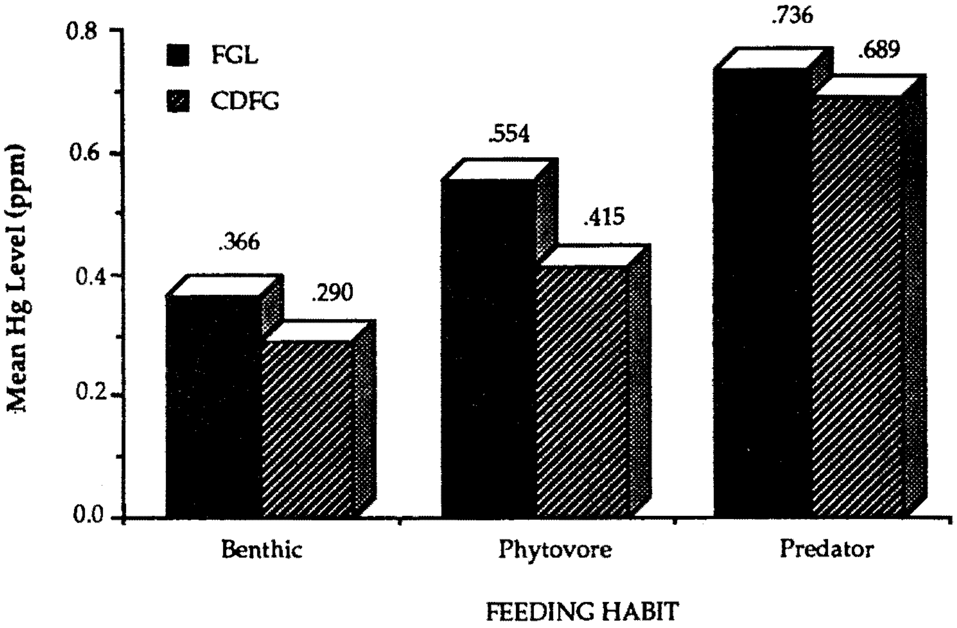


Figure 8.3. Total tissue mercury concentrations by feeding habits based on arithmetic mean values from the CDFG and FGL laboratories.

respectively). Analyses of the logarithmically transformed FGL data (Table 8.5, Figure 8.3) shows a similar pattern with the top predators with geometric mean values of 0.736 ppm and the benthic associated species with 0.336 ppm. The herbivorous species in revealed a concentration of 0.554 ppm, in excess of the 0.5000 ppm standard but closes to the 0.4575 ppm concentration for the same group in the CDFG data set.

Analyses of both CDFG and FGL laboratories data show significant differences in mercury concentrations relative to size (Table 8.5, Figure 8.4). Larger and presumably older fish have higher body burdens of mercury than smaller (younger) individuals. The FGL data resulted in a mean concentration level for larger fish of 0.7600 ppm and 0.3000 ppm for smaller individuals. Statistical analyses indicated the difference to be significant (P=0.0015). The results in the CDFG analyses show a parallel trend.

8.4. Discussion of Biological Study

The results and analyses clearly show that elevated mercury levels exist in the fish communities of the Las Tablas Creek drainage. Mercury has no known normal functional physiological role, yet its occurrence in living organisms has been widely documented (Johnels et al., 1967,1968; NRC 1978). Among the forms of mercury generally found in animals such as fish, methylmercury is by far the dominant type with percent of total mercury values on the order of 80-90% (Thompson, 1990; NRC, 1978). Methyl mercury is also regarded as the most toxic form of organic mercury with a variety of physiological effects depending on organism and concentration level. The other forms of organic mercury compounds found are more easily detoxified by conversion to other forms and/or more readily excreted (Vernberg et al., 1985; NRC, 1978; Young, 1971).

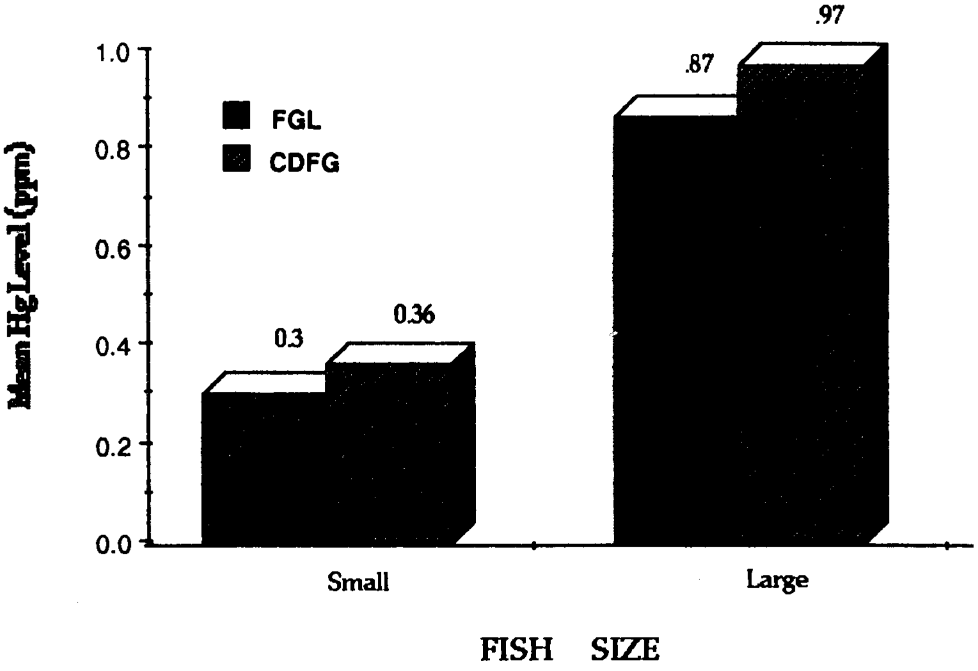


Figure 8.4. Tissue mercury concentrations by size using arithmetic mean values from the CGFG and FGL laboratories.

The primary source of methylmercury in aquatic systems are the inorganic mercury-rich sediments containing high levels organic materials in which populations of microorganisms carry out the transformations of the inorganic complexes of mercury into organic forms. The degree to which such transformations occur have also been shown to be directly related to depth, and therefore amount, of inorganic mercury-rich sediments (Jensen and Jernelov,1969, Jernelov,1970). The transformation process (methylation) occurs as microorganisms such as bacteria carry out their own necessary metabolic activities. Methylation processes may occur simultaneously with demethylation processes where the methylmercury is converted to other less toxic compounds (detoxification) and, in some instances, mineralized to some biochemically inert form. In most instances, the methylation rates are higher than other detoxification or mineralization rates.

The presence of heavy loads of inorganic mercury results in progressive increases in organic mercury within the populations of certain bacteria. The increase within the bacterial population is enhanced by a unique ability of these organisms to progressively elevate the rates of methylation as levels of inorganic mercury rise and remain high in the environment. This progressive rate elevation occurs as the bacterial population is also acquiring increasing resistance to toxic effects of mercury through processes of natural selection and genetic modification through changes in gene expression via episomes (NRC, 1978) and perhaps transposons (so-called "jumping genes"). The mechanism of this change is similar, if not identical to, that in which many bacteria attain increased resistance to antibiotics.

In terms of environmental methymercury loads, contaminated bacterial populations may continue to grow, cells may die and decompose or be consumed by other organisms. Thus organic forms of mercury may be continually be synthesized and redistributed within the immediate physical environment and the existing biota.

Organic mercury has been documented in virtually every major group of aquatic organisms in environments where heavy loads of inorganic as well as organic mercury exist. Aside from microorganisms, these include invertebrates animals such as insects, crustaceans and water fowl(mallard ducks, sea gulls, commorants, ospreys) and aquatic plants such duckweed (Elodea), filamentous algae (many species), as well as emergent aquatic vegetation. (Furness and Rainbow, 1990; NRC, 1978). It is particularly noteworthy that mercury levels in fishes have been especially well documented (Johnston et al., 1991; Young, 1971; McIntyre and Miller, 1975; NRC, 1978) and are of particular concern to scientists. This is related to the historically close relationship of man to fish in the context of a major food resource and widespread recreational fishing.

Importantly, fishes are the dominant vertebrates of the aquatic environment and are among the major consumer groups in all aquatic systems. As predators, they also dominate the apex of the trophic pyramid, the position where biomagnification of heavy metals is most apt to attain the highest concentrations as heavy metals tend to accumulate in structures and molecules (lipids, proteins) which are generally not readily metabolized or immediately eliminated from the body. Thus as the biomass of a particular trophic level is transformed to biomass at another, there is a net loss of volume (biomass) with minimal losses of non-metabolized heavy metal bearing complexes resulting greatly increased per unit volume concentrations.

Historically, the primary pathway of methylmercury has been thought to be mainly the through trophic interrelationships which accounts for the highest levels to occur in the top predators of a food web (MacCrimmon, 1983; Phillips and Buhler, 1988). As noted previously however, methylmercury also readily passes through cell membranes of a variety of organisms including phytoplankton, macrophytic aquatic plants as well as aquatic invertebrates and fishes (NRC, 1978). In fishes, methylmercury passes through the gills and probably other exposed epithelial tissues of the buccal cavity. In benthic forms, methylmercury passes through the digestive tract . Thus there is also a direct pathway into living cells.

In the case of the Las Tablas watershed, it is not surprising that the highest concentrations were found in apex predator fishes, in particular those coming from impoundments (the Harcourt and Buena Vista reservoirs) or sites where sediments tend to accumulate (the Entrance site). The latter encompasses locations of gentle topography with reduced slopes and water velocities where sediments tend to collect rather than be transported out of the system. It is very likely that the high methylmercury loads in these sampling localities are associated with the long standing high levels of inorganic mercury-rich sediments occurring in organic carbon rich substrates containing dense populations of methylating microorganisms adapted to the chemical environment of the slower parts of the Las Tablas creek watershed (see Tables 4.2 and 4.3).

While highest values were noted in these low water velocity sites, elevated values were also found in the lotic (running water) sections (Down River station). This is also related to the documented low pH conditions of the upper creek drainage (see Table 4.2) which are consistent with other studies which have demonstrated that acid conditions enhance the methylation of inorganic mercury and that this relationship in turn is also strongly correlated to observed high mercury concentrations in fish tissues (Lathrop, 1989; McMurty, et al., 1989). Low pH conditions (<6.0) are known to restrict the occurrence of a diverste invertebrate community.

In the Las Tablas system, it appears that inorganic mercury loads must have been consistently high over a relatively long period of time since samples in the lotic sections of rapid turnover and transport of materials downstream would have revealed significantly lower tissue mercury concentrations after several years, given that the half-life of mercury in predatory fish tissues approximates 2 years with other estimates for a variety of species ranging from 700 to >1200 days (Young, 1971). These biological data also suggest a continuing supply of mercury-bearing materials entering Las Tablas Creek system; most likely from eroding sediments originating at the two inactive Buena Vista and Klau mercury mines (see Tables 4.2 and 4.3 and Section 4 of this report). (The "half-life" in this instance is the period required for reduction or elimination of 50% of the organic mercury body burden.)

A small number of samples of one to three-plus year old largemouth bass (6) and two year old carp (4) taken in 1982 in a State Water Resources Control Board point survey in the Las Tablas creek drainage revealed arithmetic mean concentrations from 0.71 to 1.70 ppm for bass and 0.65 to 1.10 ppm for carp. The sampling stations in this study (1993 sample year) that are mentioned above consistently revealed high levels in excess of the widely accepted international (28+ countries) as well as state acceptable standard of 0.5000 ppm mercury concentration (NRC,1978). It appears that little has changed to reduce mercury loading in the Las Tablas drainage over the years as mercury loads in the system and body burdens within the biotic community have not abated.

Comparisons of the disjunct Ramage sample site to the primary Las Tablas sampling sites (Entrance, Down River, Harcourt Reservoir, including the Buena Vista reservoir) are instructive in that both CDFG and FGL data sets show no evidence of excessive mercury loads on the biota in the former. Interestingly, this site is fairly close to the areas of historic cinnabar mining activities but is disconnected from Las Tablas Creek proper and is upstream from the inactive mines. On the other hand, the Buena Vista reservoir site is not directly connected by water to Las Tablas Creek proper during dry periods but is in the creek drainage watershed. In this case, connection with the creek is likely during periods of high precipitation. During such times fish would be able to easily move to and from the Buena Vista reservoir location. Also, the dam material has been demonstrated to contain high mercury concentrations (Table 4.2). The Buena Vista reservoir dam materials have high levels of inorganic mercury substrate and sediments available for methylation and bioaccumulation. This water contact with the contaminated dam materials could account for the presence of fishes with high body burdens of mercury. In contast, Ramage reservoir fish have significantly lower mercury concentrations than for fish located in the primary Las Tablas Creek drainage stations as well as the Buena Vista reservoir.

Another comparison of interest was that showing relatively high values for two additional sampling sites away from the primary study area (Marina, Nacimiento River Fork) which suggest that mercury contamination in Lake Nacimiento may be widespread. Undoubtedly, however, the mouth of the Las Tablas Creek as it enters the lake proper, serves as a repository of upstream mercury bearing sediments and substrate from which methylmercury contamination may fan out. This is consistent with the indications from the mercury concentrations found in the lake sediments (Table 4-10). The relatively high mercury values in fish from the Marina site may also be a reflection of normal fish movements and redistributions over a long period, resulting in the widespread dispersal of methylmercury burdened fish.

The analyses and comparisons in this study show the highest mercury concentration among the top-predators such as the basses. This is consistent with what is generally accepted as the prevailing model for the relationship between mercury biomagnification and feeding habits (Francesconi and Lenanton, 1991; Thompson, 1990; Young, 1971; NRC, 1978; D'Itri, 1972). Benthic feeding forms such as catfish are also likely to ingest significant amounts of incidental particulate matter and sediments in their normal feeding behavior and represent another trophic model describing the pathway of mercury into fish communities (D'Itri, 1972). Thus it is not surprising to note some high levels in these fishes as well as in some carp. The higher occurrence in the threadfin shad is probably related to the high intake rate of quantities phytoplankton which can individually carry methylmercury via adsorption and absorption. The high levels noted for green sunfish are reflective of their role as trophic primary consumer functioning as a predator of small invertebrates which can have 100-fold increases in organic mercury (Johnels et al., 1967; 1968)

The relationship of mercury concentrations to fishes size (age) are also very consistent with known trends of biomagnification in fish populations. Historic background levels of mercury in predatory fish tissues from <u>uncontaminated</u> systems range between 0.02 and 0.20 ppm. Concentrations as high as >24 ppm in contaminated systems have been recorded. However, most severely contaminated environments are within the single digit tissue concentration range measured in ppm; depending on species, age, locality, degree of pollution, etc. Highest levels are generally associated with anthropogenic sources (NRC, 1978). It is noteworthy, however, that historic levels from uncontaminated waters are generally measured in terms of part per billion (ppb) (D'Itri, 1972). Since exogenous and ingested methylmercury easily passes through cell membranes and binds with structural and enzymatic proteins (metallothioneins, coenzymes) as well to lipid rich structural molecules (George, 1990; NRC, 1978) which are not readily metabolized nor readily turned over; therefore, the longer an animal lives, the greater the burden of "stored" mercury bound complexes. Thus the larger (older) fishes show significantly higher concentrations of mercury.

Finally, it should be noted that top-predator fishes also happen to be among the primary target species of recreational fishers in Lake Nacimiento. They represent a potential hazard to the public in that it is very likely that much of the catch is also consumed as food. During the course of this study, anglers were commonly observed in the vicinity of every sampling site. Anglers always target larger specimens and commonly retain them for home consumption. The potential dangers of consuming methylmercury contaminated fish have been documented in mammals and humans and range from nervous system dysfunction, decrease of reproductive potential, including observations of enhanced in utero sensitivity of the human fetus (NRC, 1978; Furness and Rainbow, 1990; McIntyre and Miller, 1975).

Other effects in a variety of other animals which have been demonstrated with organic mercury include reduced absorption of amino acids and simple sugars, spinal curvatures and inhibited osmotic and ionic regulation (Socci and Farmanfarmaian, 1985; Sharp and Neff, 1985). Mechanisms for these effects involve fundamental physiological functions which are interfered with through the strong competitive binding of mercury to both reactive and nonreactive points of certain metal containing molecules, sulfhydryl containing compounds, and nucleic acids (George, 1990; Furness and Rainbow, 1990; NRC, 1978). While previous data on mercury contamination of fish from Lake Nacimiento has been collected in the past and warnings have been issued, the previous data were based on very small numbers of animals and lacked continuity of sampling in time and space. Further, warnings issued in the most recent public sportfishing regulations document by the California Department of Fish and Game (CDFG, 1994-1996) are based on these earlier data and are restricted to only largemouth bass. Clearly, other important species targeted by recreational fishers such as white bass, smallmouth bass and channel catfish. Our data demonstrate a significant bioaccumulation of mercury in these several fish species. The data presented here represent the largest survey of mercury contamination in the Las Tablas watershed system to date. The results confirm earlier surveys and warrant the dissemination of the findings to appropriate organizations with broader warnings as deemed appropriate by the responsible government agencies.

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APPENDIX 1

National Pollutant Discharge Elimination System (NPDES) Permits and Cease and Desist Orders issued on May 19, 1993 to Buena Vista Mines, Inc.

STATE OF CALIFORNIA

PETE WILSON, *Governor*

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD — CENTRAL COAST REGION
81 HIGUERA STREET, SUITE 200
SAN LUIS OBISPO, CA 93401-5414
(805) 549-3147

May 19, 1993

Mr. Harold Biaggini, President
Buena Vista Mines, Inc.
1148 Market Street
Morro Bay, CA 93442

Dear Mr. Biaggini:

BUENA VISTA AND KLAU MINE - NPDES PERMITS AND CEASE AND DESIST ORDERS

Enclosed are your copies of Order Nos. 93-47, NPDES Permit for Buena Vista Mine; 93-56, Cease and Desist Order for Buena Vista Mine; 93-48, NPDES Permit for Klau Mine; and, 93-57, Cease and Desist Order for the Klau Mine. These Orders were adopted by this Regional Board on May 14, 1993.

In response to your request, the Board agreed to accept your April 1993 monitoring results as equivalent to May for this year only. Accordingly, your next monitoring report should cover sampling done in August 1993 and is due September 30, 1993. In addition, the Board agreed that you could defer running the acute and chronic toxicity tests until the surface water treatment systems are installed. The Board's granting of this latter request is based upon your stipulation that the surface runoff from the mines is toxic.

Questions about these Orders can be directed to <u>David Schwartzbart at 542-4643.</u>

Sincerely,

CALIFORNIA REGIONAL WATER QUALITY
CONTROL BOARD, CENTRAL COAST REGION

By William R. Leonard
WILLIAM R. LEONARD
Executive Officer

WRL/sm51:Mines.ltr

Enclosures

see next page for list of cc's

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION

81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

ORDER NO. 93-47
NPDES No. CA 0049352

WASTE DISCHARGE REQUIREMENTS FOR BUENA VISTA MINES, INC. BUENA VISTA MINE CLOSURE, POST-CLOSURE AND SURFACE WATER DISCHARGE SAN LUIS OBISPO COUNTY, CALIFORNIA

The California Regional Water Quality Control Board, Central Coast Region (hereafter Board), finds:

1. Buena Vista Mines, Inc. (BVMI), 1148 Market Street, Morro Bay, California 93442 (hereafter Discharger), owns an inactive mercury mine, the Buena Vista Mine (BVM). Mr. Harold J. Biaggini is the president of BVMI.

2. The BVM is located approximately 12 miles west of Paso Robles, California, on property owned by the Discharger as shown on Figures 1 and 2, included as part of this order. The Discharger's property which includes the BVM is located in Sections 3 and 4, T27S, R10E, and Sections 33 and 34, T26S, R10E, MDBM, Adelaida 15 minute quadrangle.

3. An application for authorization to discharge wastes under the National Pollutant Discharge Elimination System (NPDES) was submitted on July 10, 1987, by Harold Biaggini. Waste Discharge Requirements, Order No. 88-90, NPDES No. CA 0049352 was issued by the Board on June 10, 1988 and expires June 1, 1993. Surface water discharged offsite from the BVM is regulated by Order No. 88-90.

4. On July 13, 1990, the Board adopted Cease and Desist Order (CDO) No. 90-104, because discharge from the mine did not meet conditions of the NPDES permit. CDO No. 90-104 orders full compliance with NPDES permit No. CA00049352 by May 15, 1991, and references compliance with CCR Title 23, Division 3, Chapter 15, Article 7.

5. BVM surface waste water is discharged from the site at only one known point. BVM surface waste water is discharged to a culvert under the intersection of Klau Mine Road and Cypress Mountain Road (Figure 3). The discharge then flows in a drainage course on property owned by Raymond E. Dodd, et al., approximately 0.2 miles to the North Fork of Las Tablas Creek. The drainage course intersects the North Fork approximately 8.5 miles upstream of Nacimiento Reservoir as shown on Figure 4 included as part of this Order.

6. Nacimiento Reservoir is a drinking water aquifer recharge source. It has been posted in the past with warnings that fish are mercury contaminated.

7. The Regional Board Clean Water Strategy (CWS) ranks Nacimiento Reservoir A-7, one of the region's highest priority water bodies. Nacimiento Reservoir recharges the Paso Robles Ground Water Basin, also with a very high CWS rank of A-12.

8. The BVM is in structurally deformed, mineralized and chemically altered rocks near the common intersection of several faults. The rocks include silica carbonates, serpentine and the highly deformed sediments of the Franciscan Formation.

9. Ground water surfaces as springs and seeps on the BVM site. However, onsite data regarding depth to ground water, ground water flow directions and rates, chemical and physical ground water properties, etc. have not been generated.

10. Topography of the BVM and surrounding region is steep; 45 degree slopes are not uncommon (Figure 2).

11. The "California Inland Surface Waters Plan", adopted by the State Water Resources Control Board on April 11, 1991, specifies water quality objectives for inland surface waters which became effective April 1, 1992.

12. The Water Quality Control Plan, Central Coastal Basin (Basin Plan), was adopted by the Board on November 17, 1989 and approved by the State Water Resources Control Board on August 16, 1990. The Basin Plan incorporates statewide plans and policies by reference and contains a strategy for protecting beneficial uses of waters of the State.

13. The Basin Plan specifies existing and anticipated beneficial uses of Las Tablas Creek as:

    a. municipal and domestic supply;
    b. agricultural supply;
    c. ground water recharge;
    d. water contact recreation;
    e. non-contact water recreation;
    f. wildlife habitat;
    g. warm fresh water habitat; and
    h. fish spawning.

14. The Basin Plan specifies existing and anticipated beneficial uses of Nacimiento Reservoir as:

    a. municipal and domestic supply;
    b. agricultural supply;
    c. ground water recharge;
    d. water contact recreation;
    e. non-contact water recreation;
    f. wildlife habitat;
    g. cold fresh water habitat;
    h. warm fresh water habitat; and
    i. fish spawning.

15. Specific beneficial uses of the drainage course between BVMI property and Las Tablas Creek, North Fork are not listed in the Basin Plan. Based on the character of the drainage course, presumed beneficial uses are:

    a. domestic supply
    b. agricultural supply
    c. ground water recharged
    d. water contact recreation
    e. wildlife habitat
    f. warm fresh water habitat, and
    g. fish spawning.

16. California Code of Regulations (CCR) Title 23, Division 3, Chapter 15, Article 7, commencing with Section 2570 (Article 7) regulates Mining Waste Management and contains Sections regarding:

    - Applicability;
    - Groups of Mining Waste;
    - Unit Siting and Construction Standards;
    - Water Quality Monitoring (requiring Article 5 ground water, surface water and vadose zone monitoring); and
    - Closure and Post-Closure Maintenance.

The Section on Closure and Post Closure Maintenance addresses, in part:

- Water quality threat;
- Closure and Post-Closure Plans;
- Surface Mining and Reclamation Act (SMARA) approved
- mining and reclamation plans;
- Appropriate registered professionals;
- Surveyed monuments;
- Containment structures;
- Financial assurance;
- Post closure period;
- Vegetative layers and irrigation for same;
- Erosion and sedimentation;
- Final cover requirements;
- Grading requirements;
- Containment and cover maintenance;
- Leachate, collection and removal systems;
- Ground water, surface water and vadose zone monitoring;
- Drainage control;
- Surveyed monuments;
- Waste management unit free liquid; and
- Waste management unit contaminated materials.

17. BVM is not in compliance with Article 7.

18. The BVM contains overburden, waste rock, and/or solid residues, sludges and liquids from the processing of ore as shown on Figures 3 and 5, included as part of this order.

19. The BVM overburden, waste rock, and solid residues, sludges and liquids from the processing of ore are Group A and/or Group B Mining Waste, defined by Article 7, Section 2571.

20. Based on inspections, self monitoring reports and academic studies, the BVM, including BVM Group A and Group B Mining Wastes, has caused, and continues to cause, water quality degradation in Las Tablas Creek and in Nacimiento Reservoir.

21. Based on inspections, self monitoring reports and academic studies, the BVM, including BVM Group A and Group B Mining Wastes, has caused, and continues to cause, discharge violations of NPDES Permit No. CA 0049352 Order No. 88-90 and CDO No. 90-104.

22. The most recent report intended as a comprehensive assessment of the BVM physical status is "Preliminary Geologic and Hydrologic Investigations. Buena Vista Mine and Carson Drift" by Marvin R. Niccum, California Registered Geologist, dated September 30, 1988 (Report).

23. BVM Mining Waste is subject to Article 7. Based on the Report, individual BVM units potentially regulated by Article 7 include, but are not limited to the following as shown on Figure 5, included as part of this order:

Figure 5-number and/or name	Potential Type of Unit; Article 7 nomenclature
a. Retort Dump -	waste Pile
b. Pit Floor -	surface impoundment
c. 13. Terrace, Cut and Fill-	waste pile and/or surface impoundment and/or tailings pond
d. 14. Old Dumps & Portals-	waste piles
e. 4. Waste Dump -	waste pile
f. 5. & 6. Upper Catchment and Upper Catchment Dam -	tailings pond
g. 2. Surge Pile shed (and surrounding soil) -	waste pile
h. 7. Lower Parking Area -	waste pile
i. 8. & 9. Lower Catchment and Breached Catchment Dam -	waste pile or tailings pond
j. 10. Evaporation Ponds -	surface impoundment or tailings pond
k. 12. Work Yard and Parking -	waste pile
l. 1. Mine Shop -	waste pile
m. 3. Retort -	waste pile
n. BVM, Portal of BVM -	waste pile

24. No information shows ground water has ever been investigated for BVM impacts.

25. Comprehensive mitigation options were proposed by the Report in September, 1988, but have not been implemented.

26. The Discharger was notified of impending Article 7 regulation in correspondence dated March 18, 1991, July 10, 1991 and July 24, 1992. The March 18, 1991 letter listed specific requirements and included a complete copy of the regulations.

27. Waste discharge requirements for this discharge are exempt from the provisions of the California Environmental Quality Act (Public Resources Code, Section 21100, et seq.) in accordance with section 13389 of the California Water Code.

28. A permit and the privilege to discharge waste into waters of the State is conditional upon the discharge complying with provisions of Division 7 of the California Water Code and of the Clean Water Act (as amended or as supplemented by implementing guidelines and regulations) and with any more stringent effluent limitations necessary to implement water quality control plans, to protect beneficial uses, and to prevent nuisance. This Order, in part, shall serve as a National Pollutant Discharge Elimination System Permit pursuant to Section 402 of the Clean Water Act. Compliance with this Order should assure conditions are met and mitigate any potential changes in water quality due to the project.

29. On March 26, 1993, the Board notified the Discharger and interested parties of its intent to adopt Waste Discharge Requirements for the discharge. The Discharger and interested parties had the opportunity to submit written comments on this proposed Order.

IT IS HEREBY ORDERED, pursuant to authority in Sections 13263 and 13360 of the California Porter-Cologne Water Quality Control Act, that Buena Vista Mines, Inc., its agents, successors and assigns (BVMI) shall comply with the following:

A. Prohibitions

1. Discharge of material to surface waters at a point other than into the South end of the culvert under the intersection of Klau Mine Road and Cypress Mountain Road is prohibited.

2. Discharge of material not contained within the liquid phase (e.g., sediment) into the culvert specified in A.1. above is prohibited.

B. Effluent Limitations

Discharge of the liquid phase to the culvert specified in A.1. above shall not contain total concentrations in excess of the following limits:

Constituent	Units	Limit
Aluminum	mg/L	1.0
Antimony	mg/L	0.006
Arsenic	mg/L	0.005
Barium	mg/L	1.0
Beryllium	mg/L	0.004
Boron	mg/L	0.75
Cadmium	mg/L	0.0086
Chromium	mg/L	0.05
Cobalt	mg/L	0.05
Copper	mg/L	0.03
Iron	mg/L	0.3
Lead	mg/L	0.03
Lithium	mg/L	2.50
Manganese	mg/L	0.05
Mercury	mg/L	0.000012
Molybdenum	mg/L	0.01
Nickel	mg/L	0.1
Selenium	mg/L	0.01
Silver	mg/L	0.013
Sodium	mg/L	69.0
Thallium	mg/L	0.002
Vanadium	mg/L	0.1
Zinc	mg/L	0.2
pH	pH units	between 7.0 and 8.3
Turbidity	NTU	5
Total Dissolved Solids	mg/L	1500
Specific Conductance	umhos	2200
Settleable Solids	ml/L	0.5

Constituent	Units	Limit
Acute Toxicity	There shall be no acute toxicity*	
Chronic Toxicity	TUc**	1.0
Cyanide	mg/L	0.2
Fluoride	mg/L	1.5
Chloride	mg/L	600
Sulfate	mg/L	600
Dissolved Oxygen	mg/L	≥5
Color	color units	15
Odor-Threshold	units	3

* Acute toxicity is less than 90% survival, 50% of the time, and less than 70% survival, 10% of the time, of standard test organisms in undiluted effluent in a 96-hour static or continuous-flow test.

** TUc equals 100/NOEL. NOEL (No Observed Effect Level) is the maximum percent test water that causes no observed effect on a test organism, as described in a critical life stage toxicity test listed below:

Critical Life Stage Toxicity Tests

Species	**Effect**	**Test duration (days)**	**Reference**
fathead minnow (Pimephales promelas)	larval survival and growth rate	7	Horning & Weber, 1989
water flea (Ceriodaphnia dubia)	survival; number of young	7	Horning & Weber, 1989
alga (Selanastrum capricornutum)	growth rate	4	Horning & Weber, 1989

Toxicity Test Reference: Horning, W.B. and C.I. Weber (eds.). 1989. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. Second edition. U.S. EPA Environmental Monitoring Systems Laboratory, Cincinnati, Ohio. EPA/600/4-89/001.

C. Receiving Water Limitations

Receiving waters include all waters of the U.S. downstream of the Buena Vista Mine property. Discharge of the liquid phase to the culvert specified in A.1. above shall not cause violation(s) of the following narrative limits.

1. Surface water communities and populations, including vertebrate, invertebrate, and plant species, shall not be degraded as a result of the discharge.

2. The natural taste and odor of fish, shellfish, or other surface water resources used for human consumption shall not be impaired.

3. Toxic pollutants shall not be discharged at levels that will bioaccumulate in aquatic resources.

4. The concentration of contaminants in waters of the U.S. shall not occur at levels which are harmful to human health.

5. The concentrations of toxic pollutants in the water column, sediments, or biota shall not adversely affect beneficial uses.

6. Waters of the U.S. shall be free of coloration that causes nuisance or adversely affects beneficial uses.

7. Waters of the U.S. shall not contain taste or odor-producing substances in concentrations that cause nuisance, or that adversely affect beneficial uses.

8. Waters of the U.S. shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses.

9. Waters of the U.S. shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

10. Waters of the U.S. shall not contain settleable material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses.

11. Waters of the U.S. shall not contain oils, greases, waxes, or other similar materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.

12. Waters of the U.S. shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

13. The suspended sediment load of surface waters of the U.S. shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

14. Waters of the U.S. shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.

15. Water temperature shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses.

16. There shall be no acute toxicity in waters of the U.S.

17. There shall be no chronic toxicity in waters of the U.S.

18. Waters of the U.S. shall not contain concentrations of chemical constituents in amounts which adversely affect the agricultural beneficial use.

D. Provisions:

The Discharger shall eliminate all actual and potential water quality impacts from the BVM by bringing the BVM into compliance with Article 7 in accordance with Provisions 1. through 7 below.

1. The Discharger shall submit a plan by August 14, 1993 describing in detail how BVM will be brought into compliance with Article 7 (Compliance Plan). The Compliance Plan shall describe how the Discharger intends eliminating all actual and potential water quality impacts from the entire BVM. The Compliance Plan shall address, but not necessarily be limited to, all Sections, issues and units contained in Finding Nos. 16 and 23 of this Order.

   The Compliance Plan shall give detailed descriptions of the entire BVM and of each BVM unit subject to specific Article 7 requirements. The Compliance Plan shall also describe, in detail and with specific citations, which Article 7 Sections apply to which individual units and which Article 7 Sections apply to the complete BVM. The Compliance Plan shall describe the methods of achieving compliance in sufficient detail and with sufficient support and documentation to ensure feasibility, implementation and success. The Compliance Plan shall include a time schedule of events. The Compliance Plan shall be certified by the appropriate registered professionals.

2. Revisions to the Compliance Plan may be required by the Board or Board staff, and shall be submitted within 35 calendar days of written notice that they are required. All revisions shall be certified by appropriate registered professionals and shall render the Compliance Plan acceptable.

3. Implementation of the Compliance Plan shall commence within one calendar month of Executive Officer approval of the Compliance Plan.

4. Full BVM compliance with Article 7 shall be achieved within 24 calendar months of Executive Officer approval of the Compliance Plan.

5. A report certifying how the BVM was brought into compliance with Article 7 (Compliance Certification Report) shall be submitted within two calendar months of completion of Article 7 compliance activities, not to exceed 26 calendar months after Executive Officer approval of the Compliance Plan. The Compliance Certification Report must certify that all terms of the approved Compliance Plan were accomplished and describe in detail how they were accomplished. The Compliance Certification Report shall describe in detail all activities conducted pursuant to this Order and shall be certified by appropriate registered professionals.

6. Written status reports shall be submitted by BVMI every three calendar months during implementation of the Compliance Plan. The first status report shall be due three calendar months after the Compliance Plan is implemented (Provision D.3. above). Status report submittals shall continue until submittal of the Compliance Certification Report (Provision D.5. above). Status reports shall be certified by appropriate registered professionals.

7. All Compliance Plan implementation activities shall be conducted under the direct supervision of appropriate registered professionals.

8. Unpredictable events may necessitate revisions to plans, schedules, or activities. The Executive Officer shall have the authority to approve such revisions. However, the Discharger shall not implement any such revision, or discontinue previously approved or ordered terms, plans, schedules or activities prior to receiving Executive Officer approval.

9. Board staff shall be notified at least 96 hours prior to commencement of any physical activity to allow staff presence during such activity.

10. Order No. 88-90 adopted by the Board on June 10, 1988, is hereby rescinded. This recision is not a waiver of the right of the Regional Board to seek administrative civil liability or take other enforcement action for violations of Order No. 88-90 which have occurred prior to the date of this recision.

11. Discharger shall comply with "Monitoring and Reporting Program No. 93-47," as specified by the Executive Officer.

12. The Discharger shall comply with all items of the attached "Standard Provisions and Reporting Requirements for National Pollutant Discharge Elimination System Permits," dated January, 1985, (also referred to as "Standard Provisions"), except Item Nos. A.6,7,13; C.3,9; and D.1.

13. The Discharger shall inform his employees of the terms of this Order which pertain to their duties and a copy of this Order shall be available for their reference.

14. This Order expires May 14, 1998. If BVMI wishes to continue the discharge to surface water of the United States after May 14, 1998, it must file a Report of Waste Discharge (ROWD) in accordance with Title 23, of the California Code of Regulations by November 14, 1997.

I, WILLIAM R. LEONARD, Executive Officer, do hereby certify the foregoing is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, Central Coast Region, on May 14, 1993.

William R. Leonard
Executive Officer

DS:sg

FIGURE 1

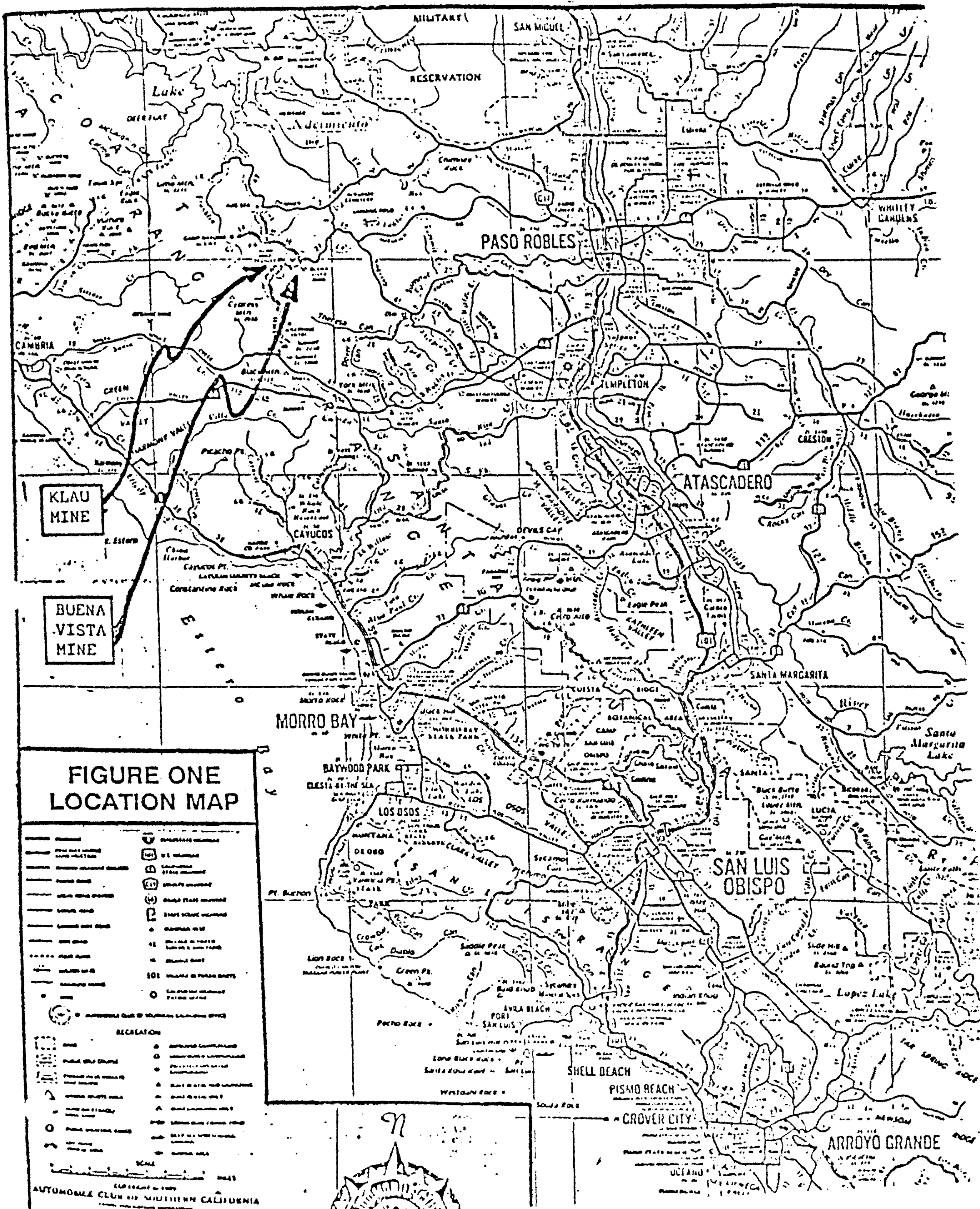


FIGURE ONE
LOCATION MAP
KLAU MINE
BUENA VISTA MINE
MILITARY RESERVATION
SAN MIGUEL
Lake Nacimiento
WHITLEY GARDENS
PASO ROBLES
CAMBRIA
TEMPLETON
CRESTON
ATASCADERO
Picacho Pt.
CAYUCOS
Cayucos Pt.
Constantine Rock
Whale Rock
Estero Bay
DEVILS GAP
SANTA MARGARITA
Santa Margarita Lake
MORRO BAY
Morro Rock
BAYWOOD PARK
CUESTA-BY-THE-SEA
LOS OSOS
SAN LUIS OBISPO
Pt. Buchon
Lion Rock
Green Pt.
Pecho Rock
AVILA BEACH
PORT SAN LUIS
SHELL BEACH
PISMO BEACH
GROVER CITY
ARROYO GRANDE
Lopez Lake
OCEANO
RECREATION
SCALE
AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA
N

FIGURE 2

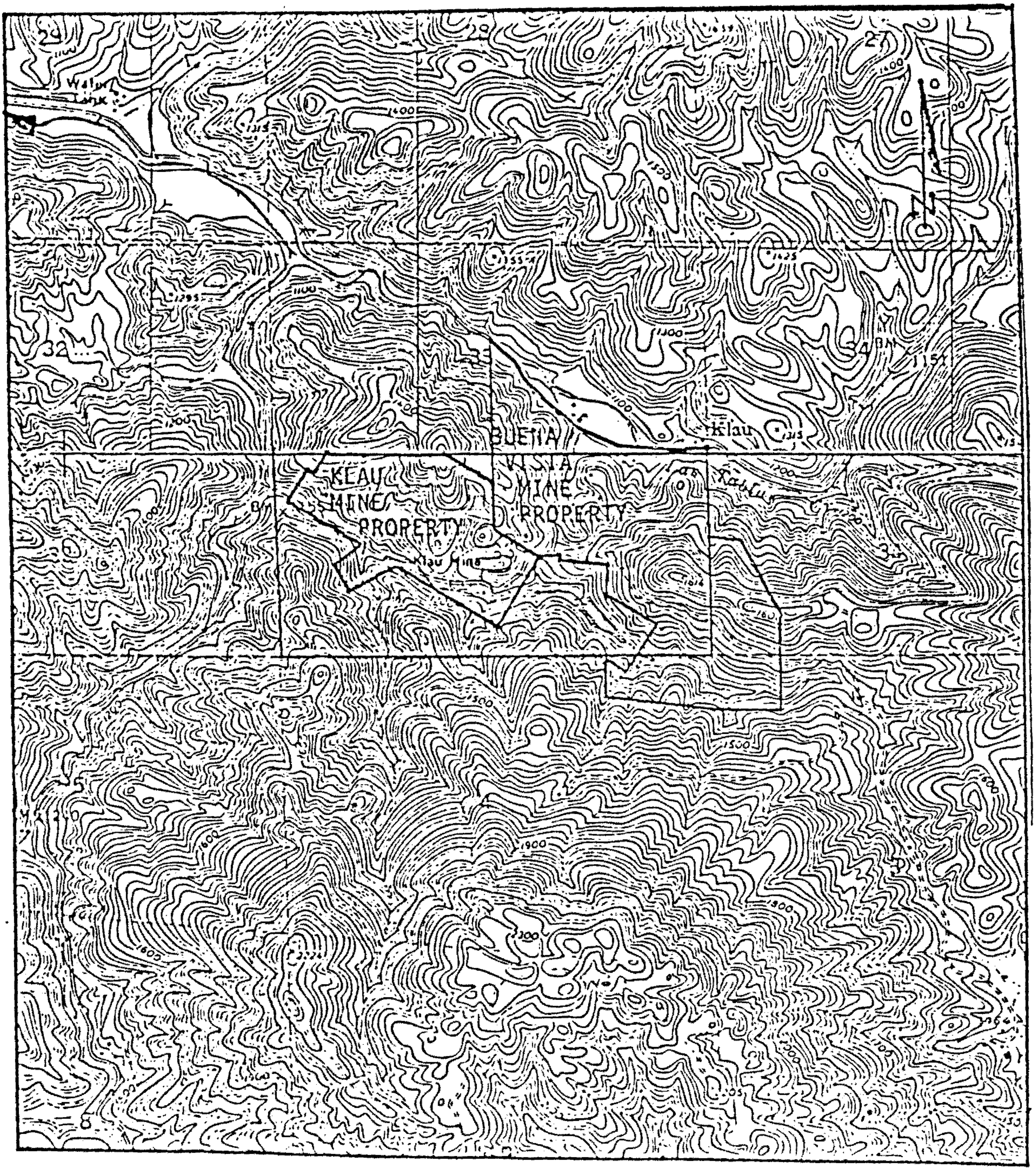


FIGURE 2: BUENA VISTA MINE &
KLAU MINE PROPERTIES

Approximate Scale (Miles)

0 ¼ ½ 1

FIGURE 3

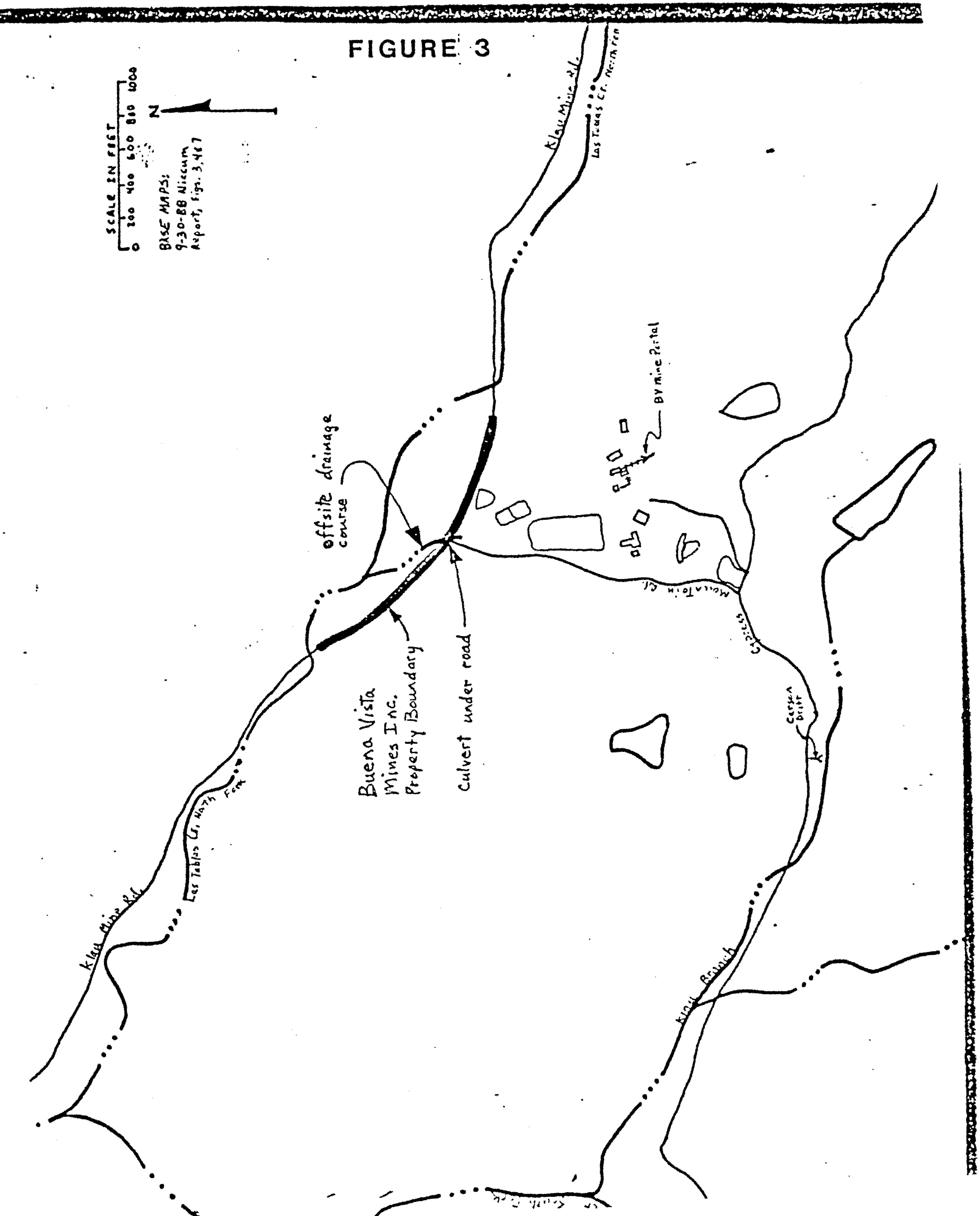

SCALE IN FEET
0
200
400
600
800
1000
N
BASE MAPS:
9-30-88 Niccum
Report, Figs. 3,4&7
Klau Mine Rd.
Las Tablas Cr. North Fork
Offsite drainage course
Buena Vista Mines Inc. Property Boundary
Culvert under road
BV mine Portal
Mountain Cr.
Chaparral
Carson Drift
Klau Branch
Klau Mine Rd.
Las Tablas Cr. North Fork

FIGURE 4

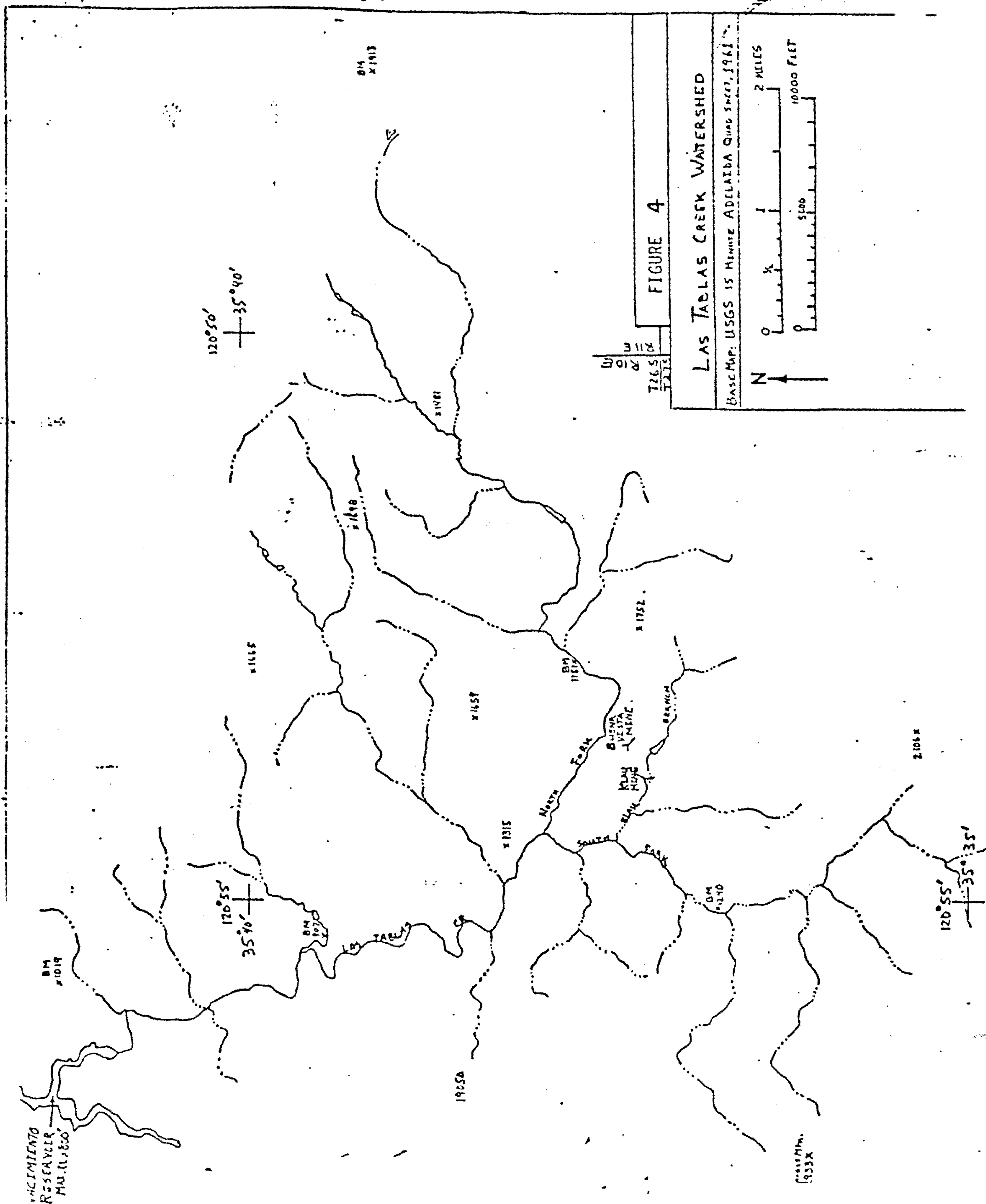


FIGURE 4
LAS TABLAS CREEK WATERSHED
BASE MAP: USGS 15 MINUTE ADELAIDA QUAD SHEET, 1961
0
½
1
2 MILES
0
5000
10000 FEET
N
T26S
T27S
R10E
R11E
BM x1913
120°50'
35°40'
x1481
x1698
x1665
x1659
BM 1151
x1752
BUENA VISTA MINE
BRANCH
NORTH FORK
KLAU MINE
KLAU
SOUTH FORK
x1315
2106x
BM 1240
120°55'
35°35'
120°55'
35°40'
BM 807
LAS TABLAS CR.
BM x1019
1905A
ACIMIENTO
RESERVOIR
MAX. EL. 800
Mtn.
1935X

FIGURE 5

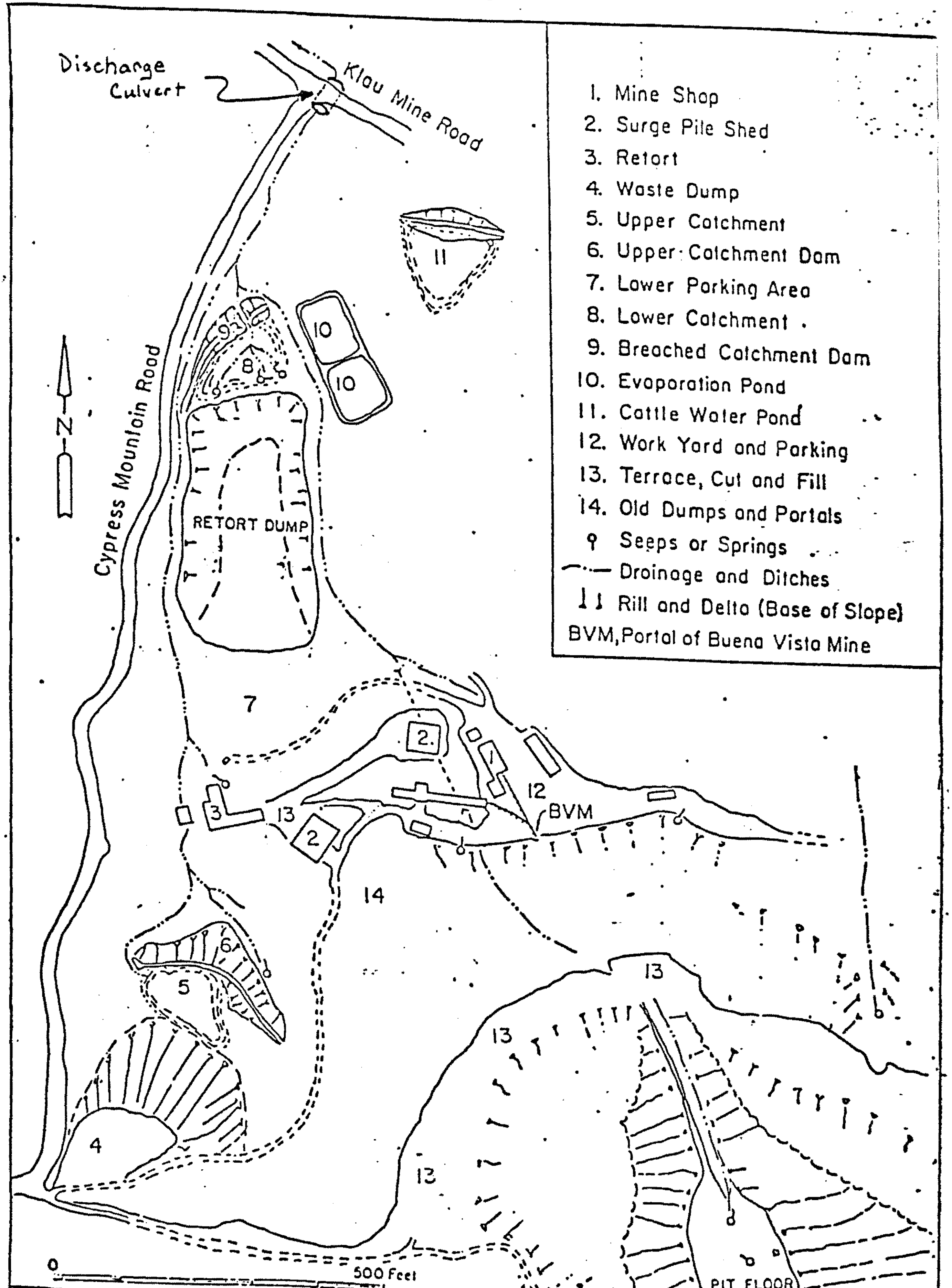


FIGURE 4. BUENA VISTA MINE SKETCH MAP

NICCUM 1982

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION
81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

MONITORING AND REPORTING PROGRAM NO. 93-47
FOR
BUENA VISTA MINES, INC.
BUENA VISTA MINE
SAN LUIS OBISPO COUNTY, CALIFORNIA

1. The liquid phase discharged from the Buena Vista Mine (BVM) into the south end of the culvert under the intersection of Klau Mine Road and Cypress Mountain Road (Discharge Point) shall be grab sampled and analyzed as follows:

Constituent	Units	Sampling and Analysis Frequency
pH	pH	Weekly
Turbidity	NTU	Weekly
Specific Conductance	umhos	Weekly
Aluminum	mg/L	Quarterly, during November, February, May and August
Antimony	"	"
Arsenic	"	"
Barium	"	"
Beryllium	"	"
Boron	"	"
Cadmium	"	"
Chromium	"	"
Cobalt	"	"
Copper	"	"
Iron	"	"
Lead	"	"
Lithium	"	"
Manganese	"	"
Mercury	"	"
Molybdenum	"	"
Nickel	"	"
Selenium	"	"
Silver	"	"
Sodium	"	"
Thallium	"	"
Vanadium	"	"
Zinc	"	"

Constituent	Units	Sampling and Analysis Frequency
Total Dissolved Solids	mg/L	Quarterly during November, February, May, and August
Settleable Solids	ml/L	Quarterly during NFMA
Acute Toxicity	-	"
Chronic Toxicity	TUc	"
Cyanide	mg/L	"
Fluoride	"	"
Chloride	"	"
Sulfate	"	"
Dissolved Oxygen	"	"
Color	color units	"
Odor-Threshold	units	"

2. This Monitoring and Reporting Program becomes effective May 14, 1993.

3. Monitoring results shall be submitted to the Board by the 30th day of the month following the month of sampling; i.e., November results by December 30, February results by March 30, May results by June 30, and August results by September 30.

4. Monitoring reports shall include observations of receiving waters with regard to compliance with Order No. 93-47, C. Receiving Water Limitations.

ORDERED BY: William R. Leonard
EXECUTIVE OFFICER

May 14, 1993
DATE

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION

81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

CEASE AND DESIST ORDER NO. 93-56

Order Requiring Buena Vista Mines, Inc. San Luis Obispo County, to Cease and Desist from Discharging and Threatening to Discharge Surface Water, From Buena Vista Mine in Violation of Requirements Contained in Waste Discharge Requirements, Order No. 88-90 and 93-47

The California Regional Water Quality Control Board, Central Coast Region, (hereafter Board), finds:

1. Buena Vista Mines, Inc. owns the Buena Vista Mine (BVM), an inactive mercury mine.

2. Surface water is discharged from the BVM to the south end of a culvert under the intersection of Klau Mine Road and Cypress Mountain Road approximately 8 1/2 miles upstream of Nacimiento Reservoir (Section 33, T26S, R10E, MD B&M; Adelaida 15 minute quadrangle).

3. The surface water discharge has been subject to Waste Discharge Requirements (WDR) Order No. 88-90, NPDES Permit No. CA0049352, adopted June 10, 1988. Order No. 88-90 specifies in part:

   A. Discharge Prohibitions

      1. Discharge to the north fork of Las Tablas Creek of other than uncontaminated stormwater or uncontaminated seepage and at a location other than Discharge Point A or B, 35°37'32" N. Latitude, 120°53'42" W. Longitude, is prohibited.

   B. Effluent Limitations

      1. Water discharged to the north fork of Las Tablas Creek shall not exceed the following limits:

Constituent	Unit of Measurement	30-Day Average	Daily Maximum
Nickel	mg/l	0.1	0.2
pH	-	-	Within range of 7.0 to 8.3
Toxicity Concentration	tu	-	0.59*

*No more than one of three consecutive flow-through bioassays shall result in less than 100% survival in undiluted effluent. No single test shall ever result in less than 90% survival in undiluted effluent.

C. Receiving Water Limitations

1. The discharge shall not cause the following limits to be exceeded in the North Fork of Las Tablas Creek or Nacimiento Lake:

Constituent	Maximum mg/l (Unless otherwise noted)
Beryllium	0.15
Cadmium	0.004
Cobalt	0.075
Iron	1.0
Manganese	0.3
Selenium	0.01
pH	Within limit of 7.0 to 8.3 at all times, and not changed more than 0.5 units.

Turbidity (NTU)	Not to exceed the following: Natural Turbidity* NTU	Maximum Increase
	< 50	20%
	50 <NT <100	10 NTU
	>100	10%

"Natural Turbidity" shall be determined from receiving water samples taken upstream of the discharge point.

Discharge shall not:

2. Cause surface waters to be greater than 15 units or 10 percent above natural background color, whichever is greater.

3. Contain taste or odor-producing substances in concentrations imparting undesirable tastes or odors to fish flesh or other edible products of aquatic origin, causing nuisance, or adversely affecting beneficial uses of surface waters.

4. Contain oils, greases, waxes, or other similar materials in concentrations resulting in a visible film or coating on the surface of the water or on objects in the water, causing nuisance, or otherwise adversely affecting beneficial uses of surface waters.

5. Contain settleable or soluble material in concentrations resulting in the deposition of material causing nuisance or adversely affecting beneficial uses of surface waters.

6. Contain floating material, including solids, liquids, foams, and scum, on concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

7. Contain suspended material in concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

8. Cause a violation of any applicable water quality standard for receiving waters adopted by the Regional Board or the State Water Resources Control Board as required by the Federal Water Pollution Control Act and regulations adopted thereunder.

4. Cease and Desist Order (CDO) No. 88-91, adopted June 10, 1988, and CDO No. 90-104, adopted July 13, 1990, require full compliance with WDR No. 88-90 by October 1, 1989 and May 15, 1991, respectively.

5. Buena Vista Mines, Inc. has not complied with WDR Order No. 88-90, CDO No. 88-91 or CDO No. 90-104 in that, based on the Discharger's self monitoring reports, BVM surface water discharge continues to exceed limits ordered by WDR Order No. 88-90, which are partially listed in Finding No. 3, above.

6. The surface water discharge is subject to WDR Order No. 93-47, adopted May 14, 1993. WDR No. 93-47 contains, in part, Prohibitions, Effluent Limitations, Receiving Water Limitations, and Provisions.

7. WDR Order No. 93-47 contains more constituents with effluent limitations and in some cases, more stringent limits than contained in WDR Order No. 88-90.

8. Based on the discharger's sample analysis data, the discharge does not meet all or some of the following WDR Order No. 93-47 effluent limitations:

"B. Effluent Limitations

Discharge shall not contain total concentrations in excess of the following limits:

Constituent	Units	Limit
Aluminum	mg/L	1.0
Antimony	mg/L	0.006
Arsenic	mg/L	0.005
Barium	mg/L	1.0
Beryllium	mg/L	0.004
Boron	mg/L	0.75
Cadmium	mg/L	0.0086
Chromium	mg/L	0.05
Cobalt	mg/L	0.05
Copper	mg/L	0.03
Iron	mg/L	0.3
Lead	mg/L	0.03
Lithium	mg/L	2.50
Manganese	mg/L	0.05
Mercury	mg/L	0.000012
Molybdenum	mg/L	0.01
Nickel	mg/L	0.1
Selenium	mg/L	0.01
Silver	mg/L	0.013
Sodium	mg/L	69.0
Thallium	mg/L	0.002
Vanadium	mg/L	0.1
Zinc	mg/L	0.2

Constituent	Units	Limit
pH	pH units	between 7.0 and 8.3
Turbidity	NTU	5
Total Dissolved Solids	mg/L	1500
Specific Conductance	umhos	2200
Settleable Solids	ml/L	0.5
Acute Toxicity	There shall be no acute toxicity*	
Chronic Toxicity	TUc**	1.0
Cyanide	mg/L	0.2
Fluoride	mg/L	1.5
Chloride	mg/L	600
Sulfate	mg/L	600
Dissolved Oxygen	mg/L	>5.0
Color	color units	15
Odor-Threshold	units	3"

* Acute toxicity is less than 90% survival, 50% of the time, and less than 70% survival, 10% of the time, of standard test organisms in undiluted effluent in a 96-hour static or continuous-flow test.

** TUc equals 100/NOEL. NOEL (No Observed Effect Level) is the maximum percent test water that causes no observed effect on a test organism, as described in a critical life stage toxicity test listed below:

Critical Life Stage Toxicity Tests

Species	**Effect**	**Test duration (days)**	**Reference**
fathead minnow (Pimephales promelas)	larval survival and growth rate	7	Horning & Weber, 1989
water flea (Ceriodaphnia dubia)	survival; number of young	7	Horning & Weber, 1989
alga (Selanastrum capricornutum)	growth rate	4	Horning & Weber, 1989

Toxicity Test Reference: Horning, W.B. and C.I. Weber (eds.). 1989. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. Second edition. U.S. EPA Environmental Monitoring Systems Laboratory, Cincinnati, Ohio. EPA/600/4-89/001.

9. This enforcement action is taken for the protection of the environment and as such is exempt from the provisions of the California Environmental Quality Act (Public Resources Code, Section 21100, et seq.) in accordance with Section 15321, Chapter 3, Title 14, California Regulatory Code.

IT IS HEREBY ORDERED pursuant to Section 13301 of the Porter-Cologne Water Quality Control Act:

Buena Vista Mines Inc. shall cease and desist from discharging wastes as specified below.

1. Buena Vista Mines, Inc. shall comply immediately with all Provisions of Order No. 93-47, NPDES Permit No. CA0049352.

2. Until November 14, 1993, Buena Vista Mines, Inc. shall comply with the following in lieu of discharge Prohibitions, Effluent Limitations and Receiving Water Limitations of Order No. 93-47:

A. Discharge Prohibitions

1. Discharge to the north fork of Las Tablas Creek of other than uncontaminated stormwater or uncontaminated seepage and at a location other than Discharge Point A or B, 35°37'32" N. Latitude, 120°53'42" W. Longitude, is prohibited.

B. Effluent Limitations

1. Water discharged to the north fork of Las Tablas Creek shall not exceed the following limits:

Constituent	Unit of Measurement	30-Day Average	Daily Maximum
Settleable Solids	ml/l	-	0.5
Mercury	mg/l	0.001	0.002
Nickel	mg/l	0.1	0.2
pH	-	-	Within range of 7.0 to 8.3
Toxicity Concentration	tu	-	0.59*

*No more than one of three consecutive flow-through bioassays shall result in less than 100% survival in undiluted effluent. No single test shall ever result in less than 90% survival in undiluted effluent.

C. Receiving Water Limitations

1. The discharge shall not cause the following limits to be exceeded in the North Fork of Las Tablas Creek or Nacimiento Lake:

Constituent	Maximum mg/l (Unless otherwise noted)
Aluminum	7.5
Antimony	9.0
Arsenic	0.05
Barium	1.0
Beryllium	0.15
Boron	1.25
Cadmium	0.004
Chromium	0.05
Cobalt	0.075
Copper	0.018
Cyanide	0.022
Fluoride	1.5
Iron	1.0
Lead	0.05
Lithium	3.75
Manganese	0.3
Mercury	0.0003
Molybdenum	0.015
Nickel	0.28
Selenium	0.01
Silver	0.004
Hydrogen Sulfide	0.0032
Vanadium	0.15
Zinc	0.12
pH	Within limit of 7.0 to 8.3 at all times, and not changed more than 0.5 units.
Temperature	Maximum increase of 5°F above natural receiving water temperature.

Turbidity (NTU) Not to exceed the following:

Natural Turbidity* NTU	Maximum Increase
< 50	20%
50 < NT < 100	10 NTU
> 100	10%

"Natural Turbidity" shall be determined from receiving water samples taken upstream of the discharge point.

Discharge shall not:

2. Cause the dissolved oxygen concentration of surface waters to be depressed below 5.0 mg/l.

3. Cause surface waters to be greater than 15 units or 10 percent above natural background color, whichever is greater.

4. Contain biostimulatory substances in concentrations promoting aquatic growths that cause nuisance or adversely affect beneficial uses of surface waters.

5. Contain taste or odor-producing substances in concentrations imparting undesirable tastes or odors to fish flesh or other edible products of aquatic origin, causing nuisance, or adversely affecting beneficial uses of surface waters.

6. Contain oils, greases, waxes, or other similar materials in concentrations resulting in a visible film or coating on the surface of the water or on objects in the water, causing nuisance, or otherwise adversely affecting beneficial uses of surface waters.

7. Contain settleable or soluble material in concentrations resulting in the deposition of material causing nuisance or adversely affecting beneficial uses of surface waters.

8. Contain floating material, including solids, liquids, foams, and scum, in concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

9. Contain suspended material in concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

10. Cause a violation of any applicable water quality standard for receiving waters adopted by the Regional Board or the State Water Resources Control Board as required by the Federal Water Pollution Control Act and regulations adopted thereunder."

3. By July 30, 1993, BVMI shall submit a report, certified by a qualified consultant, specifying how surface water discharge from the Buena Vista Mine will be brought into compliance with Order No. 93-47.

4. Effective November 14, 1993, the BVM, Inc. shall comply fully with Order No. 93-47, NPDES Permit No. CA0049352.

5. BVMI shall do anything and everything feasible to minimize and prevent violations of Order No. 93-47, NPDES Permit No. CA0049352.

Failure to comply with provisions of this Order may subject Buena Vista Mines, Inc. to further enforcement action including assessment of civil liability under Sections 13268, 13350, and/or 13385 of the California Water Code and to referral to the Attorney General for injunctive relief and civil or criminal liability.

I, WILLIAM R. LEONARD, Executive Officer of the California Regional Water Quality Control Board, Central Coast Region, do hereby certify the foregoing is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, Central Coast Region, on May 14, 1993.

William R. Leonard

Executive Officer

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION

81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

ORDER NO. 93-48
NPDES NO. CA 0049361

WASTE DISCHARGE REQUIREMENTS FOR BUENA VISTA MINES, INC. AND/OR KLAU MINE INC. C/O BUENA VISTA MINES, INC. KLAU MINE CLOSURE AND POST-CLOSURE AND SURFACE WATER DISCHARGE SAN LUIS OBISPO COUNTY, CALIFORNIA

The California Regional Water Quality Control Board, Central Coast Region (hereafter Board), finds:

1. Buena Vista Mines, Inc. or Klau Mine Inc., c/o Buena Vista Mines, Inc. (BVMI), 1148 Market Street, Morro Bay, California 93442 (hereafter Discharger), owns an inactive mercury mine, the Klau Mine. Mr. Harold J. Biaggini is the president of BVMI.

2. The Klau Mine is located approximately 12 miles west of Paso Robles, California, on property owned by the Discharger as shown on Figures 1 and 2 included as part of this order. The Discharger's property which includes the Klau Mine is located in Section 33, T26S, R10E, MDBM, Adelaida 15 minute quadrangle.

3. Surface water discharged to the Las Tablas Creek, South Fork, Klau Br. from the Carson Drift (a small portion of the Klau Mine) is regulated by Waste Discharge Requirements Order No. 88-92, NPDES No. CA 0049361, adopted by the Board on June 10, 1988.

4. On June 10, 1988, the Board adopted Cease and Desist Order No. 88-93, because discharge from the Carson Drift did not meet conditions of the NPDES permit. CDO No. 88-93 orders full compliance with NPDES permit #CA0049361 by October 1, 1989.

5. Based on inspections and samples, Carson Drift discharge often violates Order No. 88-92 and Order No. 88-93 requirements.

6. Some discharge to surface water from the Klau Mine is not currently regulated by permit.

7. Surface water discharges discontinuously from multiple uncontrolled Klau Mine locations to the Las Tablas Creek, South Fork, Klau Branch approximately 9 miles upstream of Nacimiento Reservoir as shown on Figures 3 and 4, included as part of this order.

8. Nacimiento Reservoir is a drinking water aquifer recharge source. It has been posted in the past with warnings that fish are mercury contaminated.

9. The Regional Board Clean Water Strategy (CWS) ranks Nacimiento Reservoir A-7, one of the region's highest priority water bodies. Nacimiento Reservoir recharges the Paso Robles Ground Water Basin, also with a very high CWS rank of A-12.

10. The Klau Mine is in structurally deformed, mineralized and chemically altered rocks near the common intersection of several faults. The rocks include silica carbonates, serpentine and the highly deformed sediments of the Franciscan Formation.

11. Information at Klau Mine has not been generated regarding depth to ground water, ground water flow directions and rates, chemical and physical ground water properties, etc.

12. Topography of the Klau Mine and surrounding region is steep; 45 degree slopes are not uncommon (Figure 2).

13. The Water Quality Control Plan, Central Coastal Basin (Basin Plan), was adopted by the Board on November 17, 1989 and approved by the State Water Resources Control Board on August 16, 1990. The Basin Plan incorporates statewide plans and policies by reference and contains a strategy for protecting beneficial uses of waters of the State.

14. The "California Inland Surface Waters Plan", adopted by the SWRCB April 11, 1991 specifies water quality objectives for inland surface waters which became effective April 1, 1992.

15. The Basin Plan specifies existing and anticipated beneficial uses of Las Tablas Creek as:

    a. municipal and domestic supply;
    b. agricultural supply;
    c. ground water recharge;
    d. water contact recreation;
    e. non-contact water recreation;
    f. wildlife habitat;
    g. warm fresh water habitat; and
    h. fish spawning.

16. The Basin Plan specifies existing and anticipated beneficial uses of Nacimiento Reservoir as:

    a. municipal and domestic supply;
    b. agricultural supply;
    c. ground water recharge;
    d. water contact recreation;
    e. non-contact water recreation;
    f. wildlife habitat;
    g. cold fresh water habitat;
    h. warm fresh water habitat; and
    i. fish spawning.

17. California Code of Regulations (CCR) Title 23, Division 3, Chapter 15, Article 7, commencing with Section 2570 (Article 7) regulates Mining Waste Management and contains Sections regarding:

    - Applicability;
    - Groups of Mining Waste;
    - Unit Siting and Construction Standards;
    - Water Quality Monitoring (requiring Article 5 ground water, surface water and vadose zone monitoring); and
    - Closure and Post-Closure Maintenance.

    The Section on Closure and Post Closure Maintenance addresses, in part:

    - Water quality threat;
    - Closure and Post-Closure Plans;
    - Surface Mining and Reclamation Act (SMARA) approved mining and reclamation plans;
    - Appropriate registered professionals;
    - Surveyed monuments;
    - Containment structures;
    - Financial assurance;
    - Post closure period;
    - Vegetative layers and irrigation for same;
    - Erosion and sedimentation;
    - Final cover requirements;
    - Grading requirements;
    - Containment and cover maintenance;
    - Leachate, collection and removal systems;
    - Ground water, surface water and vadose zone monitoring;
    - Drainage control;
    - Surveyed monuments;
    - Waste management unit free liquid; and
    - Waste management unit contaminated materials.

18. The Klau Mine is not in compliance with Article 7.

19. The Klau Mine contains overburden, waste rock, and/or solid residues, sludges and liquids from the processing of ore.

20. The Klau Mine overburden, waste rock, and solid residues, sludges and liquids from the processing of ore are Group A and/or Group B Mining Waste, defined by Article 7, Section 2571.

21. Based on inspections and academic studies, the Klau Mine, including Klau Mine Group A and Group B Mining Wastes, has caused, and continues to cause, water quality degradation in Las Tablas Creek and likely in Nacimiento Reservoir.

22. Ground water has never been investigated for Klau Mine impacts.

23. The Klau Mine property has never been comprehensively assessed for water quality threat.

24. The Discharger was notified of impending Article 7 regulation in correspondence dated November 19, 1992.

25. Waste discharge requirements for this discharge are exempt from the provisions of the California Environmental Quality Act (Public Resources Code, Section 21100, et seq.) in accordance with section 13389 of the California Water Code.

26. A permit and the privilege to discharge waste into waters of the State is conditional upon the discharge complying with provisions of Division 7 of the California Water Code and of the Clean Water Act (as amended or as supplemented by implementing guidelines and regulations) and with any more stringent effluent limitations necessary to implement water quality control plans, to protect beneficial uses, and to prevent nuisance. This Order shall serve as a National Pollutant Discharge Elimination System Permit pursuant to Section 402 of the Clean Water Act. Compliance with this Order should assure conditions are met and mitigate any potential changes in water quality due to the project.

27. On March 26, 1993, the Board notified the Discharger and interested parties of its intent to adopt Waste Discharge Requirements for the discharge. The Discharger and interested parties had the opportunity to submit written comments on this proposed Order.

IT IS HEREBY ORDERED, pursuant to authority in Sections 13263 and 13360 of the California Porter-Cologne Water Quality Control Act, that Buena Vista Mines, Inc. and/or Klau Mine Inc., c/o Buena Vista Mines Inc., its agents, successors and assigns (BVMI) shall comply with the following:

A. Prohibitions

1. Discharge of material to surface waters at points other than the approximate discharge locations shown on Figure 4 is prohibited. Exact discharge locations shall be defined by the submittal required in Provision 1 below. That submittal is subject to Executive Officer approval.

2. Discharge of material not contained within the liquid phase (e.g., sediment) at the locations specified in A.1. above is prohibited.

B. Effluent Limitations

Discharge of the liquid phase at locations specified in A.1. above shall not contain total concentrations in excess of the following limits:

Constituent	Units	Limit
Aluminum	mg/L	1.0
Antimony	mg/L	0.006
Arsenic	mg/L	0.005
Barium	mg/L	1.0
Beryllium	mg/L	0.004
Boron	mg/L	0.75
Cadmium	mg/L	0.0086
Chromium	mg/L	0.05
Cobalt	mg/L	0.05
Copper	mg/L	0.03
Iron	mg/L	0.3
Lead	mg/L	0.03
Lithium	mg/L	2.50
Manganese	mg/L	0.05
Mercury	mg/L	0.000012
Molybdenum	mg/L	0.01
Nickel	mg/L	0.1
Selenium	mg/L	0.01
Silver	mg/L	0.013
Sodium	mg/L	69.0
Thallium	mg/L	0.002
Vanadium	mg/L	0.1
Zinc	mg/L	0.2

Constituent	Units	Limit
pH	pH units	between 7.0 and 8.3
Turbidity	NTU	5
Total Dissolved Solids	mg/L	1500
Specific Conductance	umhos	2200
Settleable Solids	ml/L	0.5
Acute Toxicity	There shall be no acute toxicity*	
Chronic Toxicity	TUc**	1.0
Cyanide	mg/L	0.2
Fluoride	mg/L	1.5
Chloride	mg/L	600
Sulfate	mg/L	600
Dissolved Oxygen	mg/L	≥5
Color	color units	15
Odor-Threshold	units	3

* Acute toxicity is less than 90% survival, 50% of the time, and less than 70% survival, 10% of the time, of standard test organisms in undiluted effluent in a 96-hour static or continuous-flow test.

** TUc equals 100/NOEL. NOEL (No Observed Effect Level) is the maximum percent test water that causes no observed effect on a test organism, as described in a critical life stage toxicity test listed on the next page:

Critical Life Stage Toxicity Tests

Species	**Effect**	**Test duration (days)**	**Reference**
fathead minnow (Pimephales promelas)	larval survival and growth rate	7	Horning & Weber, 1989
water flea (Ceriodaphnia dubia)	survival; number of young	7	Horning & Weber, 1989
alga (Selanastrum capricornutum)	growth rate	4	Horning & Weber, 1989

Toxicity Test Reference: Horning, W.B. and C.I. Weber (eds.). 1989. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. Second edition. U.S. EPA Environmental Monitoring Systems Laboratory, Cincinnati, Ohio. EPA/600/4-89/001.

C. Receiving Water Limitations

Receiving waters include all waters of the U.S. downstream of the Klau Mine property. Discharge of the liquid phase to the locations specified in A.1. above shall not cause violation(s) of the following narrative limits.

1. Surface water communities and populations, including vertebrate, invertebrate, and plant species, shall not be degraded as a result of the discharge.

2. The natural taste and odor of fish, shellfish, or other surface water resources used for human consumption shall not be impaired.

3. Toxic pollutants shall not be discharged at levels that will bioaccumulate in aquatic resources.

4. The concentration of contaminants in waters of the U.S. shall not occur at levels which are harmful to human health.

5. The concentrations of toxic pollutants in the water column, sediments, or biota shall not adversely affect beneficial uses.

6. Waters of the U.S. shall be free of coloration that causes nuisance or adversely affects beneficial uses.

7. Waters of the U.S. shall not contain taste or odor-producing substances in concentrations that cause nuisance, or that adversely affect beneficial uses.

8. Waters of the U.S. shall not contain floating material, including solids, liquids, foams, and scum, in concentrations that cause nuisance or adversely affect beneficial uses.

9. Waters of the U.S. shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

10. Waters of the U.S. shall not contain settleable material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses.

11. Waters of the U.S. shall not contain oils, greases, waxes, or other similar materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.

12. Waters of the U.S. shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

13. The suspended sediment load of surface waters of the U.S. shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

14. Waters of the U.S. shall be free of change in turbidity that cause nuisance or adversely affect beneficial uses.

15. Water temperature shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses.

16. There shall be no acute toxicity in waters of the U.S.

17. There shall be no chronic toxicity in waters of the U.S.

18. Waters of the U.S. shall not contain concentrations of chemical constituent in amounts which adversely affect the agricultural beneficial use.

D. Provisions

1. The Discharger shall submit a report by August 14, 1993 proposing exact Klau Mine surface water discharge locations. This report shall be certified by appropriate registered professionals and is subject to Executive Officer approval.

The Discharger shall eliminate all actual and potential water quality impacts from the Klau Mine by bringing the Klau Mine into compliance with Article 7 in accordance with Provisions 2. through 9. below.

2. The Discharger shall submit a plan August 14, 1993, describing in detail how the Klau Mine will be brought into compliance with Article 7. The Compliance Plan shall describe how the Discharger intends eliminating all actual and potential water quality impacts from the entire Klau Mine.

The Compliance Plan shall give detailed descriptions of the entire Klau Mine and of each Klau Mine unit subject to specific Article 7 requirements. The Compliance Plan shall also describe, in detail and with specific citations, which Article 7 sections apply to individual units and which sections apply to the complete Klau Mine. The Compliance Plan shall describe the methods of achieving compliance in sufficient detail and with sufficient support and documentation to ensure feasibility, implementation and success. The Compliance Plan shall be certified by the appropriate registered professionals.

3. Revisions to the Compliance Plan may be required by the Board or Board staff, and shall be submitted within 35 calendar days of written notice that they are required. All revisions shall be certified by appropriate registered professionals and shall render the Compliance Plan acceptable.

4. Implementation of the Compliance Plan shall commence within one calendar month of Executive Officer approval of the Compliance Plan.

5. Full Klau Mine compliance with Article 7 shall be achieved within 36 calendar months of Executive Officer approval of the Compliance Plan.

6. A report certifying how the Klau Mine was brought into compliance with Article 7 (Compliance Certification Report) shall be submitted within two calendar months of completion of Article 7 compliance activities, not to exceed 38 calendar months after Executive Officer approval of the Compliance Plan. The Compliance Certification Report must certify that all terms of the approved Compliance Plan were accomplished and describe in detail how they were accomplished. The Compliance Certification Report shall describe in detail all activities conducted pursuant to this Order and shall be certified by appropriate registered professionals.

7. Written status reports shall be submitted by BVMI every three calendar months during implementation of the Compliance Plan. The first status report shall be due three calendar months after the Compliance Plan is implemented (Provision D.4. above). Subsequent status reports shall be due every three calendar months thereafter. Status report submittals shall continue until submittal of the Compliance Certification Report (Provision D.6. above). Status reports shall be certified by appropriate registered professionals.

8. All terms of the Executive Officer approved Compliance Plan shall be implemented as specified by the approved Compliance Plan.

9. All Compliance Plan implementation activities shall be conducted under the direct supervision of appropriate registered professionals.

10. Unpredictable events may necessitate revisions to plans, schedules, or activities. The Executive Officer shall have the authority to approve such revisions. However, the Discharger shall not implement any such revision, or discontinue previously approved or ordered terms, plans, schedules or activities prior to receiving Executive Officer approval.

11. Board staff shall be notified at least 96 hours prior to commencement of any physical activity to allow staff presence during such activity.

12. Order No. 88-92 adopted by the Board on June 10, 1988, is hereby rescinded. This recision is not a waiver of the right of the Regional Board to seek administrative civil liability or take other enforcement action for violations of Order No. 88-92 which have occurred prior to the date of this recision.

13. The Discharger shall comply with "Monitoring and Reporting Program No. 93-48," as specified by the Executive Officer.

14. The Discharger shall comply with all items of the attached "Standard Provisions and Reporting Requirements for National Pollutant Discharge Elimination System Permits," dated January, 1985, (also referred to as "Standard Provisions"), except Item Nos. A.6,7,13; C.3,9; and D.1.

15. The Discharger shall inform his employees of the terms of this Order which pertain to their duties and a copy of this Order shall be available for their reference.

16. This Order expires May 14, 1998. If BVMI wishes to continue the discharge to surface water of the United States after May 14, 1998, it must file a Report of Waste Discharge (ROWD) in accordance with Title 23, of the California Code of Regulations by November 14, 1997.

I, WILLIAM R. LEONARD, Executive Officer, do hereby certify the foregoing is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, Central Coast Region, on May 14, 1993.

William R Leonard
Executive Officer

DS:sg

sg/ds4-93-48.wdr

FIGURE 1

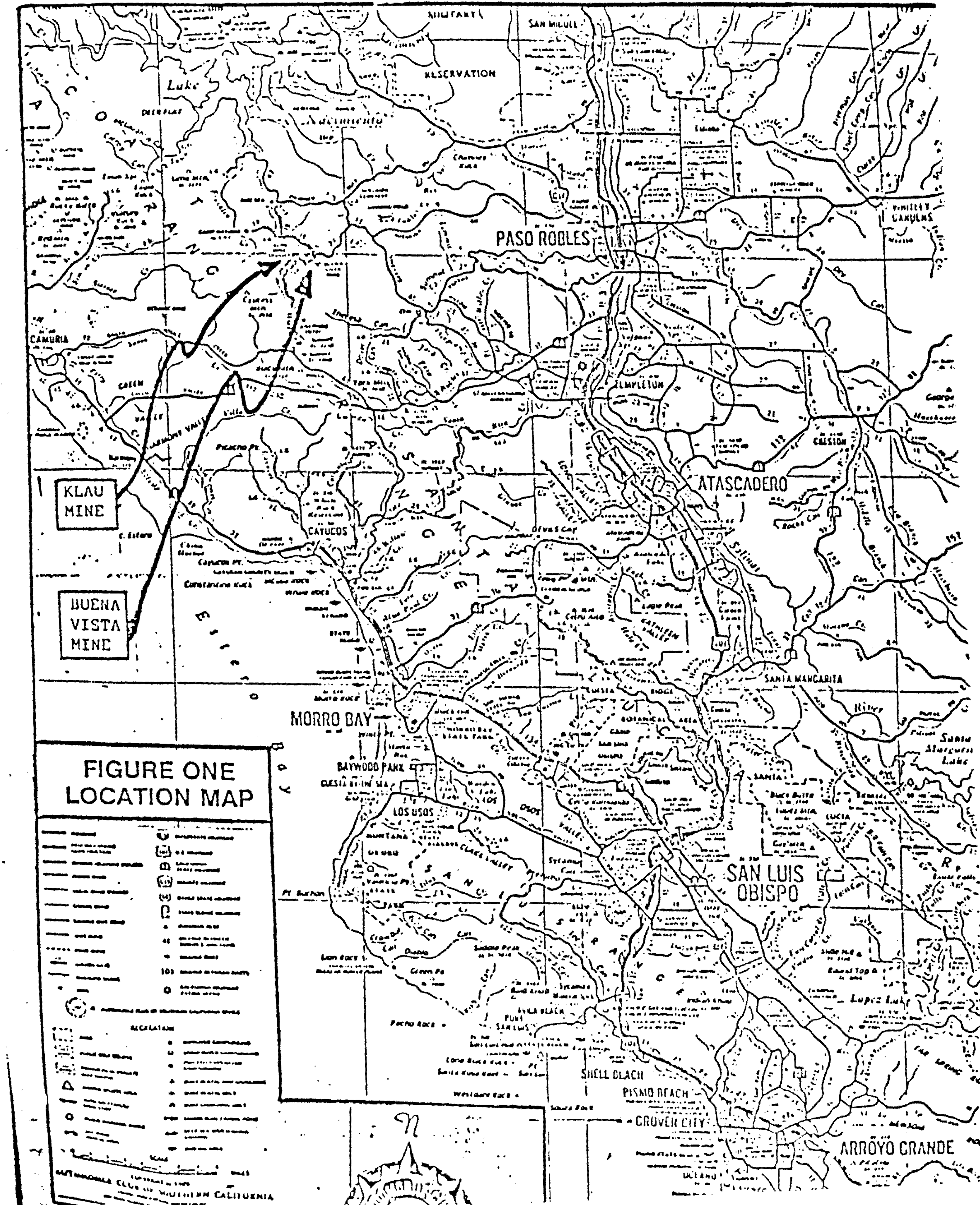


FIGURE ONE
LOCATION MAP
KLAU MINE
BUENA VISTA MINE
SAN MIGUEL
RESERVATION
Lake Nacimiento
PASO ROBLES
VINEYARD CANYONS
CAMBRIA
TEMPLETON
CRESTON
ATASCADERO
CAYUCOS
SANTA MARGARITA
Santa Margarita Lake
MORRO BAY
BAYWOOD PARK
CUESTA BY-THE-SEA
LOS OSOS
SAN LUIS OBISPO
AVILA BEACH
PORT SAN LUIS
SHELL BEACH
PISMO BEACH
GROVER CITY
ARROYO GRANDE
Lopez Lake
AUTOMOBILE CLUB OF SOUTHERN CALIFORNIA

FIGURE 2

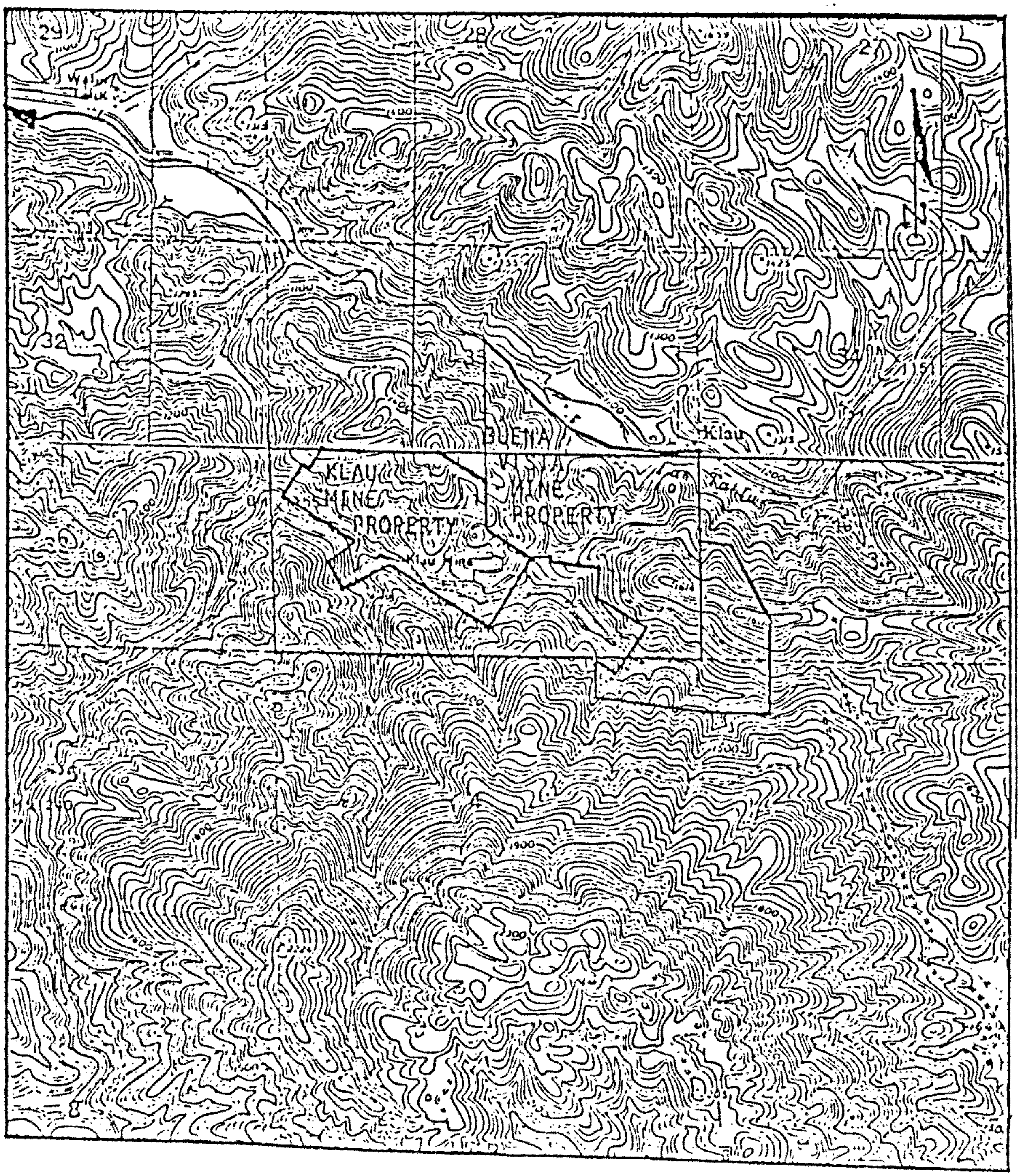
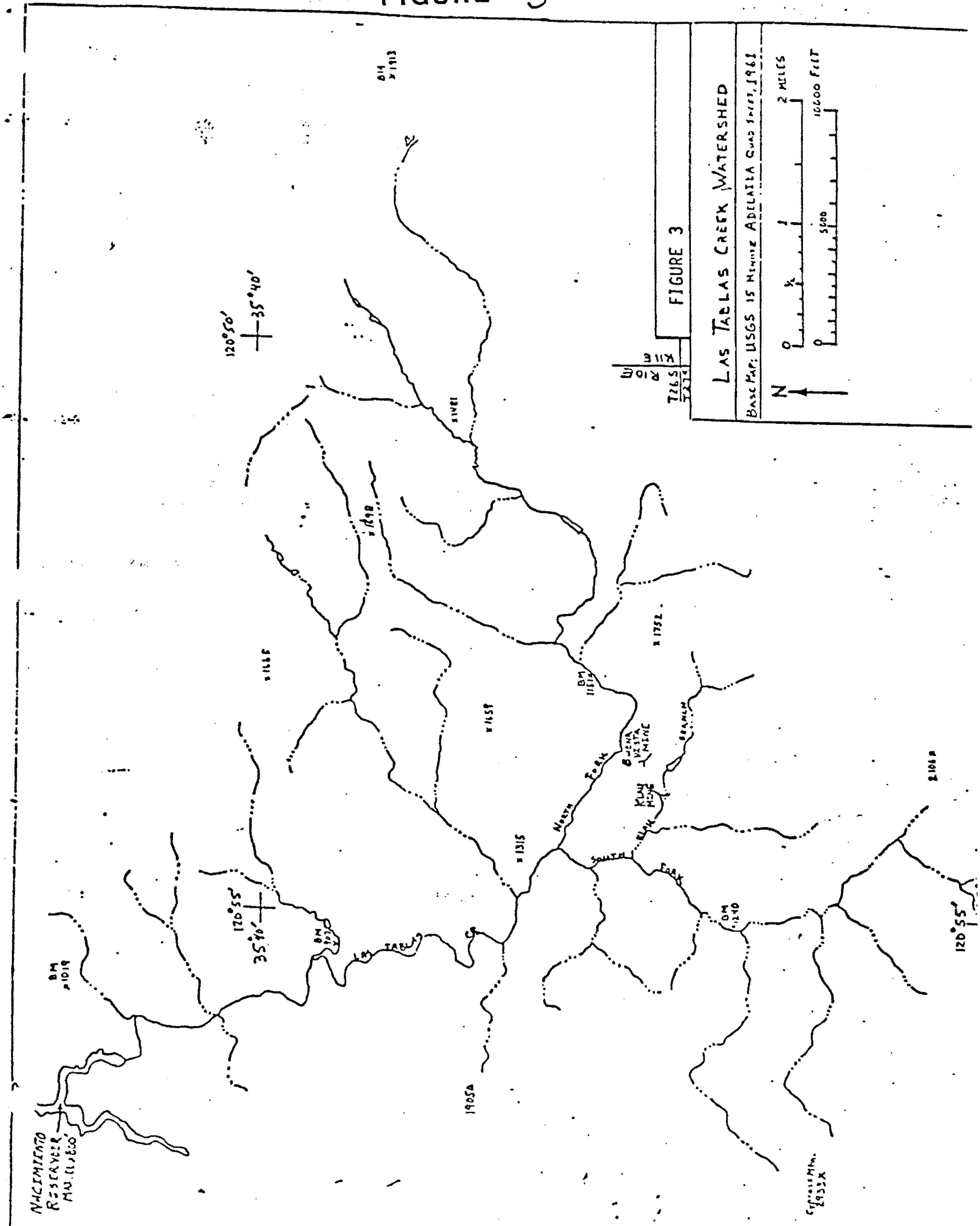


FIGURE 2: BUENA VISTA MINE &
KLAU MINE PROPERTIES

Approximate Scale (Miles)

0 ¼ ½ 1

FIGURE 3



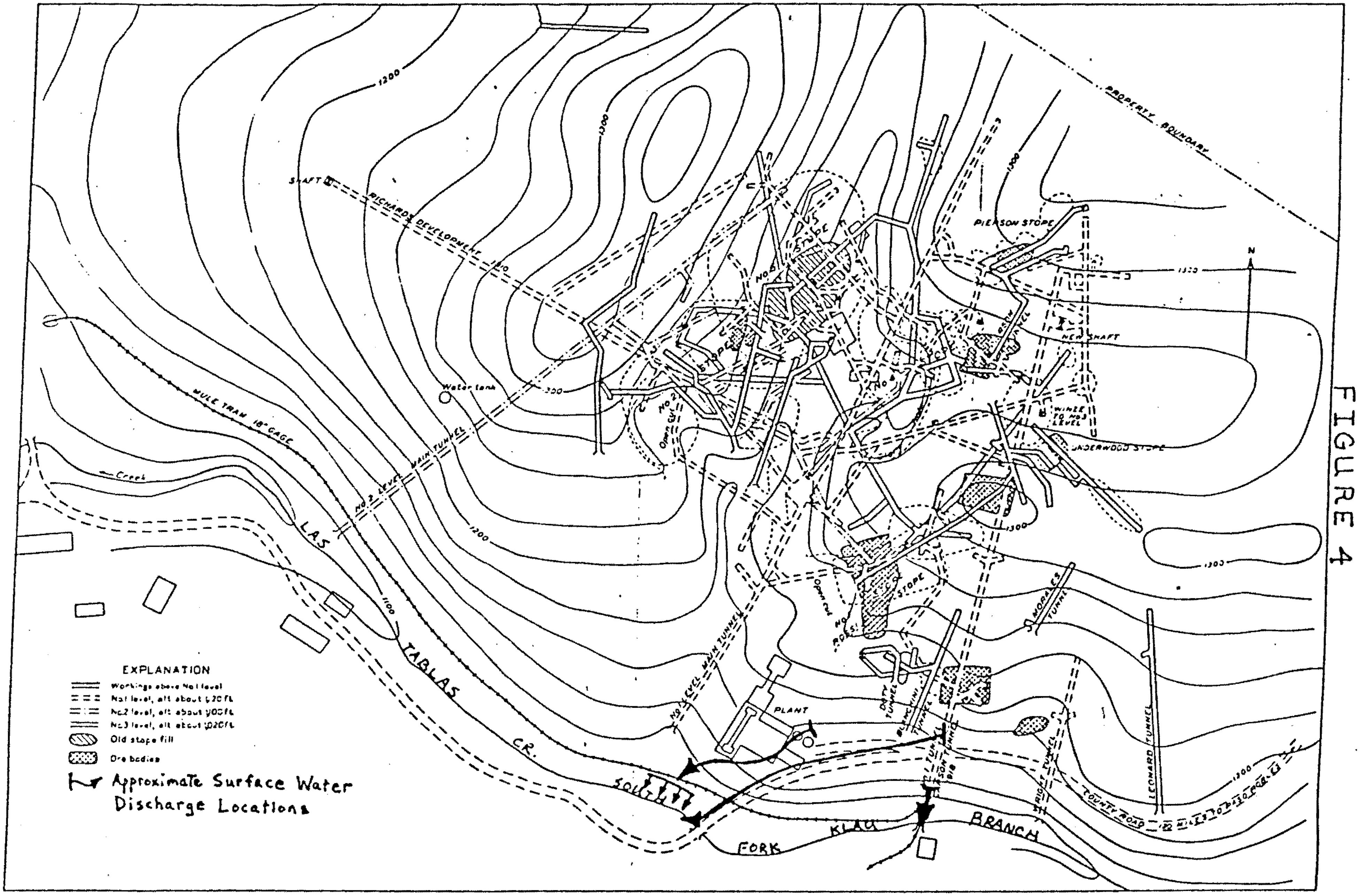
LAS TABLAS CREEK WATERSHED

BASE MAP: USGS 15 MINUTE ADELAIDA QUAD SHEET, 1961

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ECKEL, 1941
BULLETIN 922 PLATE [illegible]

FIGURE 4



MAP OF KLAU MINE WORKINGS

100 0 200 Feet

Contour interval 20 feet

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION
81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

MONITORING AND REPORTING PROGRAM NO. 93-48
FOR
BUENA VISTA MINES, INC. AND/OR KLAU MINE INC.
C/O BUENA VISTA MINES INC.
KLAU MINE
SAN LUIS OBISPO COUNTY, CALIFORNIA

1. The liquid phase discharged from the Klau Mine to surface waters of the United States from all locations specified in Order No. 93-48 shall be grab sampled and analyzed as follows:

Constituent	Units	Sampling and Analysis Frequency
pH	-	Weekly
Turbidity	NTU	Weekly
Specific Conductance	umhos	Weekly
Aluminum	mg/L	Quarterly during November, February, May, and August
Antimony	"	"
Arsenic	"	"
Barium	"	"
Beryllium	"	"
Boron	"	"
Cadmium	"	"
Chromium	"	"
Cobalt	"	"
Copper	"	"
Iron	"	"
Lead	"	"
Lithium	"	"
Manganese	"	"
Mercury	"	"
Molybdenum	"	"
Nickel	"	"
Selenium	"	"
Silver	"	"
Sodium	"	"
Thallium	"	"
Vanadium	"	"
Zinc	"	"

Constituent	Units	Sampling and Analysis Frequency
Total Dissolved Solids	mg/L	Quarterly during November, February, May and August
Settleable Solids	ml/L	"
Acute Toxicity	-	"
Chronic Toxicity	TUc	"
Cyanide	mg/L	"
Fluoride	"	"
Chloride	"	"
Sulfate	"	"
Dissolved Oxygen	"	"
Color	color units	"
Odor-threshold	units	"

2. This Monitoring and Reporting Program becomes effective May 14, 1993.

3. Monitoring results shall be submitted to the Board by the 30th day of the month following the month of sampling; i.e., November results by December 30, February results by March 30, May results by June 30, and August results by September 30.

4. Monitoring reports will include observations of receiving waters with regard to compliance with Order No. 93-48, C. Receiving Water Limitations.

ORDERED BY: William Leonard
EXECUTIVE OFFICER

May 14, 1993
DATE

sg/ds4-93-48.mrp

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION

81 Higuera Street, Suite 200
San Luis Obispo, California 93401-5427

CEASE AND DESIST ORDER NO. 93-57

Order Requiring Buena Vista Mines, Inc., &/or Klau Mine Inc. c/o Buena Vista Mines, Inc., San Luis Obispo County, to Cease and Desist from Discharging and Threatening to Discharge Surface Water, From the Klau Mine in Violation of Requirements Contained in Waste Discharge Requirements, Order No. 93-48

The California Regional Water Quality Control Board, Central Coast Region, (hereafter Board), finds:

1. Buena Vista Mines, Inc., &/or Klau Mine Inc., c/o Buena Vista Mines, Inc. (BVMI) owns the Klau Mine, an inactive mercury mine.

2. Surface water is discharged from the Klau Mine to the Klau Branch of the South Fork of Las Tablas Creek approximately 9 miles upstream of Nacimiento Reservoir (Section 33, T26S, R10E, MD B&M; Adelaida 15 minute quadrangle).

3. Surface water is discharged discontinuously from multiple Klau Mine locations, including the Carson Drift.

4. Surface water discharge from the Carson Drift has been regulated by WDR No. 88-92, adopted June 10, 1988. WDR Order No. 88-92 contains discharge prohibitions, effluent limitations and receiving water limitations, which state, in part:

   A. Discharge Prohibitions

      1. Discharge to the south fork of Las Tablas Creek of other than uncontaminated stormwater or uncontaminated seepage and at a location other than 35°37'19" N. Latitude, 120°54'0" W. Longitude, is prohibited.

   B. Effluent Limitations

      1. Water discharged to the south fork of Las Tablas Creek from the Carson Drift shall not exceed the following limits:

Constituent	Unit of Measurement	30-Day Average	Daily Maximum
Mercury	mg/l	0.001	0.002
Nickel	mg/l	0.1	0.2
pH	-	-	Within range of 7.0 to 8.3

C. Receiving Water Limitations

1. Water discharged from the Carson Drift shall not cause the following limits to be exceeded in the North Fork of Las Tablas Creek:

Constituent	Maximum mg/l (Unless otherwise noted)
Aluminum	7.5
Chromium	0.05
Cobalt	0.075
Copper	0.018
Iron	1.0
Manganese	0.3
Mercury	0.0003
Nickel	0.28
Zinc	0.12
pH	Within limit of 7.0 to 8.3 at all times, and not changed more than 0.5 units.

Discharge shall not:

2. Cause surface waters to be greater than 15 units or 10 percent above natural background color, whichever is greater.

3. Contain taste or odor-producing substances in concentrations imparting undesirable tastes or odors to fish flesh or other edible products of aquatic origin, causing nuisance, or adversely affecting beneficial uses of surface waters.

4. Contain oils, greases, waxes, or other similar materials in concentrations resulting in a visible film or coating on the surface of the water or on objects in the water, causing nuisance, or otherwise adversely affecting beneficial uses of surface waters.

5. Contain settleable or soluble material in concentrations resulting in the deposition of material causing nuisance or adversely affecting beneficial uses of surface waters.

6. Contain floating material, including solids, liquids, foams, and scum, on concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

7. Contain suspended material in concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

8. Cause a violation of any applicable water quality standard for receiving waters adopted by the Regional Board or the State Water Resources Control Board as required by the Federal Water Pollution Control Act and regulations adopted thereunder."

5. Cease and Desist Order (CDO) No. 88-93, adopted June 10, 1988 requires full compliance with WDR Order No. 88-92 by October 1, 1989.

6. Buena Vista Mines, Inc. has not complied with WDR Order No. 88-92 and CDO No. 88-93 in that Carson Drift surface water discharge continues to exceed limits ordered by WDR No. 88-92 and CDO No. 88-93 which are listed in part in Finding No. 4. above.

7. Surface water discharge from the entire Klau Mine, including the Carson Drift, is regulated by Waste Discharge Requirements Order No. (WDR) 93-48, adopted May 14, 1993. WDR No. 93-48 contains, in part, prohibitions and effluent limitations, as follows:

"A. Prohibitions

1. Discharge at a point other than the discharge locations shown on Figure 6 is prohibited.

B. Effluent Limitations

Discharge shall not contain total concentrations in excess of the following limits:

Constituent	Units	Limit
Aluminum	mg/L	1.0
Antimony	mg/L	0.006
Arsenic	mg/L	0.005
Barium	mg/L	1.0
Beryllium	mg/L	0.004
Boron	mg/L	0.75
Cadmium	mg/L	0.0086
Chromium	mg/L	0.05
Cobalt	mg/L	0.05
Copper	mg/L	0.03
Iron	mg/L	0.3
Lead	mg/L	0.03
Lithium	mg/L	2.50
Manganese	mg/L	0.05
Mercury	mg/L	0.000012
Molybdenum	mg/L	0.01
Nickel	mg/L	0.1
Selenium	mg/L	0.01
Silver	mg/L	0.013
Sodium	mg/L	69.0
Thallium	mg/L	0.002
Vanadium	mg/L	0.1
Zinc	mg/L	0.2
pH	pH units	between 7.0 and 8.3
Turbidity	NTU	5
Total Dissolved Solids	mg/L	1500
Specific Conductance	umhos	2200
Settleable Solids	ml/L	0.5
Acute Toxicity	There shall be no acute toxicity*	
Chronic Toxicity	TUc**	1.0

Constituent	Units	Limit
Cyanide	mg/L	0.2
Fluoride	mg/L	1.5
Chloride	mg/L	600
Sulfate	mg/L	600
Dissolved Oxygen	mg/L	>5.0
Color	color units	15
Odor-Threshold	units	3

* Acute toxicity is less than 90% survival, 50% of the time, and less than 70& survival, 10% of the time, of standard test organisms in undiluted effluent in a 96-hour static or continuous-flow test.

** TUc equals 100/NOEL. NOEL (No Observed Effect Level) is the maximum percent test water that causes no observed effect on a test organism, as described in a critical life stage toxicity test listed below:

Critical Life Stage Toxicity Tests

Species	Effect	Test duration (days)	Reference
fathead minnow (<u>Pimephales promelas</u>)	larval survival and growth rate	7	Horning & Weber, 1989
water flea (<u>Ceriodaphnia dubia</u>)	survival; number of young	7	Horning & Weber, 1989
alga (<u>Selanastrum capricornutum</u>)	growth rate	4	Horning & Weber, 1989

Toxicity Test Reference: Horning, W.B. and C.I. Weber (eds.). 1989. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. Second edition. U.S. EPA Environmental Monitoring Systems Laboratory, Cincinnati, Ohio. EPA/600/4-89/001.

8. Based on inspection data, the Klau Mine surface water discharge does not meet all or some of the prohibitions and effluent limitations listing in Finding No. 7, above.

9. This enforcement action is taken for the protection of the environment and as such is exempt from the provisions of the California Environmental Quality Act (Public Resources Code, Section 21100, et seq.) in accordance with Section 15321, Chapter 3, Title 14, California Regulatory Code.

IT IS HEREBY ORDERED pursuant to Section 13301 of the Porter-Cologne Water Quality Control Act:

1. Buena Vista Mines, Inc., and Klau Mines, Inc., shall immediately comply with all Provisions of Order No. 93-48.

2. Until September 15, 1994, Buena Vista Mines, Inc. and Klau Mine, Inc., shall comply with the following in lieu of Discharge Prohibitions, Effluent Limitations, and Receiving Water Limitations of Order No. 93-48:

   A. Discharge Prohibitions

      1. Discharge to the south fork of Las Tablas Creek of other than uncontaminated stormwater or uncontaminated seepage and at a location other than 35°37'19" N. Latitude, 120°54'0" W. Longitude, is prohibited.

   B. Effluent Limitations

      1. Water discharged to the south fork of Las Tablas Creek from the Carson Drift shall not exceed the following limits:

Constituent	Unit of Measurement	30-Day Average	Daily Maximum
Settleable Solids	ml/l	-	0.5
Total Suspended Solids	mg/l	20	30
Mercury	mg/l	0.001	0.002
Nickel	mg/l	0.1	0.2
pH	-	-	Within range of 7.0 to 8.3
Toxicity Concentration	tu	-	0.59*

*No more than one of three consecutive flow-through bioassays shall result in less than 100% survival in undiluted effluent. No single test shall ever result in less than 90% survival in undiluted effluent.

C. Receiving Water Limitations

1. Water discharged from the Klau Mine and Carson Drift shall not cause the following limits to be exceeded in the North Fork of Las Tablas Creek:

Constituent	Maximum mg/l (Unless otherwise noted)
Aluminum	7.5
Antimony	9.0
Arsenic	0.05
Barium	1.0
Beryllium	0.15
Boron	1.25
Cadmium	0.004
Chromium	0.05
Cobalt	0.075
Copper	0.018
Cyanide	0.022
Fluoride	1.5
Iron	1.0
Lead	0.05
Lithium	3.75
Manganese	0.3
Mercury	0.0003
Molybdenum	0.015
Nickel	0.28
Selenium	0.01
Silver	0.004
Sulfide Hydrogen Sulfide	0.0032
Vanadium	0.15
Zinc	0.12
pH	Within limit of 7.0 to 8.3 at all times, and not changed more than 0.5 units.
Temperature	Maximum increase of 5°F above natural receiving water temperature
Turbidity (NTU)	Not to exceed the following:

Natural Turbidity* NTU	Maximum Increase
< 50	20%
50 < NT < 100	10 NTU
> 100	10%

"Natural Turbidity" shall be determined from receiving water samples taken upstream of the discharge point.

Discharge shall not:

2. Cause the dissolved oxygen concentration of surface waters to be depressed below 5.0 mg/l.

3. Cause surface waters to be greater than 15 units or 10 percent above natural background color, whichever is greater.

4. Contain biostimulatory substances in concentrations which promote aquatic growths causing nuisance or adversely affecting beneficial uses of surface waters.

5. Contain taste or odor-producing substances in concentrations imparting undesirable tastes or odors to fish flesh or other edible products of aquatic origin, causing nuisance, or adversely affecting beneficial uses of surface waters.

6. Contain oils, greases, waxes, or other similar materials in concentrations resulting in a visible film or coating on the surface of the water or on objects in the water, causing nuisance, or otherwise adversely affecting beneficial uses of surface waters.

7. Contain settleable or soluble material in concentrations resulting in the deposition of material causing nuisance or adversely affecting beneficial uses of surface waters.

8. Contain floating material, including solids, liquids, foams, and scum, on concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

9. Contain suspended material in concentrations causing nuisance or adversely affecting beneficial uses of surface waters.

10. Cause a violation of any applicable water quality standard for receiving waters adopted by the Regional Board or the State Water Resources Control Board as required by the Federal Water Pollution Control Act and regulations adopted thereunder.

3. Effective September 15, 1994, Buena Vista Mines, Inc., and Klau Mine, Inc., shall comply fully with Order No. 93-48, NPDES Permit No. CA0049361.

4. Buena Vista Mines, Inc. and/or Klau Mine, Inc. c/o BVMI shall do anything and everything feasible to minimize and prevent violations of Order No. 93-48, NPDES Permit No. CA0049361.

5. By November 8, 1993, BVMI and/or Klau Mine, Inc., c/o BVMI shall prevent erosion of sediment from the Klau Mine to surface water.

6. By November 8, 1993, BVMI and/or Klau Mine, Inc., c/o BVMI shall submit a report, certified by a qualified consultant, specifying how surface water discharge from the Klau Mine will be brought into compliance with Order No. 93-48.

Failure to comply with provisions of this Order may subject the Discharger to further enforcement action including assessment of civil liability under Sections 13268, 13350, and/or 13385 of the California Water Code and/or referral to the Attorney General for injunctive relief and civil or criminal liability.

I, WILLIAM R. LEONARD, Executive Officer of the California Regional Water Quality Control Board, Central Coast Region, do hereby certify the foregoing is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, Central Coast Region, on May 14, 1993.

William R Leonard
Executive Officer

sue**/cdo.klm

APPENDIX 2

Local Newspaper Articles from 1966 through 1988 regarding Mercury Mines in the Lake Nacimiento Watershed

Source: "S.L.O. Telegram-Tribune", 2/10/66.

Planners recommend Klau Mine operation

Continued operation of the historic Klau Mine in the Adelaida area was recommended Wednesday by the County Planning Commission.

The commission recommended, however, that only limited processing be permitted. The recommendation must be approved by the Board of Supervisors.

A conditional use permit to continue the operation was requested by Buena Vista Mines, Inc., which is mining quicksilver from the main Buena Vista Mine adjacent to the Klau claims.

Although adjacent property owners protested the operation of the Buena Vista Mine, the commission noted it could not control the operation since it had been in existence since before the current ordinance went into effect.

Operation of the Klau mine had lapsed for several years, bringing the reopening back under the ordinance.

Planning director Ned Rogoway noted that the Regional Water Quality Control Board has issued a cease and desist order on the Buena Vista operation, because of stream pollution in the Las Tablas Creek.

Board representative Dave Larson said, however, that there was no pollution problem with the Klau mine since little processing is being conducted there. The firm is working with the board on solution to the pollution problem, he added.

Attorney Charles Ogle noted that the Buena Vista mine has been operated since 1866 and the Klau mine since about the same time on land originally patented for mining.

The Klau mine was acquired by Buena Vista last year.

Ogle requested approval of the permit, subject to compliance with state and federal agencies which control various aspects of mining.

Company president Harold Biaggini said the only processing on the property was in a small 12 by 4-foot processer. He said the mining there was primarily of an exploratory nature.

Ogle agreed that if extensive mining were found feasible, the firm should apply for another permit if processing were desired.

The commission recommended approval of the operation for the mines five claims, the Atlas, Empire, Santa Cruz, Adelaida and Last Chance locations.

Ray Dodd, owner of property adjacent to the Buena Vista Mine, asked that the permit be denied. He said the processing operation had done extensive damage to his property and he has pending a lawsuit against the mine company.

Ogle argued, however, that complaints regarding the Buena Vista operation were not germain to the application, which applied only to the Klau mine.

Source:
"The Cambrian," 7/30/70.

Mercury Mines

For more than a hundred years, San Luis Obispo county mines have been producing mercury for the world market and today the historic Buena Vista is one of tho biggest producers to be found anywhere.

Harold J. Biaggini, member of a prominent Cayucos family, is owner of the mine, said to have yielded more than $25,000,000 worth of mercury since 1957.

The Buena Vista had first been opened in the known cinnabar mining area of teh county, north of Cayucos and west of Paso Robles, in 1866. Biaggini set out to re-discover it and after a search that extended over several years, he hit the jackpot. Drilling located the vein and strip mining revealed cinnabar resources of a yet undetermined amount.

After the cinnabar vein slanted into a mountain side it was followed with a series of tunnels. The rock is dynamited, the ore hauled out in cars and processed in a mill, some of the machinery having been devised by Biaggini.

Mercury is measured, stored and sold by the flask. A flask is 2½ quarts, weighs about 85 pounds, and is worth around $500, depending on the day to day market.

California mines produce about nine-tenths of the mercury produced in the United States. Biaggini points out that this country produces about 30,000 flasks of mercury annually and uses 60,000. Most of the import comes from Spain. In addition to its use in such common items as thermometers and barometers, mercury is used in the space program, medicine and manufacture of ammunition.

Biaggini also owns the Klau and the Oceanic mines in the same area, both historic producers of mercury.

The Buena Vista employs 58 men.

Source: "S.L.O. Telegram-Tribune," 2/10/71.

San Luis Obispo County (Calif.) Telegram-Tribune, Wednesday, Feb. 10, 1971

Mercury mine faces new curbs

A new restriction on the discharge of waste water from the Buena Vista mercury mine west of Paso Robles will be considered by the Regional Water Quality Board.

The board will take up the matter when it meets Thursday in Santa Cruz.

Kenneth Jones, executive officer for the WQCB, said results of waste water samples received in the past few days indicate excessive concentrations of mercury in the mine's discharge which flows into Las Tablas Creek. The creek drains into Nacimiento Lake and reservoir.

Jones said he would recommend to the board that discharges into the creek from Buena Vista be prohibited after March 1.

The WQCB established new waste water requirements for Buena Vista during a meeting in December.

The requirements were patterned to fit a new system being adopted by the firm's owner, Harold Biaggini, in which the waste will first be ponded and then disposed of by means of spray irrigation on the surrounding hillsides. At present, the waste is collected in a pond which periodically overflows into the east fork of Las Tablas Creek.

The board originally gave Biaggini until June 1 to put the new system into operation and thus eliminate the system of discharging into the creek.

Jones said the sample results, however, now make it necessary to reduce by 90 days the time allowed for the changeover.

"We think they should start construction on the new system immediately," Jones said today.

Samples from three separate spots at the mine were taken last summer and submitted to the water quality office of the Federal Environmental Protection Agency for analysis.

The results recently received indicate that all three sources of the samples showed parts of mercury far in excess of the allowable 5 micrograms per million parts of water.

Jones said a supplementary report by a WQCB biologist indicated that the concentration of mercury has had "considerable toxic effect in the creek."

Jones emphasized, however, that Biaggini had been cooperative in helping to correct the situation. And the new system for waste water discharge being established at the mine is a good one, he said.

Source:
"Sun Bulletin," 2/11/71.

Buena Vista mercury mine

The multi-million dollar Buena Vista mercury mine near Paso Robles is putting up to 25 times legal limits of waste mercury into Las Tablas Creek and state water pollution experts will ask that the mine's anti-pollution construction time-table be advanced to stop the pollution.

There is no immediate threat to the public from the mercury wastes, a state spokesman said, but the creek feeds into Lake Nacimiento, which in turn replenishes underground rivers that supply drinking water to cities north of Camp Roberts. No one in San Luis Obispo County drinks Nacimiento water. Large quantities of mercury taken over a long period of time damages the body's central nervous system and can cause madness, a state spokesman said.

The matter will be on the agenda of the California Regional Water Quality Control Board Central Coast Region when it meets in Santa Cruz City Hall, Feb. 11, at 10 a.m.

The board's executive officer, Kenneth R. Jones, said he will ask the board to give Buena Vista only until March 1 to complete new construction that will reduce the current high levels of mercury discharged into Las Tablas Creek. Buena Vista had been granted until June 1 to complete the construction.

Jones said that the earlier date had been granted without the results of more recent tests in recent days that showed 125 parts of mercury per million in the exhaust water from the mercury mining operation. State regulations allow mercury discharges up to 5 parts per million. In addition, recent tests show 84 parts per million of mercury in waste water from the mine's mill operation and 770 parts per million in the water in a holding pond at the mine. The holding pond water, though highest in mercury concentration, poses the least danger unless a big rainstorm washes it into the Creek.

Mine operator Harold J. Biaggini has grossed $25 million worth of mercury, but, last year, ran into underground springs on the main shaft.

Surrounding land-owners complained of the red muck that the mercury refining process produces and that was washed out by the underground springs.

Biaggini was forced to close the main shaft, laying off many of his 58 employees and costing him an estimated $1.5 million gross revenue. New shafts were drilled by Boyles Brothers, Salt Lake City, to find a new tunnel location on the property, at an extra $225,000, and he plans to sink another main shaft for another $700,000. Total outlays, including shifting to cleaner-burning propane for light, will amount to $3 million.

Biaggini's pollution problem stems from the high sulfurous acid content of his water. Mercury by itself does not dissolve in water, but settles out. With such acid water, however, the mercury is dissolved in it and is carried wherever the water goes. Just treating the waste water is costly, and includes adding fertilizer grade ammonia to the acidic wastes. The ammonia neutralizes the sulfuric acid and converts the iron sulfate into rust. The solids settle in a sludge to the bottom and the water on top is usable for irrigation. It is construction on this waste process that the Water Quality Control Board will be asked to speed up.

Source: "S.L.O. Telegram-Tribune," 2/12/71.

Mercury mine restricted

The Regional Water Quality Control Board yesterday put a new time restriction on the Buena Vista mercury mine west of Paso Robles.

The board, meeting in Santa Cruz, told the operators of the mine that they must install a new system of disposing of waste water by March 1. Originally, following a decision last November, Buena Vista was given until June 1 to change its method of discharging wastes into Las Tablas Creek.

The board's executive officer, Ken Jones, recommended the speedup in schedule for the new discharge system because of sample results that were received from Washington last week, showing inordinately high concentrations of mercury in the plant's discharge.

Jones said today the plant actually had been in conformance with the order because it has been shut down for about the past two months.

The new system planned by the company will dispose of waste by spraying it on dry land owned by Buena Vista.

Huge load of mercury leaves Paso under guard

A $1.3 million shipment of mercury from the Buena Vista mine left the Paso Robles railroad yards this morning under heavy guard, headed for Sparks, Nev.

Tony McLean, director of research for the mine, said it was believed to be the largest single shipment of precious metal ever made from a California mine.

The mercury represented 10 months of production from the Buena Vista mine in the Adelaida area, 17 miles west of Paso Robles. The mine is not operating at present and the mercury had been stored for several months at a building on the mine property.

Harold Biaggini, owner of the mine, decided recently that safety precautions dictated a move to a more secure location. At Sparks, near Reno, the quicksilver will be stored in a bonded warehouse, where it will also have the advantage of temperature control.

The mercury is contained in 378 flasks, weighing about 248,000 pounds. The movement from mine to railroad began early yesterday morning on heavy trucks, escorted by deputy sheriffs. The job was completed about midnight last night when the two box cars of precious metal were sealed. Southern Pacific Railroad security guards will accompany the shipment to Sparks.

McLean said the American Quicksilver Institute had recently reported three cases of highjacking of quicksilver shipments, another reason for taking extra precautions with the Buena Vista cargo.

Biaggini is not selling the mercury at this time, but will keep it in storage at Sparks. It is reported to be the largest stockpile of mercury owned by anyone except the United States government.

The Buena Vista mine is closed while problems of mercury contaminated water from the mine are being resolved.

Source: San Luis Obispo County
Telegram-Tribune
102nd YEAR. NO. 171 20 PAGES TODAY PRICE TEN CENTS Date: Wednesday, February 24, 1971

A2-6

Source: "S.L.O. Telegram-Tribune," 12/2/71.

Mercury found in Nacimiento, tributary

A high concentration of mercury in the silts and mud of Nacimiento Reservoir and its tributary Las Tablas Creek was confirmed today by the Central Coast Regional Water Quality Control Board.

The examination was ordered by the U.S. Environmental Protection Agency and the state Water Resources Board, according to Willard Branson, chairman of the regional water quality board.

The silt and bottom mud samplings from both the creek and reservoir produced concentrations of 4.75 and 6.03 parts per million of mercury. Water samplings from both sources for mercury concentration were insignificant, Branson said.

Tom Bailey, senior engineer for the regional water board, said the statewide examination of streams and reservoirs in the vicinity of mercury mining operations has been under way for a year.

The Nacimiento River drainage basin in Monterey and San Luis Obispo counties has been a mercury mining area for many years, Branson said, resulting in mercury deposits downstream from such operations.

The old Klau Mine in the Adelaida east of Paso Robles was a big producer years ago, but has long been closed down.

The Buena Vista Mine nearby is one of the prime producers in the state and is located on a tributary to Las Tablas Creek.

Last year, Harold Biaggini, operator of the Buena Vista, closed down the operation to prevent all discharge into the creek from the processing operation.

"In my opinion," Branson said, "the mercury concentration is restricted to Las Tablas Creek and probably is not of significance to the whole of Nacimiento Reservoir.

"However, we have asked the Department of Fish and Game to investigate further to determine if the problem is extensive. The Board will decide if action is required to abate a problem."

Branson said there is no cause for widespread alarm, but that the matter is of concern and will be investigated fully by the board.

Source: "S.L.O. Telegram-Tribune," 10/14/74.

Panel to probe iron in mine water

SANTA CRUZ — The Regional Water Quality Control Board Friday created a special panel to consider swift enforcement action to stop "very acid wastewater" from an abandoned mercury mine west of Paso Robles.

The panel will meet Oct. 25 in Paso Robles to hear testimony about a high concentration of iron in water running into Las Tablas Creek from the Buena Vista Mercury Mine about 12 miles west of Paso Robles.

Executive Director Kenneth Jones said at Friday's meeting here that some of the polluted water may reach the Nacimiento Reservoir, but by the time it gets there it has no harmful effect.

The drastic effects of the toxic wastes are further upstream where the iron turns the water and surrounding creekbed a severe rust color "that looks like hell," Jones said.

The mine, owned by Harold Biaggini of Cayucos, has been closed for more than three years, Jones said, but rainwater running through a mercury tailings pile and a pond backed up at the tailings pile are what is causing the problem.

The panel appointed by Chairman Norman Caldwell to consider the problem includes board members Dr. Harold Cota of San Luis Obispo, Floyd M. Grigory of San Ardo and Mrs. Frank Thompson of Santa Barbara.

The panel will then forward its recommendation to the full board at its next meeting Nov. 8 in Santa Barbara for consideration of a cease and desist order.

Board considers polluted water from old mine

By Phil Dirkx
Telegram-Tribune

ADELAIDA — Nothing seems to be able to live in the water that flows from the old Buena Vista Mercury Mine at Cypress Mountain Drive and Klau Mine Road.

The mine has been shut down since 1970.

"There appears to be no life in the creek below the mine," said John Goni, associate engineer with the state Regional Water Quality Control Board.

That board is scheduled to hold a public hearing on the mine's water problems at 9 a.m. Friday, June 10 in the Seaside City Council Chamber.

The water from the mine flows into Las Tablas Creek and eventually gets to into Nacimiento Lake about 8½ miles downstream.

Even though the water comes from an old mercury mine, the trouble isn't too much mercury. It's too much iron and a condition Goni referred to as "low pH," which means the water is very acid.

The mercury found in the water doesn't exceed the allowable level of .0003 milligram per liter, he said.

Although mercury has been found in the flesh of fish from Nacimiento Lake, Goni doesn't blame that condition on the mine.

"The watershed area naturally contains mercury," he said.

The low-pH level of the mine water is toxic, he said, and the iron in the water clings to fishes' gills.

The iron also forms velvet-like deposits on the creek bottom. The reddish-brown desposits are unslightly and kill small forms of life, Goni said.

The iron gets into the water as it seeps through the tailings on the mine property, he said, and a chemical reaction also takes place that creates the low pH condition.

The tailings may have to be removed or capped with an impervious layer, or the water may have to be diverted away from them, he said.

At the hearing June 10, the board will consider setting purity standards for mine property runoff.

It will also consider issuing cease and desist orders.

Please see Mine, Back Page

Phil Dirkx/Telegram-Tribune

Polluted water leaking from the Buena Vista Mine will be the subject of a state hearing June 10.

Warnings about fish with high mercury levels

NACIMIENTO LAKE — Pregnant women and nursing mothers should not eat largemouth bass from Nacimiento Lake.

Neither should children under six or women who expect to get pregnant soon, according to the health warnings in the state fishing regulations issued on March 1.

The regulations said the state Department of Health Services has determined that the lake's largemouth bass contain elevated mercury levels.

The warning also says no one should eat more than four meals per month of largemouth bass from Nacimiento Lake.

Nacimiento wasn't the only lake mentioned for having fish with too much mercury. In other parts of the

Please see Warnings, Back Page

Mine

Continued from Page 1

Similar action will also be considered for the nearby Carson Drift, which is under the same ownership.

It is a tunnel mine into the side of a hill. Water flows from it into another branch of Las Tablas Creek, Goni said.

The water board has known of the problems at Buena Vista Mine since 1971.

That was when the board first adopted purity standards for the water from the Buena Vista Mine.

Then in 1974 it issued a cease and desist order in the case, Goni said.

In 1975 the matter was referred to state Attorney General's office, which returned the matter to the water board in 1987, to have new purity standards issued, Goni said.

The mine's owner, however, hasn't just ignored the matter, Goni said, but has made attempts to solve the problem.

Harold Biaggini of Cayucos is president of Buena Vista Mines Inc.

"We have cooperated," he said.

Biaggini said his company tried things suggested by the water board's staff, but they haven't worked.

He estimates about 5 gallons of water per minute is now flowing from the Buena Vista Mine's dump.

He concedes there is a problem, and he said his organization is now looking for a way to reprocess the waste piles to remove the deleterious materials.

He said he hopes to get an answer in a month or two on whether that process will work at the Buena Vista Mine.

He estimates his company has spent $250,000 trying to clean up the problem.

Source: "S.L.O. Telegram-Tribune," 6/2/88.

Warnings

Continued from Page 1

state, three lakes, three reservoirs, a river, two creeks and the San Francisco Bay Delta Region were also mentioned. Some waters had several types of fish that were effected.

The fishing regulations also contain warnings about other hazards in other bodies of water, such as elevated DDT and PCB levels in Santa Monica Bay and elevated selenium levels in both the Salton Sea and the Grassland area in Merced County.

Paul Jagger of the state Regional Water Quality Control Board staff said that there is probably no one source for the mercury found in fish in Nacimiento Lake.

But he added that mercury is found in the geologic formations of the lake's drainage basin.

APPENDIX 3

Selected papers related to a "Complaint for Injunction, Breach of Contract, and for Damages"; Case No. 31361, filed August 2, 1965 in the Superior Court of the State of California, County of San Luis Obispo.

(SPACE BELOW FOR FILING STAMP ONLY)

MADDEN & HART
ATTORNEYS AT LAW
810 - 12TH STREET
P. O. BOX 306
PASO ROBLES CALIFORNIA
TELEPHONE 238-2484

Attorneys for Plaintiff

FILED
AUG 2 - 1965
A. E. MALLAGH, County Clerk
By [illegible] DEPUTY CLERK

8/2

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA
IN AND FOR THE COUNTY OF SAN LUIS OBISPO

RAYMOND E. DODD and EVELYN C. DODD, Plaintiffs, vs. BUENA VISTA MINES, a corporation; ~~HAROLD~~ BIAGGINI; JOHN DOE I through V; ROE and ROE, a co-partnership, Defendants.	No. 31361

COMPLAINT FOR INJUNCTION, BREACH OF CONTRACT AND FOR DAMAGES.

COMES NOW the Plaintiffs and for cause of action against the Defendants allege as follows:

I

That the Plaintiffs, at all times herein mentioned were and are the owners of certain agricultural real property with improvements thereon located in the County of San Luis Obispo, State of California, and described as follows:

> Government Lots 1, 2, and 4 in the Southeast quarter of Section 33, Township 26 South, Range 10 East, Mount Diablo Meridian, in the County of San Luis Obispo, State of California as per government plat thereof approved January 30, 1880 by the surveyor general.
>
> Except from said Lot 1 that portion thereof, described as follows: Commencing at the quarter section corner common to Sections 33 and 34, Township 26 South, Range 10 East, Mount Diablo Meridian, thence

South 89° 58' West, along the North line of said Lot 1 634.92 feet more or less to a half inch iron pipe; thence South 5° 17' East 230.64 feet to a 1-1/2 inch iron pipe; thence North 71° 10' 30" East 648.39 feet, more or less to the section line common to said Sections 33 and 34; thence North 0° 02' West along said section line 50 feet, more or less to the point of beginning.

II

That the Plaintiffs do not know the true names or capacities, whether individual, corporate, associate or otherwise, of Defendants sued herein as JOHN DOE I through V, ROE and ROE, a co-partnership, and Plaintiffs will ask leave to amend this complaint to show their true names and capacities when the same have been ascertained.

III

The Defendant, BUENA VISTA MINES, a California corporation, is now and has been for some time last past the owner and operator of quicksilver, mercury and other mineral mines engaging in mining operations upon lands immediately adjacent to the said real property of the Plaintiffs

IV

That the Defendants, HAROLD BIAGGINI, JOHN DOE I through V and ROE and ROE, a co-partnership, were and at all times herein mentioned agents,servants and employees of the defendant corporation and acting within the scope of said agency.

V

That for more than three (3) years continuously last past the Defendants and each of them have engaged in mining procedures, both open cut and underground operations, immediately adjacent to Plaintiffs' said property in such a manner so as to wrongfully cause, permit and allow noxious fumes, gases, and sulfer deposits to pollute the air and settle in and upon the said lands of the Plaintiffs and improvements thereon belonging to Plaintiffs; that the said mining operations of the Defendants and each of them has caused portions of Plaintiffs'lands to cave in and slide; that the Defendants and each of them in connection with said mining operations have caused and permitted mining waste materials to be deposited upon portions of Plaintiffs' said lands.

VI

That as a direct and approximate result of said wrongfull conduct on the part of the Defendants and each of them and the conditions wrongfully created thereby,the Plaintiffs' property has been damaged as follows:

D-10 a) Approximately forty (40) acres of Plaintiffs' grazing land located on said government lots 1 and 2 have become and now are sterile lands.

b) Approximately one (1) acre of alfalfa has been completely damaged and destroyed.

c) Approximately two (2) miles of barbed wire fence has been completely destroyed by rust.

d) That deer netting metal fence around the alfalfa field has been completely destroyed and rusted.

e) That the screendoors, window screens, metal locks and latches of doors and windows have rusted and become destroyed.

f) That numerous trees and shrubbery on Plaintiffs' property have been destroyed and killed.

g) That the metal and tin roofs of the houses and out buildings on Plaintiffs' land have rusted and deteriorated to the extent that they no longer serve their intended purposes.

h) That certain items of farm equipment consisting of John Deere hay chopper, Oliver grain drill, Teco squeeze chute, harrow, springtooth and disk have rusted to the extent that they can no longer be used.

i) That cracks and separations of the structures and foundations of improvements on Plaintiffs' lands have occurred by reason of the Defendants' blasting operations on adjacent properties.

j) That certain portions of Plaintiffs' lands located in the said covernment lot 4 have caved in and slid into the open pits of Defendants' mining property.

k) That miscellaneous hand tools and building materials have been rusted and damaged beyond use.

l) That three head of cattle belonging to Plaintiffs have been lossed and destroyed by reason of the above said cave-ins and land slides.

m) That waste materials consisting of mud and silt have been deposited by Defendants upon Plaintiffs' property and certain ranch roads causing said lands to be useless and the roads impassable.

VI

That the Plaintiffs are informed and believe and therefore allege that the pollution of the air by the Defendants as aforesaid is dangerous and detrimental to the health and well-being of persons on Plaintiffs' property as well as adjoining properties.

VII

That the full nature and extent of monitary damages suffered and sustained by the Plaintiffs as aforesaid, by reason of the foregoing acts and conduct on the part of the Defendants, is unascertainable at this time, and Plaintiffs ask leave of court to amend this complaint when the same is ascertained or upon proof thereof; that further additional damage will be suffered by Plaintiffs each day said mining operations are continued and carried on as in the past.

VIII

That the Plaintiffs have no adequate remedy at law for said injuries, and unless the Defendants and each of them are enjoined and restrained by order of court, great and irreparable, continuing injury will be suffered and sustained by the Plaintiffs in that the activities of the Defendants and resulting damage thereof as hereinabove enumerated will continue; that the repairing and replacing of the items subject to repair and replacement will likewise be damaged in the future and will require constant repair and/or replacement, and that the grasslands and alfalfa fields will continue to suffer and sustain damage and said damage and will increase in intensity and in area; that the value and extent and amount of future additional damages is not ascertainable at this time and Plaintiffs ask leave of court to amend this complaint when the same is ascertainable, or upon proof thereof.

AS AND FOR A SECOND, SEPARATE AND DISTINCT CAUSE OF ACTION THE PLAINTIFFS ALLEGE AS FOLLOWS:

I

That the Plaintiffs incorporate by reference herein their allegations contained in paragraphs I, II, III and IV of the first cause of action with the same force and effect as if fully set forth hereat.

II

That on or about July 30, 1963, the Plaintiff, RAYMOND E. DODD, entered into an oral contract with the Defendants, BUENA VISTA MINES, a corporation, and HAROLD BIAGGINI, wherein the said Plaintiff agreed to permit the said Defendants to use water from a spring located on said government lot 1 in connection with the Defendants' mining operations and the said Defendants agreed to install a permanent water system to supply water to said mining operations and to the two residences located upon Plaintiff's property and the said Defendants further agreed to replace the water from said Plaintiff's water supply which was to be used and was used by said Defendants in connection with their said mining operations; that the said Plaintiff has fully performed under said contract and the same is an executed contract insofar as the said Plaintiff is concerned.

III

That the said Defendants, BUENA VISTA MINES and HAROLD BIAGGINI, have failed and refused to install said permanent water system; that the said Defendants use of said water has caused the said water supply to be dissipated and the spring to dry up, and said Defendants and each of them have failed, refused and neglected to replace said water supply.

IV

That by reason of the breach of said contract on the part of said Defendants, the Plaintiffs have been damaged in an amount not ascertainable at this time and ask leave of court to amend this complaint when the same is ascertainable, or upon proof thereof.

WHEREFORE, Plaintiffs and each of them pray for judgment against the Defendants and each of them as follows:

1. For a permanent injunction enjoining and restraining the Defendants and each of them from engaging in mining operations which cause, allow or permit noxious fumes and gases to pollute the air and be deposited upon the real property and improvements and crops of the Plaintiffs, from causing or permitting Plaintiffs' lands to cave in and slide and from depositing or causing to be deposited debris and silt upon Plaintiffs' land.

2. For damages under the first cause of action in such amount or amounts as is found by the evidence.

3. For damages under the second cause of action for breach of contract in such amount as is determined by the evidence.

4. For costs of suit incurred herein.

5. For such other and further relief as to the Court deems just and proper in the premises.

MADDEN & HART
BY: Paul T. Hart
PAUL T. HART

STATE OF CALIFORNIA)
: ss.
COUNTY OF SAN LUIS OBISPO)

RAYMOND E. DODD, being first duly sworn, deposes and states:

That he is one of the Plaintiffs in the above entitled action; that he has read the foregoing COMPLAINT FOR INJUNCTION,

BREACH OF CONTRACT AND FOR DAMAGES, and knows the contents thereof; that the same is true of his own knowledge, except as to the matters which are therein stated upon his information or belief and as to those matters that he believes it to be true.

I declare under penalty of perjury that the foregoing is true and correct.

Dated this 30 day of July, 1965, at Paso Robles, California.

Raymond E. Dodd
RAYMOND E. DODD

T/O
~~10-9~~
10-13

MADDEN & HART
ATTORNEYS AT LAW
[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

September 26, 1967

Judge Timothy I. O'Reilly
Judge of the Superior Court
County Courthouse Annex
San Luis Obispo, California 93401

Re: Dodd vs. Buena Vista Mines
SLO No.31361

Dear Judge O'Reilly:

Enclosed herewith you will find the original Findings of Fact and Conclusions of Law in the above matter together with an original and copy of proposed judgment and original cost bill.

A copy of this letter together with a copy of the Findings of Fact and Conclusions of Law, proposed judgment and copy of cost bill is being forwarded to the firm of Chinello, Chinello & Maddy and to Charles Ogle, the attorneys for the defendants.

Very truly yours,

Paul T. Hart
PAUL T. HART

PTH:rg

enclosures-4

cc: Charles E. Ogle
Attorney At Law
770 Morro Bay Boulevard
Morro Bay, California 93442

Chinello, Chinello & Maddy
Attorneys at Law
616 First Western Bank Building
Fresno, California 93721

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RECEIVED
SEP 29 1967

MADDEN & HART
ATTORNEYS AT LAW
630 - 12th Street
P. O. Box 306
PASO ROBLES, CALIFORNIA
Telephone 238-3464

Attorneys for Plaintiffs

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA
IN AND FOR THE COUNTY OF SAN LUIS OBISPO

RAYMOND E. DODD and EVELYN C. DODD,
Plaintiffs,
-vs-
BUENA VISTA MINES, a Corporation; HAROLD BIAGGINI; JOHN DOE I through V; ROE and ROE, A co-partnership,
Defendants.

No. 31361

FINDINGS OF FACT
AND
CONCLUSIONS OF LAW

The above entitled matter came on regularly for trial in Department I of the above entitled court on March 21, 1967 and was heard and tried on that day and on March 22, 23, and 24, 1967, before the honorable Timothy I. O'Reilly Judge presiding, sitting without a jury, both sides having waived a jury trial and the plaintiffs appeared in person and by and through their counsel MADDEN & HART by PAUL T. HART and the defendants BUENA VISTA MINES, a corporation and HAROLD BIAGGINI appeared in person and by and through their counsel, CHARLES E. OGLE and CHINELLO, CHINELLO & MADDY, and evidence, both oral and documentary having been introduced and the trial of the matter having been concluded on March 24, 1967 and the matter having been submitted to the court for its decision after receipt of briefs of both sides, on July 28, 1967 and the court being fully advised does hereby make its findings of fact and conclusions of law, to wit:

FINDINGS OF FACT

I

That the allegations contained in paragraph I of the complaint are found to be true.

II

That the allegations contained in paragraph III of the complaint are found to be true.

III

That it is found to be true that the defendant, HAROLD BIAGGINI at all times mentioned in the complaint was and now is an agent, servant and employee of the defendant corporation and acting within the scope of said agency.

IV

That the allegations contained in paragraph V of the complaint are found to be true.

V

That the allegations contained in paragraph VI of the complaint are found to be true.

VI

That with reference to the allegations contained in paragraphs VII and VIII of the complaint the court finds that it is true that the plaintiffs are entitled to injunctive relief requiring the defendants to install a sufficient and adequate smoke and fume arrestor on the smoke stack of the smelting processes engaged in by the defendants and that the plaintiffs have no adequate remedy of law in connection therewith and the court further finds that the plaintiffs have been damaged within the three year period immediately preceeding the date of the filing of this action as follows:

1) Twenty acres of grazing land damaged in the amount of $581.76.

2) Cords of firewood destroyed and damaged in the amount

of $454.50.

3) Barbed wire fences were destroyed and damaged in the amount of $472.68.

4) Deer netting fencing was damaged and destroyed in the amount of $254.52.

5) Window and door screens and locks were damaged in the amount of $90.90.

6) Farm implements including hay chopper, grain drill, and squeeze chute were damaged in the amount of $227.25.

7) Metal buildings were damaged in the amount of $145.08.

8) Damages for cleaning corrals and removal of debris in the amount of $180.00.

9) Loss of three head of cattle in the amount of $275.00

10) Loss of cattle feed in the amount of $1,401.25.

VII

That with reference to paragraph II of the Second Cause of Action the court finds that the plaintiff, RAYMOND E. DODD entered into an oral contract with the defendant BUENA VISTA MINES, a corporation and HAROLD BIAGGINI on or about July 30, 1963 wherein the said plaintiff agreed to permit the defendants to use water from said spring located on plaintiffs' property and that the said plaintiff has fully performed under said contract.

VIII

That with reference to paragraph III of the Second Cause of Action the court finds that the defendants failed and refused to install the required pipeline and water system under the said contract.

IX

That with reference to paragraph IV of the Second Cause of Action, the court finds that there has been no evidence of damages suffered and sustained by said plaintiffs by reason of said breach and therefor finds untrue the plaintiffs' allegations of damages.

X

That with reference to the allegations contained in the defendants' First Affirmative Defense of the answer the court:

a) Finds that on or about November 1, 1959 a written leasing agreement was entered into between the plaintiffs and the BUENA VISTA MINES where in the plaintiffs leased certain property to the said defendant for the purpose of storage of slag and waste materials and that the said agreement was for a period not to exceed fifty years from date of agreement.

b) That on or about December 7, 1961 a written leasing agreement was entered into between the plaintiffs and the defendant BUENA VISTA MINES wherein the plaintiffs leased additional lands to the said defendant for the purpose of storing slag and waste materials which agreement was to be for a term of five years with an option to renew for an additional five year period.

c) That on or about May 18, 1961 a written agreement was entered into between the plaintiffs and the defendant, BUENA VISTA MINES wherein the said defendant was to construct a certain earthen dam and spillway on plaintiffs' property.

Dam

d) The Court finds that said dam and spillway were constructed on plaintiffs' property with plaintiffs' consent and knowledge.

e) The Court finds that the plaintiffs' are not estopped from asserting rights to damages from fumes or pollution of air caused by the defendants and finds that they have not waived any rights to such damages.

f) That with reference to the remaining allegations in the defendants' First Affirmative Defense, not herein specifically found to be true or untrue are found to be untrue.

XI

That with reference to the defendants' Second Affirmative Defense contained in Defendants' answer the Court finds all of the allegations therein contained to be untrue.

XII

That with reference to the Third Affirmative Defense contained in defendants' answer, the Court finds all of said allegations to be untrue.

XIII

That with reference to the Fourth Affirmative Defense contained in defendants' answer the Court finds all of the allegations therein contained to be untrue.

XIV

That with reference to the remaining allegations contained in the plaintiffs' complaint and/or the defendants' answer and affirmative defenses therein not specifically found to be true or untrue are found to be untrue.

CONCLUSIONS OF LAW

As conclusions of law from the foregoing findings of fact, the Court concludes:

1) That the plaintiffs and each of them are entitled to a judgment in their favor and against the defendants, BUENA VISTA MINES and HAROLD BIAGGINI, their agents, servants and employees, for mandatory injunction requiring the defendants to install a sufficient and adequate smoke and fume arrestor commonly known in the trade as a "caustic scrubber" on the smoke stack of the defendants' smelting operation.

2) That the plaintiffs and each of them are entitled to a judgment against the defendants, BUENA VISTA MINES and HAROLD BIAGGINI for damages as follows:

a) In the sum of $581.76 for damages to grazing land;

b) In the sum of $454.50 for damage to fire wood;

c) In the sum of $472.68 for damage to barbed wire fencing;

d) In the sum of $254.52 for damage to deer netting fencing;

e) In the sum of $90.90 for damage to window and door screens and locks;

f) In the sum of $227.25 for damage to farm implements;

g) In the sum of $145.08 for damage to metal buildings;

h) In the sum of $180.00 for cleaning corrals and removal of debris;

i) In the sum of $275.00 for loss of three head of cattle;

j) In the sum of $1,401.25 for loss of cattle feed;

All of the foregoing damages totaling $4,082.95 plus interest thereon at the rate of 7% per annum from August 2, 1965 until paid.

3) That the plaintiffs and each of them are entitled to judgment in their favor and against the defendants, BUENA VISTA MINES and HAROLD BIACCINI for costs of suit incurred herein.

LET JUDGMENT BE ENTERED ACCORDINGLY

Dated this 16th day of October, 1967.

JUDGE OF THE SUPERIOR COURT

LAW OFFICES OF
CHINELLO, CHINELLO & MADDY
616 FIRST WESTERN BANK BUILDING
FRESNO, CALIFORNIA 93721
TELEPHONE AREA CODE 209 233-2834

FILED
APR 29 1968
[illegible], COUNTY CLERK
By Wanita Smith
DEPUTY CLERK

ATTORNEYS FOR Defendants

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF SAN LUIS OBISPO

RAYMOND E. DODD and EVELYN C. DODD,

Plaintiffs,

vs

BUENA VISTA MINES, a corporation; HAROLD BIAGGINI; JOHN DOE I through V; ROE and ROE, a co-partnership,

Defendants.

No. 31361

PARTIAL SATISFACTION OF JUDGMENT

Receipt of Four Thousand Eighty-two Dollars and 94/100 ($4,082.94), plus costs of One Hundred Ninety-nine Dollars and 60/100 ($199.60) and interest in the sum of Seventy-four Dollars and 94/100 ($74.94), for the total sum of Four Thousand Three Hundred Fifty-seven Dollars and 48/100 ($4,357.48) from BUENA VISTA MINES, a corporation, and HAROLD BIAGGINI, is acknowledged by RAYMOND E. DODD and EVELYN C. DODD, judgment creditors in full satisfaction of the money judgment entered in this action on January 2, 1968, in Judgment Book, Volume No. 45, Page 291.

✓

DATED this 16th day of April, 1968.

Evelyn C Dodd
One of the Plaintiffs.

MADDEN & HART

By
Attorneys for Plaintiffs.

APPENDIX 4

Private and Public Letters regarding two Mercury Pollution Sources, Mines and Roads in the Lake Nacimiento Watershed

July 16, 1979 ①

Dear Mr. Jones,

As a landowner on Las Tablas Creek and a concerned citizen of San Luis Obispo County, I would appreciate knowing what, if any progress is being made to clean up the iron oxide runoff from the Buena Vista Mine. Have there been containment measure taken? If not, what would your opinion be to correct the problem? Have any recent investigations been made?

I would truly appreciate knowing what your feelings on this matter are.

Sincerely,

Donna M. Harcourt
Los Tablas Creek Ranch
Adelaide Route
Paso Robles. Ca

P.S. Enclosed, please find photograph of mine tributary merging with Las Tablas Creek.

DMH.

② August 25, 197

Dear Mr. Kenneth Jones: or to whom it may concern

On July 16, 1979, I mailed to you a letter asking what progress has been made in cleaning up the Buena Vista Mine. So far I have received nothing.

Would you please be so kind as to keep me up to date on its progress, and, or what can be done to correct the problem.

Sincerely

Donna M. Harcourt
Las Tablas Creek Ranch
Adelaide Route
Paso Robles. Ca 93446

(3)

STATE OF CALIFORNIA — RESOURCES AGENCY

EDMUND G. BROWN JR., Governor

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD—
CENTRAL COAST REGION
122-A LAUREL LANE
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 549-3147

August 27, 1979

Mrs. Donna M. Harcourt
Las Tablas Creek Ranch
Adelaida Rd.
Paso Robles, CA 93446

Re: Buena Vista Mines

Dear Mrs. Harcourt:

Your letter dated July 16, 1979, raises some interesting questions about correcting the pollution problems caused by Buena Vista Mine drainage. Unfortunately, any solution is inherently complex. As a result the matter is unresolved not only at Buena Vista Mine, but throughout the state.

As you are probably aware, this Regional Board imposed requirements on the mine's operators when the operation was still active during the early seventies. After recurring violations of the discharge permit and several varied, but futile, attempts by the discharger to remedy problems, this Board took inforcement action. First, a cleanup and abatement order was issued, then a cease and desist order. Eventually continued unsatisfactory performance resulted in referral to the State Attorney General. After several ineffective remedial actions by mine owners and an assessment of the mine by the California Division of Mines and Geology, the Deputy Attorney General assigned to this case advised us that little could be done. The copy of his December 14, 1976, letter is attached.

For the past two years, this agency has been reviewing the situation of inactive and abandoned mines, including assessment of mine impacts and current legal recourses available to this agency and others. The program has been concentrated within the Central Valley Regional Board with assistance from the State Water Resources Control Board. The results from these efforts ranked the relative severity of mine problems in the Central Valley. As resources become available, the problems are to be handled according to their severity. Copies of the Central Valley's proposed basin plan amendment and summary report concerning this issue are attached. The program is proposed to be expanded statewide. This is explained in the attached "Notice of Public Hearing" You can support funding this item by writing the State Water Resources Control Board.

Monies for problem correction, if and when available, have generally been advanced from State and Federal sources, not mine owners. Naturally, they are allocated by need on a statewide basis. For example, this agency has approved expenditure of over a million dollars

④

to correct one major mine drainage problem in the Sierra Nevada Mountains. Other funds have been allocated to better define technology of mine drainage solutions for application.

An institutional and legal analysis of means presently available to control water pollution from inactive mineral mines problem was recently completed by State Board staff. A copy of the report is available at this office if you wish to review it.

Last month, staff members from this office and the Department of Fish and Game collected fish specimen from various points in Las Tablas Creek for bioassays. Once the results were available, we, as well as Fish and Game, will determine our next course of action.

If you wish to discuss this further, or, if you wish to review our office files on this discharge, please contact Bert Van Voris, our staff enforcement officer.

Very truly yours,

KENNETH R. JONES
Executive Officer

KRJ:BVV:kg

Attachments: 4

⑤

George Deukmejian
(PRONOUNCED DUKE-MAY-GIN)
Attorney General
State of California

Please send reply to:
3580 Wilshire Blvd.,
Suite 800
Los Angeles, CA 90010
Telephone (213) 736-2273

February 24, 1982

Mr. E.L. Decker
5199 E. Pacific Coast Highway, #310
Long Beach, California 90804

Dear Mr. Decker:

This is in response to your letter regarding the Buena Vista Mine.

As of January 21st, we sent a letter to the mine owner to confirm the steps the owner had agreed to take to end this problem.

Prior to this letter the Regional Water Quality Control Board met with the mine owner to try and work out a solution. The agreement stipulates that the mine owner will empty the pond near his slag heap; take steps to divert as much water from the pond as possible in the interim; and, in the summer, hire a soil engineer to put a clay cap on the pond. This should alleviate any pollutants from entering the stream, since water will no longer be able to percolate through the mercury deposits below the pond.

According to the deputies in my office looking into the case, the agreement was amicable and the mine owner seems willing to carry out this plan of action.

I hope this clears up the situation to you and your daughter's satisfaction.

Most cordially,

George

George Deukmejian

cc: Mr. Bill Dalessi
Attorney at Law
444 W. Ocean Blvd.
The Fourth Floor
Long Beach, California 90802

cn

⑥

E.L.Decker

March 3, 1982

Kenneth R. Jones,
Executive Officer
California Regional Water Quality
Control Board,
Central Coast Region
1102 A Laurel Lane
San Luis Obispo, Ca. 93401

Dear Mr. Jones:

In a letter written by you to Attorney General George Deukmejian on October 5, 1981, you set out four possibilities for the elimination of the existing polution problem at the Buena Vista mine in San Luis Obispo County.

In a letter from Attorney General George Deukmejian dated February 24, 1982, the Attorney General advises that according to the deputies in his office looking into the case, an agreement was amicably reached between the mine owner and the deputies whereby the owner seems willing to carry out a plan of action.

The interest of the writer in this matter is that his daughter, Donna Harcourt, owns a ranch known as the Las Tablas Creek Ranch through which the poluted water of Las Tablas Creek runs.

The writer would be very much obliged to you if you would elaborate on your Item No. 2 in your letter of October 5, 1981 relative

⑦

the clay cover to be used over the slag pile. Are there native clays or adobe soils in the area which would serve the purpose enumerated in Item No. 2, or would something like bentonite be required to accomplish the purpose.

Any information in this connection would be very much appreciated, and the writer sincerely thanks you in advance for any effort you may expend.

Sincerely,

E. L. Decker

E. L. Decker

ELD-f

(8)

E. L. Decker

March 26, 1982

Kenneth R. Jones, Exec. Officer
California Regional Water Quality
Control Board,
Central Coast Region
1102 A Laurel Lane
San Luis Obispo, Ca. 93401

Dear Mr. Jones:

Further to my letter of March 3, I just learned last evening that the white bass being taken from Lake Nacimiento have been found to contain mercury in sufficient quantities to possibly have bad effects on humans who might eat them in some quantity. Could this possibly be the result of leeching from the Buena Vista mine?

I would greatly appreciate your comments on this as well as hearing from you relative my letter of March 3.

Thank you.

Sincerely,

E. L. Decker

E. L. Decker

ELD-f

9

STATE OF CALIFORNIA — RESOURCES AGENCY

EDMUND G. BROWN JR., Governor

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD—
CENTRAL COAST REGION
2 A LAUREL LANE
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 549-3147

April 12, 1982

E. L. Decker
5199 E. Pacific Coast Highway, #310
Long Beach, CA 90804

Dear Mr. Decker:

SUBJECT: BUENA VISTA MINE

Thank you for your letters of March 3 and March 26, 1982, expressing concern over the water quality impacts from Buena Vista Mine.

Referring to your March 3, 1982, letter, we did recommend placement of an impermeable clay cover over the slag pile. Clay was not specifically mentioned because of known natural deposits in close proximity to the mine, but rather because of its low permeability. We have not investigated, nor do we know, whether there is adequate clay available in the area. If local deposits of clay can be found which meet the permeability requirement when placed, and which are not likely to be degraded by the slag, then they may certainly be used. The intent of the permeable cap is to minimize water contacting slag and subsequent generation of leachate.

Concerning your March 26, 1982, letter, it is not probable mercury concentrations found in white bass at Nacimiento Lake can be the result of activities at Buena Vista Mine. Mercury is naturally present in other areas of the Nacimiento Lake watershed, perhaps throughout the watershed. Erosion and transport of the natural deposits may be the underlying cause of the mercuty appearing in the white bass. Information available at this time is not complete enough to pinpoint the origin of the mercury.

Again, thank you for your concern about water quality impacts of the Buena Vista Mine.

Very truly yours,

KENNETH R. JONES
Executive Officer

JG:bf

10

ROGERS & SHEFFIELD
ATTORNEYS AND COUNSELORS AT LAW
427 E. CARRILLO STREET
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B. KEITH MARTIN

WILLIAM K. ROGERS
MICHAEL S. LONDON, P.C.
ANTHONY C. FISCHER, P.C.
GLEN P. BURN

BERT G. WETHERBY
RETIRED

May 25, 1988

California Regional Water Quality Control Board
Central Coast Region
1102 Laurel Lane, Suite A
San Luis Obispo, California 93401

Attention: Mr. John Goni and Mr. Jay Cano

Re: Application for Waste Discharge Requirements
for Buena Vista Mines, Inc., and Carson Drift,
Buena Vista Mines, Inc.
MPDES No.: CA0049352/CA0049361

Dear Mr. Goni and Mr. Cano:

I represent Donna Harcourt, who, together with Security Pacific National Bank as Trustee of the Alma Decker Trust, is the owner or beneficial owner of Las Tablas Creek Ranch, a 1,000 acre holding located 12 miles outside of Paso Robles, California.

We are in receipt of your Notice of Public Hearing in connection with the application for waste discharge requirements for Buena Vista Mines, Inc., and Carson Drift, Buena Vista Mines, Inc..

Under separate cover, Ms. Harcourt is writing a letter detailing and outlining her sad and sorry past experiences with the mine in question and the effect it has had on Las Tablas Creek. I enclose an 8" x 10" color print which dramatically depicts what happens to the creek when the waste from the closed mine is discharged.

It appears abundantly clear from the history of the mine operation and the State of California's attempts to get the mine owner to respect the environment that we are dealing with an owner who can best be described as a scofflaw who has thus far successfully escaped both regulation of his operation and punishment for his disrespect for the law. It appears that one state agency or another has been attempting for nearly two decades to remedy the deplorable situation which exists because of the mine's pollution of Las Tablas Creek.

I have retained the services of an expert, Mike Hoover, to assist me and my client in our support of your efforts. Mr. Hoover informs me that the time horizon requiring compliance by October 1, 1989 is reasonable under the circumstances. However, Ms. Harcourt suggests that, in the interim year's period, the mine owner be required to pump out and haul away the discharge rather than permit it to go into Las Tablas Creek. This interim requirement would be short-lived and would bring about an immediate temporary cure to the problem.

Mr. Hoover also informs me that the standards set forth by your office are fair, just and reasonable. We support those standards, and we oppose any attempt on the part of the mine operator to weaken the standards.

The one area which I do not feel was adequately addressed by you is the area of sanctions. Since we are obviously dealing with a despoiler of the environment and a scofflaw who has evaded even the state Attorney General, I believe that sanctions should be set forth clearly in advance so as to give the mine owner notice of the cost of continuing to dally.

I suggest that you provide a fine of Five Hundred Dollars ($500.00) a day for each day beyond October 1, 1988 that the engineering report and implementation schedule for achieving full compliance is not completed. Further, I suggest that you provide that the mine operator be fined Two Thousand Five Hundred Dollars ($2,500.00) a day for each day after October 1, 1989 that full compliance is not achieved.

My client and I and Mr. Hoover look forward to appearing before the board on June 10th, 1988.

Very truly yours,

R Bruce MacKenzie

R. BRUCE MacKENZIE

cc: Ms. Donna Harcourt
Mr. Mike Hoover
RBM/de

⑫

(received 5/26/88)

Las Tablas Creek Ranch
Adelaide Route
Paso Robles, California 93446

Dear Mr. Cano,

The issue of the Buena Vista Mines, Inc. has long been a sore subject. I've sent you a copy of my letter to Marilyn Britton which covers only a minute amount of information, but with your knowledge and the active help of the Dept. of Fish and Game; I feel justice will prevail.

When the article (enclosed) came out in the Paso Robles Daily Press, I was convinced some action would be taken. Until now, nothing has been done to accomplish the ultimate goal: Clean water! How many people that fish Lake Nacimiento are aware of the health hazards of fish containing unsafe levels of Mercury? There is not one person I've discussed this issue with that is against cleaning up the mines.

So, with this letter and its enclosures, I hope and pray we can get this problem cleared up once and for all.

Yours truly,
Donna M. Harcourt

P.S. Marilyn Britton, as you probably know is with the S.L.O. County Farm Bureau.

P.S.S. Fish and Game Code 5650 states that "any material that is deleterious to fish or game is strictly illegal." Doesn't this say it all?
D.

[redacted] [redacted]

LAS TABLAS CREEK RANCH
ADELAIDE ROUTE
PASO ROBLES, CALIFORNIA 93446

To: Marilyn Britton of the Co., ~~County~~ SLO Farm Bureau

Dear Marilyn,

Rather than write on the subject of the Buena Vista Mine Pollution Problem I'll tell you briefly what the concerns of Adelaide landowners are. The Buena Vista mine has never been repaired since the early days when it was in full operation. It is privately owned. The mercury and Iron Oxide that is emitted from the mine each year is considered deleterious to fish and game; not to mention people. It flows down Las Tablas Creek and eventually spills into Lake Nacimiento. I'm enclosing an article published by the P.R. Daily Press and written by the State Water Resources Control Board.

I believe that this is the first time ever that there has been a public hearing on this issue. I also believe that we finally have something to sink our teeth into! I'm going ahead and giving copies of this Public Notice to Adelaide neighbors. I'm also hiring my attorney from Santa Barbara to help. He in turn is consulting with a geologist in Santa Barbara to do further studies.

Last night I spoke with Ral Koch (Fish and Game) and he was unaware of the hearing, but expressed himself by saying, "Its finally time!" He is notifying Mike Rugg in Yountville, Ca. Mr Rugg is a biologist with the Water Quality Control Board and has visited the mine several times.

This issue has been given the run around for many years. I have copies of letters in protest written ~~to~~ by my neighbor Jo Irving (who passed away 2 years ago). But, her son is very excited by this hearing.

Don Bonnheim has sent me photographs of the situation which shows the iron oxide joining or merging with Las Tablas Creek.

I could go on and on. Marilyn, but possibly we, the people of Adelaide, and the public in general who consume the fish out of Lake Nacimiento, could receive some help from the SLO Farm Bureau and get them to back us.

All the materials coming from Buena Vista Mine are, to my knowledge, toxic. And, in this day and age where clean water is an issue — it should be no exception.

I've written this in haste so you can become aware of the problem. If you wish contact ROBERT KOCH (FISH & GAME) 4341929 or
Mike Rugg 707 9445500 or
Todd Tognazzini (FISH & GAME) 238423
DONN BONNHEIM 2384497
Jim IRVING 2385435
JERRY & DORIS AHRENS 2310367

And the list goes on. Please do so.

I've fought this battle for 4 years. Even had Carol Hallett working on it. Deukmejian, when he was attorney general wrote to the Water Quality Control Board. Since then, I guess the wheels have been turning and the laws stricter.

Thank you for your attention

John Harcourt

P.S. Excuse my messy penmanship - but I'd like you to study this & see for yourself - and get your letter or letters out in protest - before May 26.

15

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B. KEITH MARTIN

WILLIAM K. ROGERS
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ANTHONY C. FISCHER, P.C.
JAMES E. HERMAN

BERT G. WETHERBY
RETIRED

October 14, 1988

RECEIVED
WATER QUALITY CONTROL BOARD
OCT 17 1988
1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

Mr. John Goni
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352)

Carson Drift, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049361)

Dear Mr. Goni:

On June 10, 1988, I attended and spoke before the Regional Board Meeting held at the Seaside City counsel chambers in Seaside, California, in connection with the above referenced mines. I appeared on behalf of Donna Harcourt, the owner of the Las Tablas Creek Ranch.

As I understand the results of that meeting, the Board gave Buena Vista Mines, Inc. until October 1, 1988 to produce an engineering report and plan which, in turn, will enable it to achieve full compliance with all conditions of the permit by October 1, 1989.

I assume that the report was submitted in a timely fashion. On behalf of my client, I ask that you supply me with a copy of said report.

Sent
10/21/88 by Maura
JFC

Cordially,

RB MacKenzie

R. BRUCE MacKENZIE

cc: Ms. Donna Decker Harcourt

RBM/de

⑯

ROGERS & SHEFFIELD
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RETIRED

January 19, 1989

CENTRAL COASTAL REGIONAL WATER QUALITY CONTROL BOARD
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JAN 20 1989
1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

Mr. John Goni
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352)

Carson Drift, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049361)

Dear Mr. Goni:

When Mr. Biaggini's report was filed in a relatively timely fashion last fall, we were encouraged in thinking that he would commence remedial work in rapid order.

My client, Donna Harcourt, informs me that she has recently visited the mine site and that nothing whatsoever has occurred. Once again this year we have experienced relatively little rain, so the problem has not been as bad this year as in the past. This is a fortunate situation in the sense that it is an ideal time for the remedial work to be commenced.

Please inform me what steps, if any, you have taken to obtain assurances from Mr. Biaggini that he is diligently pursuing the recommendations of his experts.

Cordially,

R. BRUCE MacKENZIE

cc: Ms. Donna Decker Harcourt

RBM/de

17

ROGERS & SHEFFIELD
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ANTHONY C. FISCHER, P.C.
JAMES E. HERMAN

BERT G. WETHERBY
RETIRED

7
~~January~~ 19, 1989
Feb.

Mr. John Goni
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352)

Carson Drift, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049361)

Dear Mr. Goni:

It has been three weeks now since inquired as to the status of affairs in connection with the above referenced matter.

I will appreciate a response to my inquiry at your earliest convenience.

Cordially,

R. BRUCE MacKENZIE

cc: Ms. Donna Decker Harcourt

RBM/de

CENTRAL COASTAL REGIONAL WATER QUALITY CONTROL BOARD
RECEIVED
FEB 21 1989
1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

(18)

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD —
CENTRAL COAST REGION
102 A LAUREL LANE
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 549-3147

March 2, 1989

Mr. Harold J. Biaggini, President
Buena Vista Mine, Inc.
1164 Market Street
Morro Bay, CA 93442

Dear Mr. Biaggini:

SUBJECT: BUENA VISTA MINE, SAN LUIS OBISPO COUNTY

This letter is in response to your September 30, 1988, report entitled, "Preliminary Geologic and Hydrologic Investigation Buena Vista Mine and Carson Drift", prepared by Mr. Marvin R. Niccum, geologist. This report does not satisfy all of the requirements of Waste Discharge Requirement Order No. 88-90 and Cease and Desist Order No. 88-91.

The report was submitted in response to this Board's Order No. 88-90 and Cease and Desist Order No. 88-91. Provision D.5. of Order No. 88-90 requires:

> "In order to insure compliance with this Order, the Discharger shall submit an engineering report with the implementation schedule by October 1, 1988, addressing compliance with all terms of this Order and with the standards for Mining Waste Management as specified in the California Regulatory Code, Title 23, Chapter 3, Subchapter 15, "Discharge of Wastes to Land", and Finding No. 6 of this Order. The implementation schedule must bring Buena Vista into full compliance by October 1, 1989."

Provisions of Order No. 88-91 require:

> "2. Buena Vista Mines, Inc., shall cease and desist from discharging waste in violation of Order No. 88-90, and shall achieve full compliance with standards for Mining Waste Management Units, according to the following compliance schedule:

Task	Due Date
Submit Engineering Report with implementation schedule describing the method for achieving full compliance with Order No. 88-90	October 1, 1988

> "4. All engineering reports required in conjunction with this Order shall include a statement by the Discharger or an authorized representative of the Discharger certifying under penalty of perjury under the laws of the State of California that the report is true, complete, and accurate. Technical reports and plans shall be prepared and signed by a registered geologist, registered engineer, or certified engineering geologist."

Specifically, the following deficiencies are noted:

1. Pages 7-10, 32-34, 39-43 and Appendix B discuss alternatives (options), but in insufficient detail to determine if the alternatives will bring the discharge into compliance with Order No. 88-90. In particular, all terms of Order No. 88-90 must be addressed, as well as sections of the California Regulatory Code listed in Finding No. 6, as follows:

   > Sections 2572(c),(d),(e),(f),(g),(h), Mining Waste Management Unit Siting and Construction Standards; Section 2573(a), Water Quality Monitoring for Mining Waste Management Units; and Sections 2574(a),(b),(d),(e),(f),(g), Closure and Post Closure Maintenance of Mining Waste Management Units.

2. An implementation schedule describing the method for achieving full compliance with Order No. 88-90, needs to be included in the report.

Keep in mind that Waste Discharge Requirements still require full compliance by October 1, 1989. Therefore, please submit an appropriate response satisfying conditions of Order Nos. 88-90 and 88-91 by April 3, 1989. We are sorry these comments could not be sent more promptly, but you are still required to adhere to your compliance schedule.

Please direct questions to John Goni or Jay Cano at this office.

Very truly yours,

William R. Leonard
WILLIAM R. LEONARD
Executive Officer

FJD/se biaggini.ltr/19

c: Bruce MacKenzie, P. O. Box 22257, Santa Barbara 93121-2257
Marvin Niccum, 3152 Sun Ridge Court, LaFayette 94549

20

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R. BRUCE MacKENZIE
JAMES E. HERMAN

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MICHAEL S. LONDON
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BERT G. WETHERBY
RETIRED

October 9, 1989

CENTRAL COASTAL REGIONAL WATER QUALITY CONTROL BOARD
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OCT 12 1989
1102 LAUREL LANE
SAN LUIS OBISPO

Mr. John Goni
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352),

Carson Drift, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049361)

Dear Mr. Goni:

On June 10, 1988, I attended and spoke before the Regional Board Meeting held at the Seaside City counsel chambers in Seaside, California. I appeared on behalf of Donna Harcourt, the owner of the Las Tablas Creek Ranch.

During the meeting, the Board gave Buena Vista Mines, Inc. until October 1, 1988 to produce an engineering report and plan which, in turn, would enable it to achieve full compliance with all conditions of the permit by October 1, 1989.

Please update me in connection with this matter.

Cordially,

R. Bruce MacKenzie

cc: Ms. Donna Decker Harcourt

RBM/de

21

ROGERS & SHEFFIELD
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SCOTT B. CAMPBELL

WILLIAM K. ROGERS
MICHAEL S. LONDON
B. KEITH MARTIN
PHILIP I. MONCHARSH
SAYRE MACNEIL

BERT G. WETHERBY
RETIRED

CENTRAL COASTAL REGIONAL WATER QUALITY CONTROL BOARD
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1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

December 1, 1989

Mr. John Goni
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352)

Carson Drift, Buena Vista Mines, Inc.
<u>San Luis Obispo County (Permit No. CA0049361)</u>

Dear Mr. Goni:

I represent Donna Harcourt, an owner of property through which Las Tablas Creek runs.

Ms. Harcourt and other property owners in the Las Tablas Creek area grow increasingly concerned about the Board's apparent lack of action against Buena Vista Mines, Inc. in connection with the creekbed pollution problem. Even though the Board gave Buena Vista Mines, Inc. until October 1, 1989 to complete the remedial work required, a trip to the creek evidences the fact that little progress has been made.

Over the past year or so I have written several letters to you inquiring about the status of affairs in connection with the above referenced matter. To date, I have received no reply.

I would greatly appreciate an update of the situation at hand. Please respond to this letter.

Cordially,

RB MacKenzie

R. BRUCE MacKENZIE

cc: Ms. Donna Decker Harcourt

RBM/de

22

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD —
CENTRAL COAST REGION
1102 A LAUREL LANE
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 549-3147

January 30, 1990

R. Bruce MacKenzie
Rogers & Sheffield
P.O. Box 22257
Santa Barbara, CA 93121-2257

Dear Mr. MacKenzie:

Subject: Buena Vista Mines, Inc.

Thank you for your letter asking about the status of the Buena Vista Mines, Inc., facilities. This Board and its staff are very concerned with these discharges. Enclosed is a letter to the mine owner, dated January 29, 1990, describing the progress at the facilities up to January 16, 1989.

While the owner has made many improvements, the facilities are not in compliance with the permit standards. This Board's staff anticipates presenting further enforcement action to the Board to force a completion of the work started. The mine owner has stated his intent to treat the water before it leaves the Buena Vista Mine property. We are presently working with the mine owner to establish a reasonable time schedule for full compliance with the standards. You will be advised of any proposed action by this Board.

Please direct questions to John Goni or Jay Cano at this office.

Very truly yours,

William R. Leonard
WILLIAM R. LEONARD
Executive Officer

JG:js

JG/1/js/3:harcrtl.ltr

Attach: letter to (Harold Biagginni, Buena Vista Mines, (1/29/90)

23

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, *Governor*

**CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD —
CENTRAL COAST REGION**
1102 A LAUREL LANE
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 549-3147

January 29, 1990

Mr. Harold Biaggini
Buena Vista Mines, Inc.
1164 Market Street
Morro Bay, CA 93442

Dear Mr. Biaggini:

SUBJECT: COMPLIANCE STATUS, CARSON DRIFT & BUENA VISTA MINE

This Board's staff inspected the Carson Drift and Buena Vista Mine on November 1, 1989, and January 16, 1990. As you are aware, these discharges were required to be in full compliance with permit conditions by October 1, 1989. The observations made during the inspections, compliance status, and actions required by you are as described below:

Carson Drift -

> The drift was found to be in compliance with the Regional Board NPDES Permit and Cease and Desist Order (Order Nos. 88-92 and 88-93, respectively), on November 1, 1989, as the drift has been plugged with concrete and the discharge eliminated. The plug is approximately seventy-five feet from the opening, but of a flow too small to measure or sample. It appeared this seepage was residual moisture draining from the sediment on the drift flow, and was of too little volume be of significance. No effects of the seepage were visible upon the adjacent south fork of Las Tablas Creek.
>
> The inspection on January 16, 1990, revealed the creek to be flowing from the recent rains. The creek was observed to be discolored, presumably by residual deposits from the old discharge, or the discharge had started once again. An inspection of the drift was not possible during this inspection.

Although the discharge may have been stopped, Monitoring and Reporting Program No. 88-92 shall remain in effect. Therefore, you are still required to monitor and inspect the drift and the creek. Effluent monitoring for settleable solids, pH, and suspended solids will not be needed as long as there is no discharge from the drift.

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A statement to that effect may be submitted in lieu of the above effluent monitoring. Toxicity Concentration shall continue to be monitored upstream and downstream of the discharge point.

Receiving Water Monitoring shall also be continued. However, as you requested, analyses for beryllium, cadmium, molybdenum, and selenium are no longer necessary. The monitoring report also shall include a summary of observations of the plug and whether liquid is escaping from the drift. A revised Monitoring and Reporting Program No. 88-92, incorporating the above requirements, is enclosed. Once we are assured the plug in the drift is not leaking and effects of the drift on the creek no longer exist, the monitoring may be reduced to periodic inspections of the drift to confirm there is no discharge. You will be notified when monitoring is no longer needed.

Buena Vista Mine -

> The November 1, 1989, inspection revealed the mine was not in compliance with the Regional Board NPDES Permit or Cease and Desist Order (Order Nos. 88-90 and 88-91, respectively), as the continued discharge was not meeting the permit standards. Some improvements were done and other improvements are in the process of being made to achieve compliance. The improvements included construction of a ground water cutoff trench at the upper end of the waste pile, regrading of the waste pile area, construction of diversion ditches to carry uncontaminated storm run-off around the waste pile, installation of a clay cap on the waste pile, and spreading of hay on the waste pile for erosion control purposes.
>
> The January 16, 1990, inspection revealed the clay cap was intact and the erosion control vegetation had sprouted on the regraded waste pile. However, Buena Vista Mine again was found not in compliance with permit standards, as the discharge was still occurring. The inspection also revealed water from the retort area had a reddish color.

Since the discharge from Buena Vista Mine does not meet the permit conditions, you are considered to be in violation at this facility. We appreciate the effort you made to achieve compliance, but the Cease and Desist Order required full compliance by October 1, 1989. The reports submitted to date do not give a final compliance date. This Board has no choice, but to take further enforcement action to set a final compliance date. Therefore, you are directed to: implement the enclosed monitoring program (revised as above to eliminate monitoring of beryllium, cadmium, molybdenum, and selenium); submit a current summary of conditions and compliance status at the Buena Vista Mine and Carson Drift; and submit a

25

schedule for achieving full compliance. The summary, compliance status and time schedule is due to this Board's staff by February 20, 1990. When we receive this schedule, we will recommend the Board adopt an enforcement order requiring compliance within a reasonable time.

Please direct questions to John Goni or Jay Cano at this office.

Very truly yours,

William R. Leonard
WILLIAM R. LEONARD
Executive Officer

JG/se

c: Steve Little, Earth Systems Environmental, Inc., 170-A
Granada Drive, San Luis Obispo, CA 93401

26

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B. KEITH MARTIN
SAYRE MACNEIL

BERT G. WETHERBY
RETIRED

RECEIVED
FEB 06 1990
1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

February 5, 1990

Mr. John Goni
Mr. Jay Cano
California Regional Water Quality Control Board
Central Coast Region
1102-A Laurel Lane
San Luis Obispo, California 93401

Re: Buena Vista Mine, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049352),

Carson Drift, Buena Vista Mines, Inc.
San Luis Obispo County (Permit No. CA0049361)

Dear Mr. Goni and Mr. Cano:

I am in receipt of a letter from William R. Leonard dated January 30, 1990, together with a copy of his letter to Harold Biaggini dated January 29, 1990.

It appears that, while Mr. Biaggini has made some efforts, the work has not been completed and the efforts have not yet produced compliance.

I am most interested, on behalf of my client, in learning what the time table is now for compliance and any proposed action by the Board.

Cordially,

R. Bruce MacKenzie

cc: Ms. Donna Decker Harcourt

RBM/de

FILE COPY (2

HWA : Buena Vista Mine

ROGERS & SHEFFIELD
ATTORNEYS AND COUNSELORS AT LAW
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B. KEITH MARTIN
PHILIP I. MONCHARSH
SAYRE MACNEIL

RETIRED
BERT G. WETHERBY
MICHAEL S. LONDON

May 7, 1991

California Regional Water Quality Control Board
Central Coast Region
1102 Laurel Lane, Suite A
San Luis Obispo, California 93401

CENTRAL COASTAL REGIONAL WATER QUAL
RECEIVED
MAY 08 1991
1102 LAUREL LANE
SAN LUIS OBISPO
CALIFORNIA

Attention: Mr. John Goni and Mr. Jay Cano

Re: Buena Vista Mines, Inc.
Compliance Status Request
<u>Order Nos. 88-90 and 88-91</u>

Dear Mr. Goni and Mr. Cano:

As you may recall, I represent Donna Harcourt, who, together with Security Pacific National Bank as Trustee of the Alma Decker Trust, is the owner or beneficial owner of Las Tablas Creek Ranch, a 1,000 acre holding located 12 miles outside of Paso Robles, California.

Back in June of 1988, the California Regional Water Quality Control Board initiated a monitoring program and issued the above numbered Cease and Desist Orders against Buena Vista Mines, Inc., ordering it to clean up the waste discharge seeping from its inactive mercury mine located approximately 12 miles west of Paso Robles at the intersection of Klau Mine Road and Cypress Mountain Drive, not far from and upstream of my client's ranch. The Board gave Mr. Biaggini, the owner of the mine, until October 1, 1989 to clean up the pollution.

Subsequently, on November 1, 1989 and again on January 16, 1990, the Board inspected the mine site and found that compliance with the Regional Board NPDES Permit or Cease and Desist Orders had not been achieved, as discharge from the mine was still occurring. At that time, the Board indicated that it would pursue further enforcement action.

On July 13, 1990, the Board held a hearing in the San Luis Obispo City Council Chambers. Item 10 on the agenda was the Buena Vista Mine issue. Evidently, the Board had again inspected the mine and found that the pollution had not been cleaned up in compliance with its Orders. At that meeting, Chairman James M. Stubacher indicated that Mr. Biaggini had been given his last chance to complete the cleanup and that the next step would be to either involve the Attorney General or impose Administrative Civil Liabilities. To my knowledge no such steps were ever taken.

Although nearly two years have passed since the Board's original October 1, 1989 clean up deadline date, it appears to the untrained eye that the pollution in the creek still remains. Ms. Harcourt informs me that she recently visited the mine site and found that the level of contamination appears to be the same as it was when the original Cease and Desist Orders were issued back in 1988. Of course, the recent rains may have caused more of the pollution to surface, making the creek's contaminated condition even more evident.

As I am sure you will agree, Mr. Biaggini has been given more than ample time and opportunity to clean up the mess caused by Buena Vista Mines. It is now time for the Board to use a strong hand in forcing the clean up.

Please investigate this matter and then bring it to the Board's immediate attention. Although Ms. Harcourt and the other property owners in the Las Tablas Creek area sincerely appreciate the steps taken by the Board to date, they grow increasingly concerned over Mr. Biaggini's non-compliance with the Board's Orders. Over three years have passed since the Board was first notified of the Buena Vista Mine pollution problem. Surely the Board must at some time take strong affirmative measures demanding that Mr. Biaggini comply with the clean up Orders. That time is <u>now</u>.

The Board's prompt attention to the concerns discussed herein will be greatly appreciated.

Cordially,

RB MacKenzie

R. Bruce MacKenzie

cc: Ms. Donna Harcourt
RBM/de

ATTACHMENT 5

HINA: BVM Inc.

PRODUCERS OF MERCURY

BUENA VISTA MINES, Inc.

HAROLD J. BIAGGINI, President
ED BIAGGINI III, Executive Vice President
1164 MARKET STREET
MORRO BAY, CALIFORNIA 93442

AREA CODE 805
OFFICES: 772-2158
MINE: 238-1981

(NOTE: 3/31/93)

RECEIVED
APR 02 1992
SAN LUIS OBISPO, CALIFORNIA

March 31, 1992

Mr. William Leonard, Executive Officer
California Regional Water Quality Control Board
Central Coast Region
81 Higuera St. #200
San Luis Obispo, CA 93401-5427

SUBJECT: BOARD LETTER DATED 3/25/92

Dear Mr. Leonard:

From the response we received regarding our request to rescind the NPDES permit No. 0049361 for the Carson Drift, it seems as if you completely ignored the information included in our letter of February 13, 1992.

As we explained to you in that letter, there was a very simple reason why the Carson Drift was discharging on April 19th, 1991. We had a break in a pipe. It was quickly repaired and there has not been a problem since. We have documented that event in other writings to the board. Why won't you acknowledge that fact?

Accidents like the one mentioned above can happen no matter what steps are taken to comply. This one small event is meaningless in the overall scheme of things. It is our responsibility to monitor the Carson Drift, not the RWQCB. It is our responsibility to request a NPDES permit, not the RWQCB.

The renewal fee for the permit is a ridiculous $1,331.00. This is a 270% increase from just 18 months ago. We cannot afford to pay this fee and under the circumstances we will not pay it. If you feel that it is absolutely necessary to make us keep this permit, maybe you should consider waiving the fees until renewal time.

We have spent tens of thousands of dollars to bring the Carson Drift into compliance with the board's orders. Don't you think it is time that the Staff of the RWQCB acknowledge our efforts and do the right thing?

Ed Biaggini III

Ed Biaggini III
Vice President
Buena Vista Mines, Inc.

April 30, 1992

Harold Biaggini
1148 Market St.
Morro Bay, CA 93442

Dear Mr. Biaggini:

This is in response to your question. There was some mine slag used to gravel portions of Dover Canyon Rd. One place was the portion between Elmer Cherry's field and Jim Sampson's field where the road goes in a southerly direction. The other portion that we remember is next to our corral. We don't remember the date, but it could be around twenty-five years ago.

Sincerely,
Louis & Phyllis Bergman
9070 Dover Canyon Rd.
Paso Robles, CA 93446

OFFICE OF THE

COUNTY COUNSEL

COUNTY OF SAN LUIS OBISPO
COUNTY GOVERNMENT CENTER, ROOM 386
SAN LUIS OBISPO, CA 93408
TELEPHONE 549-5400, 549-5401
FAX 549-4221
(AREA CODE 805)

JAMES B. LINDHOLM, JR.
COUNTY COUNSEL

ASSISTANT
JAC A. CRAWFORD

CHIEF DEPUTY
R. WYATT CASH

DEPUTIES
BRUCE M. COOK
JOHN PAUL DALY
THOMAS P. CONROY
JON M. JENKINS
JAMES B. ORTON
WARREN R. JENSEN
MARY A. TOEPKE
RAYMOND A. BIERING
A. EDWIN OLPIN
PATRICIA A. STEVENS
BARBARA G. TOLEIKIS
KATHY BOUCHARD

May 28, 1992

Thomas J. Rice, PhD
Soil Science Department
California Polytechnic State University
San Luis Obispo, CA 93407

Re: Clean Lakes Assistance Program for Lake Nacimiento

Dear Dr. Rice:

Your letter to James Lindholm, dated May 7, 1992, was referred to me for review and response. I have referred the matter to the County Engineer and have requested a response with regard to the types of documents which may be available in County Engineering pertaining to calcine retort slag or mine tailings from mercury mines in the Adelaida area between the period of 1957 through 1970. As soon as I have received a response from County Engineering, I will be in touch with you.

If you have any questions or if I can otherwise be of assistance to you, please let me know.

Very truly yours,

JAMES B. LINDHOLM, JR.
County Counsel

R. Biering

By: Raymond A. Biering
Deputy County Counsel

RAB:kt

cc: Clinton Milne, County Engineering
Supervisor Laurence L. Laurent
Supervisor Harry Ovitt

1313.kt
PENG
920846

SAN LUIS OBISPO COUNTY ENGINEERING DEPARTMENT

COUNTY GOVERNMENT CENTER • ROOM 207 • SAN LUIS OBISPO, CALIFORNIA 93408

CLINTON MILNE
County Engineer
PHONE (805) 549-5252 • FAX (805) 546-1229

GLEN L. PRIDDY
DEPUTY COUNTY ENGINEER
ENGINEERING SERVICES
NOEL KING
DEPUTY COUNTY ENGINEER
ADMINISTRATION

ROADS
TRANSIT
FLOOD CONTROL
WATER CONSERVATION
COUNTY SURVEYOR
SPECIAL DISTRICTS

June 8, 1992

Thomas J. ~~Y.~~ Rice
Cal Poly State University
Soil Science Department
San Luis Obispo, CA 93401

Subject: Cypress Mountain Drive and Klan Mine, Adelaida, Chimney Rock Roads, County Road No. 5265

Dear Mr. Rice:

The County Engineering Department does not have any records that would show use of mercury mine tailings for road base on the above mentioned roads.

In my position of Road Maintenance Superintendent beginning in 1979, I can say the County has not used any mercury mine tailings for this purpose. My predecessor, Loren Ballaugh, may have some knowledge of this situation. He lives in Arroyo Grande at 1740 Newport (489-2893).

Please excuse this late response. I was sure I had sent this to you the day after your telephone call on April 27 and thus no answer to your following letter. If I can be of further help, please feel free to call me.

Sincerely,

Dan Beck

DAN BECK
Road Maintenance Superintendent

dpb\rice.ltr.cmc

APPENDIX 5

Maps and Location Information for the Biological, Sediment, Soil, and Water Sample Sites in the Lake Nacimiento Watershed

Locations of sample sites in Las Tablas watershed

Sample site	Latitude/longitude	Legal description
Las Tablas Creek: Klau Branch & South Fork Sediment		
CM18S1	35°35'00"N/120°54'35"W	SW1/4,NE1/4,SE1/4, Sec. 17,T.27S.,R.10E.
CM20S1	35°36'37"N/120°55'15"W	SW1/4,SE1/4,SW1/4, Sec. 5,T.27S.,R.10E.
CM10S1	35°36'58"N/120°53'02"W	NE1/4,NW1/4,NW1/4, Sec. 3,T.27S.,R.10E.
CM21S1	35°36'12"N/120°53'43"W	NE1/4,SW1/4,SE1/4, Sec. 33,T.26S.,R.10E.
CM11S1	35°37'06"N/120°53'38"W	SW1/4,SE1/4,SE1/4, Sec. 33,T.26S.,R.10E.
CM16S1	35°35'48"N/120°54'37"W	NE 1/4,SW 1/4,SE 1/4, Sec. 8, T.27 S. R 10 E.
CM17S1	35°36'47"N/120°55'05"W	NE 1/4,SW 1/4,NW 1/4, Sec. 5, T.27 S. R 10 E.
CM15S1	35°37'12"N/120°54'18"W	NE 1/4,SW 1/4,SW 1/4, Sec. 33, T.26 S. R 10 E.
CM7S1	35°37'12"N/120°54'03"W	NE1/4,SE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
CM8S1	35°37'15"N/120°54'08"W	NW1/4,SE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
CM2S1	35°37'17"N/120°54'16"W	SE1/4,NW1/4,SW1/4, Sec. 33,T.26S.,R.10E.
LM9S1	35°37'52"N/120°54'23"W	NW1/4,NW1/4,NW1/4, Sec. 33,T.26S.,R.10E.
LM9S2	35°37'52"N/120°54'23"W	NW1/4,NW1/4,NW1/4, Sec. 33,T.26S.,R.10E.
Las Tablas Creek: North Fork Sediment		
A2S1	35°38'27"N/120°52'37"W	SE 1/4,NE 1/4,NE 1/4, Sec. 27, T.26 S. R 10 E.
CM5S1	35°37'22"N/120°53'15"W	SE1/4,NW1/4,SE1/4, Sec.33,T.26S.,R.10E.
CM4S1	35°37'25"N/120°53'42"W	NE1/4,NW1/4,SE1/4, Sec. 33,T.26S.,R.10E.
CM3S1	35°37'27"N/120°53'43"W	NE1/4,NW1/4,SE1/4, Sec. 33,T.26S.,R.10E.
LM1S1	35°37'34"N/120°53'44"W	SE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM3S1	35°37'37"N/120°53'47"W	NE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM4S1	35°37'38"N/120°53'47"W	NE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM5S1	35°37'42"N/120°53'55"W	NW1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.

Sample site	Latitude/longitude	Legal description
Las Tablas Creek: Upstream from Harcourt Dam		
LM14S1	35°38'10"N/120°55'09"W	SW1/4,NE1/4,SW1/4, Sec. 29,T.26S.,R.10E.
LM8S1	35°38'59"N/120°55'21"W	SE1/4,NW1/4,SW1/4, Sec. 20,T.26S.,R.10E.
LM20S1	35°39'35"N/120°55'42"W	NW1/4,NE1/4,NE1/4, Sec. 19,T.26S.,R.10E.
LM6S1	35°39'42"N/120°55'47"W	SW1/4,SW1/4,SE1/4, Sec. 18,T.26S.,R.10E.
LM31S1	35°40'49"N/120°56'21"W	SW.1/4,NE 1/4,SW 1/4, Sec. 7, T.26 S. R 10 E.
LM12S1	35°41'07"N/120°56'16"W	NW1/4,SE1/4,NW1/4, Sec. 7,T.26S.,R.10E.
Las Tablas Creek: Downstream from Harcourt Dam		
LM10S1	35°41'12"N/120°56'21"W	SE1/4,NW1/4,NW1/4, Sec.1,T.26S.,R.9E.
LM30S1	35°41'14"N/120°56'28"W	SE 1/4,NW 1/4,NW 1/4, Sec. 7, T.26 S. R 10 E.
LM11S1	35°41'21"N/120°56'50"W	NW1/4,NE1/4,NE1/4, Sec. 12,T.26S.,R.9E.
LM19S1	35°41'40"N/120°56'43"W	SE1/4,NE1/4,SE1/4, Sec. 1,T.26S.,R.9E.
LM17S1	35°41'55"N/120°56'59"W	SE1/4,SW1/4,NE1/4, Sec. 1,T.26S.,R.9E.
LM13S1	35°40'52"N/120°56'55"W	NW1/4,NE1/4,SE1/4, Sec. 12,T.26S.,R.9E.
Soils in the Las Tablas Creek Watershed		
CM14S1	35°37'30"N/120°53'20"W	NW 1/4,NW 1/4,SW 1/4, Sec. 34, T.26 S. R 10 E.
CM6S1	35°37'21"N/120°53'21"W	SE1/4,NW1/4,SE1/4, Sec. 33,T.26S.,R.10E.
LM2S1	35°37'33"N/120°53'46"W	SE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM7S1	35°37'35"N/120°53'37"W	NW1/4,SE1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM33S1	35°37'58"N/120°54'28"W	SW 1/4,SW 1/4,SW 1/4, Sec. 28, T.26 S. R 10 E.
CM9S1	35°37'12"N/120°54'07"W	NW1/4,SE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
LM15S1	35°38'09"N/120°55'14"W	SW1/4,NE1/4,SW1/4, Sec. 29,T.26S.,R.10E.
LM16S1	35°38'10"N/120°55'11"W	SW1/4,NE1/4,SW1/4, Sec. 29,T.26S.,R.10E.
LM23S1	35°39'29"N/120°55'06"W	SE1/4,NE1/4,NW1/4, Sec. 20,T.26S.,R.10E.
LM22S1	35°39'24"N/120°56'06"W	NE1/4,SE1/4,NW1/4, Sec. 19,T.26S.,R.10E.

Sample site	Latitude/longitude	Legal description
Soils in the Las Tablas Creek Watershed (continued)		
LM24S1	35°40'19"N/120°55'53"W	SE1/4,NW1/4,NE1/4, Sec. 18,T.26S.,R.10E.
LM32S1	35°40'52"N/120°56'06"W	NW 1/4,NW 1/4,SE 1/4, Sec. 7, T.26 S. R 10 E.
Las Tablas Creek Watershed: Soil Profiles		
LM40S1	35°37'37"N/120°53'43"W	NE1/4,SW1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM40S2	35°37'37"N/120°53'43"W	NE1/4,SW1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM40S3	35°37'37"N/120°53'43"W	NE1/4,SW1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM41S1	35°37'42"N/120°53'34"W	SW1/4,NE1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM41S2	35°37'42"N/120°53'34"W	SW1/4,NE1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM41S3	35°37'42"N/120°53'34"W	SW1/4,NE1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM41S4	35°37'42"N/120°53'34"W	SW1/4,NE1/4,NE1/4, Sec.33,T.26S.,R.10E.
LM42S1	35°37'59"N/120°53'29"W	SE1/4,SE1/4,SE1/4, Sec.28,T.26S.,R.10E.
LM42S2	35°37'59"N/120°53'29"W	SE1/4,SE1/4,SE1/4, Sec.28,T.26S.,R.10E.
LM42S3	35°37'59"N/120°53'29"W	SE1/4,SE1/4,SE1/4, Sec.28,T.26S.,R.10E.
LM43S1	35°37'56"N/120°54'27"W	SW1/4,SW1/4,SW1/4, Sec.28,T.26S.,R.10E.
LM44S1	35°37'58"N/120°54'30"W	SE1/4,SE1/4,SE1/4, Sec.29,T.26S.,R.10E.
LM45S1	35°38'11"N/120°55'13"W	SW1/4,NE1/4,SW1/4, Sec.29,T.26S.,R.10E.
LM45S2	35°38'11"N/120°55'13"W	SW1/4,NE1/4,SW1/4, Sec.29,T.26S.,R.10E.
LM45S3	35°38'11"N/120°55'13"W	SW1/4,NE1/4,SW1/4, Sec.29,T.26S.,R.10E.
LM46S1	35°38'13"N/120°55'16"W	SW1/4,NE1/4,SW1/4, Sec.29,T.26S.,R.10E.

Sample site	Latitude/longitude	Legal description
Las Tablas Creek watershed: Road Samples		
RD1S1	35°37'53"N/120°54'2"W	NE1/4,NW1/4,NW1/4, Sec.33,T.26S.,R.10E.
RD2S1	35°38'01"N/120°54'28"W	SW1/4,SW1/4,SW1/4, Sec.28,T.26S.,R.10E.
RD3S1	35°38'17"N/120°55'12"W	SW1/4,NE1/4,SW1/4, Sec.29,T.26S.,R.10E.
RD4S1	35°38'32"N/120°55'09"W	NW1/4,SE1/4,NW1/4, Sec.29,T.26S.,R.10E.
RD5S1	35°38'44"N/120°55'10"W	SW1/4,NE1/4,NW1/4, Sec.29,T.26S.,R.10E.
RD6S1	35°39'14"N/120°55'14"W	NE1/4,NW1/4,SW1/4, Sec.20,T.26S.,R.10E.
RD7S1	35°39'20"N/120°55'02"W	SE1/4,SE1/4,NW1/4, Sec.20,T.26S.,R.10E.
RD8S1	35°35'04"N/120°54'36"W	SW1/4,NE1/4,SE1/4, Sec.17,T.27S.,R.10E.

Locations of sample sites in Lake Nacimiento Watershed

Sample site	Latitude/longitude	Legal description
Naci. River sites: upstream from lake from north to south		
CP1S1	36°00'47"N/121°25'11"W	Los Padres Nat. For. Fort H-L # 42.3, 86.4
CP2S1	36°00'47"N/121°25'14"W	LOS PADRES NAT. FOR. F.H.L. 42.3,86.6
CP3S1	36°00'42"N/121°25'08"W	LOS PADRES NAT. FOR. F.H.L. 42.4,86.4
AP4S1	35°55'40"N/121°16'38"W	San Miguelito Grant Fort H-L # 55.4,77.2
J1S1	35°53'20"N/121°13'56"W	San Miguelito Grant Fort H-L # 59.5,72.8
BP4S1	35°52'24"N/121°13'00"W	El Piojo Grant Fort H-L # 61.0,71.2
BP5S1	35°50'52"N/121°11'43"W	NE 1/4,SW 1/4,NE 1/4, Sec. 15, T.24 S. R 7 E.
BP7S1	35°49'48"N/121°08'49"W	NW 1/4,NE 1/4,SW 1/4, Sec. 19, T.24 S. R 8 E.
B2S1	35°47'55"N/121°06'28"W	NE 1/4,NW 1/4,SE 1/4, Sec. 33, T.24 S. R 8 E.
B7S1	35°47'13"N/121°05'28"W	SE 1/4,SW 1/4,NE 1/4, Sec. 3, T.25 S. R 8 E.
B8S1	35°45'53"N/121°04'50"W	SE 1/4,NE 1/4,SW 1/4, Sec. 11, T.25 S. R 8 E.
Tributaries to Naci. River from north to south		
AP2S1	35°58'40"N/121°21'03W	San Miguelito Grant Fort H-L #48.5,83.5
AP3S1	35°56'53"N/121°18'16"W	San Miguelito Grant Fort H-L # 52.7,79.5

Sample site	Latitude/longitude	Legal description
Tributaries to Naci. River from north to south (continued)		
AP1S1	35°57'28"N/121°57'38"W	San Miguelito Grant Fort H-L # 55.3,80.4
AP5S1	35°55'56"N/121°16'37"W	San Miguelito Grant Fort H-L # 55.4,77.6
AP6S1	35°53'27"N/121°15'39"W	San Miguelito Grant Fort H-L # 57.2,73.5
J2S1	35°53'34"N/121°13'17"W	El Piojo Grant Fort H-L # 59.5,73.3
BP1S1	35°51'11"N/121°08'17"W	SW 1/4,SE 1/4,SE 1/4, Sec. 7, T.24 S. R 8 E.
BP2S1	35°51'11"N/121°08'28"W	SE 1/4,SW 1/4,SE 1/4, Sec. 7, T.24 S. R 8 E.
BP3S1	35°51'08"N/121°08'36"W	SW 1/4,SW1/4,SE 1/4, Sec. 7, T.24 S. R 8 E.
BP6S1	35°50'06"N/121°09'10"W	NW 1/4,NW 1/4,NW 1/4, Sec. 19, T.24 S. R 8 E.
B1S1	35°47'37"N/121°05'27"W	SE 1/4,SE 1/4,SW 1/4, Sec. 34, T.24 S. R 8 E.
B3S1	35°47'57"N/121°06'15"W	NE 1/4,SW 1/4,SE 1/4, Sec. 33, T.24 S. R 8 E.
B4S1	35°45'58"N/121°02'26"W	NE 1/4,NW 1/4,SE 1/4, Sec. 7, T.25 S. R 9 E.
B5S1	35°45'40"N/121°00'42"W	NE 1/4,NW 1/4,NW 1/4, Sec. 16, T.25 S. R 9 E.
B6S1	35°46'20"N/121°00'08"W	NW 1/4,SE 1/4,NE 1/4, Sec. 9, T.25S. R 9 E.
PS1S1	35°44'37"N/121°05'48"W	SE 1/4,NE 1/4,NW 1/4, Sec.22, T.25 S. R 8 E.
PS3S1	35°42'10"N/121°04'09"W	NW 1/4,NW 1/4,NW 1/4, Sec. 1, T.26 S. R 8 E.
PS4S1	35°42'08"N/121°04'05"W	SE 1/4,NW 1/4,NW 1/4, Sec. 1, T.26 S. R 8 E.
PS5S1	35°43'34"N/121°04'08"W	NW 1/4,NW 1/4,NW 1/4, Sec. 1, T.26 S. R 8 E.
PS2S1	35°44'33"N/121°05'48"W	NE 1/4,SE 1/4,NW 1/4, Sec. 22, T.25 S. R 8 E.
PS6S1	35°43'30"N/121°03'07"W	NW 1/4,NW 1/4,SE 1/4, Sec. 25, T.25 S. R 8 E.
Tributaries to Naci. Lake from north to south		
LM34S1	35°41'52"N/120°58'52"W	NE 1/4,NE 1/4,SE 1/4, Sec. 3, T.26 S. R 9 E.
TRM1S1	35°45'05"N/120°59'07"W	NE 1/4,SW 1/4,SE 1/4, Sec. 15, T.25 S. R 9 E.
A1S1	35°43'08"N/120°52'22"W	NE 1/4,NE 1/4,NE 1/4, Sec. 34, T.25 S. R 10 E.
A2S1	35°38'27"N/120°52'37"W	SE 1/4,NE 1/4,NE 1/4, Sec. 27, T.26 S. R 10 E.

Locations of sample sites in Lake Nacimiento

Sample site	Latitude/longitude	Legal description
Lake Nacimiento Sediment and Water Samples		
LK1S1	35°44'26"N/121°02'37"W	NE1/4,NE1/4,SW1/4 Sec.19,T.25S.,R.9E.
LK1W1	35°44'29"N/121°02'34"W	NE1/4,NE1/4,SW1/4 Sec.19,T.25S.,R.9E.
LK1W2	35°44'29"N/121°02'34"W	NE1/4,NE1/4,SW1/4 Sec.19,T.25S.,R.9E.
LK2S1	35°44'37"N/120°59'55"W	NE1/4,SE1/4,NE1/4, Sec.21,T.25S.,R.9E.
LK2W1	35°44'37"N/120°59'55"W	NE1/4,SE1/4,NE1/4, Sec.21,T.25S.,R.9E.
LK2W2	35°44'37"N/120°59'55"W	NE1/4,SE1/4,NE1/4, Sec.21,T.25S.,R.9E.
LK3S1	35°42'48"N/120°56'57"W	SW1/4,SE1/4, NE1/4 Sec.36,T.25S.,R.9E.
LK3W1	35°42'48"N/120°56'57"W	SW1/4,SE1/4, NE1/4 Sec.36,T.25S.,R.9E.
LK3W2	35°42'48"N/120°56'57"W	SW1/4,SE1/4, NE1/4 Sec.36,T.25S.,R.9E.
LK4S1	35°43'51"N/120°57'33"W	SE1/4,NW1/4,NW1/4, Sec.25,T.25S.,R.9E.
LK4W1	35°43'51"N/120°57'33"W	SE1/4,NW1/4,NW1/4, Sec.25,T.25S.,R.9E.
LK4W2	35°43'51"N/120°57'33"W	SE1/4,NW1/4,NW1/4, Sec.25,T.25S.,R.9E.
LK5S1	35°44'36"N/120°57'27"W	NW1/4,SE1/4,NW1/4, Sec.24,T.25S.,R.9E.
LK5W1	35°44'36"N/120°57'27"W	NW1/4,SE1/4,NW1/4, Sec.24,T.25S.,R.9E.
LK5W2	35°44'36"N/120°57'27"W	NW1/4,SE1/4,NW1/4, Sec.24,T.25S.,R.9E.
LK6S1	35°43'45"N/120°55'45"W	NW1/4,SE1/4,NE1/4, Sec.30,T.25S.,R.10E.
LK6W1	35°43'45"N/120°55'45"W	NW1/4,SE1/4,NE1/4, Sec.30,T.25S.,R.10E.
LK6W2	35°43'45"N/120°55'45"W	NW1/4,SE1/4,NE1/4, Sec.30,T.25S.,R.10E.
LK7S1	35°44'51"N/120°55'48"W	NE1/4,NW1/4,NE1/4, Sec.19T.25S.,R.10E.
LK7W1	35°44'51"N/120°55'48"W	NE1/4,NW1/4,NE1/4, Sec.19,T.25S.,R.10E.
LK7W2	35°44'51"N/120°55'48"W	NE1/4,NW1/4,NE1/4, Sec.19,T.25S.,R.10E.
LK8S1	35°43'54"N/120°52'56"W	SE1/4,NE1/4,NE1/4, Sec.29,T.25S.,R.10E.

Sample site	Latitude/longitude	Legal description
Lake Nacimiento Sediment and Water Samples (continued)		
LK8W1	35°43'54"N/120°52'56"W	SE1/4,NE1/4,NE1/4, Sec.29,T.25S.,R.10E.
LK8W2	35°43'54"N/120°52'56"W	SE1/4,NE1/4,NE1/4, Sec.29,T.25S.,R.10E.
LK9W1	35°44'34"N/120°54'07"W	SW1/4,SE1/4,NW1/4, Sec.21,T.25S.,R.10E.
LK9W2	35°44'34"N/120°54'07"W	SW1/4,SE1/4,NW1/4, Sec.21,T.25S.,R.10E.
LK10W1	35°45'28"N/120°53'42"W	NE1/4,SW1/4,NW1/4, Sec.15,T.25S.,R.11E.
LK10W2	35°45'28"N/120°53'42"W	NE1/4,SW1/4,NW1/4, Sec.15,T.25S.,R.11E.
LK11W1	35°43'47"N/120°55'42"W	NW1/4,SE1/4,NE1/4, Sec.30,T.25S.,R.10E.
LK12W1	35°44'17"N/120°54'27"W	SE1/4,NE1/4,SE1/4, Sec.20,T.25S.,R.10E.
LK13W1	35°45'24"N/120°54'22"W	NW1/4,SW1/4,NW1/4, Sec.16,T.25S.,R.11E.

Locations of water sample sites in Las Tablas watershed

Sample site	Latitude/longitude	Legal description
Las Tablas Creek: Klau Branch & South Fork Sediment		
CM10W1	35°36'58"N/120°53'02"W	NE1/4,NW1/4,NW1/4, Sec. 3,T.27S.,R.10E.
C11W1	35°37'06"N/120°53'38"W	SW1/4,SE1/4,SE1/4, Sec. 33,T.26S.,R.10E.
CM12W1	35°37'23"N/120°53'58"W	NE1/4,NE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
CM7W1	35°37'12"N/120°54'03"W	NE1/4,SE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
CM8W1	35°37'15"N/120°54'08"W	NW1/4,SE1/4,SW1/4, Sec. 33,T.26S.,R.10E.
CM2W1	35°37'17"N/120°54'16"W	SE1/4,NW1/4,SW1/4, Sec. 33,T.26S.,R.10E.
LM9W1	35°37'52"N/120°54'23"W	NW1/4,NW1/4,NW1/4, Sec. 33,T.26S.,R.10E.
Las Tablas Creek North Fork		
CM13W1	35°37'28"N/120°53'23"W	NW1/4,NW1/4,SW1/4, Sec. 34,T.26S.,R.10E.
LM4W1	35°37'38"N/120°53'47"W	NE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
CM1W1	35°37'26"N/120°53'45"W	NE1/4,NW1/4,SE1/4, Sec. 33,T.26S.,R.10E.
LM29W1	35°37'32"N/120°53'44"W	SE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM29W2	35°37'32"N/120°53'44"W	SE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.

Sample site	Latitude/longitude	Legal description
Las Tablas Creek: Klau Branch & South Fork Sediment (continued)		
LM1W1	35°37'34"N/120°53'44"W	SE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM3S1	35°37'37"N/120°53'47"W	NE1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
LM5W1	35°37'42"N/120°53'55"W	NW1/4,SW1/4,NE1/4, Sec. 33,T.26S.,R.10E.
Las Tablas Creek: Upstream from Harcourt Dam		
LM28W1	35°38'27"N/120°55'28"W	NW1/4,SW1/4,NW1/4, Sec. 29,T.26S.,R.10E.
LM8S1	35°38'59"N/120°55'21"W	SE1/4,NW1/4,SW1/4, Sec. 20,T.26S.,R.10E.
LM21W1	35°39'12"N/120°55'23"W	NE1/4,NW1/4,SW1/4, Sec. 20,T.26S.,R.10E.
LM23W1	35°39'29"N/120°55'06"W	SE1/4,NE1/4,NW1/4, Sec. 20,T.26S.,R.10E.
LM20S1	35°39'35"N/120°55'42"W	NW1/4,NE1/4,NE1/4, Sec. 19,T.26S.,R.10E.
LM6S1	35°39'42"N/120°55'47"W	SW1/4,SW1/4,SE1/4, Sec. 18,T.26S.,R.10E.
LM25W1	35°40'33"N/120°56'01"W	SW1/4,SW1/4,SE1/4, Sec. 7,T.26S.,R.10E.
LM12S1	35°41'07"N/120°56'16"W	NW1/4,SE1/4,NW1/4, Sec. 7,T.26S.,R.10E.
Las Tablas Creek: Downstream from Harcourt Dam		
LM10S1	35°41'12"N/120°56'21"W	SE1/4,NW1/4,NW1/4, Sec.1,T.26S.,R.9E.
LM26W1	35°41'15"N/120°56'27"W	NW1/4,NW1/4,NW1/4, Sec. 7,T.26S.,R.10E.
LM27W1	35°41'17"N/120°56'37"W	NW1/4,NW1/4,NW1/4, Sec. 7,T.26S.,R.10E.
LM11S1	35°41'21"N/120°56'50"W	NW1/4,NE1/4,NE1/4, Sec. 12,T.26S.,R.9E.
LM18W1	35°41'40"N/120°56'55"W	SW1/4,NE1/4,SE1/4, Sec. 1,T.26S.,R.9E.
LM19S1	35°41'40"N/120°56'43"W	SE1/4,NE1/4,SE1/4, Sec. 1,T.26S.,R.9E.
LM13S1	35°40'52"N/120°56'55"W	NW1/4,NE1/4,SE1/4, Sec. 12,T.26S.,R.9E.

NOTE: The general locations for the biological samples are indicated as circles on Figures 2, 11, 15, 20, 21, 22, and 24. The specific sediment, soil and water sample sites are indicated by sample numbers and arrows.

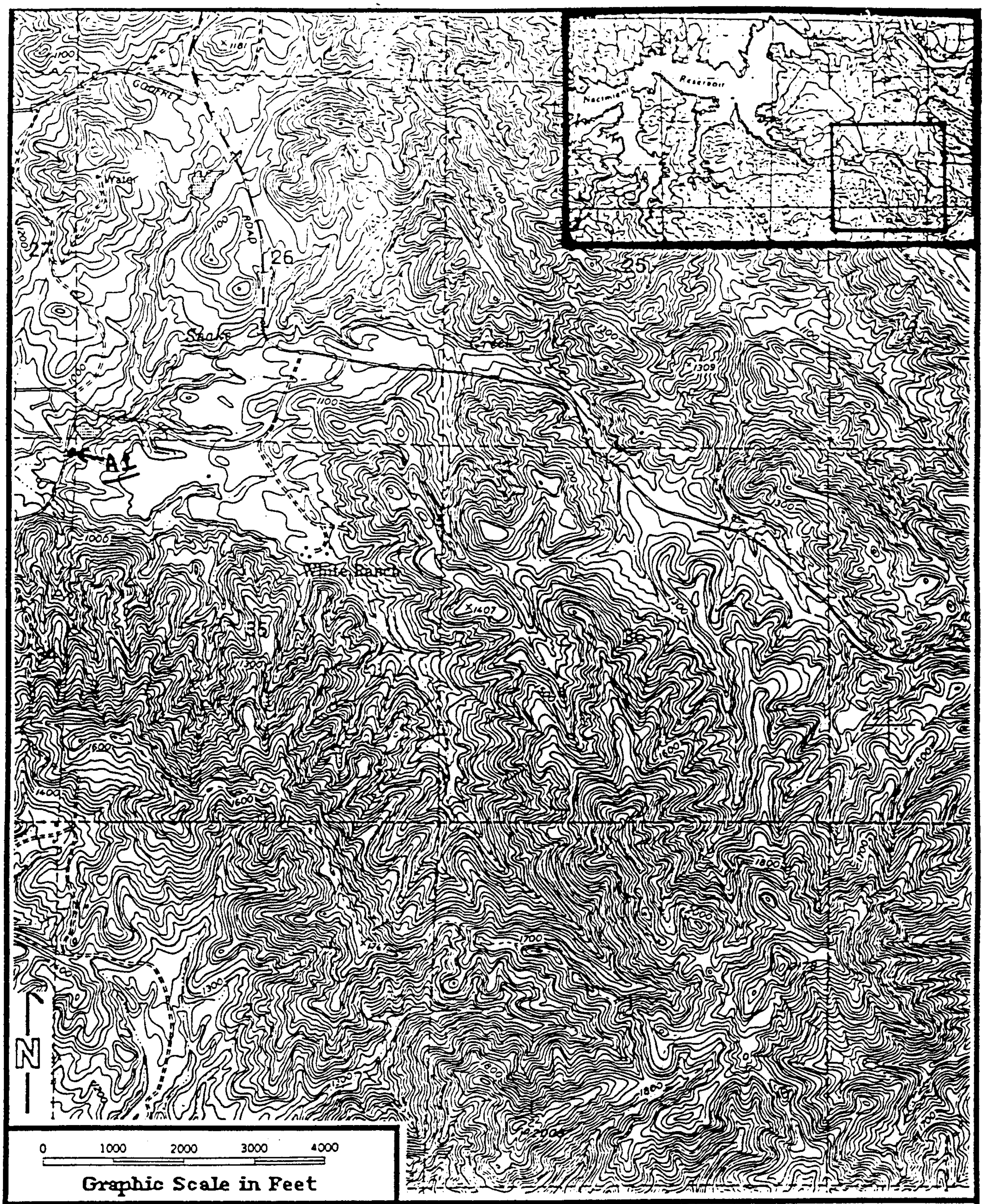

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Figure 1: Sample
Locations in Adelaida
Topo. Quad.

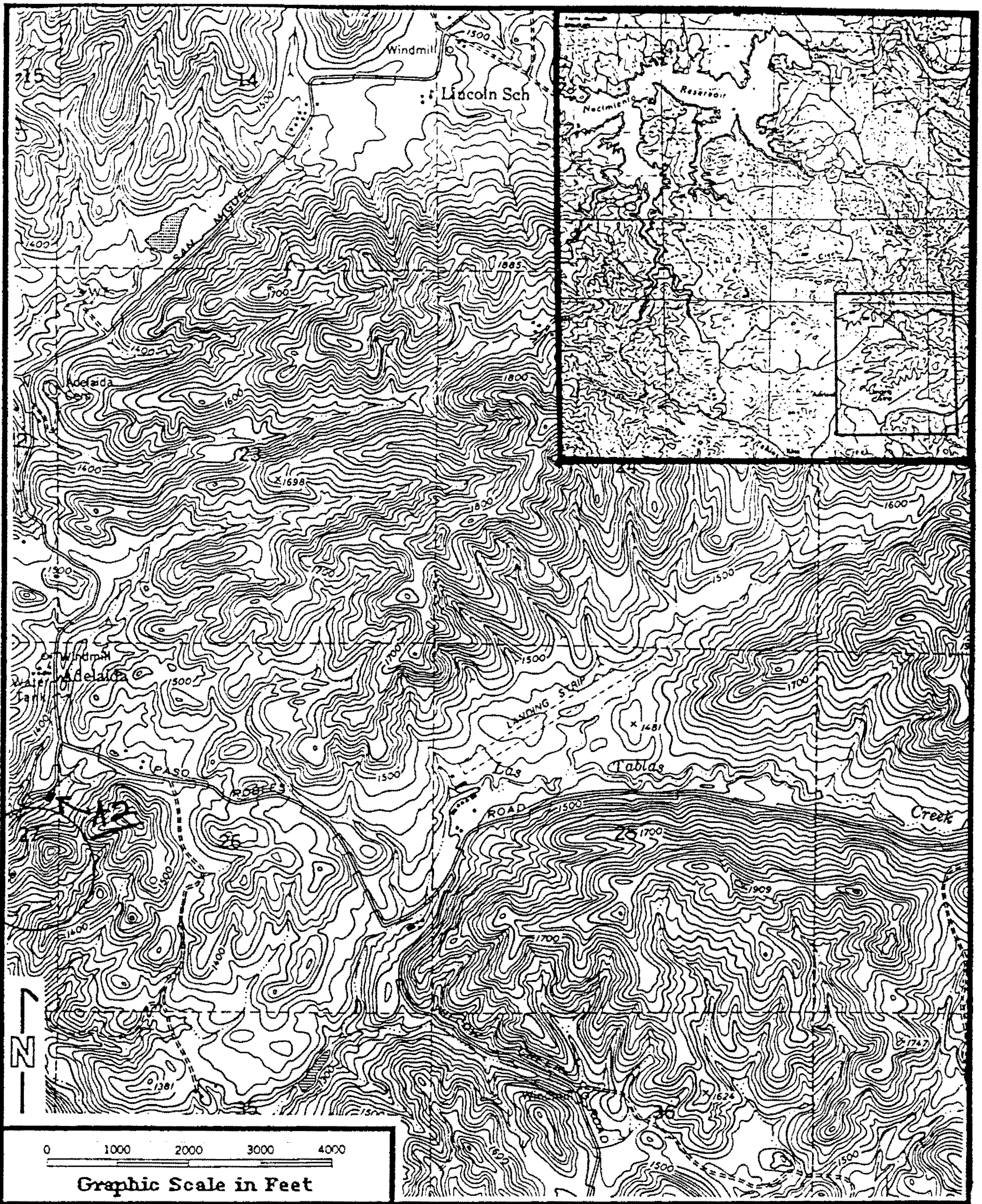

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Figure 2: Sample Locations in Adelaida Topo. Quad.

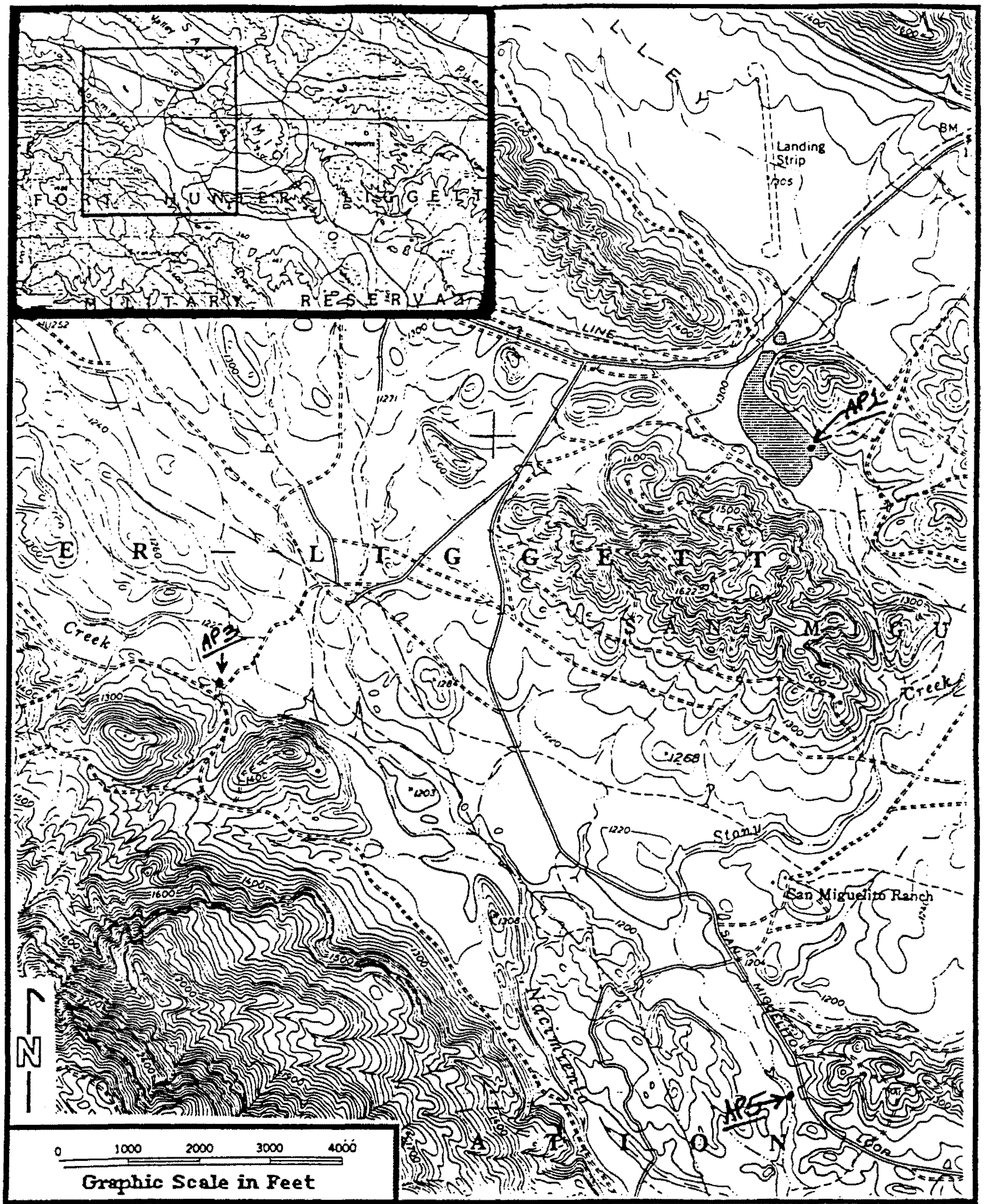

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Figure 3: Sample
Locations in Alder
Peak Topo. Quad.

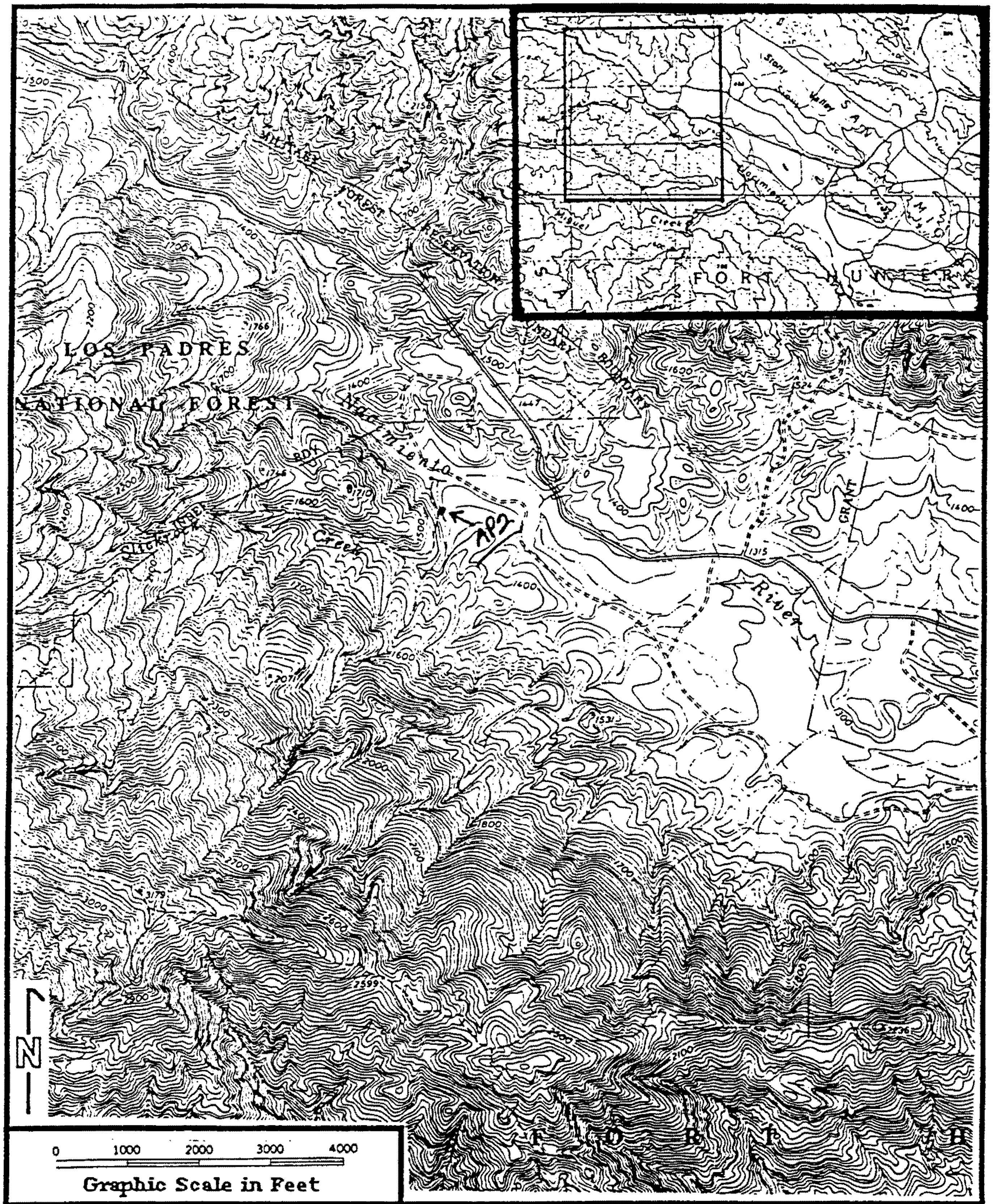

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Figure 4: Sample
Locations in Alder
Peak Topo. Quad.

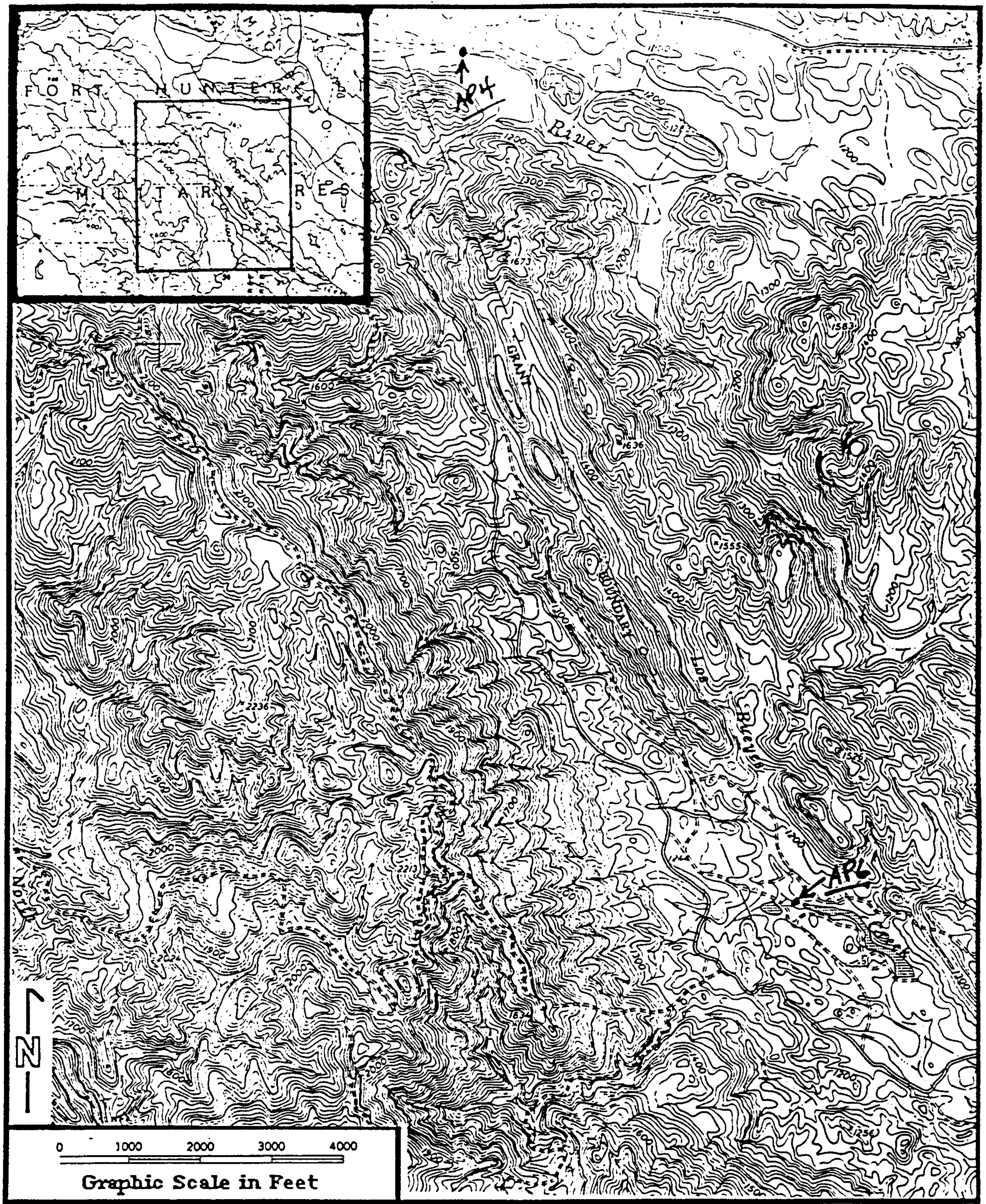

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Figure 5: Sample Locations in Alder Peak Topo. Quad.

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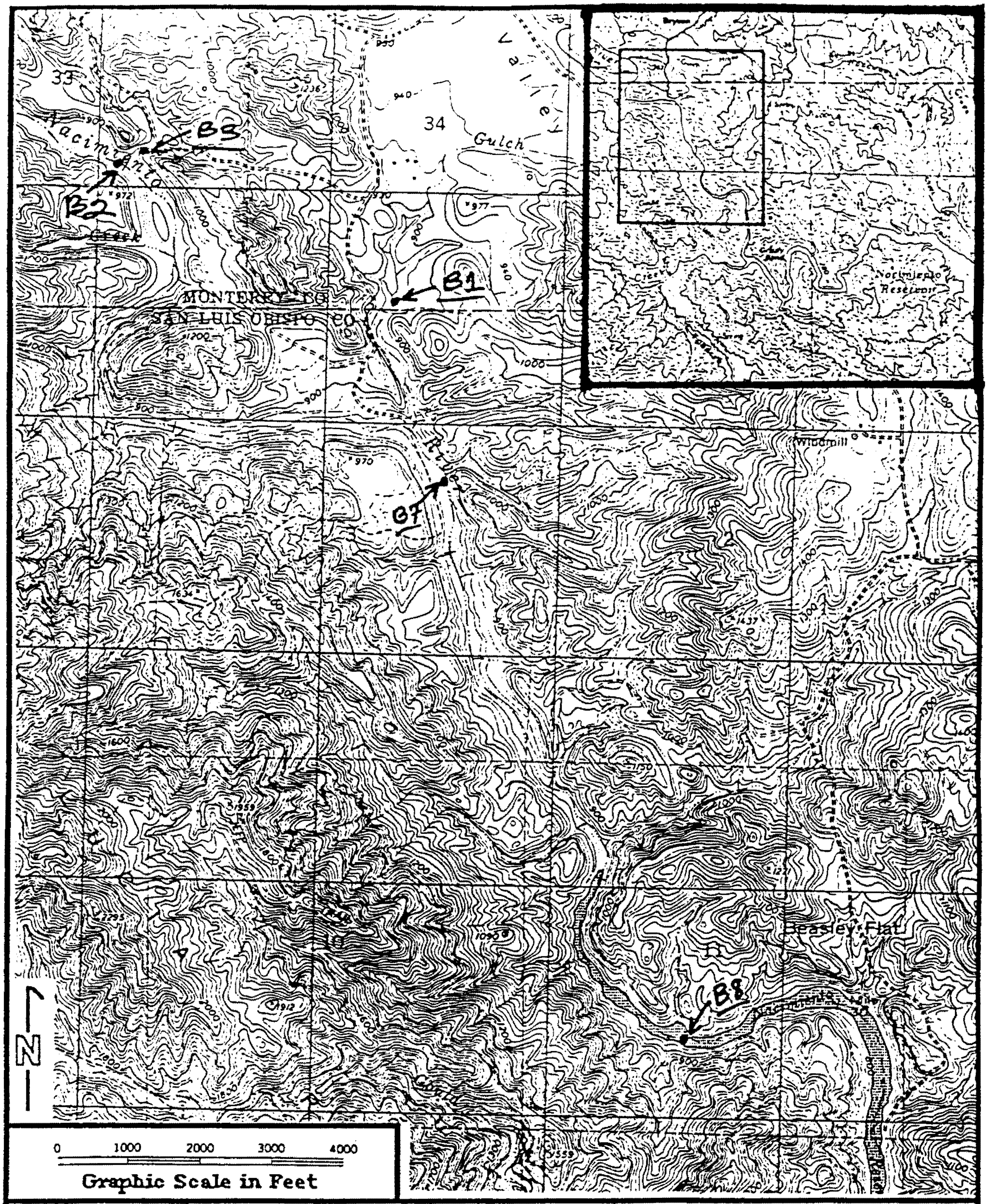

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Figure 6: Sample
Locations in Bryson
Topo. Quad.

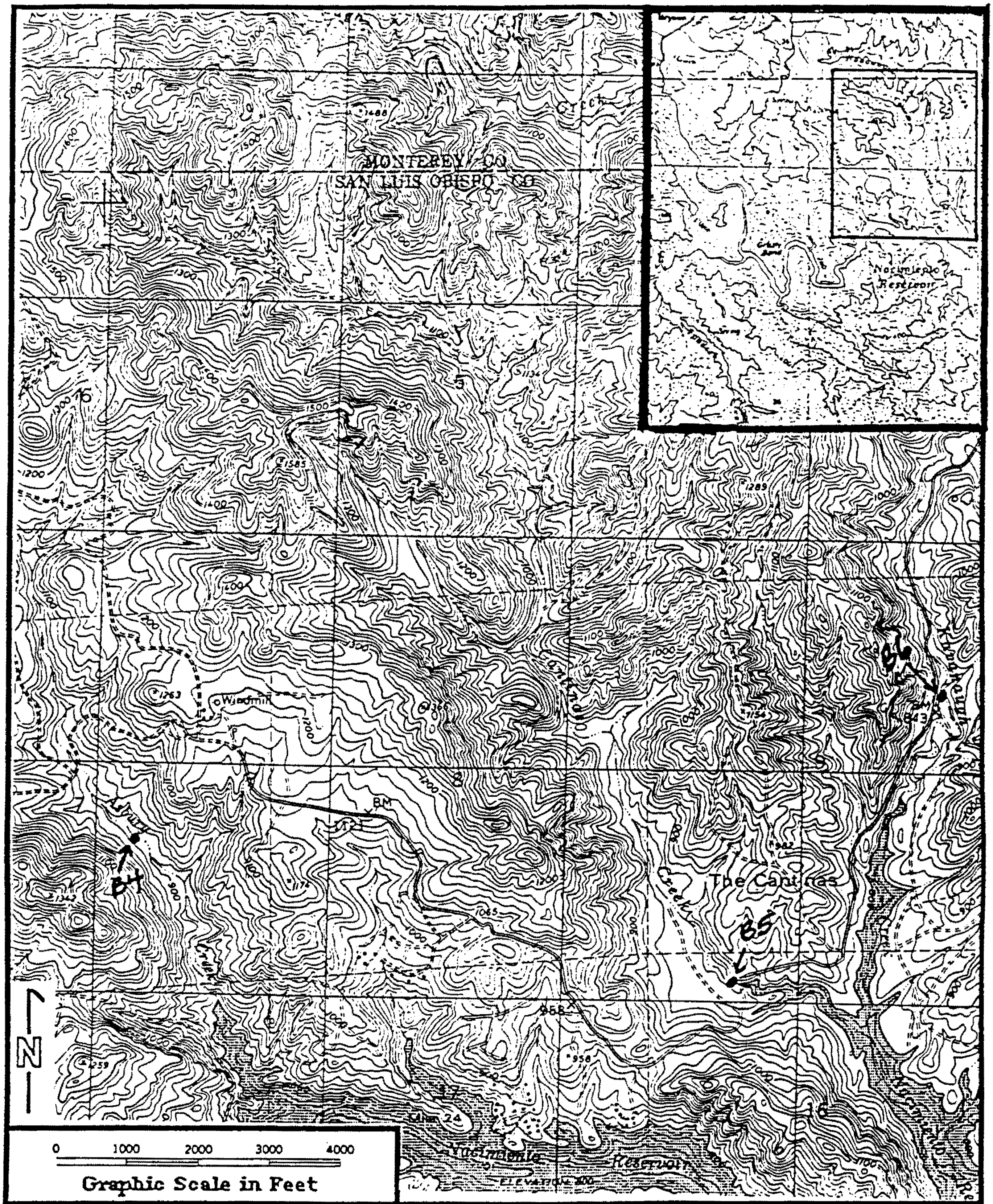

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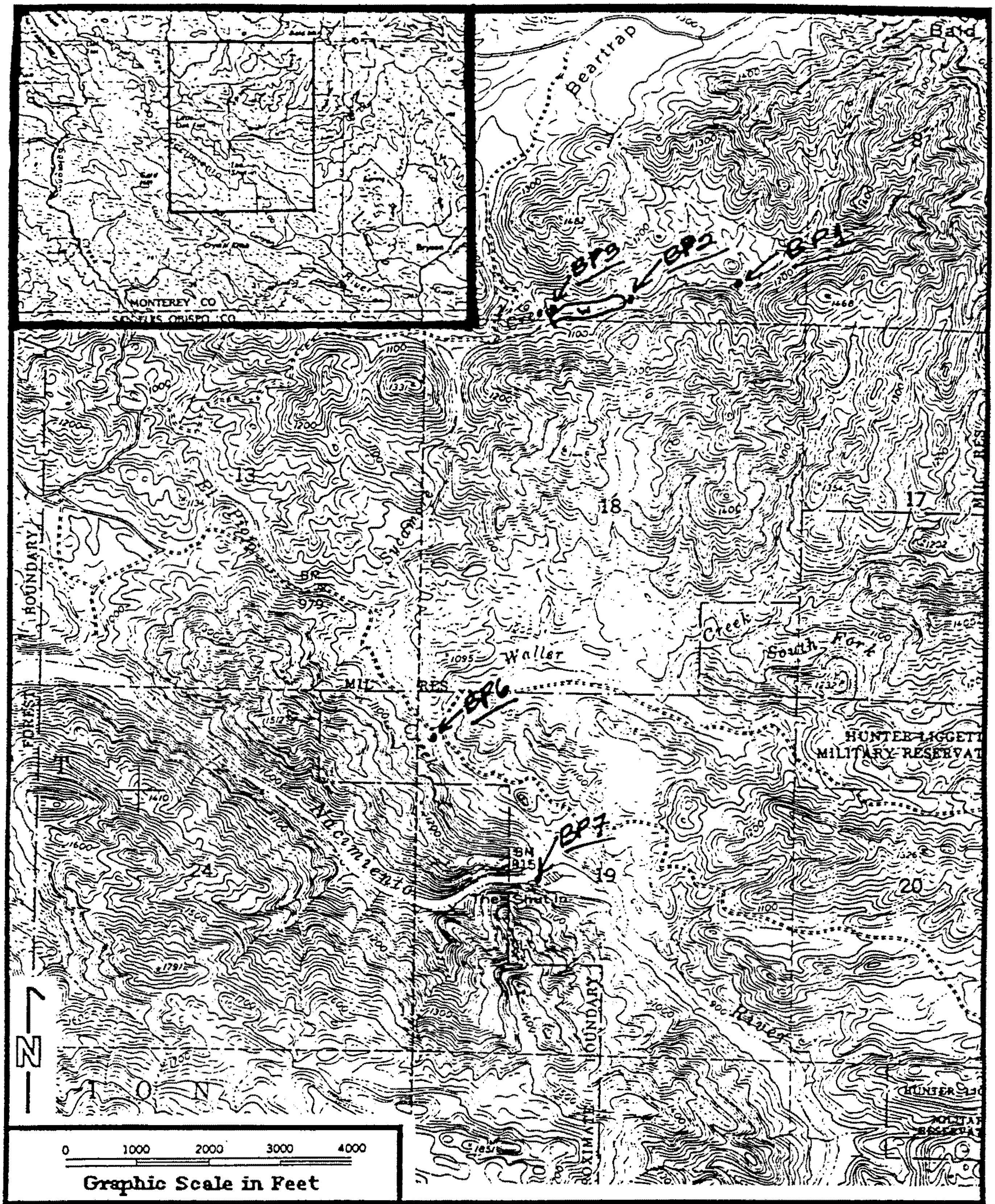
Figure 7: Sample
Locations in Bryson
Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 8: Sample Locations in Burnett Peak Topo. Quad.
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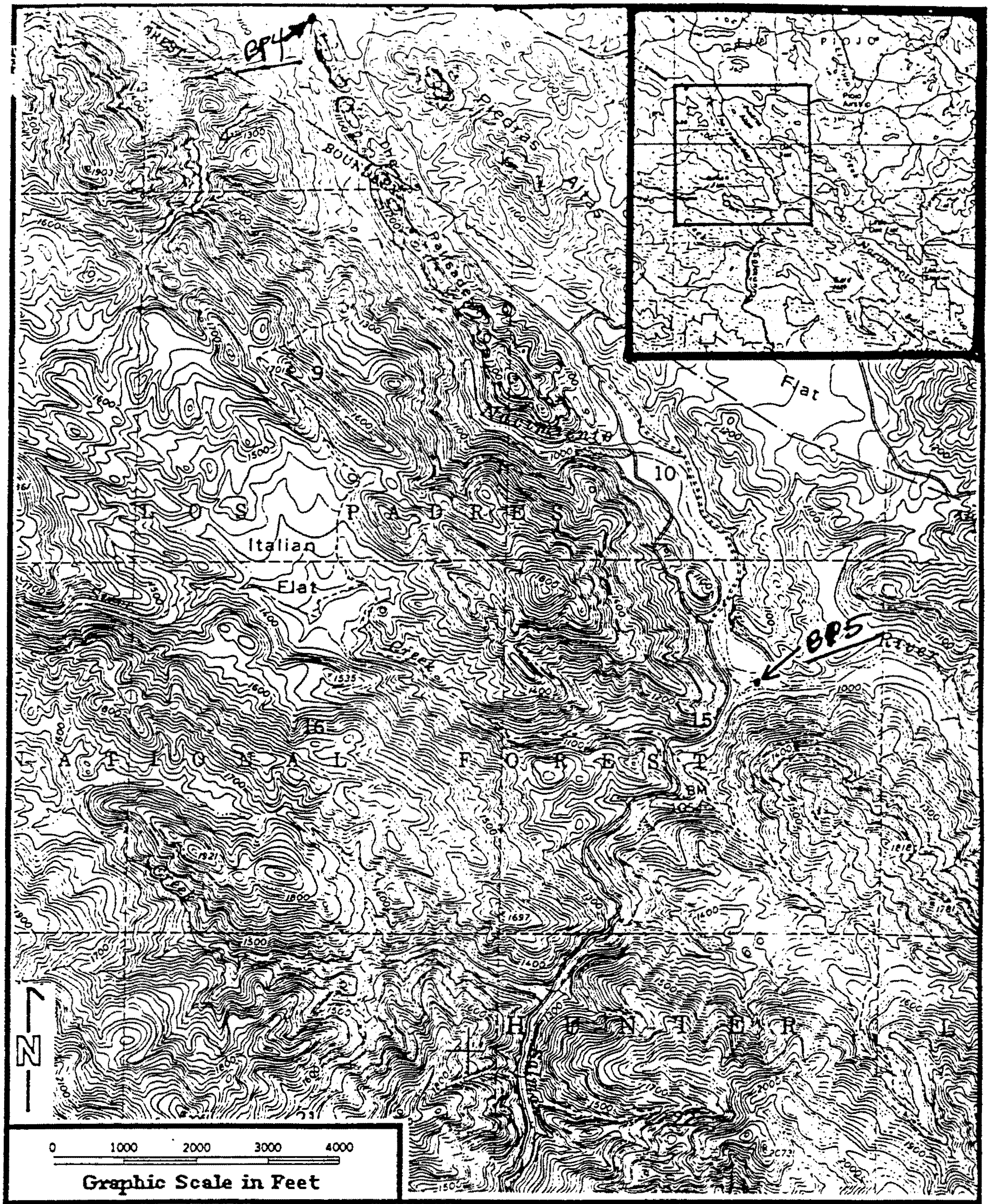

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Figure 9: Sample Locations in Burnett Peak Topo. Quad.

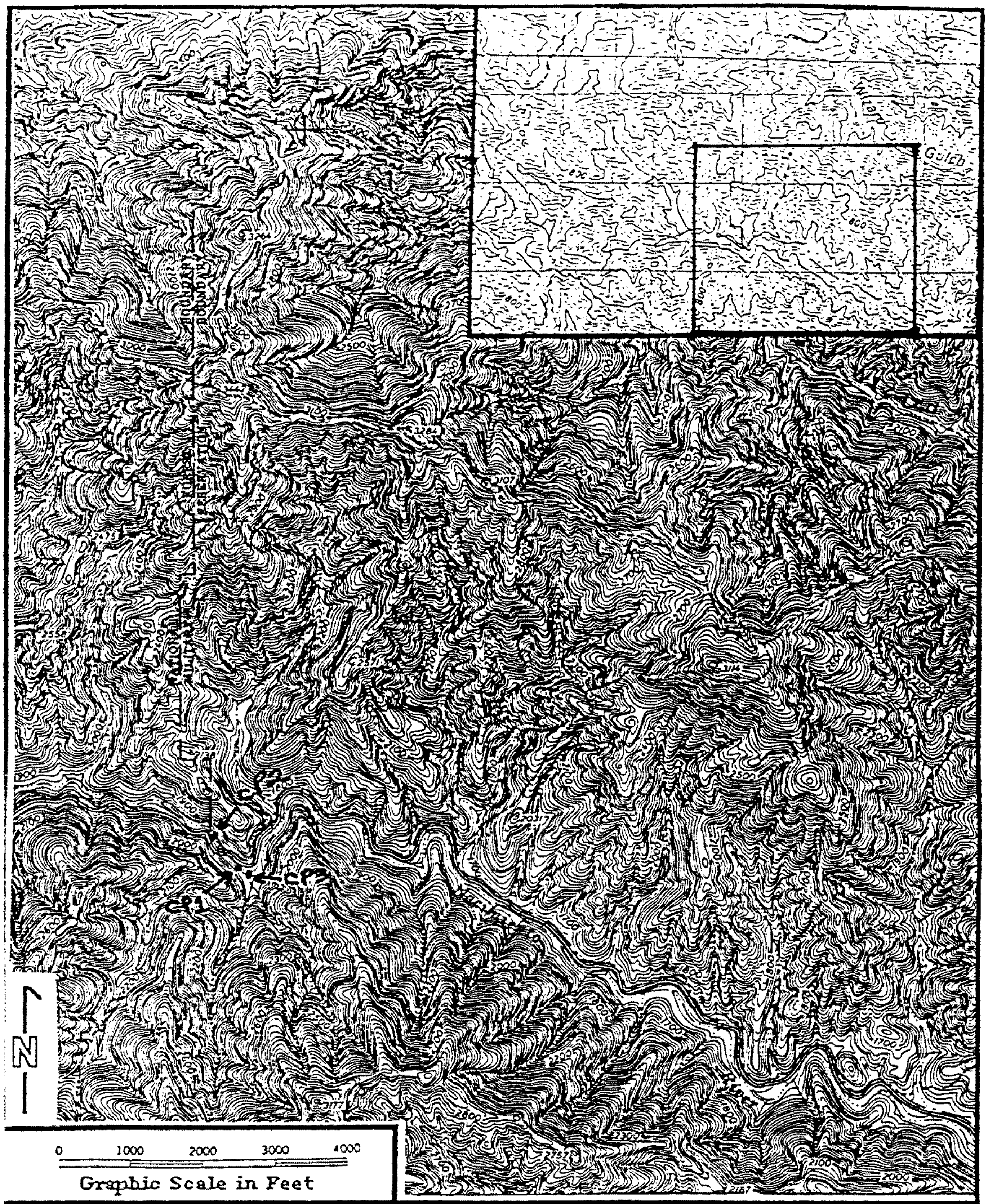

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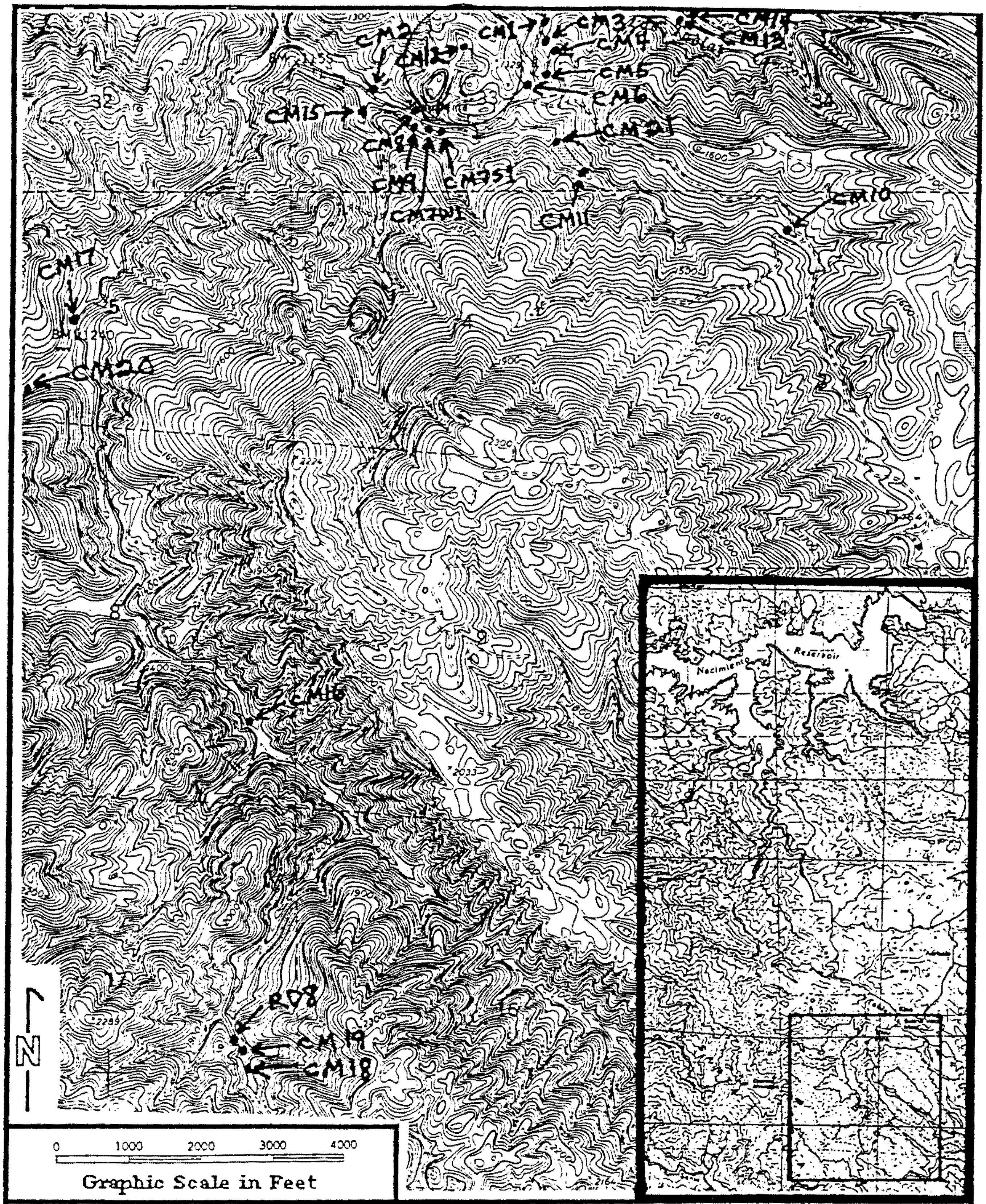
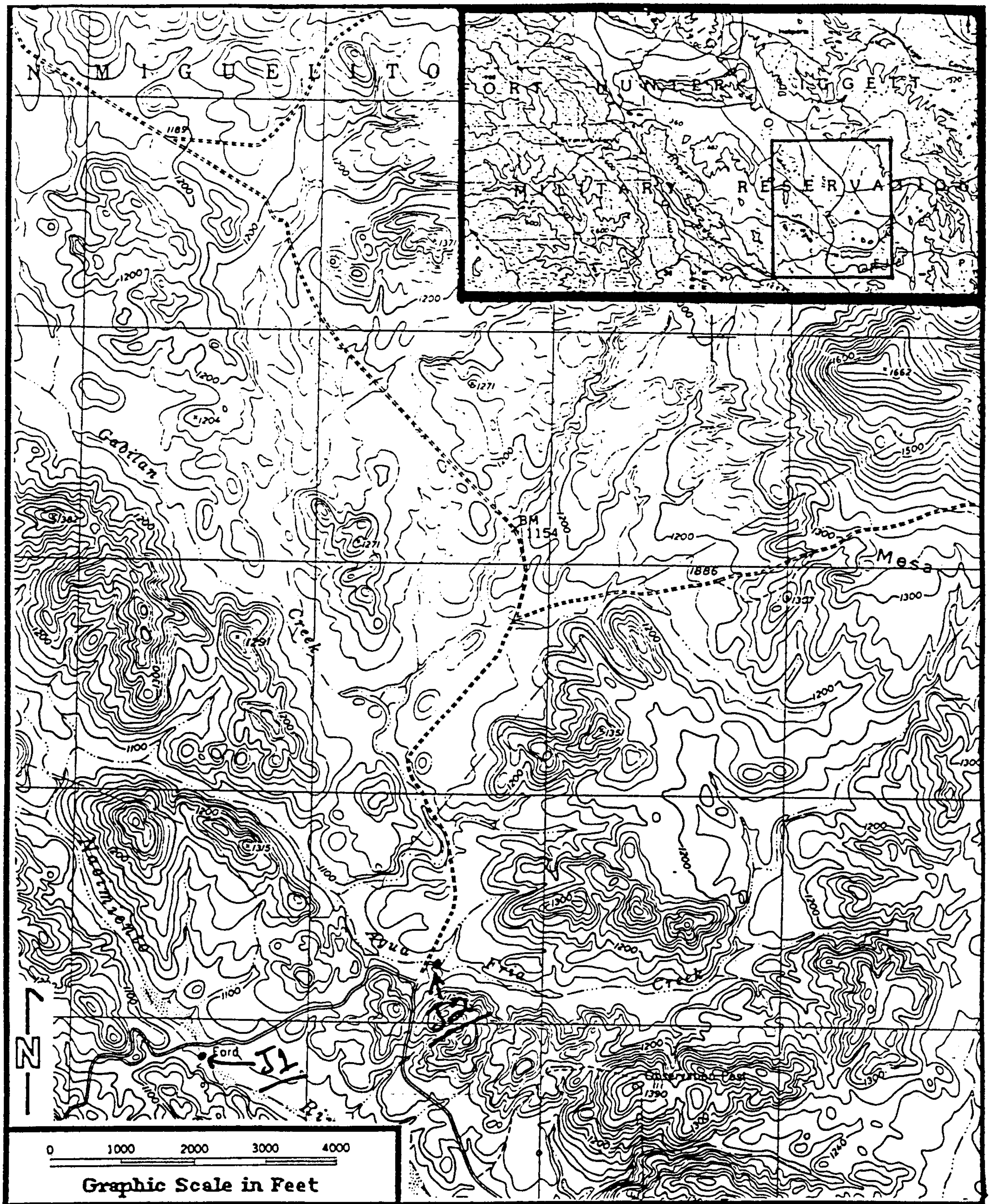
Figure 10: Sample
Locations in Cone
Peak Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 11: Sample Locations in Cypress Mountain Topo. Quad.
California Polytechnic State University		



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 12: Sample Locations in Jolon Topo. Quad.
California Polytechnic State University		

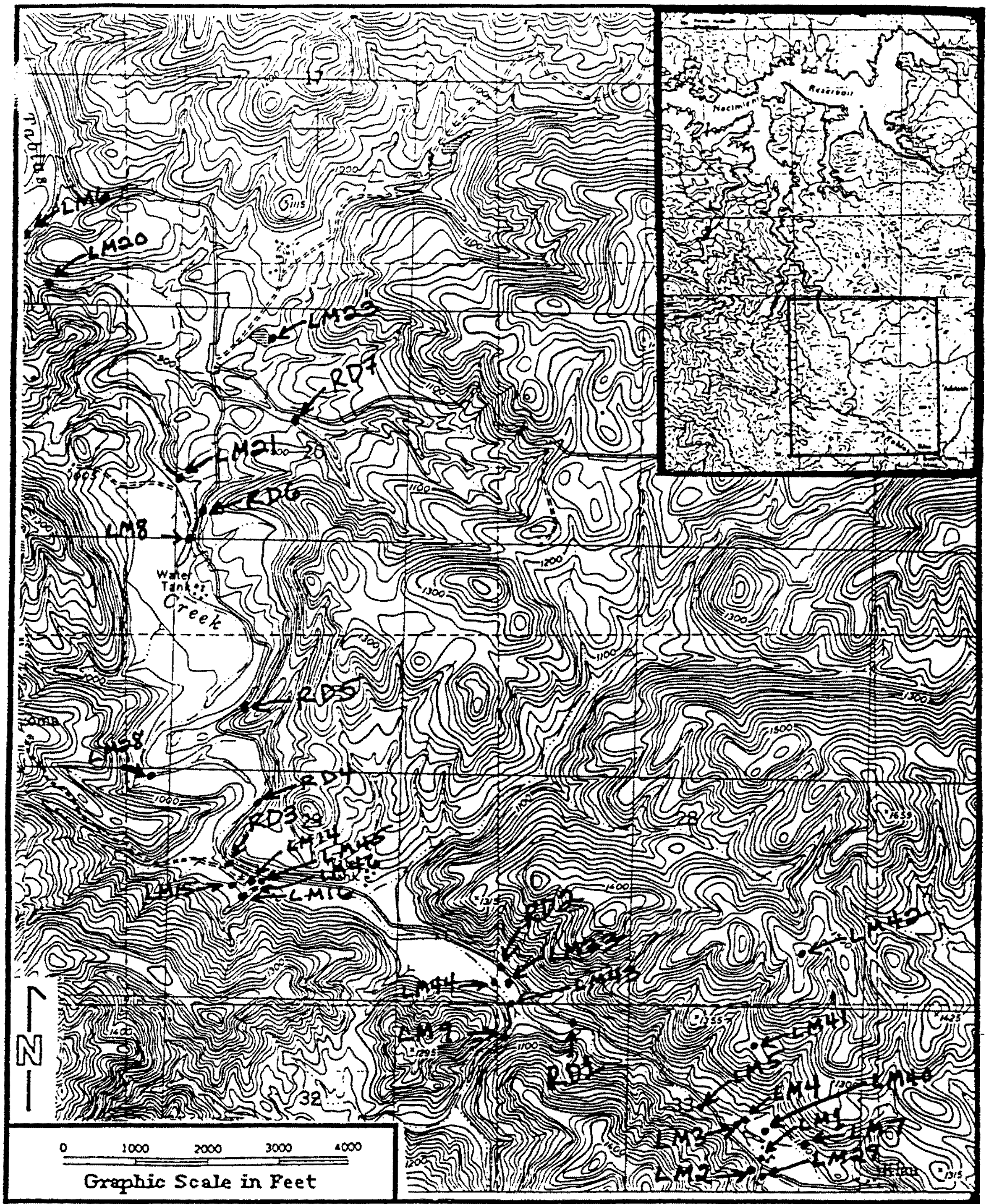


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Figure 13: Sample
Locations in Lime
Mountain Topo. Quad.

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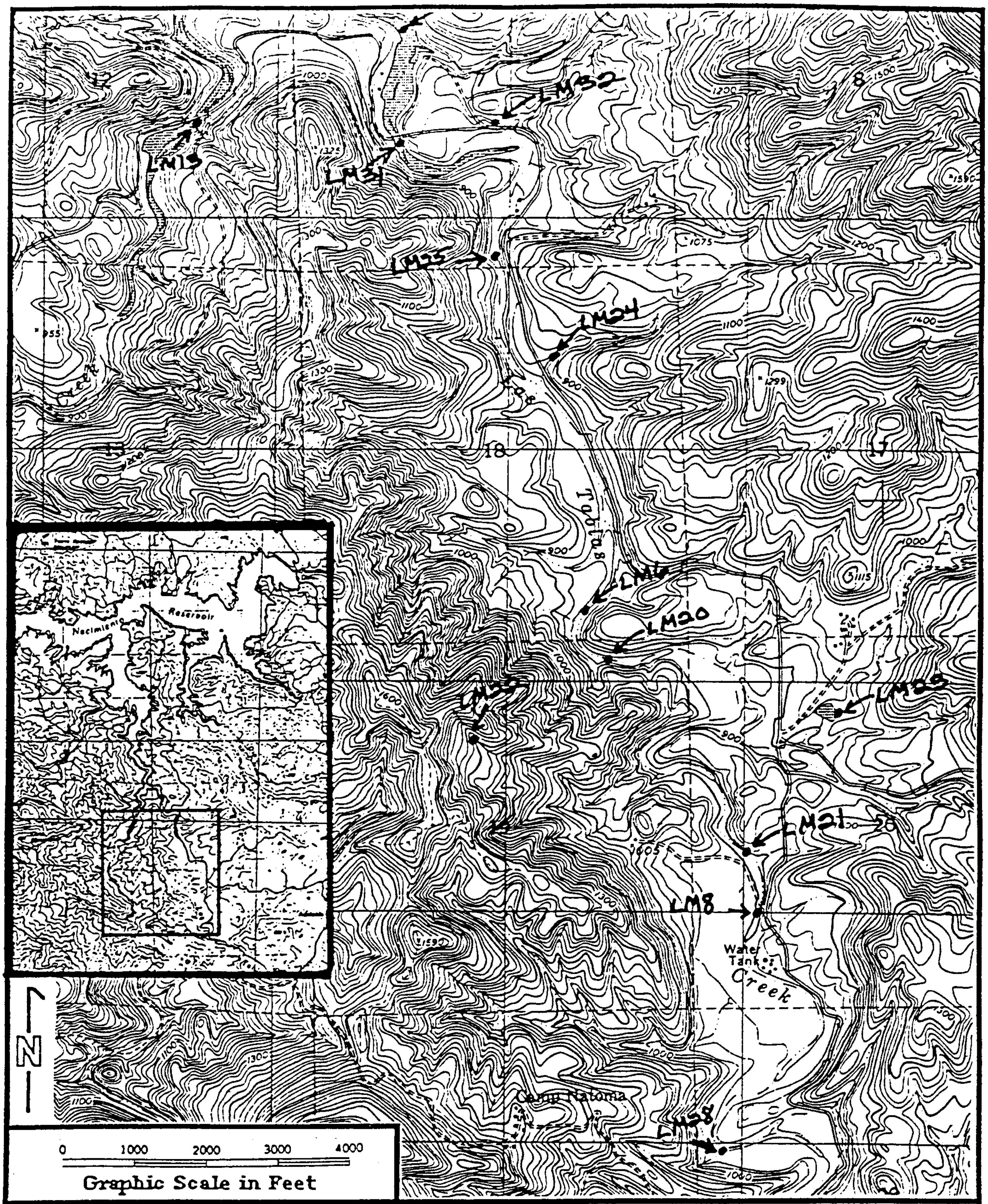

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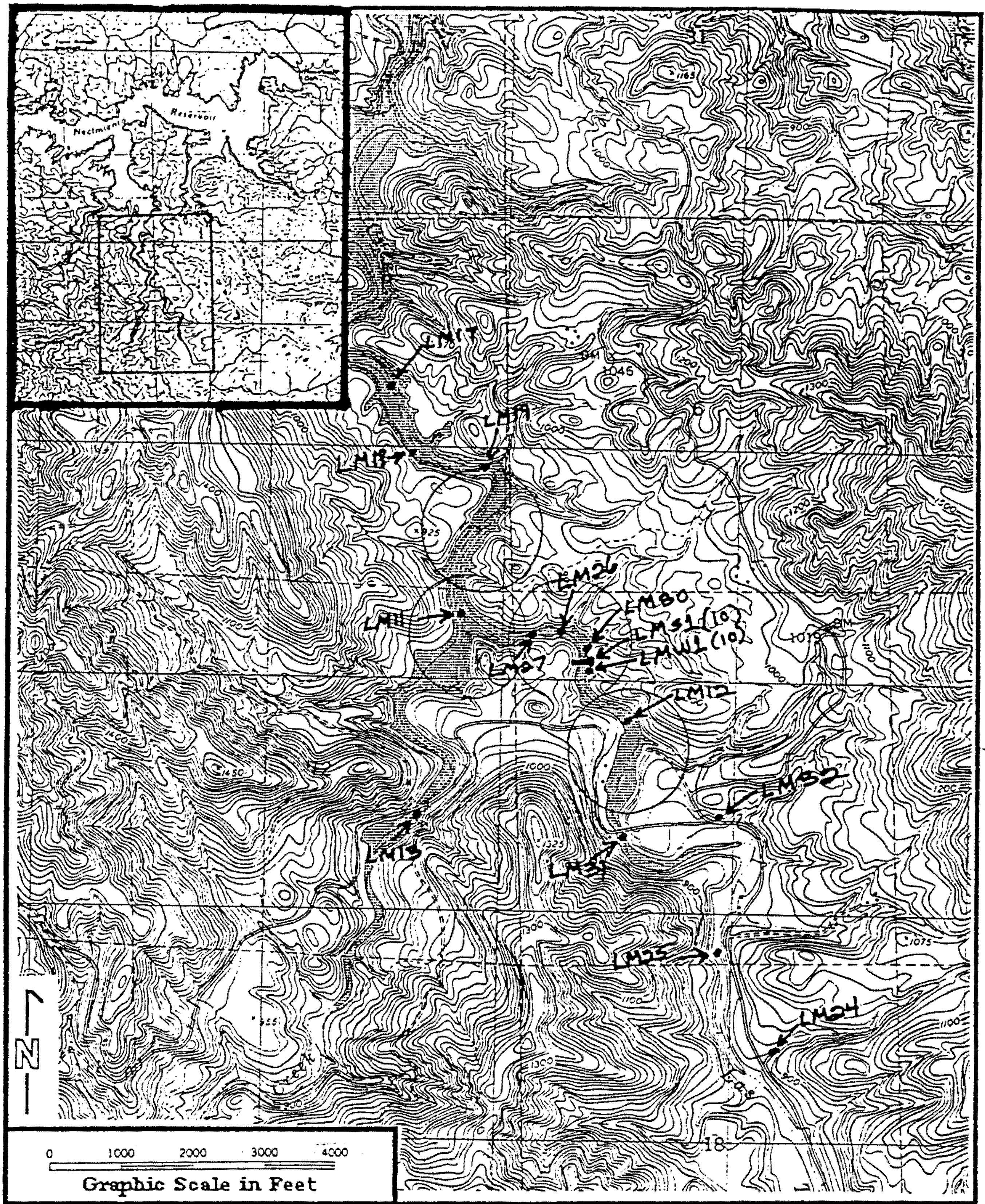
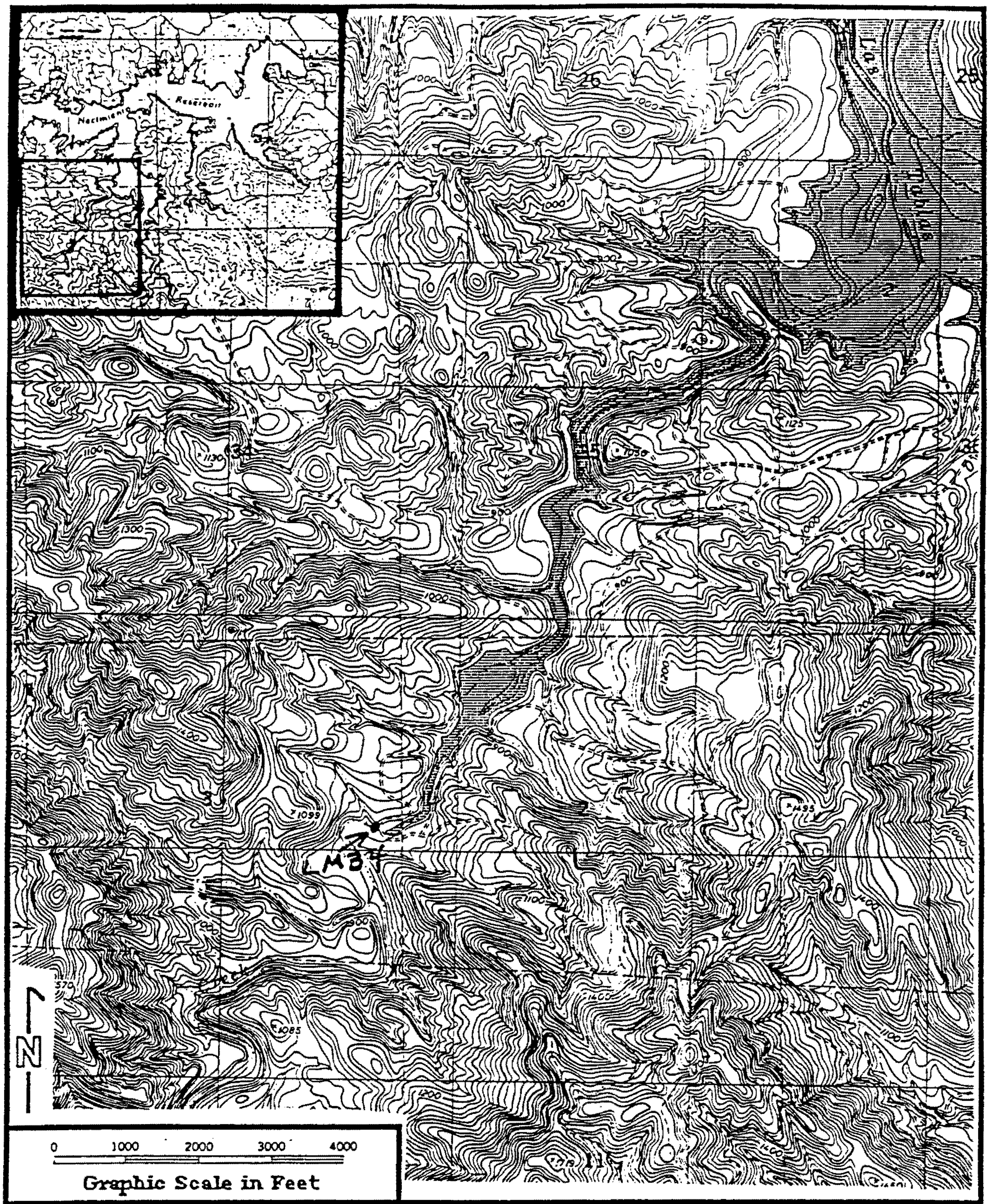
Figure 14: Sample Locations in Lime Mountain Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 15: Sample Location in Lime Mountain Topo. Quad.
California Polytechnic State University		



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 16: Sample Location in Lime Mountain Topo. Quad.
California Polytechnic State University		

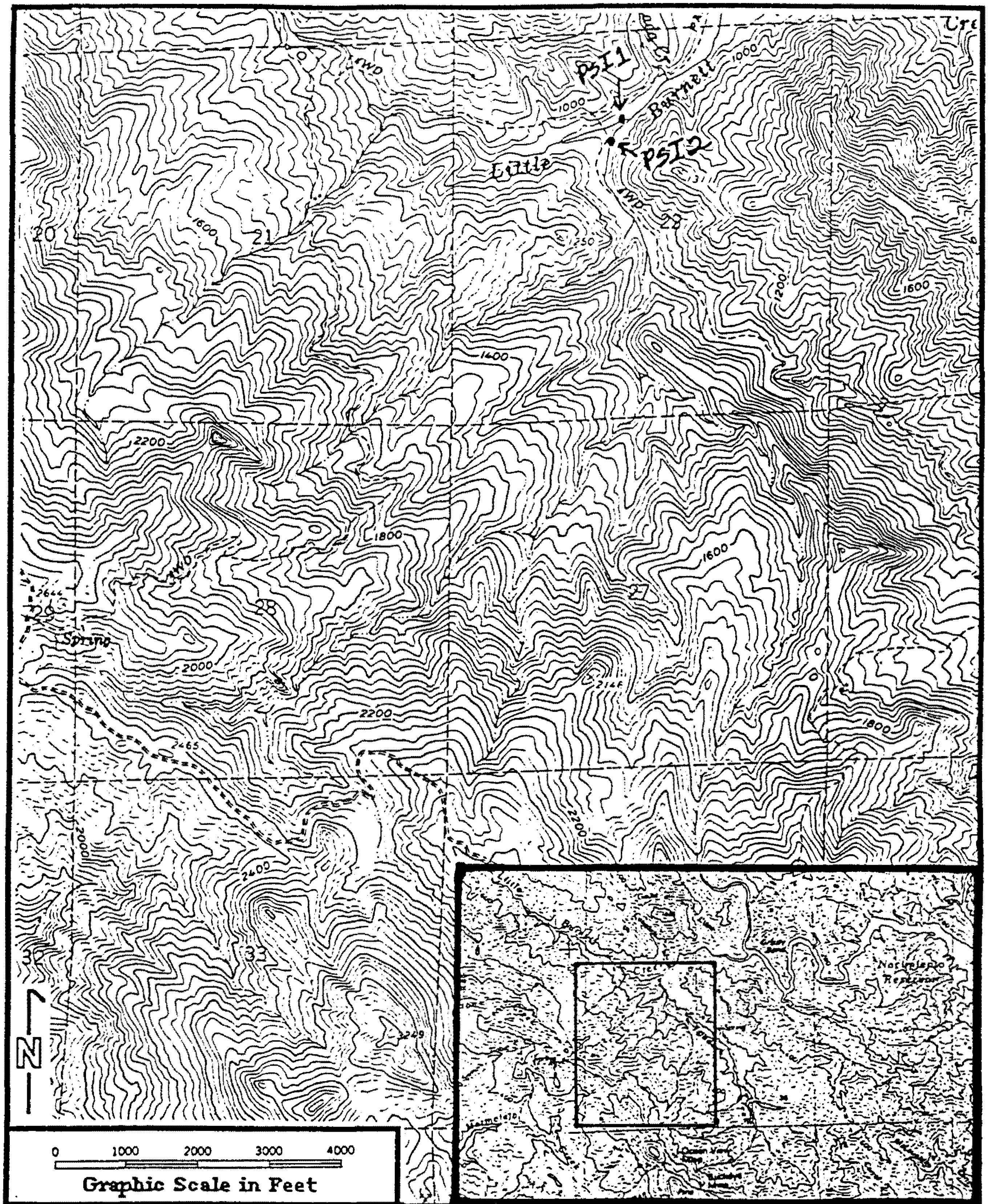


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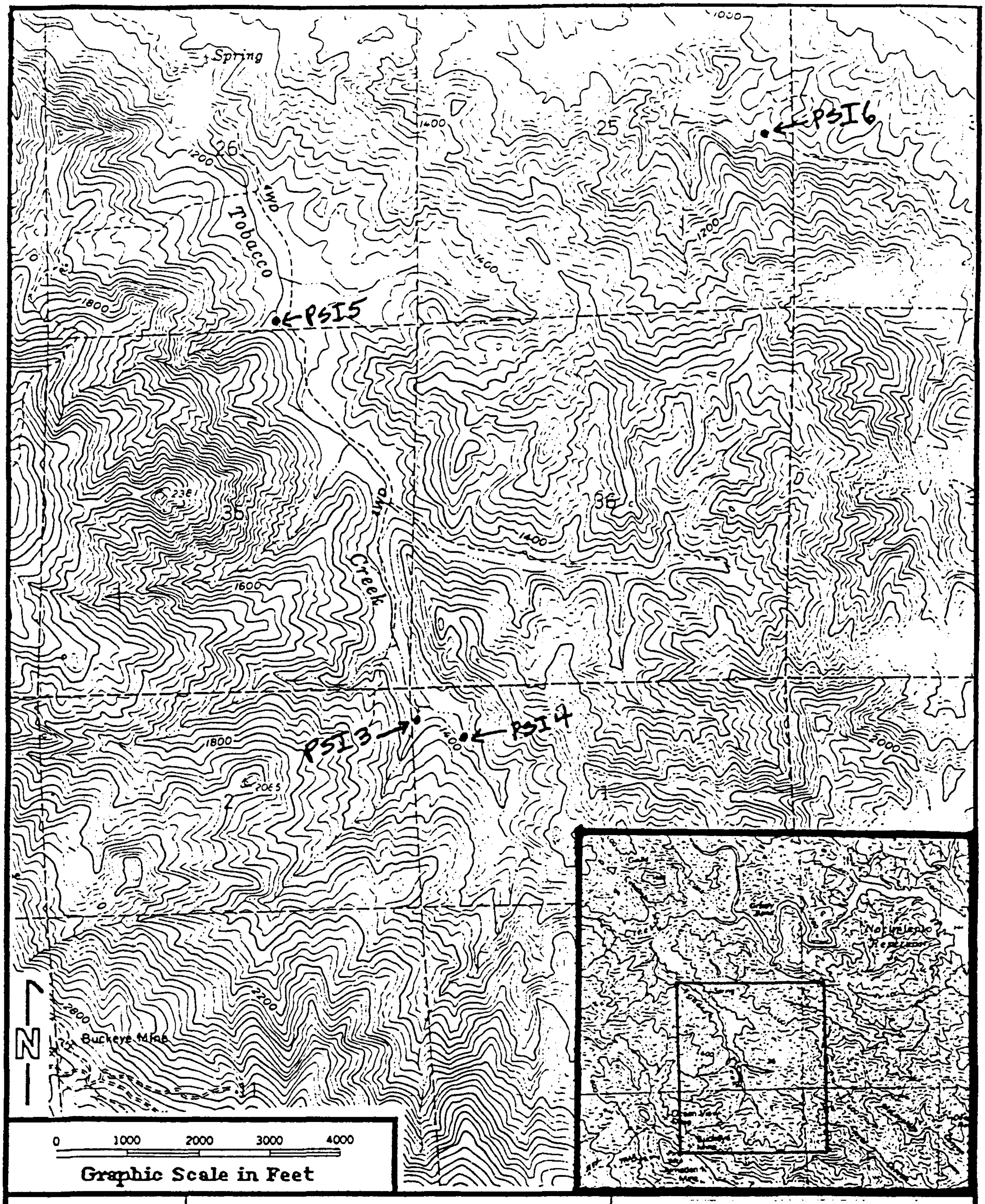
Figure 17: Sample
Sites in Pebblestone
Shut-In Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 18: Sample Sites in Pebblestone Shut-In Topo. Quad.
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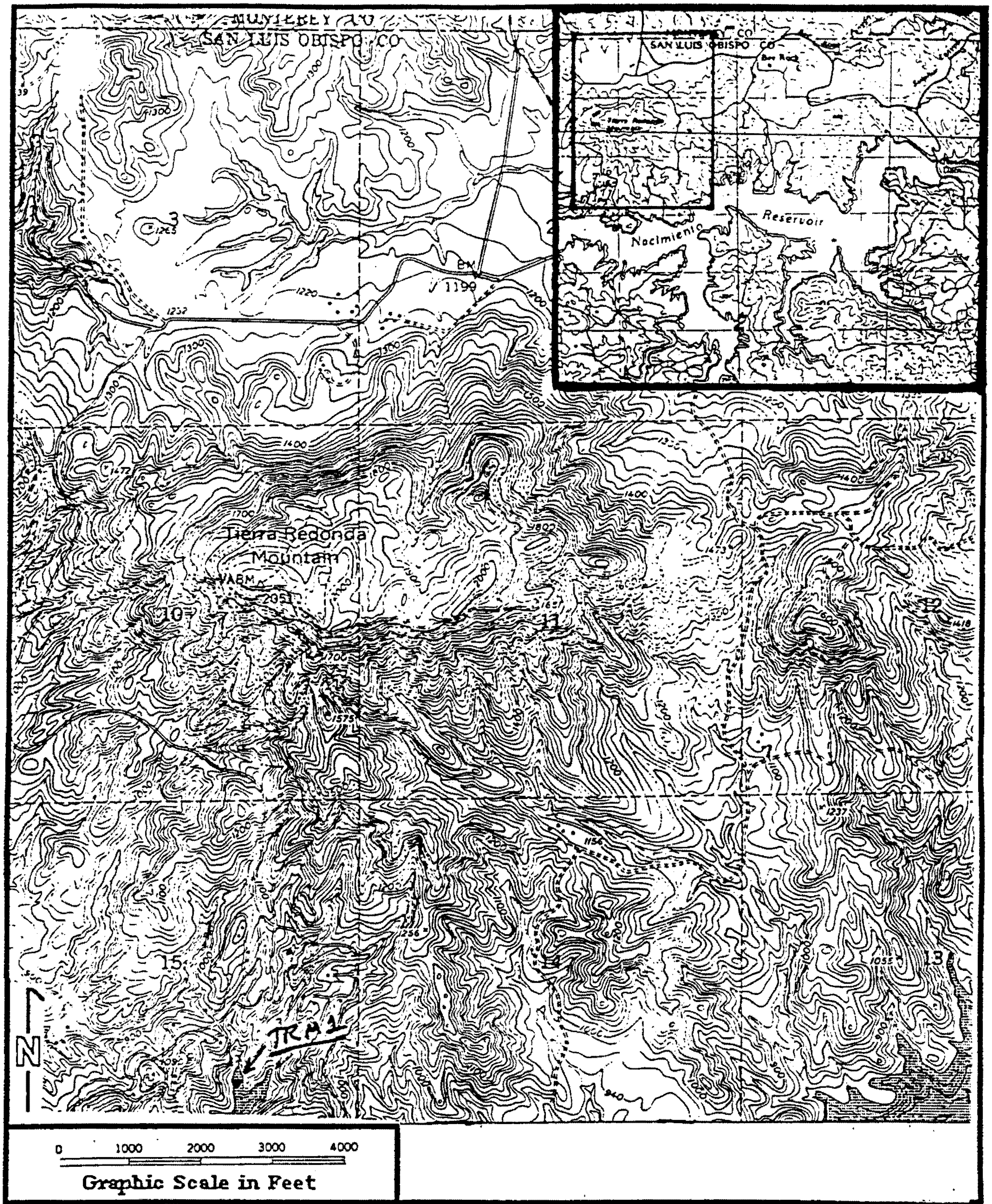

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Figure 19: Sample Sites in Tierra Redondo Mountain Topo. Quad.

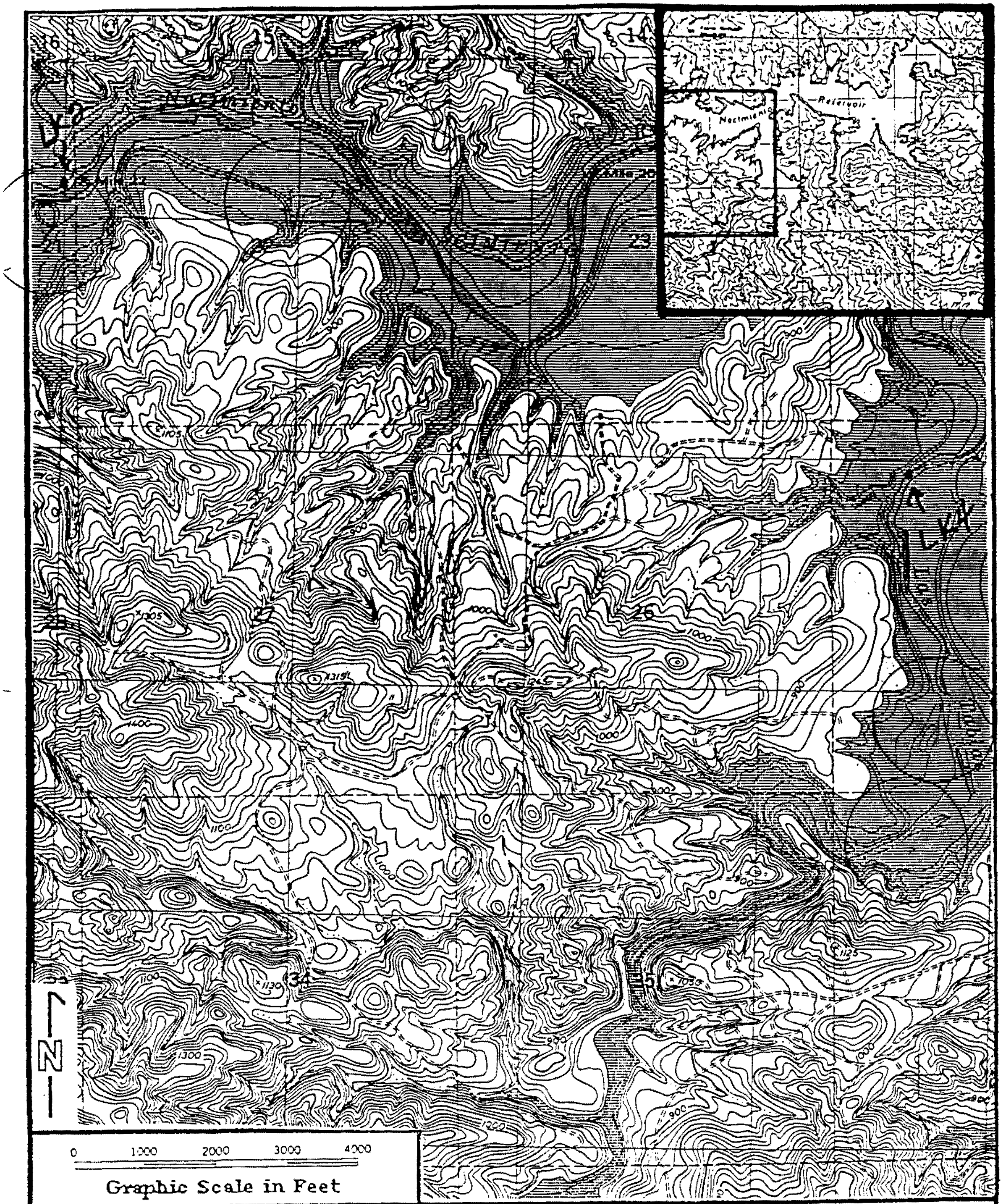

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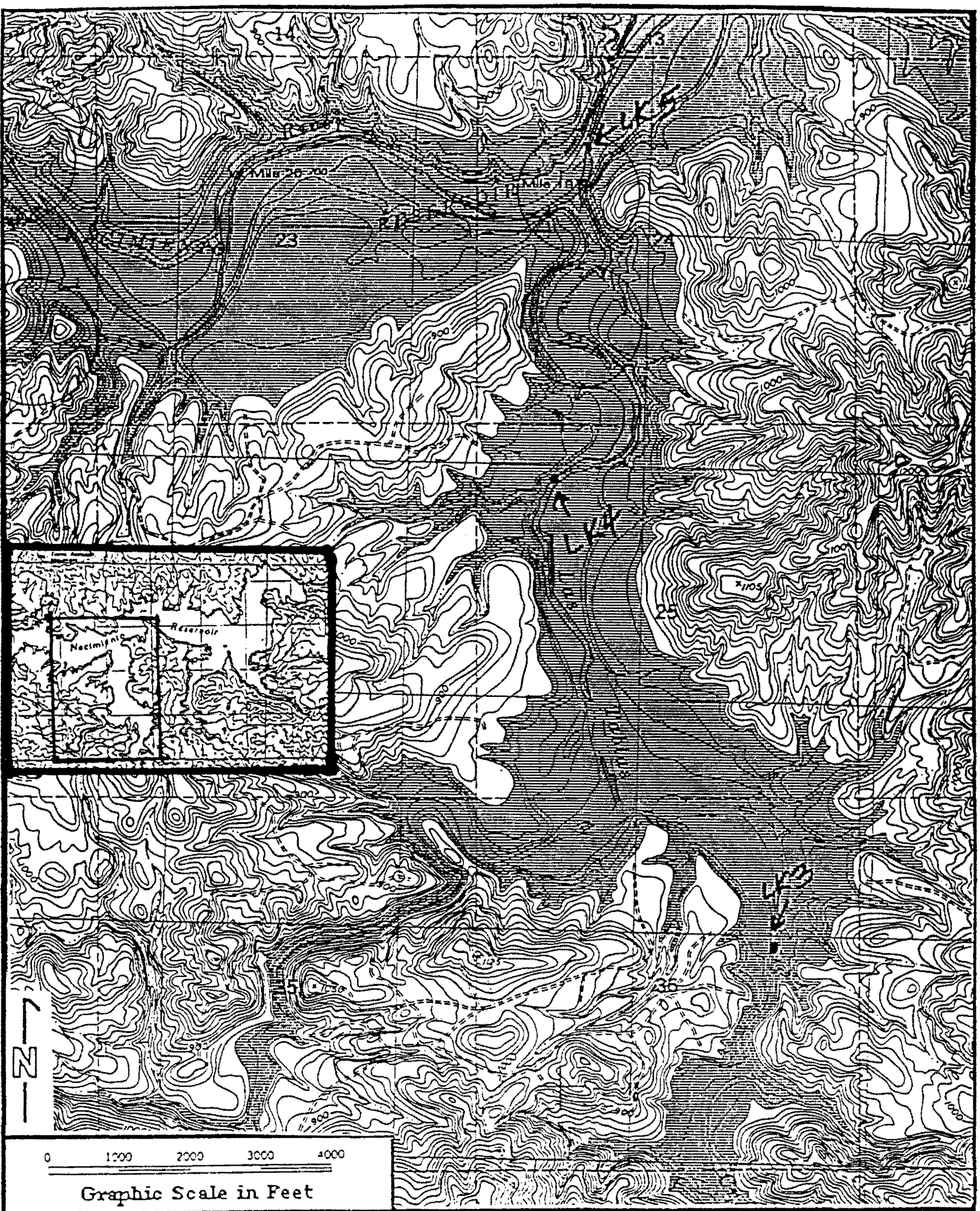
Figure 20: Lake Sample Locations in Lime Mountain Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 21: Lake Sample Locations in Lime Mountain Topo. Quad.
California Polytechnic State University		

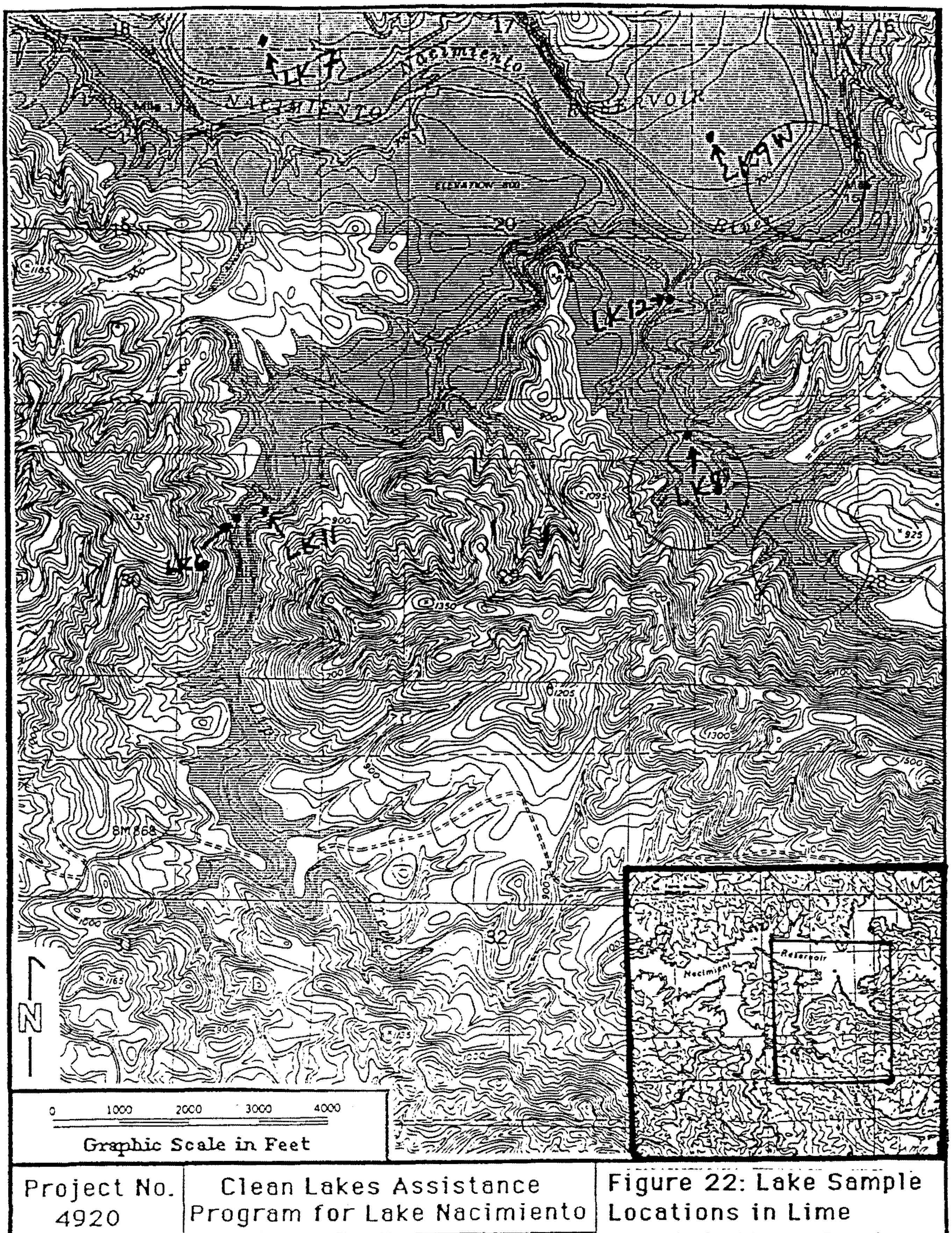


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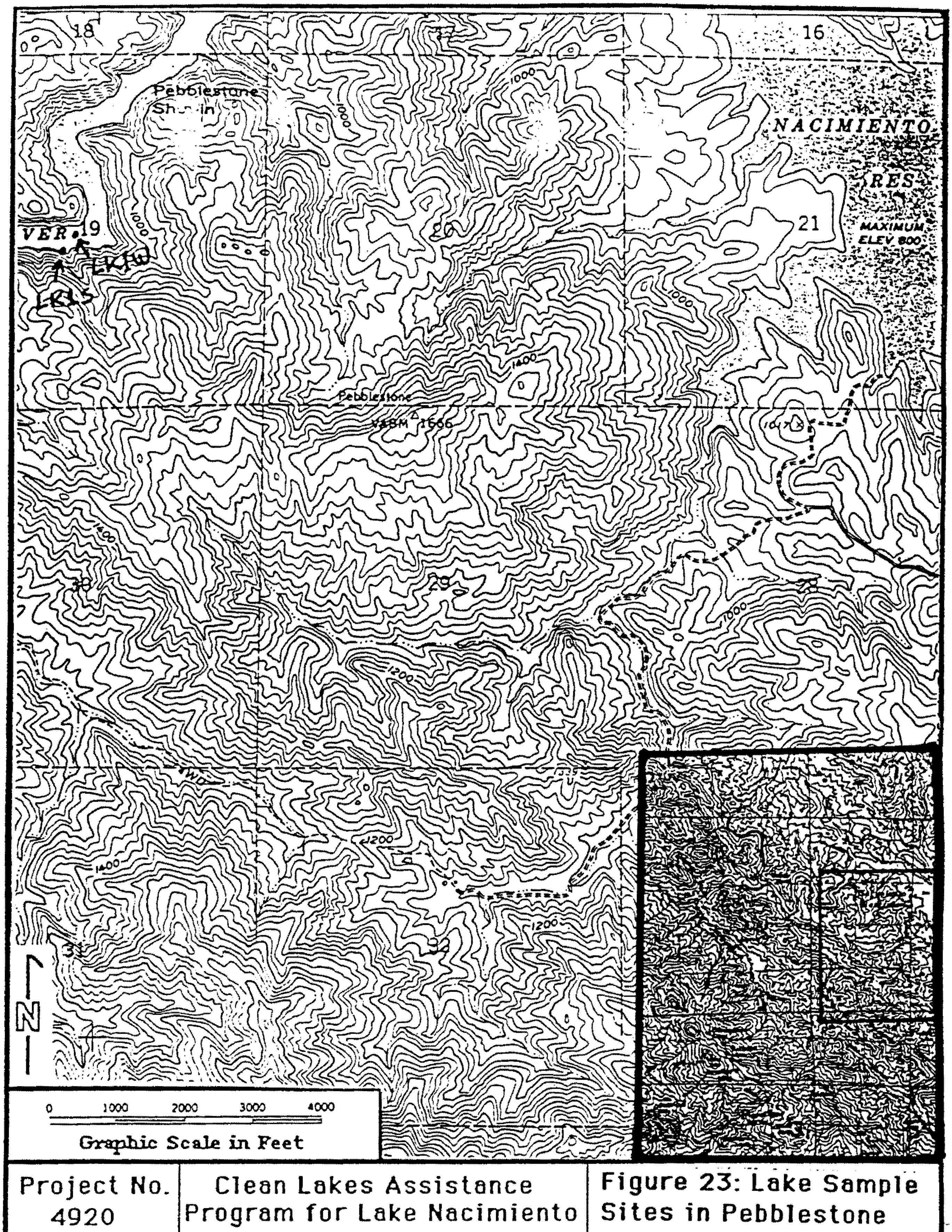
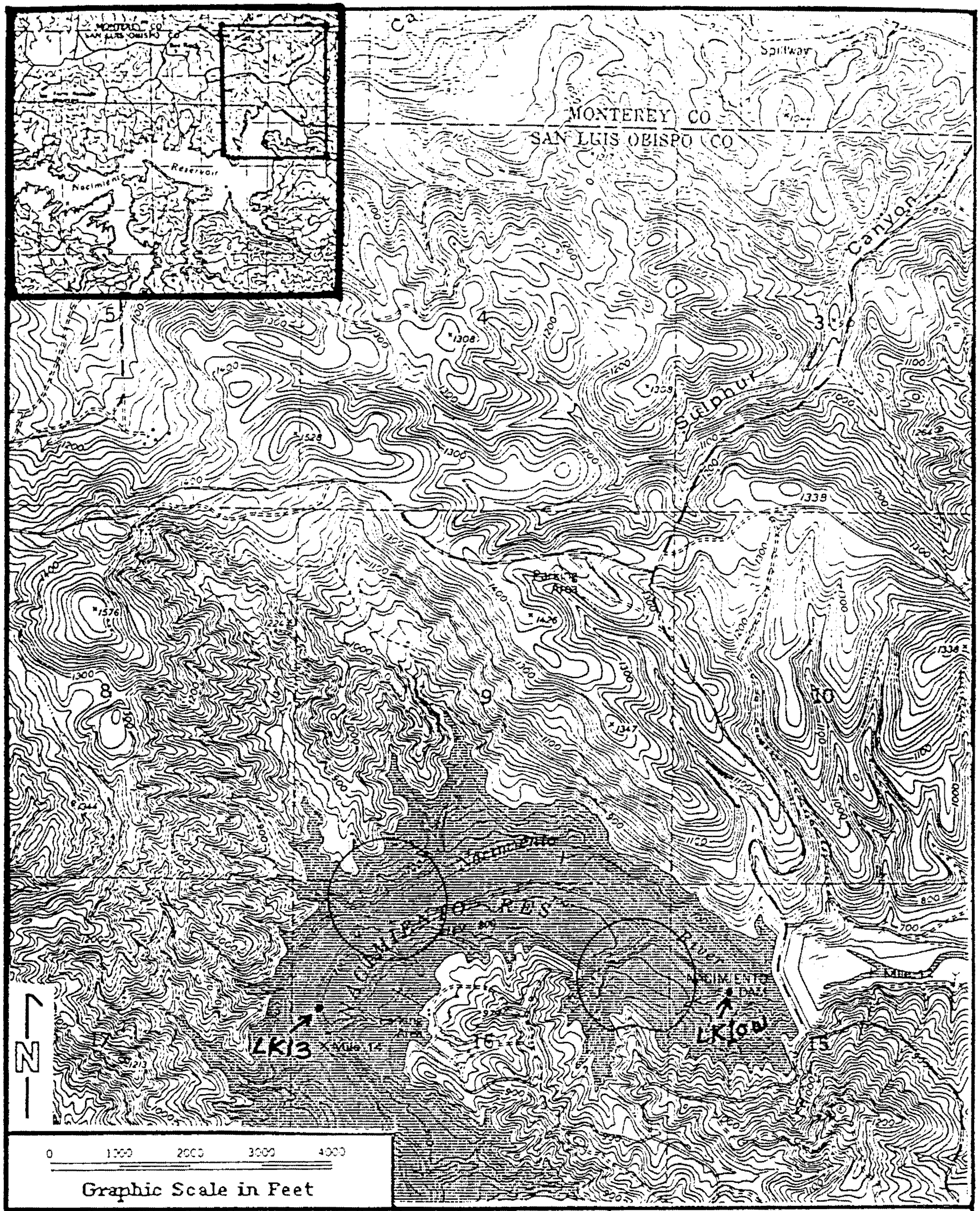
Figure 22: Lake Sample Locations in Lime Mountain Topo. Quad.



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 23: Lake Sample Sites in Pebblestone Shut-In Topo. Quad.
California Polytechnic State University		



Project No. 4920	Clean Lakes Assistance Program for Lake Nacimiento	Figure 24: Lake Sample Sites in Tierra Redondo Mountain Topo. Quad.
California Polytechnic State University		

APPENDIX 6

Discussion of Pollution Abatement and Remediation Measure Options for Buena Vista Mine; Adelaida Region, San Luis Obispo County, California

DISCUSSION OF POLLUTION ABATEMENT AND REMEDIATION MEASURE OPTIONS FOR BUENA VISTA MINE

by David H. Chipping, Ph.D., based on a December, 1992 inspection visit.

A6-1.0 Description of Dumps and Mine Structures

The Buena Vista Mine consists of a number of distinct parts as of January 1, 1993. At the highest elevations is the open pit mine used in the final phase of operation. The pit is in the form of a deeply incised, but narrow, valley cut into the hillslope near the hill summit. Much of the overburden from that operation is stored in piles flanking the pit opening to the natural side of the hill. Large storage piles are located on the south flank of the pit, on the west side of the pit in the old sawmill area, and north of the pit above the corrugated metal assay sheds. Overburden was dumped over the original hillside in the area above the old mine tunnel entrance, where the overburden veneer may be locally as much as 30 feet (ft.) thick.

The underground mine and ore processing facilities are below the open pit and associated overburden piles. The mine itself has a blocked tunnel. A rail spur runs from the mine to a wooden viaduct tipple from which ore could be dumped to a crusher, and from which waste rock could be dumped into a holding area. The waste rock was then removed by truck, and may have been routed to a mine dump to the south (the "head of valley dump" discussed below), just northeast of the high point on Cypress Mountain Road on the divide to the Klau Branch of Las Tablas Creek. Some of the waste appears to have been utilized in the construction of the dam on the Klau Branch of Las Tablas Creek, or was placed in stockpiles between the dam and the topographic divide with the Buena Vista operations. The ore was crushed at the tipple, and conveyed to a stockpile in the large shed that is presently used for heavy equipment storage. From the shed stockpile, ore was carried to the head of the smelter and condenser unit. It is presumed that the smelter waste was collected from the bottom of the unit, and carried to the main waste dump that is north of the buildings and adjacent to Cypress Mountain Road. A large shed, immediately above the smelter, was possibly used as a stockpile area, but it is presently empty.

It is likely that the routing of mine spoils and processing wastes was substantially altered after 1959, when strip mine operations began (Waller, 1979). Ore was removed from the top of the hill, and possibly from a smaller strip operation just south of the smelter. The viaduct tipple was linked by rail to the mine adit, so that waste materials were probably not dumped at the tipple after the upper strip mine became the principle source of ore. However, the crusher on the tipple was linked to the haul road by a bridge, and crushing of ore from the pit would have continued along the processing flow path as before. Thus all of the smelted ore waste from both underground and open pit operations would have ended up at the base of the hill, and in the main waste dump.

The waste dumps on the floor of the original valley consist of a very large dump south of the intersection of Cypress Mountain Road and Klau Mine Road. This will hereafter be called the "main dump". The surface of this dump has been extensively reworked and graded in the last decade, mainly in an attempt to stabilize the dump and to contain leachate and runoff. Waste ore from the smelter is presumed to have been taken to this dump. Waller (1979) states, from an interview with the mine owner, that the dump received mine overburden at this stage, although it is unlikely that substantial volumes of overburden from the upper pit would have been carried so far, except as a stabilizing cover over the dusty smelter waste. Overburden from the pit south of the smelter could have gone to this dump.

The large dump at the head of the valley, (the "head of valley dump"), located south of the smelter contains a large amount of gray clayey sediment and, on the surface, minor amounts of the sandstone of the Vaqueros Formation from the pit at the top of the hill. Since much of the wall in the open pit mine is a decomposed clayey material typical of the hydrothermal zones containing mercury (Hg), it is likely that substantial portions of this pile could have come from the overburden from the upper pit. However, the gray clays are also found under the viaduct tipple, so that some mine waste could have been carried up from the old mine to this dump.

The dump is also closely associated with a debris dam and associated slimes pond, built to contain materials washing from the steep face of the dump pile. The pond is presently filled to brimming with slimes, and some are starting to flow over to the drainage that passes below the smelter. There was no discussion of this dump by Waller (1979). The dam does not have the appearance or odor of smelter-derived waste, nor was acid leachate detected.

The last element of the mine is a dam that was apparently constructed of mine waste on adjoining property to the south managed by the Bureau of Land Management. Samples from the dam have a relatively high total Hg content (30.00 $mg \cdot kg^{-1}$) is present in the fine off-white dusts that cover the surface (Table 4-2). The dusts may be derived from kaolinized clays from the ore body, removed as overburden, or they could be partly derived from fly ash and smelter wastes brought uphill from the smelter. There is a significant amount of Vaqueros Formation debris in the dam, and no indication of a nearby borrow pit was seen except for the open pit on the mine itself, to which the dam is directly connected by road. There is a possibility that a limited borrow pit could have been excavated upstream of the dam, and that the pit is concealed beneath the waters of the reservoir. Thus it is reasonable to presume that the dam is constructed largely of overburden from the mine operations, and probably includes some highly mineralized gangue overburden from the ore zone. The latter may possibly have appealed to the dam builders as it is fine grained and may have seemed to be an appropriate seal for the dam. The site was visited in late December, 1992, when the surface of the dam was water saturated. The dam surface was covered by slimy muds, and these were being washed from both sides of the structure into the reservoir and downstream into the Klau Branch of Las Tablas Creek. Although this is a very subjective indicator of smelter waste, the rocks on the dam had an sulfurous odor typical of wetted smelter waste.

Just north of the dam is a long stockpile or dump of materials similar to those found in the dam. The top of the long, curved pile is composed of the same gray, clayey sediments found in the dam, in the open pit mine, and below the viaduct tipple. These are deposited above a pile of obvious overburden from the open pit mine, containing both blocks of Vaqueros Formation and some of the iron oxide gossan associated with mineralization in the basal Vaqueros Formation. The stockpile likely has elevated Hg levels, similar to those in the face of the dam, and should be analyzed. The gray clays, like those of the dam, had the sulfurous smell of smelter waste.

A6-2.0 Computations On Mine Waste Production

Waller (1979) obtained production information for Buena Vista Mine. Additional information on early production is also available (Eckel et al., 1941). The mine was in operation between 1874 and 1970, when production shut down. The cumulative production was 4,178 flasks of Hg by 1948, produced from ore that averaged 10 lbs. Hg per ton of ore. Waller (1979) calculated that 31,750 tons of ore would have been processed through the smelter, and that this was placed in the main dump. Waller (1979) gives no indication of the amount of mine waste of lower Hg content that was not smelted, but which was transported to the dump directly from the tipple. A conservative estimate would be a doubling of the processed ore volume, so that perhaps 100,000 tons of rock could come out of the mine and reached the dump.

Waller (1979) quotes Mr. Harold Biaginni, the mine owner, as indicating that the average grade of Hg ore increased to 25 lbs. Hg/ton from the operations between 1959 and 1970. This was when strip mine operations began, and presumably ore would be taken mainly from the hill summit. Waste ore from the smelter was calculated by Waller (1979) at 142,350 tons, with no calculation of overburden volumes or locations. Waller (1979) states "the overburden and the waste ore during this period formed the main tailings pile", although it is clear that very substantial amounts of overburden remain at the top of the hill or were dumped down the natural slope of the hill.

Thus at least 174,100 tons of smelter waste and waste ore is in the main dump, according to information provided by Biaginni to Waller (1979). This would be a volume of approximately 46,500 cubic yards (yd^3).

A6-3.0 Waste Volumes Survey (as of December, 1992)

A cursory survey of mine waste was made as part of this Clean Lakes Assistance Program for Lake Nacimiento in December, 1992. The broad dimensions of each feature, and its calculated volume are given. The volumes were calculated from rough-measured cross sections obtained by tape and level. These figures are very approximate, as no accurate survey was made, and the shape of the bottoms of the waste piles could only be approximated. We would recommend an accurate resurvey of the mine if volume calculations are needed for contractual treatment or earth moving contracts. A description of each portion of Buena Vista Mine follows.

A6-3.1 Main Dump

The main dump north of the processing buildings has been the site of most recent attempts to control leachate and runoff. It is essentially a rectangular structure with rounded ends, varying in depth from a few feet at the southern end to about 60 ft. near the northern end. In the section of greatest width and cross section volume, where the northernmost piezometer has been installed, the vertical drop from the crest of the dump to the eastern flank is about 15 ft., but the western flank (at the drainage ditch along Cypress Mountain Road) it is about 30 ft.. It is presumed that the natural drainage channel ran approximately under the current long axis of the dump, and this is where the greatest thickness of dump material is thought to exist. The length of the dump is about 400 ft. Divided into eight 50-foot segments, nine cross sections were calculated to have areas of 120, 1,000, 2,500, 4,000, 5130, 5130, 5,000, 3,000 and 0 square feet. From these measurements, the volume of the dump material was calculated to be about 47,800 yd^3.

Waller (1979) noted that 46,500 yd^3 of processed ore must have entered the dump. This is a little too close to our measured volume of 47,800 yd^3, as it leaves little room to accommodate unprocessed mine waste and overburden. Some of the "missing" volume may be found as fill in the now covered drainage pond and evaporation ponds mapped by Waller (Fig. 5.1, 1979), or as a thin veneer of waste that occurs between the southern end of the dump and the ore storage barn, where the heavy earth moving equipment is currently stored. Some waste has been spread thinly in the area southwest of the small pond adjoining Klau Mine Road. It is possible to account for several thousand cubic yards of waste in this manner.

Material has been spread in an irregular manner across the land surface as far as the southernmost gate access, although much of it resembles the overburden material from the open pit mine at the top of the hill, and there are clear indications of recent excavation of those materials in the area around the sawmill.

A6-3.2 Head of Valley Dump and Slimes Pond

The volume of this dump can only be very approximately calculated, as the detailed form of the landscape under the dump is not known. The volume was calculated to be approximately 20,000 yd^3 at an elevation higher than the present top of the slimes pond. The slimes in the pond, and the extension of the dump below the slimes pond surface would essentially double the volume, so that the dump and pond complex would contain about 40,000 yd^3 of material of unknown Hg content. There are no indications of smelter waste in this dump, and runoff from the dump does not show iron staining typical of acid mine drainage.

A6-3.3 Dam on Klau Branch, Las Tablas Creek

Using cross sections from water surface on the pond to the downstream toe of the dam, the 325 ft. length of the dam was divided into segments 50 ft. apart, measured from the spillway northward, with a final 25 ft segment. Cross sectional areas were measured at 0, 400, 1340, 2660, 4040, 2660, 1340, and 0 ft.^{2}, resulting in a calculated dam volume of about 23,600 yd^3. The upstream dimensions could not be measured, but the dam volume would be approximately 25,000 yd^3, which is probably too low an estimate. A recent (March 22, 1993) inspection and calculations by David Mraz of the California Department of Water Resources, Division of Safety of Dams, estimates the total volume of the dam to be about 61,000 yd^3.

A6-3.4 Dump on North Side of Dam on Klau Branch, Las Tablas Creek

This dump consists of about 8,000 yd^3 of gray colored material that is either mineralized overburden or smelter waste. These gray clayey sediments are mounded in a long curved dump about 420 ft. long, 50 ft. wide and 10 ft. deep. These gray clayey sediments are dumped above material that resembles the Vaqueros Formation-derived overburden produced from the open pit mine at the top of the hill, but only a lower cross section of this material is exposed along the cut of the track leading to the dam. Assuming an areal extent similar to the overlying gray clay, a volume of about 7,000 yd^3 would be present. Thus the dump contains about 15,000 yd^3 of material. If it is determined that the gray clay has the same total Hg levels as those in the dam, all of this dump will have to be considered in any remediation effort, since there is some interbedding and mixing between the gray clayey sediments and the Vaqueros Formation-derived overburden.

A6-3.5 Overburden in the Vicinity of the Open Pit Mine

No detailed survey was made of the volumes of mine overburden piled on either side of the open pit mine, or on the slopes above the mine buildings. The veneer of material pushed down the slope below the sawmill is thin, generally being less than 10 ft. However, there is possibly a varied topography on the buried surface of the natural hillside, and the thickness could locally exceed 20 ft. The overburden around the sawmill is dominated by materials derived from the Vaqueros Formation and a zone of iron-oxide bearing gossans associated with the hydrothermal mineralization of the Vaqueros Formation. A very cursory examination of the area indicates that about 500,000 yd^3 of material may have been displaced around the open pit mine. Many of these piles are partially revegetated, and only one area appears to be highly unstable. The unstable area is located on either side of the drainage channel from the open pit mine, where it empties down the face of the hill. Debris flows have developed in this section of fill, apparently since it contains more Franciscan Formation shale debris than other portions of the fill. In general the dump piles above the mine buildings are at, or are close to, the angle of repose. It is likely that some of these slopes will have to be regraded to prevent both further debris flows and rock falls. The Hg content is likely to highly variable in this material, and small amounts of iron oxide-rich leachate emerges in scattered locations on the surface indicating that sulfur-bearing materials, likely associated with Hg, are locally present.

A6-4.0 Evidence of Acid Mine Drainage from Buena Vista Mine

In the December, 1992 survey of the mine, which was conducted after the ground had become saturated from rains, there was an attempt to locate points at which potentially polluting waters were being discharged. In the last decade, there has been an almost continual discharge from pipes emerging from the site of the old drainage pond below the main dump. These pipes were flowing at about 1 gallon per minute and the water appears polluted. Several old seeps in the side of the main dump adjacent to the channel along Cypress Mountain Road have been buried under a veneer of recently placed cover soil and straw. No active seeps could be seen, but some blackening (acid-induced?) of the straw had taken place at one location. There were active seeps near the top of the main dump, west of the crest, and along the track on the east side, which were seeping water which had killed grass at one location. Apparently the cap of overburden above the dump is porous, and larger volume seeps can be expected with an increase in cumulative rainfall. There were some seeps over the graded surface between the main dump and the mine buildings. A highly polluted, low volume stream of acid waste water was flowing eastward from the vicinity of the old mine shaft toward the assay sheds, but the source could have been either leachate from the mine or runoff through the mine overburden dumped down the hillside above the mine shaft. Another stream of water flows northward from the west side of the mine portal area, passing under the viaduct tipple, then around the crushed ore storage, down the road in an eroded gully, and then into a channel cut to bedrock on the east side of the main dump, and finally into the North Fork of Las Tablas Creek just above the old drainage pond. This channel is iron oxide stained, and can be expected to contain relatively high total Hg contents as it drains close to areas where Hg ore was handled (Table 4-2).

On the south side of the hill, there are some seeps from the dump above the dam on the Klau Branch of Las Tablas Creek that are iron oxide stained and are discharging into the creek. Small seeps also occur over much of the overburden-covered area around the open pit mine, including a point just above the location where the drainage from the pit drops over the top of the main hillslope. Seeps from the "head of the valley" dump are generally not iron stained, and may not be enriched in Hg.

This leachate and runoff survey was made at a time (December, 1992) when surface layers of the dumps and facilities were saturated, but cumulative rainfall for the year was still low and the deeper layers in fills would still be relatively dry. Much higher seepage volumes, and new seep locations would be expected at the end of a long, heavy rainy season. A thorough investigation of the surface and subsurface hydrologic conditions at Buena Vista Mine should be undertaken as part of any engineered remediation and restoration effort.

A6-5.0 Contaminated Materials around Buena Vista Mine

The mine buildings associated with the smelter complex and condenser unit are highly contaminated with both metallic Hg and with smelter-derived waste (Table 4-2). Beads of elemental Hg contaminate the buildings and adjacent sediments, including redwood tubs at ground level outside the condenser unit. It is likely that all the sediments and soils around the smelter are highly Hg-contaminated. In addition, the buildings themselves have been bathed in Hg vapors, and are therefore also Hg-contaminated. All roads used to haul ore to the smelter are Hg-contaminated with spilled ore, and the ore stockpile building has a floor of sulfurous, oxidized crushed ore. Therefore, complete remediation and restoration of the mine site may require all buildings that were part of the ore processing system to be dismantled and treated as toxic waste, and will require a couple of feet of contaminated sediment and soil to be removed from throughout the processing area. One problem of grading the area is that the mine processing facilities sit directly on portions of the ore body, so that grading will expose more cinnabar-rich materials.

A6-6.0 Suggestions for the Reduction of Waste Discharge

A6-6.1 The "Arlo Guthrie Principle"

Arlo Guthrie, in his famous song in the movie "Alice's Restaurant," noted that one pile of garbage is better than two piles. This principle applies to Buena Vista Mine, as the area exposed to erosion will determine the rate of release of Hg waste towards Lake Nacimiento. At this time there is a poorly stabilized, seep-prone, poorly sealed "Main Dump" situated below highly Hg-contaminated mine buildings and mineral processing equipment, which is situated below an erosion prone "head of the valley" dump and sediment-filled slime pond. On the south side of the divide, there is a dam which is composed of materials classified as hazardous waste and an associated dump that is probably similarly Hg-contaminated. If all of these areas are to be isolated from the environment, they must either be buried in place, or carried off to another location and buried. The large volume of waste belies any idea of moving the waste off-site, where the existing large surface area will require very large areas of land to be capped with impermeable landfill.

Remediation and restoration of the site may be accomplished by dismantling the mine buildings and dumping the debris uphill at the slime pond area. The mine operations area could then be graded to a depth of a couple of feet, pushing contaminated material into a valley fill around the slime pond. Deep excavation of the old pond sites below the "Main Dump", and excavation of the main dump would remove Hg-contaminated materials from that area and the material could be pushed to the head of the valley. Thus all waste would be pushed into the head of the valley between the smelter site and the slime pond, the surface of the pile being graded to a 3:1 slope. To this, material from the dam site and associated dump could be removed, trucked up the old haul road, and deposited in the valley. The unstable materials around the open pit site would then, as they have been already, used as a cover. Standard landfill procedures including liners could be used to seal the dump.

Waller (1979) has discussed other methods to stabilize the acid leachate coming from the existing dumps. Limestone tends to self-seal and fails to neutralize acid waste after a brief period, and requires both large volumes of limestone and periodic earthwork to dispose of old stock and replace it with fresh rock. An anhydrous ammonia treatment of the waste stream is effective, removing a Hg-iron floc from solution but requires supervision and periodic disposal of the toxic effluent from the process. As Waller (1979) notes, treatment systems should only be considered for active mines, where they can be serviced. Waller (1979) suggests that the best way of limiting leachate is to exclude waters from the dumps by sealing their surfaces and be diverting surface waters. By taking the waste dump up to the extreme headwaters of the creek, diversion is achieved by reducing the drainage area above the waste. Percolating waters would be minimized by increasing the volume of the fill relative to its surface area, and by using geotextile liners and sealants in the subsurface of the fill.

The open pit mine at the top of the hill is generally in a stable state, although the State Mining and Reclamation Act (SMARA) should be reviewed to see if the open pit meets SMARA standards, as several small slides have taken place on the sides of the pit, which are not fully stabilized. However, the pit has a low gradient floor which is revegetated with willows and tules, forming an excellent filter for fines derived from within the quarry. I would not recommend that the pit remain in its present form, but the pit may have to serve as the repository for some of the unstable overburden that has been stored around the pit. Slopes on the north side of the pit, where the drainage channel from the floor of the pit drops down the steep hill, are unstable and have produced debris flows. If overburden was to be regraded on this slope, some may have to be moved into the valley, to the detriment of the biological filter on the existing floor of the pit. SMARA prefers landscape restoration to take place, and thus filling some of the pit should be expected. There was considerable runoff from the pit, apparently relatively clean of acid waste, but this could deteriorate if the pit is refilled with permeable overburden.

If the benches and limited cuts around the sawmill are regraded, care should be taken to keep new cinnabar-rich outcrops from being exposed on the steep slopes.

APPENDIX 7

Individuals Contacted and their Affiliations; as part of the Clean Lakes Assistance Program for Lake Nacimiento

Individuals Contacted and their Affiliations (alphabetical order):
Clean Lakes Assistance Program for Lake Nacimiento

Individual (Address, Phone) (phone numbers not listed for private landowners)	Title; Affiliation
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APPENDIX 8

Analytical Methods and QA/QC Results for Mercury Analyses performed by the Chemistry Department, California Polytechnic State University, San Luis Obispo

ANALYTICAL METHODS AND QA/QC RESULTS

Sample Analysis

Soil, sediment and water samples were analyzed for total mercury by EPA Method 245.1 and 245.5 (Methods for Chemical Analysis of Water and Wastes, EP-600/4-82-055, December, 1982). Digestion procedures described in SW-846 Methods 7470 and 7471 (Test Methods for Evaluating Solid Waste Vol IA: Laboratory Manual Physical/Chemical Methods EP-SW-846 (Third Edition), November 1986) were used to prepare soil and sediment samples for analysis. All samples were analyzed using an Instrument Laboratories IL 551 Atomic Absorption Spectrophotometer with a Buck Scientific Cold Vapor Mercury Kit.

A complete set of calibration standards was analyzed at the beginning of each day of analysis. Standard stock solutions were prepared from Baker Instra Analyzed Reagents certified suitable for mercury analysis from J. T. Baker Chemical Co. Secondary dilution standards were prepared from the stock standards at least monthly. Analytical blanks were run each day analyses were made. Record books, sample logs, instrument maintenance and calibration checks were done in accordance with the QA/QC protocol.

Data validation was accomplished through duplicate split, and spiked samples. The limit of detection (LOD) for the analytical method was 0.004 micrograms of mercury and the limit of quantification was 0.0134 absorbance units or 0.016 micrograms of mercury. Data used to determine the calibration curves are given on the following pages and are summarized in Tables 4-1 through 4-11. The relation between absorbance and concentration was linear up to 0.25 absorbance units. A second order polynomial equation was used for absorbance measurements between 0.25

and 0.80. A third order polynomial equation was used for absorbance readings between 0.80 and 1.25. For soil or sediment samples with high mercury concentrations an aliquot of the digestion solution was analyzed to keep the absorbance readings within the limits of the calibration data. Method blanks were run at the beginning of each day of analysis. If the blank results were out of line, analyses were not run until the problem was identified and corrected.

A total of fifty field-collected samples of soil and sediment and fifty field-collected water samples were analyzed. Eighteen soil samples were run in duplicate and eleven soil samples were run as split samples. An additional eleven water samples were run in duplicate and four water samples were run as split samples. The duplicate soil samples gave a relative mean deviation between duplicates of 0.020 micrograms of Hg per gram with a standard deviation of 0.033. The split soil samples gave a mean deviation of W 0.017 micrograms of Hg per gram with a standard deviation of 0.021. The duplicate water samples shoed a mean relative deviation between duplicates of 0.070 micrograms of Hg per liter with a standard deviation of 0.062. The split water samples gave a mean deviation of 0.026 micrograms of Hg per liter with a standard deviation of 0.017. The results of eight spiked soil samples gave an average of 98.8% recovery of mercury with a standard deviation of 14.3%. For five spiked water samples the percent mercury recovered was 112.1% with a standard deviation of 8.5%.

Cal Poly Calibration Data, Mercury by Cold-vapor Atomic Absorption
For range of 0.0 to 2.0 ug Hg

ug Hg		Absorption	x-mean	(x-mean)*2
0.00		0.0080	0.00183	0.0000033
0.00		0.0040	-0.00217	0.0000046
0.00		0.0050	-0.00117	0.0000013
0.00		0.0070	0.00083	0.0000006
0.00		0.0050	-0.00117	0.0000013
0.00		0.0080	0.00183	0.0000033
	mean	0.0062		
0.03		0.0200	0.00144	0.0000020
0.03		0.0130	-0.00556	0.0000308
0.03		0.0220	0.00344	0.0000118
0.03		0.0140	-0.00456	0.0000207
0.03		0.0140	-0.00456	0.0000207
0.03		0.0170	-0.00156	0.0000024
0.03		0.0330	0.01444	0.0002086
0.03		0.0130	-0.00556	0.0000308
0.03		0.0210	0.00244	0.0000059
	mean	0.0186		
0.05		0.0280	-0.00133	0.0000017
0.05		0.0300	0.00067	0.0000004
0.05		0.0300	0.00067	0.0000004
	mean	0.0293		
0.10		0.0510	-0.00167	0.0000027
0.10		0.0540	0.00133	0.0000017
0.10		0.0530	0.00033	0.0000001
	mean	0.0527		
0.20		0.1040	0.00433	0.0000187
0.20		0.0980	-0.00167	0.0000027
0.20		0.0970	-0.00267	0.0000071
	mean	0.0997		
0.50		0.2460	-0.00367	0.0000134
0.50		0.2520	0.00233	0.0000054
0.50		0.2510	0.00133	0.0000017
	mean	0.2497		
1.00		0.4680	-0.00167	0.0000027
1.00		0.4670	-0.00267	0.0000071
1.00		0.4740	0.00433	0.0000187
	mean	0.4697		
2.00		0.7940	-0.00475	0.0000225

2.00		0.7780	-0.02075	0.0004305
2.00		0.8160	0.01725	0.0002975
2.00		0.8050	0.00625	0.0000390
2.00		0.8140	0.01525	0.0002325
2.00		0.7890	-0.00975	0.0000950
2.00		0.8030	0.00425	0.0000180
2.00		0.7910	-0.00775	0.0000600
	mean	0.7988		

sum(x-mean)*2 = 0.0004343
std dev*2 = 0.0000149
std dev = 0.0038702

Cal Poly Calibration Data Summary, Mercury by Cold-vapor Atomic Absorption

std dev	0.00387
mean std dev	0.00072
95% confidence	0.00147

ug Hg = 2.500 0.0286(Absorbance)-0.0374 0.0553

ug Hg	Abs
0.00	0.0080
0.00	0.0040
0.00	0.0050
0.00	0.0070
0.00	0.0050
0.00	0.0080
0.03	0.0200
0.03	0.0130
0.03	0.0220
0.03	0.0140
0.03	0.0140
0.03	0.0170
0.03	0.0330
0.03	0.0130
0.03	0.0210
0.05	0.0280
0.05	0.0300
0.05	0.0300
0.10	0.0510
0.10	0.0540
0.10	0.0530
0.20	0.1040
0.20	0.0980

Regression Output:	
Constant	0.016065
Std Err of Y Est	0.022058
R Squared	0.995296
No. of Observations	38
Degrees of Freedom	36
X Coefficient(s)	0.398099
Std Err of Coef.	0.004561

Regression Output:	
Constant	-0.03746
Std Err of Y Est	0.055278
R Squared	0.995296
No. of Observations	38
Degrees of Freedom	36
X Coefficient(s)	2.500121
Std Err of Coef.	0.028645

0.20	0.0970
0.50	0.2460
0.50	0.2520
0.50	0.2510
1.00	0.4680
1.00	0.4670
1.00	0.4740

EQUATIONS USED FOR CALCULATION OF ug Hg FROM MEASURED ABSORBANCE

Linear Range: Absorbance of 0 to 0.25

$$\text{ug Hg} = 2.0432(\text{Absorbance}) - 0.00891$$

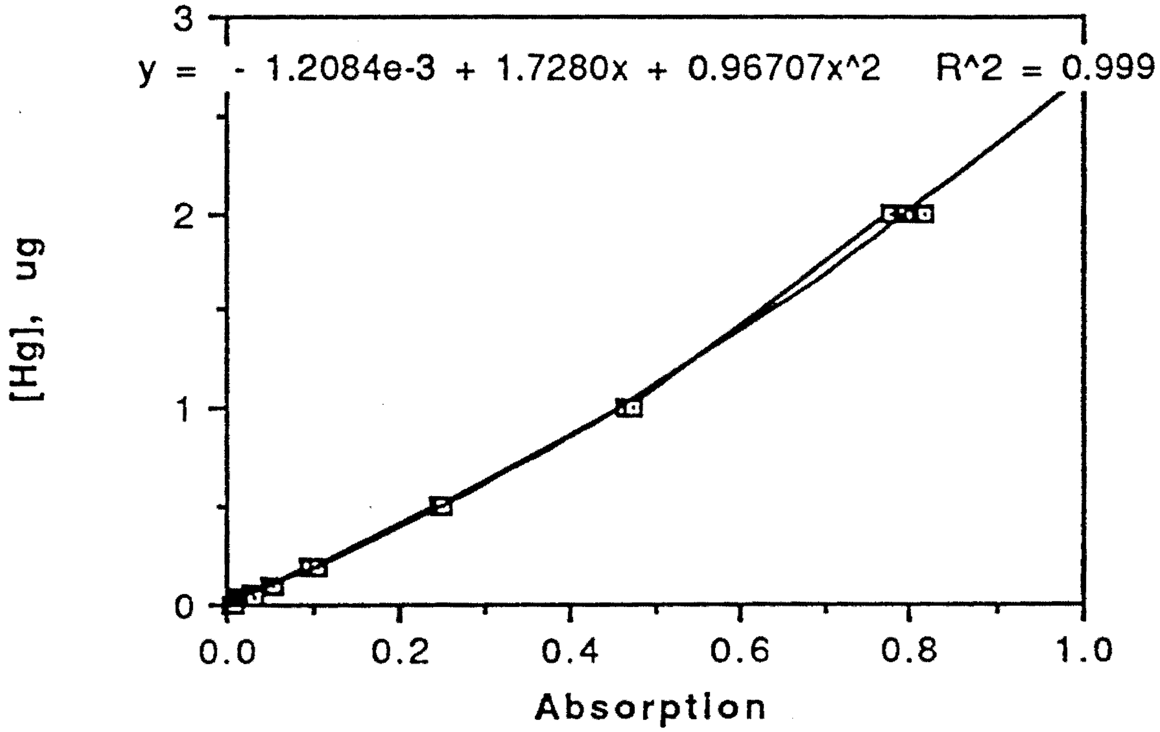
Second order polynomial, Absorbance of 0.25 to 0.80

$$\text{ug Hg} = -0.0012084 + 1.7280(\text{Absorbance}) + 0.96707(\text{Absorbance})^2$$

Third order polynomial, Absorbance of 0.8 to 1.25

$$\text{ug Hg} = -0.020665 + 2.5164(\text{Absorbance}) - 1.9448(\text{Absorbance})^2 + 2.4312(\text{Absorbance})^3$$

Mercury Calibration Data **Cal Poly** **Oct 30, 1992**



Limit of Detection: 0.004 micrograms of Hg

Limit of Quantification: 0.0134 absorbance, or 0.016 micrograms of Hg

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 16-Feb-93

Results of Water Analysis for Mercury Cal Poly

Sample No.	Analysis Date	Absorbance 100mL Aliquot	Measured Mercury Concentration (ug/L)	Blank Corrected Mercury Concentration (ug/L)
CM01W1	04Feb1992	0.018	0.279	0.204
CM01W1(DUP)	20Apr1992	0.013	0.177	0.151
CM02W1	30Jan1992	0.013	0.177	0.129
CM07W1	30Jan1992	0.022	0.360	0.313
CM07W1(DUP 1)	21Apr1992	0.016	0.238	0.212
CM07W1(DUP 1, SPLIT)	22Apr1992	0.021	0.340	0.315
CM07W1(DUP 2)	30Apr1992	0.029	0.503	0.478
CM08W1	30Jan1992	0.002	-0.048	-0.095
CM10W1	30Jan1992	0.004	-0.007	-0.055
CM11W1	30Jan1992	0.002	-0.048	-0.095
CM12W1	04Feb1992	0.007	0.054	-0.020
CM13W1	04Feb1992	0.007	0.054	-0.020
LM01W1	06Feb1992	0.043	0.789	0.715
LM01W1(DUP 1)	20Apr1992	0.049	0.912	0.887
LM01W1(DUP 2)	07May1992	0.046	0.851	0.797
LM02W1	20Apr1992	0.009	0.095	0.069
LM03W1	30Jan1992	0.025	0.422	0.375
LM03W1(DUP 1)	20Apr1992	0.039	0.708	0.682
LM03W1(DUP 2)	07May1992	0.016	0.238	0.184
LM04W1	30Jan1992	0.005	0.013	-0.034
LM04W1(SPLIT)	30Jan1992	0.004	-0.007	-0.055
LM05W1	20Apr1992	0.007	0.054	0.029
LM05W1(DUP)	07May1992	0.000	-0.089	-0.143
LM06W1	30Jan1992	0.005	0.013	-0.034
LM08W1	30Jan1992	0.006	0.033	-0.014
LM09W1	30Jan1992	0.006	0.033	-0.014
LM10W1	30Jan1992	0.005	0.013	-0.034
LM11W1	04Feb1992	0.004	-0.007	-0.082
LM12W1	30Jan1992	0.011	0.136	0.088
LM13W1	30Jan1992	0.001	-0.069	-0.116
LM18W1	30Jan1992	0.006	0.033	-0.014
LM19W1	30Jan1992	0.007	0.054	0.007
LM20W1	30Jan1992	0.033	0.585	0.538
LM21W1	04Feb1992	0.004	-0.007	-0.082
LM21W1(SPLIT)	04Feb1992	0.002	-0.048	-0.123
LM23W1	04Feb1992	0.003	-0.028	-0.102
LM25W1	06Feb1992	0.013	0.177	0.102
LM26W1	06Feb1992	0.001	-0.069	-0.143
LM27W1	04Feb1992	0.004	-0.007	-0.082
LM28W1	04Feb1992	0.006	0.033	-0.041
LM29W1	06Feb1992	0.006	0.033	-0.041
LM29W1(SPLIT)	06Feb1992	0.008	0.074	0.000

Results of Water Analysis for Mercury (Continued) Cal Poly

Sample No.	Analysis Date	Absorbance 100mL Aliquot	Measured Mercury Concentration (ug/L)	Blank Corrected Mercury Concentration (ug/L)
Blank	30Jan1992	0.007	0.054	
Blank	30Jan1992	0.005	0.013	
Blank	04Feb1992	0.008	0.074	
Blank	20Apr1992	0.008	0.074	
Blank	21Apr1992	0.007	0.054	
Blank	22Apr1992	0.004	-0.007	
Blank	23Apr1992	0.005	0.013	
Blank	30Apr1992	0.004	-0.007	
Blank	07May1992	0.007	0.054	
Ave Blank	Jan	0.007	0.047	
Ave Blank	Feb	0.008	0.074	
Ave Blank	Apr	0.006	0.025	

ug Hg/L = (2.0432(Absorbance) - 0.00891)(1000/100) - Ave Blank

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 16-Feb-93

Results of Lake Water Analysis for Mercury Cal Poly

Sample No.	Analysis Date	Absorbance 100mL Aliquot	Measured Mercury Concentration (ug/L)	Blank Corrected Mercury Concentration (ug/L)
LK1W1	27Jul1992	0.007	0.054	0.057
LK1W2	04Aug1992	0.000	-0.089	-0.086
LK2W1	04Aug1992	0.006	0.033	0.037
LK2W2	04Aug1992	0.008	0.074	0.078
LK2W2(Dup)	04Aug1992	0.011	0.136	0.139
LK3W1	27Jul1992	0.007	0.054	0.057
LK3W2	27Jul1992	0.009	0.095	0.098
LK4W1	27Jul1992	0.042	0.769	0.772
LK4W2	27Jul1992	0.011	0.136	0.139
LK5W1	27Jul1992	0.044	0.810	0.813
LK5W2	27Jul1992	0.047	0.871	0.874
LK5W2(Dup)	27Jul1992	0.042	0.769	0.772
LK6W1	27Jul1992	0.007	0.054	0.057
LK6W2	04Aug1992	0.009	0.095	0.098
LK7W1	04Aug1992	0.007	0.054	0.057
LK7W2	04Aug1992	0.008	0.074	0.078
LK8W1	04Aug1992	0.007	0.054	0.057
LK8W2	04Aug1992	0.012	0.156	0.159
LK9W1	27Jul1992	0.005	0.013	0.016
LK9W2	27Jul1992	0.004	-0.007	-0.004
LK10W1	25Jul1992	0.007	0.054	0.057
LK10W2	25Jul1992	0.012	0.156	0.159
LK10W2(Dup)	25Jul1992	0.015	0.217	0.221
Blank	14Jul1992	0.000	-0.089	
Blank	14Jul1992	0.004	-0.007	
Blank	24Jul1992	0.004	-0.007	
Blank	27Jul1992	0.006	0.033	
Blank	04Aug1992	0.007	0.054	
Ave Blank		0.004	-0.003	

ug Hg/L = (2.0432(Absorption) - 0.00891)(1000/100) - Ave Blank

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 16-Feb-93

Results of Soil Analysis for Mercury Cal Poly

Sample No.	Analysis Date	Absorbance	Aliquot (ug Hg)	Aliquot Blank Corrected (ug Hg)	Sample Volume (mL)	Aliquot Volume (mL)	Wet Sample Mass (grams)	Dry Sample Mass (grams)	Blank Corrected Mercury Concentration Dry Mass Basis (ug/g)	Percent Moisture Content by Mass (Dry Basis)
LM22S1	11Feb1992	0.529	1.184	1.179	100	100.0	9.99	7.13	0.165	40.04
LM22S1(SPLIT)	13Feb1992	0.356	0.737	0.732	100	100.0	10.01	7.15	0.102	40.04
LM22S1(DUP)	11Feb1992	0.021	0.034	0.029	100	100.0	10.01	7.15	0.004	40.04
LM22S1(DUP,SPLIT)	13Feb1992	0.001	-0.007	-0.011	100	105.0	10.01	7.15	-0.002	40.04
LM23S1	11Feb1992	0.158	0.314	0.309	100	100.0	10.42	3.92	0.079	165.65
LM23S1(SPLIT)	13Feb1992	0.114	0.224	0.219	100	100.0	10.42	3.92	0.056	165.65
LM23S1(DUP)	11Feb1992	0.010	0.012	0.007	100	100.0	10.35	3.90	0.002	165.65
LM23S1(DUP,SPLIT)	13Feb1992	0.003	-0.003	-0.007	100	100.0	10.35	3.90	-0.002	165.65
LM24S1	11Feb1992	0.001	-0.007	-0.011	100	100.0	10.41	8.10	-0.001	28.55
LM24S1(SPLIT)	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.02	7.79	-0.001	28.55
LM24S1(DUP)	11Feb1992	0.000	-0.009	-0.013	100	100.0	10.48	8.15	-0.002	28.55
AP01S1	15Feb1992	0.001	-0.007	-0.011	100	100.0	10.02	4.63	-0.002	116.3
AP02S1	15Feb1992	0.155	0.308	0.303	100	100.0	10.03	8.59	0.035	16.72
AP02S1(DUP 1)	27Mar1992	0.206	0.412	0.408	100	100.0	10.00	8.57	0.048	16.72
AP02S1(DUP 2)	16Apr1992	0.190	0.379	0.376	100	91.0	10.01	8.58	0.048	16.72
AP02S1(DUP 3)	20Apr1992	0.162	0.322	0.318	100	100.0	10.00	8.57	0.037	16.72
AP02S1(DUP 4)	21Apr1992	0.165	0.328	0.325	100	100.0	10.02	8.58	0.038	16.72
AP02S1(DUP 4, SPLIT)	21Apr1992	0.174	0.347	0.343	100	87.0	10.02	8.58	0.046	16.72
AP02S1(DUP 5)	22Apr1992	0.191	0.381	0.378	100	100.0	9.99	8.56	0.044	16.72
AP02S1(DUP 5, SPLIT 1)	23Apr1992	0.207	0.414	0.410	100	100.0	10.02	8.58	0.048	16.72
AP02S1(DUP 5, SPLIT 2)	23Apr1992	0.190	0.379	0.376	100	95.5	10.06	8.62	0.046	16.72
AP02S1(DUP 6)	30Apr1992	0.172	0.343	0.339	100	93.5	10.08	8.64	0.042	16.72
AP02S1(DUP 7)	05Aug1992	0.192	0.383	0.380	100	93.5	10.08	8.64	0.047	16.72
AP03S1	16Apr1992	0.144	0.268	0.264	100	91.5	10.08	6.69	0.043	50.64
AP03S1(DUP 1)	20Apr1992	0.121	0.222	0.218	100	100.0	10.15	6.74	0.032	50.64
AP03S1(DUP 2)	21Apr1992	0.110	0.201	0.197	100	100.0	10.05	6.67	0.030	50.64
AP03S1(DUP 2, SPLIT)	23Apr1992	0.143	0.266	0.262	100	91.0	10.05	6.67	0.043	50.64
AP03S1(DUP 3)	22Apr1992	0.112	0.204	0.201	100	100.0	9.99	6.63	0.030	50.64
AP03S1(DUP 4)	30Apr1992	0.116	0.212	0.209	100	97.0	10.03	6.66	0.032	50.64
AP04S1	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.07	6.93	-0.002	45.35
AP04S1(DUP)	11Aug1992	0.035	0.063	0.060	100	100.0	10.07	6.93	0.009	45.35

Results of Soil Analysis for Mercury (Continued) Cal Poly

Sample No.	Analysis Date	Absorbance	Aliquot (ug Hg)	Aliquot Blank Corrected (ug Hg)	Sample Volume (mL)	Aliquot Volume (mL)	Wet Sample Mass (grams)	Dry Sample Mass (grams)	Blank Corrected Mercury Concentration Dry Mass Basis (ug/g)	Percent Moisture Content by Mass (Dry Basis)
AP05S1	15Feb1992	0.025	0.042	0.038	100	100.0	10.00	6.94	0.005	44.07
AP06S1	15Feb1992	0.019	0.030	0.025	100	100.0	10.00	7.27	0.003	37.47
B1S1	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.02	7.51	-0.002	33.51
B3S1	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.05	8.05	-0.001	24.86
B3S1 (SPLIT)	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.05	8.05	-0.001	24.86
B3S1 (DUP)	13Feb1992	0.029	0.050	0.046	100	100.0	10.14	8.95	0.005	13.25
BP01S1	13Feb1992	0.005	0.001	-0.003	100	100.0	10.07	7.58	0.000	32.86
BP02S1	13Feb1992	0.052	0.097	0.093	100	100.0	10.02	4.01	0.023	149.70
BP03S1	15Feb1992	0.001	-0.007	-0.011	100	100.0	9.98	2.80	-0.004	255.93
BP04S1	15Feb1992	0.026	0.044	0.040	100	100.0	9.99	6.90	0.006	44.76
BP05S1	13Feb1992	0.001	-0.007	-0.011	100	100.0	10.04	7.33	-0.002	36.99
BP06S1	13Feb1992	0.080	0.155	0.150	100	100.0	10.09	7.54	0.020	33.87
BP07S1	13Feb1992	0.002	-0.005	-0.009	100	100.0	10.00	8.22	-0.001	21.67
BP07S1(DUP)	13Feb1992	0.002	-0.005	-0.009	100	100.0	10.00	8.22	-0.001	21.67
CP01S1	13Feb1992	0.051	0.095	0.091	100	100.0	10.05	6.46	0.014	55.56
J1S1	13Feb1992	0.003	-0.003	-0.007	100	100.0	10.02	7.50	-0.001	33.62
J1S1 (DUP)	05Aug1992	0.005	0.001	-0.002	100	100.0	10.00	7.48	0.000	33.62
J2S1	13Feb1992	0.000	-0.009	-0.013	100	100.0	10.01	6.30	-0.002	58.92
Blank	11Feb1992	0.005	0.001							
Blank	13Feb1992	0.004	-0.001							
Blank	13Feb1992	0.004	-0.001							
Blank	14Feb1992	0.008	0.007							
Blank	15Feb1992	0.012	0.016							
Blank	27Mar1992	0.006	0.003							
Blank	16Apr1992	0.009	0.009							
Blank	20Apr1992	0.008	0.007							
Blank	21Apr1992	0.007	0.005							
Blank	22Apr1992	0.004	-0.001							
Blank	23Apr1992	0.005	0.001							
Blank	30Apr1992	0.004	-0.001							
Blank	05Aug1992	0.007	0.005							
Blank	10Aug1992	0.005	0.001							
Blank	10Aug1992	0.006	0.003							

		Absorbance	ug Hg
Mean Blank Value	Feb	0.007	0.005
Mean Blank Value	Mar, Apr	0.006	0.004
Mean Blank Value	Aug	0.005	0.003

ug Hg = 2.0432(Absorbance)-0.00891 for Absorbance < 0.25

ug Hg = 2.1332(Absorbance)-0.01271 for Absorbance > 0.25

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 18-Feb-93

Results of Soil Analysis for Mercury Cal Poly

Sample No.	Analysis Date	Absorbance	Aliquot (ug Hg)	Aliquot Blank Corrected (ug Hg)	Sample Volume (mL)	Aliquot Volume (mL)	Wet Sample Mass (grams)	Dry Sample Mass (grams)	Blank Corrected Mercury Concentration Dry Mass Basis (ug/g)	Percent Moisture Content by Mass (Dry Basis)
A1S1	27Mar1992	0.068	0.130	0.125	107.0	100.0	10.00	7.39	0.018	35.4
A1S1(DUP)	29Mar1992	0.063	0.120	0.114	100.0	100.0	9.99	7.38	0.016	35.4
A2S1	29Mar1992	0.132	0.261	0.255	96.0	10.0	9.98	7.93	0.309	25.9
B4S1	27Mar1992	0.018	0.028	0.022	92.5	82.3	10.00	7.46	0.003	34.1
B5S1	27Mar1992	0.096	0.187	0.182	84.0	84.0	10.00	7.64	0.024	30.9
B6S1	29Mar1992	0.078	0.150	0.145	104.5	94.0	10.09	8.28	0.019	21.8
B7S1	28Mar1992	0.212	0.424	0.419	91.5	84.1	10.02	8.69	0.052	15.3
B8S1	29Mar1992	0.042	0.077	0.072	102.3	90.0	10.01	9.00	0.009	11.2
CM14S1	29Mar1992	0.074	0.142	0.137	109.1	2.0	10.00	7.26	1.029	37.7
CM15S1	27Mar1992	0.058	0.110	0.104	93.0	15.0	9.96	7.57	0.085	31.6
CM16S1	27Mar1992	0.541	1.217	1.211	89.0	5.0	10.03	8.29	2.600	20.9
CM17S1	27Mar1992	0.095	0.185	0.180	94.3	5.0	9.98	9.22	0.368	8.2
CP2S1	27Mar1992	0.102	0.199	0.194	81.6	74.0	10.04	7.05	0.030	42.5
CP3S1	27Mar1992	0.065	0.124	0.119	88.0	80.2	10.03	7.32	0.018	37.1
LM30S1	28Mar1992	0.892	2.402	2.397	104.2	20.0	9.95	8.07	1.548	23.4
LM31S1	27Mar1992	0.379	0.793	0.787	108.2	5.0	10.06	5.54	3.073	81.5
LM32S1	27Mar1992	0.058	0.110	0.104	86.2	82.0	10.00	8.68	0.013	15.2
LM33S1	27Mar1992	0.704	1.695	1.689	79.5	5.0	10.01	9.87	2.720	1.4
LM34S1	28Mar1992	0.081	0.157	0.151	104.5	88.5	10.11	9.58	0.019	5.5
PS11S1	28Mar1992	0.167	0.332	0.327	101.0	84.0	10.02	8.69	0.045	15.4
PS12S1	28Mar1992	0.185	0.369	0.364	92.0	85.5	10.03	7.47	0.052	34.3
PS13S1	29Mar1992	0.403	0.852	0.847	95.5	10.0	9.97	9.00	0.898	10.7
PS14S1	28Mar1992	0.026	0.044	0.039	98.7	10.0	9.97	8.71	0.044	14.5
PS15S1	28Mar1992	0.056	0.106	0.100	101.0	5.0	9.97	8.97	0.226	11.2
PS16S1	29Mar1992	0.091	0.177	0.172	105.1	95.0	9.99	7.47	0.025	33.7
TRM1S1	29Mar1992	0.142	0.281	0.276	106.0	95.0	10.04	7.22	0.043	39.0
LK01S2	14Jul1992	0.014	0.020	0.025	100.0	100.0	10.02	6.61	0.004	51.5
LK03S2	14Jul1992	0.009	0.009	0.014	100.0	100.0	10.00	10.00	0.001	
LK04S1	14Jul1992	0.042	0.077	0.082	100.0	100.0	10.00	10.00	0.008	
LK04S2	14Jul1992	0.011	0.014	0.018	100.0	100.0	10.00	10.00	0.002	

Results of Soil Analysis for Mercury (Continued) Cal Poly

Sample No.	Analysis Date	Absorbance	Aliquot (ug Hg)	Aliquot Blank Corrected (ug Hg)	Sample Volume (mL)	Aliquot Volume (mL)	Wet Sample Mass (grams)	Dry Sample Mass (grams)	Blank Corrected Mercury Concentration Dry Mass Basis (ug/g)	Percent Moisture Content by Mass (Dry Basis)
LK05S1	14Jul1992	0.049	0.091	0.096	100.0	100.0	10.00	10.00	0.010	
LK05S2(SPLIT)	14Jul1992	0.042	0.077	0.082	100.0	100.0	10.00	10.00	0.008	
LK05S2(DUP)	14Jul1992	0.047	0.087	0.092	100.0	100.0	10.00	10.00	0.009	
Blank	27Mar1992	0.006	0.003							
Blank	27Mar1992	0.009	0.009							
Blank	28Mar1992	0.009	0.009							
Blank	29Mar1992	0.004	-0.001							
Blank	14Jul1992	0.004	-0.001							
Blank	14Jul1992	0.000	-0.009							
Ave Blank	March	0.008	0.005							
Ave Blank	July	0.002	-0.005							

$\text{ug Hg} = 2.0432(\text{Absorbance}) - 0.00891$ for Absorbance < 0.25

$\text{ug Hg} = -0.0012084 + 1.7280(\text{Absorbance}) - 0.96707(\text{Absorbance})^2$ for Absorbance > 0.25 < 0.80

$\text{ug Hg} = -0.020665 + 2.5164(\text{Absorbance}) - 1.9448(\text{Absorbance})^2 + 2.4312(\text{Absorbance})^3$ for Absorbance > 0.8

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 18-Feb-93

Results of Mercury Analysis of Soil Fractions Cal Poly

Sample No.	Analysis Date	Sample Media	Sample Volume (mL)	Volume of Aliquot Analyzed (mL)	Absorbance of Aliquot	Mercury in Aliquot (ug Hg)	Mercury in Vol Used for Analysis (ug Hg)	Blank Corrected Hg in Vol Used for Analysis (ug Hg)	Mercury Conc Wet Basis (ug Hg/L)	Percent Moisture	Dry Sample Mass (grams)	Mercury Conc Dry Basis (ug Hg/g)
CM3S1	26Mar1992	sand	50	0.003	0.162	0.322	5368.140	5368.12	107362.4	145.2	20.39	263.252
CM3S1	26Mar1992	clay	100	0.003	0.058	0.110	3653.187	3653.16	36531.6	75400.0	0.13	27581.389
CM3S1	02Apr1992	silt	50	100.000	1.684	10.312	5.156	5.13	102.7	795.7	5.58	0.920
CM6S1	26Mar1992	sand	50	10.500	0.256	0.505	2.403	2.38	47.6	325.2	11.76	0.202
CM6S1	26Mar1992	clay	100	3.000	0.377	0.788	26.257	26.23	262.3	5800.0	1.69	15.478
CM6S1	26Mar1992	silt	50	3.000	0.609	1.410	23.497	23.47	469.5	280.0	13.16	1.784
CM9S1	26Mar1992	sand	100	5.000	0.175	0.349	6.973	6.95	69.5	66.5	60.08	0.116
CM9S1	26Mar1992	clay	100	3.000	0.122	0.240	8.012	7.99	79.9	242.8	29.17	0.274
CM9S1	26Mar1992	clay	100	3.000	0.112	0.220	7.331	7.31	73.1	242.8	29.17	0.251
CM9S1	26Mar1992	silt	50	3.000	0.232	0.465	7.752	7.73	154.6	282.7	13.07	0.592
LM5S1	25Feb1992	sand	50	5.000	0.590	1.355	13.549	13.53	270.5	253.3	14.15	0.956
LM5S1	02Apr1992	clay	100	100.000	1.396	6.316	6.316	6.29	62.9	205000.0	0.01	629.387
LM5S1	26Mar1992	silt	100	50.000	0.355	0.734	1.468	1.45	14.5	474.1	17.42	0.083
LM9S2	26Mar1992	sand	100	5.000	0.054	0.101	2.028	2.01	20.1	21937.0	0.45	4.421
LM9S2	25Feb1992	clay	100	100.000	1.436	6.782	6.782	6.76	67.6	29185.0	0.34	19.794
LM9S2	25Feb1992	clay	100	100.000	1.446	6.902	6.902	6.88	68.8	22500.0	0.44	15.548
LM9S2	26Mar1992	silt	100	1.000	0.616	1.430	143.020	143.00	1430.0	783.6	11.32	12.635
LM12S1	26Mar1992	sand	100	3.000	0.266	0.527	17.562	17.54	175.4	381.9	20.75	0.845
LM12S1	26Mar1992	clay	100	0.500	0.055	0.103	20.693	20.67	206.7	44478.0	0.22	92.146
LM12S1	26Mar1992	silt	90	0.500	0.540	1.214	218.504	218.48	2427.6	386.4	18.50	11.807
Blank	26Mar1992		100	100.000	0.008	0.007	0.007					
Blank	25Apr1992		100	100.000	0.023	0.038	0.038					
Mean Blank Value					0.016		0.023					

ug Hg = 2.0432(Absorbance) - 0.00891 for Absorbance < 0.25

ug Hg = - 0.0012084 + 1.7280(Absorbance) - 0.96707(Absorbance)^2 for Absorbance > 0.25 < 0.80

ug Hg = - 0.020665 + 2.5164(Absorbance) - 1.9448(Absorbance)^2 + 2.4312(Absorbance)^3 for Absorbance > 0.8

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 16-Feb-93

Results of Mercury Analyses of Duplicate and Split Water Samples

Sample No.	Analysis Date	Absorbance	Blank Corrected Mercury Concentration (ug/L)
CM01W1	04Feb1992	0.018	0.204
CM01W1(DUP)	20Apr1992	0.013	0.151
CM07W1	30Jan1992	0.022	0.313
CM07W1(DUP 1)	21Apr1992	0.016	0.212
CM07W1(DUP 1, SPLIT)	22Apr1992	0.021	0.315
CM07W1(DUP 2)	30Apr1992	0.029	0.478
LM01W1	06Feb1992	0.043	0.715
LM01W1(DUP 1)	20Apr1992	0.049	0.887
LM01W1(DUP 2)	07May1992	0.046	0.797
LM03W1	30Jan1992	0.025	0.375
LM03W1(DUP 1)	20Apr1992	0.039	0.682
LM03W1(DUP 2)	07May1992	0.016	0.184
LM04W1	30Jan1992	0.005	-0.034
LM04W1(SPLIT)	30Jan1992	0.004	-0.055
LM05W1	20Apr1992	0.007	0.029
LM05W1(DUP)	07May1992	0.000	-0.143
LM21W1	04Feb1992	0.004	-0.082
LM21W1(SPLIT)	04Feb1992	0.002	-0.123
LM29W1	06Feb1992	0.006	-0.041
LM29W1(SPLIT)	06Feb1992	0.008	0.000
LK2W2	04Aug1992	0.008	0.078
LK2W2(DUP)	04Aug1992	0.011	0.139
LK5W2	27Jul1992	0.047	0.874
LK5W2(DUP)	27Jul1992	0.042	0.772
LK10W2	25Jul1992	0.012	0.159
LK10W2(DUP)	25Jul1992	0.015	0.221

Statistical Analysis of Results of Mercury Analyses of Duplicate and Split Water Samples

Sample No.	Hg Conc (ug/L)	Duplicate Hg Conc (ug/L)	Split Hg Conc (ug/L)	Average Hg Conc (ug/L)	Deviation Duplicate Analyses (ug/L)	Deviation Split Analyses (ug/L)
CM01W1	0.204	0.151		0.178	-0.026	
CM07W1	0.313	0.212 0.478	0.315	0.334	-0.122 0.144	-0.019
LM01W1	0.715	0.887 0.797		0.800	0.087 -0.003	
LM03W1	0.375	0.682 0.184		0.414	0.268 -0.230	
LM04W1	-0.034		-0.055	-0.045	0.045	-0.010
LM05W1	0.029	-0.143		-0.057	-0.086	
LM21W1	-0.082		-0.123	-0.068	0.068	-0.055
LM29W1	-0.041		0.000	-0.021	0.021	0.021
LK2W2	0.078	0.139		0.109	0.031	
LK5W2	0.874	0.772		0.823	-0.051	
LK10W2	0.159	0.221		0.190	0.031	

Mean Deviation of Duplicate Analyses	0.070
Standard Deviation of Duplicate Analyses	0.062
Mean Deviation of Split Analyses	0.026
Standard Deviation of Split Analyses	0.017

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 16-Feb-93

Results of Mercury Analyses of Duplicate and Split Soil Samples

Sample No.	Analysis Date	Absorption	Blank Corrected Mercury Concentration Dry Mass Basis (ug/g)
A1S1	27Mar1992	0.068	0.018
A1S1(DUP)	29Mar1992	0.063	0.016
AP02S1	15Feb1992	0.155	0.035
AP02S1(DUP 1)	27Mar1992	0.206	0.048
AP02S1(DUP 2)	16Apr1992	0.190	0.048
AP02S1(DUP 3)	20Apr1992	0.162	0.037
AP02S1(DUP 4)	21Apr1992	0.165	0.038
AP02S1(DUP 4, SPLIT)	21Apr1992	0.174	0.046
AP02S1(DUP 5)	22Apr1992	0.191	0.044
AP02S1(DUP 5, SPLIT 1)	23Apr1992	0.207	0.048
AP02S1(DUP 5, SPLIT 2)	23Apr1992	0.190	0.046
AP02S1(DUP 6)	30Apr1992	0.172	0.042
AP03S1	16Apr1992	0.144	0.043
AP03S1(DUP 1)	20Apr1992	0.121	0.032
AP03S1(DUP 2)	21Apr1992	0.110	0.030
AP03S1(DUP 2, SPLIT)	23Apr1992	0.143	0.043
AP03S1(DUP 3)	22Apr1992	0.112	0.030
AP03S1(DUP 4)	30Apr1992	0.116	0.032
B3S1	13Feb1992	0.001	-0.001
B3S1(SPLIT)	13Feb1992	0.001	-0.001
B3S1(DUP)	13Feb1992	0.029	0.005
BP07S1	13Feb1992	0.002	-0.001
BP07S1(DUP)	13Feb1992	0.002	-0.001
LK05S2	14Jul1992	0.049	0.010
LK05S2(SPLIT)	14Jul1992	0.042	0.008
LK05S2(DUP)	14Jul1992	0.047	0.009
LM9S2	25Feb1992	1.446	15.548
LM9S2(DUP)	25Feb1992	1.454	15.769
LM22S1	11Feb1992	0.529	0.165
LM22S1(SPLIT)	13Feb1992	0.356	0.102
LM22S1(DUP)	11Feb1992	0.021	0.004
LM22S1(DUP, SPLIT)	13Feb1992	0.001	-0.002
LM23S1	11Feb1992	0.158	0.079
LM23S1(SPLIT)	13Feb1992	0.114	0.056
LM23S1(DUP)	11Feb1992	0.010	0.002
LM23S1(DUP, SPLIT)	13Feb1992	0.003	-0.002
LM24S1	11Feb1992	0.001	-0.001
LM24S1(SPLIT)	13Feb1992	0.001	-0.001
LM24S1(DUP)	11Feb1992	0.000	-0.002

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 18-Feb-93

Statistical Analysis of Results of Mercury Analyses of Duplicate and Split Soil Samples

Sample No.	Hg Conc (ug/g)	Duplicate Hg Conc (ug/g)	Split Hg Conc (ug/g)	Average Hg Conc (ug/g)	Deviation Duplicate Analyses (ug/g)	Deviation Split Analyses (ug/g)
A1S1	0.018	0.016		0.017	-0.001	
AP02S1	0.035	0.048		0.043	0.005	
		0.048			0.005	
		0.037			-0.006	
		0.038	0.046		-0.005	0.003
		0.044	0.048		0.001	0.005
			0.046			0.003
		0.042			-0.001	
AP03S1	0.043	0.032		0.035	-0.003	
		0.030	0.043		-0.005	0.008
		0.030			-0.005	
		0.032			-0.003	
B3S1	-0.001		-0.001	0.001	-0.001	-0.002
		0.005			0.004	
BP07S1	-0.001	-0.001		-0.001	0.000	
LK05S2	0.010		0.008	0.009	-0.009	-0.001
		0.009			0.000	
LM9S2	15.548	15.769		15.659	0.111	
LM22S1	0.165		0.102	0.067	-0.067	0.035
		0.004	-0.002		-0.063	-0.069
LM23S1	0.079		0.056	0.034	-0.034	0.022
		0.002	-0.002		-0.032	-0.036
LM24S1	-0.001		-0.001	-0.001	0.001	0.000
		-0.002			-0.001	

Mean Deviation of Duplicate Analyses	0.020
Standard Deviation of Duplicate Analyses	0.033
Mean Deviation of Split Analyses	0.017
Standard Deviation of Split Analyses	0.021

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 18-Feb-93

Results of Mercury Analyses of Spiked and Unspiked Water Samples

Sample No.	Analysis Date	Amount of Spike (ug Hg)	Absorbance	Blank Corrected Mercury Concentration (ug/L)	Total Sample Volume (mL)	Aliquot Volume Analyzed (mL)	ug Hg Found in Aliquot	Spike Recovery (ug Hg)	Percent Relative Recovery
LM18W1	30Jan1992	----	0.006	-0.014	100	100	-0.001		
LM18W1(SPIKED)	30Jan1992	0.200	0.115	2.213	100	100	0.221	0.223	111.4
LM25W1	06Feb1992	----	0.013	0.102	100	100	0.010		
LM25W1(SPIKED)	06Feb1992	0.200	0.108	2.043	100	100	0.204	0.194	97.1
LK3W1	27Jul1992	----	0.007	0.057	100	100	0.006		
LK3W1(SPIKED)	27Jul1992	1.000	0.58	11.765	100	100	1.177	1.171	117.1
LK8W1	04Aug1992	----	0.007	0.057	100	100	0.006		
LK8W1(SPIKED)	22Jul1992	0.100	0.062	1.181	100	100	0.118	0.112	112.4
LK8W2	04Aug1992	----	0.012	0.159	100	100	0.016		
LK8W2(SPIKED)	04Aug1992	0.100	0.072	1.385	100	100	0.139	0.123	122.6

Average Percent Relative Recovery: 112.1

Standard Deviation: 8.5

Results of Mercury Analyses of Spiked and Unspiked Soil Samples

Sample No.	Analysis Date	Absorption	Amount of Spike (ug Hg)	Blank Corrected Mercury Concentration Aliquot (ug/g)	Total Volume of Digested Sample (mL)	Aliquot Analyzed (mL)	ug Hg Found in Aliquot	Spike Recovery (ug Hg)	Percent Relative Recovery
AP02S1	15Feb1992	0.155	----	0.303	100	100	0.303		
AP02S1(SPIKED)	15Feb1992	0.190	0.100	0.375	100	100	0.375	0.072	72.0
AP02S1	05Aug1992	0.192	----	0.38	100	93.5	0.406		
AP02S1(SPIKED)	05Aug1992	0.417	0.500	0.84	100	100	0.840	0.434	86.7
AP03S1	21Apr1992	0.110	----	0.197	100	100	0.197		
AP03S1(SPIKED)	21Apr1992	0.163	0.100	0.303	100	100	0.303	0.106	106.0
B8S1	29Mar1992	0.042	----	0.072	102.3	90	0.082		
B8S1(SPIKED)	29Mar1992	0.093	0.100	0.176	102.3	90	0.200	0.118	118.2
J1S1	10Aug1992	0.020	----	0.029	100	100	0.029		
J1S1(SPIKED)	10Aug1992	0.268	0.500	0.539	100	100	0.539	0.510	102.0
LM5S1(Sand)	25Feb1992	0.590	----	1.355	50	5	13.550		
LM5S1(SPIKED)	25Feb1992	0.594	0.100	1.366	50	5	13.660	0.110	110.0
LM9S2(Clay)	25Feb1992	1.446	----	6.88	100	100	6.880		
LM9S2(SPIKED)	25Feb1992	1.454	0.100	6.977	100	100	6.977	0.097	97.0

Average % Relative Recovery: 98.8

Standard Deviation: 14.3

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 14-Aug-92

Results of Kinetic Studies of Hg Transport
Between Contaminated Water and Clean Soil

	Sample No.	Sample Media	Volume Taken From Shaker Flask (mL)	Grams Soil After Filtering (gm)	Moisture Content %	Grams Soil Dry Basis (gm)	Absorbance	Absorbance of Reagent Blank	Mercury in Aliquot (ug Hg)	Blank Corrected Hg in Aliquot (ug Hg)	Mercury Conc in Soil Dry Basis (ug Hg/gm)
24 hr	AP1S1		50.0	0.85	10.59	0.77	0.072	0.013	0.138	0.121	0.157
	AP4S1		48.9	2.03	1.97	1.99	0.052	0.013	0.097	0.080	0.040
	BP3S1		50.0	0.42	0.26	0.42	0.279	0.013	0.583	0.565	1.349
	J1S1		50.0	1.97	0.00	1.97	0.062	0.013	0.110	0.092	0.047
	J1S2		50.2	0.30	0.00	0.30	0.042	0.013	0.073	0.055	0.185
1 week	AP1S1		40.5	2.50	0.13	2.50	0.177	0.008	0.335	0.328	0.131
	AP4S1		22.8	3.60	0.19	3.59	0.159	0.025	0.316	0.274	0.076
	BP3S1		20.0	0.43	0.05	0.43	0.285	0.015	0.573	0.552	1.284
	J1S1		20.0	2.97	0.10	2.97	0.112	0.025	0.220	0.178	0.060
	J1S2		20.0	0.15	0.35	0.15	0.111	0.008	0.179	0.171	1.146
1 month	AP1S1		50.0	2.32	40.50	1.65	0.446	0.003	0.962	0.965	0.584
	AP4S1		50.0	1.77	1.20	1.75					
	BP3S1		50.3	1.10	5.50	1.04	0.309	0.006	0.625	0.622	0.596
	J1S1		46.5	4.30	2.50	4.20	0.035	0.003	0.063	0.065	0.016
	J1S2		51.0	1.68	36.60	1.23					
	AP1S1(Dup)		50.0	2.27	54.60	1.47	0.228	0.003	0.443	0.446	0.304
	Blank						0.003		-0.003		
	Blank						0.006		0.003		
	Blank						0.008		0.007		
	Blank						0.013		0.018		
	Blank						0.015		0.022		
	Blank						0.025		0.042		

	Initial Soil Mass (gm)	Initial Volume 1 ppm Hg Water (mL)
AP1S1	20.10	200
AP4S1	20.07	200
BP3S1	20.00	200
J1S1	20.12	200
J1S2	20.09	200

ug Hg = 2.0432(Absorption)-0.00891 for Absorbance < 0.25
ug Hg = -0.0012084+1.7280(Absorption)-0.96707(Absorbance)^2 for Absorbance > 0.25 < 0.80

CLEAN LAKES ASSISTANCE PROGRAM FOR LAKE NACIEMENTO 14-Aug-92

Results of Kinetic Studies of Hg Transport
Between Contaminated Soil and Clean Water

	Sample No.	Sample Media	Volume Taken From Shaker Flask (mL)	Volume After Filtering (mL)	Volume of Aliquot After Digestion (mL)	Volume of Aliquot Used For Analysis (mL)	Absorbance of Aliquot	Absorbance of Reagent Blank	Mercury in Aliquot (ug Hg)	Blank Corrected Hg in Aliquot (ug Hg)	Mercury Conc in Water (ug Hg/L)
	Blank					100	0.008		0.007		
	Blank					100	0.012		0.016		
24 hr	LM3S1		50.5	46.0	127.0	100.0	0.010	0.008	0.012	0.004	0.113
	LM4S1		50.5	45.0	136.0	100.0	0.002	0.008	-0.005	-0.012	-0.371
	LM10S1		50.0	45.0	127.5	100.0	0.030	0.012	0.053	0.038	1.063
	LM12S1		50.0	46.1	134.0	100.0	0.003	0.008	0.004	-0.003	-0.100
	CM3S1		50.2	46.0	139.0	3.0	0.129	0.008	0.238	0.230	6.961
1 week	LM3S1		50.5	45.0	150.8	100.0	0.008	0.012	0.013	-0.003	-0.098
	LM4S1		51.5	46.0	141.5	100.0	0.007	0.012	0.005	-0.010	-0.314
	LM10S1		50.9	46.0	128.0	50.0	0.007	0.012	0.005	-0.010	-0.284
	LM12S1		50.1	42.0	134.5	100.0	0.005	0.012	0.001	-0.014	-0.458
	CM3S1		50.2	43.5	141.9	1.0	0.363	0.012	0.499	0.483	15.756
1 month	LM3S1		52.9	30.9	134.5	100.0	0.063	0.012	0.111	0.096	4.174
	LM4S1		52.0	38.7	132.0	100.0	0.012	0.012	0.020	0.004	0.138
	LM10S1		51.1	35.5	133.9	100.0	0.011	0.012	0.007	-0.009	-0.333
	LM12S1		53.0	46.0	136.8	100.0	0.050	0.012	0.088	0.072	2.141
	CM3S1		50.5	44.1	260.8	0.3	0.077	0.012	0.148	0.133	7.854
	CM3S1(Dup)		44.0	19.5		0.5					

	Initial Soil Mass (gm)	Initial Volume Water (mL)
LM3S1	20.0	200
LM4S1	20.1	200
LM10S1	20.09	200
LM12S1	20.12	200
CM3S1	20.33	200

ug Hg = 2.0432(Absorption)-0.00891 for Absorbance < 0.25

ug Hg = -0.0012084+1.7280(Absorption)-0.96707(Absorbance)^2 for Absorbance > 0.25 < 0.80

APPENDIX 9

Biological Data Results for Total Mercury performed by FGL Laboratories, Santa Paula, CA and the California Department of Fish and Game Department Laboratories, Sacramento, CA

Raw data from FGL laboratories for all species collected as part of the biological study of the Lake Nacimiento watershed.

Species	Wt. (g)	L (cm)	Hg (ppm)	Location	Feed Habit
I.nebulosus	357	27.5	6.4	Harcourt	Benthic
M.salmoides	2038	50.3	4.36	B.V. Reservoir	Predator
M. salmoides	1662	46.2	3.48	B.V. Reservoir	Predator
D.petenense	44.3	16.4	1.57	Entrance	Phytovore
M.salmoides	485	32.5	1.5	Harcourt	Predator
M.salmoides	505	33.3	1.23	Down River	Predator
I.catus	287	32	1.2	Harcourt	Benthic
L.cyanellus	41	13.5	1.2	Harcourt	Phytovore
M.chrysops	353	28.5	1.06	Entrance	Predator
M.chrysops	266	26.5	0.91	Entrance	Predator
M.salmoides	389	29	0.8	Down River	Predator
I.punctatus	258	31	0.8	Down River	Benthic
M.dolomieui	285	26.2	0.76	Down River	Predator
M.salmoides	711	35.4	0.75	Entrance	Predator
M.dolomieui	297	26.6	0.71	Entrance	Predator
I.punctatus	359	34.5	0.6	Harcourt	Benthic
L.macrochirus	113	12.5	0.6	Harcourt	Phytovore
L.macrochirus	63	15	0.6	Harcourt	Phytovore
M.salmoides	214	25	0.6	Down River	Predator
L.macrochirus	138	19	0.6	Down River	Phytovore
C.occidentalis	572	36.8	0.6	Entrance	Benthic
L.cyanellus	130	17.2	0.5	Harcourt	Phytovore
L.macrochirus	61	14.8	0.5	Harcourt	Phytovore
M.salmoides	283	28	0.5	Down River	Predator
I.punctatus	324	35	0.5	Down River	Benthic
C.carpio	762	39	0.43	Entrance	Benthic
L.macrochirus	88	15	0.4	Harcourt	Phytovore
L.macrochirus	92	15.5	0.4	Down River	Phytovore
L.macrochirus	55	14.3	0.36	Entrance	Phytovore
C.carpio	214.5	37.3	0.33	Entrance	Benthic
I.nebulosus	202	24	0.29	Entrance	Benthic
L.macrochirus	41	13	0.26	Down River	Phytovore
M.salmoides	117	21	0.2	Harcourt	Predator
I.nebulosus	128	21	0.2	Down River	Benthic
I.nebulosus	62	17	0.17	Ramage	Benthic
I.nebulosus	56	17.1	0.17	Ramage	Benthic
Pacifasticus sp.	24.5	4.6	0.06	Ramage	Benthic
Pacifasticus sp.	38.5	5.1	0.05	Ramage	Benthic
I.nebulosus	343	27	0	Harcourt	Benthic

Raw data from CDFG labs for all species collected as part of the biological study of the Lake Nacimiento watershed.

Species	Wt. (g)	L (cm)	Hg (ppm)	Location	Feed Habit
M.salmoides	511	32.5	2	B.V. Reservoir	Predator
M.salmoides	563	33.4	1.4	B.V. Reservoir	Predator
M.salmoides	457	30.6	1.3	B.V. Reservoir	Predator
M.chrysops	558	34.5	1.2	Entrance	Predator
D.petenense	37.5	16.8	1.2	Entrance	Phytovore
M.dolomieui	312.5	29.3	1.1	Marina Forks	Predator
M.salmoides	494	33.2	1	Harcourt	Predator
M.salmoides	467	32.3	1	Nac. Riv Fork	Predator
M.salmoides	690	35.7	1	Nac. Riv Fork	Predator
M.salmoides	281	27.3	0.98	Harcourt	Predator
M.salmoides	604	34.3	0.98	Marina Forks	Predator
M.salmoides	481	32.5	0.94	Harcourt	Predator
M.dolomieui	532	34.7	0.94	Marina Forks	Predator
M.chrysops	346	29.5	0.81	Entrance	Predator
M.chrysops	352	30.5	0.8	Entrance	Predator
M.dolomieui	349	30.8	0.78	Marina Forks	Predator
M.dolomieui	429	31.3	0.78	Nac. Riv. Fork	Predator
M.salmoides	482	33.8	0.78	Nac. Riv. Fork	Predator
C.carpio	1160	46.6	0.77	Nac. Riv. Fork	Benthic
M.dolomieui	422	31.5	0.75	Nac. Riv. Fork	Predator
M.dolomieui	422	30.8	0.75	Nac. Riv. Fork	Predator
L.macrochirus	50	13.5	0.74	Harcourt	Phytovore
M.salmoides	668	35.4	0.72	Nac. Riv. Fork	Predator
M.chrysops	328	28.8	0.7	Entrance	Predator
M.salmoides	496	34.1	0.69	Nac. Riv. Fork	Predator
M.dolomieui	484	33.3	0.69	Nac. Riv. Fork	Predator
M.chrysops	326	29.3	0.68	Entrance	Predator
M.dolomieui	407	31.4	0.68	Nac. Riv. Fork	Predator
L.cyanellus	27	12	0.68	Harcourt	Phytovore
M.salmoides	587	33.1	0.67	Nac. Riv. Fork	Predator
M.salmoides	491	31	0.66	Nac. Riv. Fork	Predator
L.cyanellus	39	12.5	0.66	Harcourt	Phytovore
M.dolomieui	173	24.9	0.65	Nac. Riv Fork	Predator
C.carpio	1550	50.8	0.65	Nac. Riv Fork	Benthic
M.dolomieui	264	26.3	0.63	Marina Forks	Predator
L.macrochirus	64	15.1	0.62	Harcourt	Phytovore
L.macrochirus	59	13.5	0.62	Harcourt	Phytovore
D.petenense	37.5	16.8	0.61	Entrance	Phytovore
I.punctatus	243	30	0.6	Down River	Benthic

Raw data from CDFG labs for all species collected as part of the biological study of the Lake Nacimiento watershed.

Species	Wt. (g)	L (cm)	Hg (ppm)	Location	Feed Habit
M.salmoides	341	28.6	0.57	Entrance	Predator
M.salmoides	325.5	27.8	0.57	Nac. Riv. Fork	Predator
C.carpio	1256	43.6	0.57	Nac. Riv Fork	Benthic
M.salmoides	350	28.4	0.56	Nac. Riv. Fork	Predator
M.dolomieui	417	31.7	0.56	Marina Forks	Predator
L.macrochirus	64	15	0.56	Down River	Phytovore
M.dolomieui	256	26.1	0.56	Nac. Riv Fork	Predator
M.salmoides	127	18.7	0.55	Harcourt	Predator
M.dolomieui	300	31.1	0.54	Nac. Riv. Fork	Predator
L.macrochirus	66	14.5	0.54	Down River	Phytovore
M.salmoides	27	13	0.54	Down River	Predator
L.macrochirus	57	14	0.53	Down River	Phytovore
M.salmoides	628	35.2	0.51	Nac. Riv. Fork	Predator
C.occidentalis	556	34.6	0.5	Entrance	Benthic
M.salmoides	330	27.8	0.47	Nac. Riv. Fork	Predator
I.punctatus	162	24	0.47	Down River	Benthic
M.salmoides	403	31.3	0.45	Entrance	Predator
C.occidentalis	402	32.7	0.44	Marina Forks	Benthic
C.carpio	1160	46.6	0.4	Nac. Riv. Fork	Benthic
M.dolomieui	174	23.5	0.4	Entrance	Predator
D.petenense	13	11.5	0.39	Nac. Riv Fork	Phytovore
C.carpio	1256	43.6	0.38	Nac. Riv. Fork	Benthic
M.salmoides	249.5	26.1	0.36	Marina Forks	Predator
L.macrochirus	60	14.7	0.36	Marina Forks	Phytovore
M.salmoides	421	29.3	0.35	Marina Forks	Predator
C.carpio	1550	50.8	0.34	Nac. Riv. Fork	Benthic
L.macrochirus	43	12.5	0.34	Harcourt	Phytovore
C.occidentalis	536	34.8	0.34	Marina Forks	Benthic
L.macrochirus	149.8	19.2	0.33	Marina Forks	Phytovore
C.occidentalis	491	33.1	0.33	Nac. Riv Fork	Benthic
C.occidentalis	453	32.4	0.33	Nac. Riv Fork	Benthic
L.macrochirus	34	12.4	0.33	Marina Forks	Phytovore
L.macrohcirus	60	16	0.31	Marina Forks	Phytovore
C.occidentalis	428	33.3	0.3	Entrance	Benthic
M.chrysops	164.6	23.3	0.28	Marina Forks	Predator
L.macrochirus	64	14.8	0.28	Nac. Riv Fork	Phytovore
M.salmoides	259	25.4	0.26	Nac. Riv. Fork	Predator
I.nebulosus	72	17.5	0.24	Down River	Benthic
L.macrochirus	41	12.9	0.23	Marina Forks	Phytovore
L.macrochirus	49	14	0.23	Marina Forks	Phytovore

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Raw data from CDFG labs for all species collected as part of the biological study of the Lake Nacimiento watershed.

Species	Wt. (g)	L (cm)	Hg (ppm)	Location	Feed Habit
L.macrochirus	55	14.6	0.2	Marina Forks	Phytovore
L.macrochirus	42.5	13.3	0.2	Marina Forks	Phytovore
C.occidentalis	402	32.7	0.19	Marina Forks	Benthic
I.nebulosus	69.5	17.7	0.14	Ramage	Benthic
Pacifasticus sp.	36.5	5.5	0.09	Ramage	Benthic
Coccidentalis	536	34.8	0.08	Marina Forks	Benthic
Pacifasticus sp.	16.3	3.8	0.07	Ramage	Benthic
Pacifasticus sp.	15	3.7	0.06	Ramage	Benthi
Pacifasticus sp.	36.5	5.5	0.03	Ramage	Benthic