FINAL TECHNICAL MEMORANDUM NO. 2A - MINE DRAINAGE
CALIFORNIA URBAN WATER AGENCIES
STUDY OF DRINKING WATER QUALITY IN DELTA TRIBUTARIES

April 12, 1994

In the State Water Project (SWP) Sanitary Survey, the impacts of mine drainage from the Central Valley watershed were determined to be of less concern to Delta drinking water supplies than other sources of contaminants to the Delta (Brown and Caldwell, 1990). The primary reason for that determination was that although metals concentrations in mine drainage often exceed the 1991 Inland Surface Waters Plan (ISWP) objectives for aquatic life (California State Water Resources Control Board, 1991), they are typically well below current drinking water standards. Additional information collected on mine drainage in the Central Valley since completion of the SWP Sanitary Survey was reviewed to reassess the potential impacts of mine drainage on drinking water quality of Delta tributaries. The purpose of this technical memorandum is to address the significance of mine drainage as a source of: (1) contaminants of concern selected specifically for this study, (2) other principal mine drainage contaminants in terms of current and future drinking water standards, and (3) concern to other drinking water issues.

Contaminants of concern selected specifically for loads evaluation in this study are shown in Table 1. These contaminants were selected for evaluation because they are, for the most part, contaminants for which drinking water standards may be difficult to achieve for Delta water users. Arsenic is the only one of these contaminants of concern for which mine drainage is a significant source. The significance to this study of including mine drainage arsenic data in the loads evaluation is therefore discussed.

Mine drainage is considered the principal source of cadmium, copper, and zinc in the Sacramento River. Therefore, the effect of mine drainage on the ability of the Sacramento River to meet current and future drinking water standards for these metals is reviewed.

There are drinking water issues not related to drinking water standards and treatability issues. These other issues, for example, involve concerns such as the contribution of metals in drinking water to wastewater treatment plant effluent and sludge. Wastewater discharges are being required to meet increasingly stringent effluent limitations. Wastewater treatment plant sludge is required to meet metals concentration limits both for classification as "clean sludge" and for land application uses. These requirements are described in the U.S. Environmental Protection Agency's (EPA's) Part 503 "Technical Regulation for Sewage Sludge Use and Disposal" and are for the following metals: arsenic, cadmium, chromium, copper, mercury, molybdenum, nickel, lead, selenium, and zinc. Mine drainage is the principal source of copper, which is, so far, the metal of primary concern in drinking water contributions to wastewater treatment plants.

Table 1. Contaminants of Concern

1. Disinfection by-product precursors, surrogates, and control parameters

   THMFP and TFPC (THM formation potential carbon)
   Organic carbon (total (TOC) and dissolved (DOC))
   Humic and fulvic acids
   UV 254
   Bromide
   Chlorophyll a or pheophytin
   pH and alkalinity

2. Microbiological contaminants

   Coliforms
   Giardia
   Cryptosporidium
   Viruses
   Turbidity (interferes with microbiological tests)

3. Nutrients

   Ammonia
   Nitrate
   Phosphorus

4. Arsenic

5. Total dissolved solids

6. Pesticides/herbicides

The first section of this Technical Memorandum provides background information on mines in the Central Valley watershed. The second section discusses the significance of mines to this study in terms of the three issues described above.

BACKGROUND INFORMATION ON MINES IN THE CENTRAL VALLEY WATERSHED

Mining operations in central and northern California have been primarily for the recovery of: (1) copper, zinc, and other nonferrous metals from sulfide ore bodies, (2) gold, and (3) mercury. Mining of sulfide ore bodies has occurred primarily in the Lake Shasta area and also in the foothills of the Sierra Nevada. Mining for gold has centered in the Sierra Nevada foothills. Mercury mining has been primarily in the Coast Ranges.

Regulation of Mines in the Central Valley

The California Regional Water Quality Control Board, Central Valley Region (Regional Board) manages active and inactive mines in the Central Valley under the Waste Discharge Requirement program, the National Pollutant Discharge Elimination System (NPDES) permitting program, and on a case-by-case basis. Permit conditions for active mines allow only inert or non-hazardous waste releases. Active mining operations meet these conditions by controlling the acidity of their discharges and by other best management practices.

Several thousands of mines have been worked and later abandoned. Discharges from these inactive mines constitute a significantly greater threat to water quality than discharges from active mines. Therefore, only inactive mines are discussed further.

Historically, the Regional Board has had difficulty in addressing inactive mines due to insufficient resources and concern over the state assuming liability for the clean-up. Many inactive mines have either no principle responsible party (PRP) or no PRP willing to accept or capable of accepting the financial consequences of mine discharge abatement. In addition, in the instance of Penn Mine, where the Regional Board initiated abatement, subsequent litigation from The Friends of the Mokelumne River to force the Regional Board to assume comprehensive liability for abatement of Penn Mine discharges to meet water quality standards, has delayed further Regional Board sponsored abatement projects.

As directed under the Pollutant Policy Document, the Regional Board must limit mass loadings of arsenic, cadmium, copper, mercury, selenium, silver, and polynuclear aromatic hydrocarbons to the Delta (California State Water Resources Control Board, 1990). The Regional Board has added lead and zinc to this list. In developing their mass loading reduction strategy, the Regional Board has developed load estimates for five of these pollutants from the major sources in the Central Valley. These load estimates are shown in Table 2. It should be noted that these mass load estimates are preliminary, unrefined numbers. For some sources, there are insufficient quantified data for factors affecting mass load estimates. Because inactive mines are the principle source of several of these pollutants, mine abatement projects are receiving renewed attention.

In addition, the ISWP, adopted in April 1991, listed numeric water quality objectives for a variety of pollutants (including metals) to be met in nonpoint sources (such as inactive mines) as well as in point source discharges. The fact that inactive mines are the principle source of several of the metals (cadmium, copper, and zinc) for which the ISWP objectives are exceeded in the Sacramento River at Freeport further focused Regional Board attention on mine discharge abatement (Larry Walker Associates, 1992). The ISWP objectives are currently being reconsidered by the State Water Resources Control Board pursuant to a recent court ruling that all legally required considerations were not taken into account in developing the objectives. In addition to state regulation, two of the major inactive mine sites in the Central Valley (Iron Mountain Mine and Sulfur Bank Mine) are federal Superfund sites.

Table 2. Estimated Sources of Metals Loadings to the Sacramento River

Source	Estimated percent of total load in the Sacramento River at Freeport				
	As	Cd	Cu	Pb	Zn
Inactive mines	11	72	59	2.5	60
Urban runoff	24	12	11	80	20
Agricultural drainage	61	15	28	15	17
NPDES discharges	4	1	2	2.5	3
Total	100	100	100	100	100

Source: Regional Board (1993a).

Mine Drainage Quality

Sulfide ore mines produce acid mine drainage. Acid mine drainage is formed primarily from the oxidation of pyrite sulfide ores within mine workings and at the surface of waste rock piles. This reaction produces sulfuric acid with a pH ranging from about 0.5 to 3. The low pH dissolves metals in the surrounding rock generating a discharge containing high dissolved metals concentrations. Acid mine drainage can contain elevated levels of copper, cadmium, and zinc and, usually lower concentrations of other metals such as nickel, lead, and chromium. Acid mine drainage may also carry radionuclides. Radionuclide levels in Central Valley acid mine drainage have not been studied. Drainage from gold mines can contain elevated levels of arsenic (from the host rock) and mercury (once used in the gold amalgamation process). Drainage from mercury mines can contain elevated levels of mercury.

Mine drainage is carried out of the mine when infiltrating water floods the interior to the top level of the lowest adit (underground shaft). Mine drainage is also discharged from waste rock piles when rainfall or streamflow contact the piles.

Key Mine Discharges

The Regional Board (1979) ranked the largest inactive mines according to their threat to downstream water quality. Inactive mines with high and medium rankings as of 1979 are listed in descending order in Table 3. Abatement projects have been implemented at seven of these mines and therefore, the threat to water quality may have been reduced since the initial rating in 1979. The locations of these mines are shown on Figures 1 and 2. Eleven of the inactive mines listed in Table 3 are located upstream of reservoirs. Some unknown percent of the contaminants in the drainage from these mines is entrained within the sediments of the downstream reservoirs.

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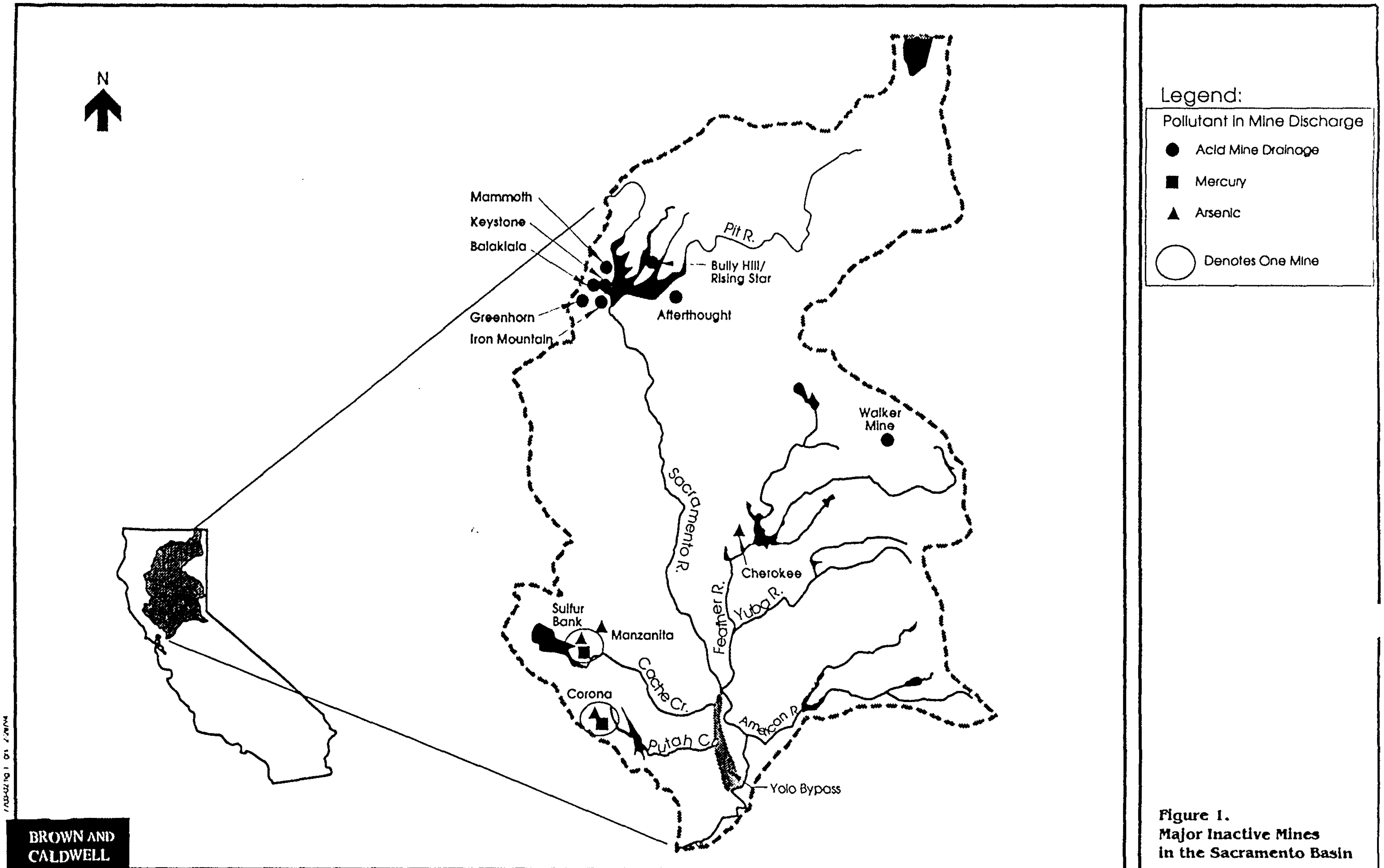

BROWN AND CALDWELL

Figure 1.
Major Inactive Mines in the Sacramento Basin

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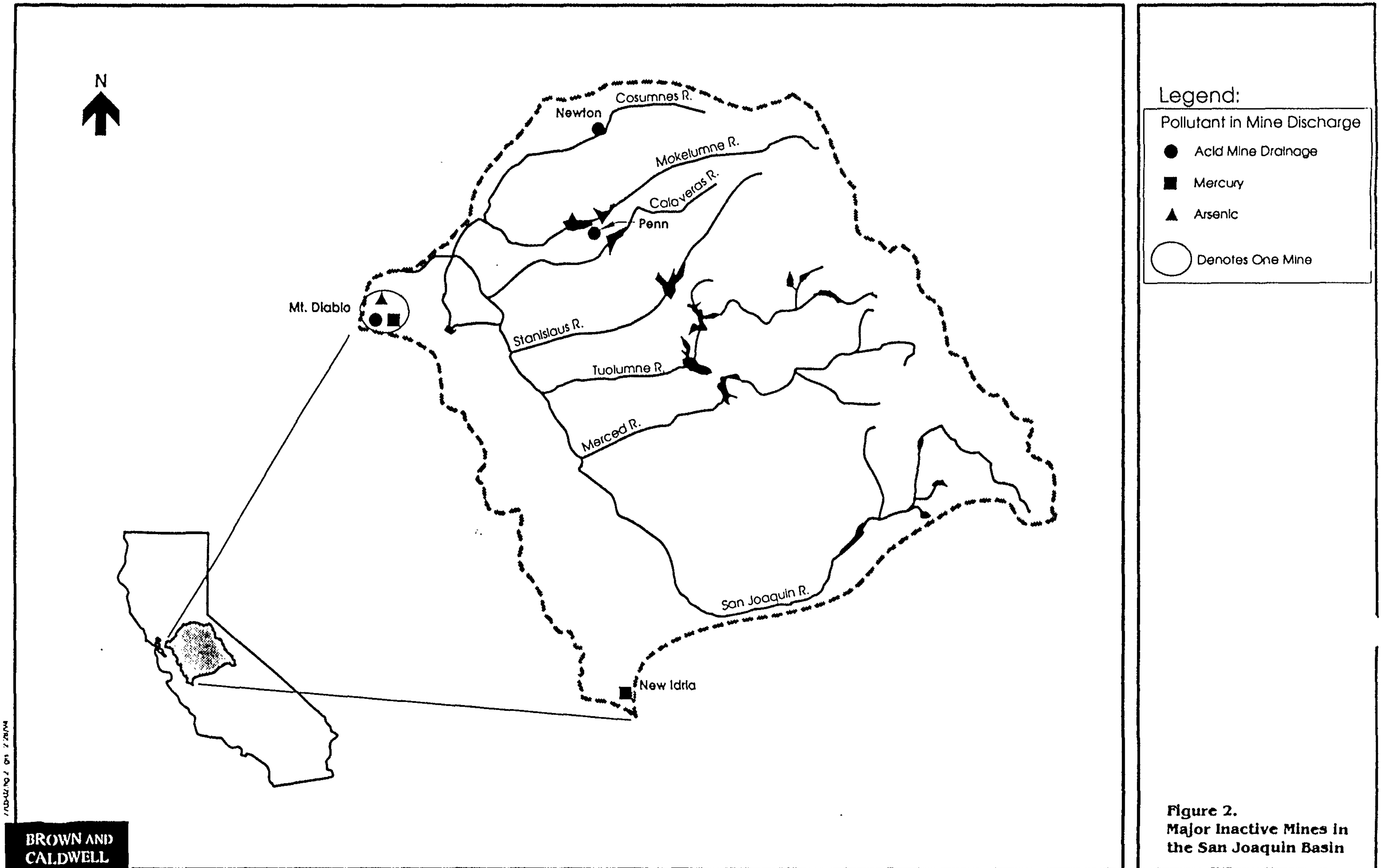

Figure 2.
Major Inactive Mines in the San Joaquin Basin

Abatement Projects at Key Mines. Abatement projects have been or are being implemented at several of the key mines listed in Table 3. These control actions are described below. The effectiveness of the controls has not yet been completely evaluated and the total reduction in loads to the Sacramento River has not been estimated.

1. Iron Mountain Mine. The most significant abatement project underway is at Iron Mountain Mine. Iron Mountain Mine is the largest inactive mine pollutant source in the Central Valley and is estimated to contribute over 50 percent of the copper, arsenic, cadmium, chromium, zinc and lead loadings from inactive mines to the Sacramento Basin (Regional Board, 1989). Existing controls include the Spring Creek Diversion Dam, rerouting of surface drainage, and capping major infiltration areas. The Spring Creek Diversion Dam collects and discharges water from the entire Spring Creek watershed including mine drainage and background stream flow. Work is underway to construct a treatment plant to remove copper, cadmium, and zinc from adit flows. The Spring Creek Diversion Dam is scheduled to be enlarged by 1995-96. Control actions are projected to reduce copper loads from the mine to the Sacramento River by at least 70 percent (Regional Board, 1993b).

Table 3. Major Inactive Mines in the Watersheds Rated as High or Medium Threat to Water Quality in 1979

Mine	Watershed location
Iron Mountain[a]	Sacramento
Mammoth[a]	Sacramento
Penn[a]	San Joaquin
Balaklala[a]	Sacramento
Keystone[a]	Sacramento
Afterthought	Sacramento
Mt. Diablo	San Joaquin
Bully Hill	Sacramento
Rising Star	Sacramento
Walker[a]	Sacramento
Sulfur/Sulphur Bank[a]	Sacramento
Newton	San Joaquin
Greenhorn	Sacramento
New Idria	San Joaquin
Corona	Sacramento
Manzanita	Sacramento
Cherokee	Sacramento

[a]Abatement projects have been implemented at these mines since the initial rating.

Source: Regional Board (1985).

2. Mammoth Mine. Portal sealing began in 1981 but was interrupted by owner bankruptcy and change in the PRP. Additional portal sealing was completed in 1993. Estimates of copper load reductions from the portals are in the order of 90 percent (Regional Board, 1993b).

3. Penn Mine. Evaporation ponds were constructed in 1979 to control the discharge of acid mine drainage from storm runoff. Discharges occurred to Camanche Reservoir during very heavy storms prior to the onset of the recent drought. During the 1987 to 1992 drought, there were no discharges from these ponds. The East Bay Municipal Utility District (EBMUD) constructed an in-line lime treatment plant in the spring of 1993 that removes approximately 98 percent of the cadmium, copper, and zinc load (Personal Communication, Richard Sykes, EBMUD and Tom Pinkos, Regional Board). In December 1993, the EPA issued an Order that required EBMUD to finance studies and waste rock and groundwater clean-up activities at the mine. The Regional Board and EBMUD responded to the Order stating that EPA had no authority under the Clean Water Act to require EBMUD to clean-up the site. EPA has not yet reacted to the Regional Board and EBMUD response.

4. Balaklala Mine. Abatement projects have included sealing of the Balaklala and Weil portals (Larry Walker Associates, 1992).

5. Keystone Mine. Portal sealing was completed in 1992. Estimates of copper load reductions from the portal are in the order of 90 percent (Regional Board, 1993b).

6. Walker Mine. Portal sealing in 1989 resulted in an estimated 98 percent reduction in the copper load from the portal. Abatement of the tailings piles is currently being studied (Regional Board, 1993b).

7. Sulfur/Sulphur Bank Mine. The existing abatement project involves a diversion dam (Larry Walker Associates, 1992).

Additional mines (not shown in Table 2) where abatement projects are existing or underway include Sutro Mine, Golinsky Mine, Early Bird Mine, Shasta King Mine, and Stowell Mine (Larry Walker Associates, 1992). With the exception of Stowell Mine, these mines are all upstream of Lake Shasta.

Mine Drainage Contaminants of Concern

Most inactive mines do not have extensive drainage quality monitoring systems. Therefore, limited drainage quality data are available. Table 4 shows average mine drainage quality from three inactive mines and the Spring Creek Diversion Dam. The most complete drainage quality data are from Spring Creek Diversion Dam which has been studied extensively. Cadmium, copper, and zinc concentrations in drainage from Spring Creek Diversion Dam, Afterthought Mine, and Rising Star Mine exceed drinking water standards. Arsenic concentrations are above the range (0.5 to 20 micrograms per liter (μg/l)) that is currently being considered for the maximum contaminant level (MCL).

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Table 4. Comparison of Average Metals Concentrations in Mine Drainage to Drinking Water Standards

Constituent, µg/l	Maximum contaminant level	Spring Creek Diversion Dam (Upper Sacramento River)	Afterthought Mine (Upper Sacramento River)	Rising Star Mine (Shasta Lake)	Brush Creek Mine (Yuba River)
Arsenic	50[a]	44	25	865	62-221
Cadmium	5	94	340	130	<0.1
Chromium	100	11	2	3	2.1
Copper	1,300	3,077	14,000	3,100	<1-1
Lead	--	20	91	45	<5
Nickel	100	12	32	12	29-133
Zinc	5,000[b]	19,460	93,000	30,000	<10

[a]The arsenic MCL will likely be reduced in the next few years. The range that is being considered is 0.5 to 20 µg/l.
[b]Secondary standard.

Source: Regional Board (1992).

Although the concentrations of several metals in mine drainage exceed drinking water standards, the concentrations in downstream rivers used as drinking water supplies are consistently below drinking water standards. The City of Redding takes water from the Sacramento River downstream of Lake Shasta. They have been able to consistently meet drinking water standards for metals in their water supply. Redding is notified by the Bureau of Reclamation when uncontrolled releases occur from the Spring Creek Diversion Dam. As a general rule, Redding does not pump water from the river during these periods due to customer concerns rather than water quality concerns (Personal Communication, Mike Robertson, City of Redding). Further downstream the City of Sacramento pumps water from the Sacramento River. As with Redding, metals concentrations are well below current drinking water standards. Arsenic concentrations in both the Redding and City of Sacramento water supplies may exceed the drinking water standard if it is set in the 0.5 to 20 µg/l range.

Of the contaminants of concern which are the focus of this Study of Drinking Water Quality in Delta Tributaries, the one contaminant for which mine drainage is a source, is arsenic. As shown in Table 1, the Regional Board estimates that mine drainage is the source of about 11 percent of the arsenic load in Central Valley streams. The primary source of the arsenic is from arsenopyrite rock associated with gold mines (Regional Board, 1992).

Table 5 shows mines with average arsenic concentrations in their mine drainage greater than 20 μg/l. These mines are mostly near Lake Shasta or in the Yuba/Bear Rivers watershed. Mine drainage from other mines in the Yuba River watershed has significantly higher arsenic concentrations. The drainage from 16 to 1 Mine contains about 1 to 2 milligrams per liter (mg/l) of arsenic and Goodyear's Bar Mine, arsenic concentrations exceed 5 mg/l. (Personal Communication, Bill Johnson, Regional Board). Arsenic concentrations in creeks downstream of these mining areas can range from nondetectable to 170 μg/l in Buckeye Ravine in the Yuba River watershed and 23 μg/l in Cline Creek in the Sacramento River watershed. (Regional Board, 1992). Fifty to 90 percent of the arsenic in the Yuba/Bear River's watershed is in the dissolved form due to low iron content and near neutral pH in mine drainage from this particular area. Arsenic concentrations in the Yuba River downstream of the monitored creeks are below 5 μg/l (Regional Board, 1992). If the arsenic MCL is established at the lower end of the range that is being considered (0.5-20 μg/l), Sacramento River water suppliers may have difficulty meeting this standard. Based on bimonthly samples collected since late 1990 for the Sacramento Coordinated Monitoring Program, arsenic concentrations in the Sacramento River in the vicinity of Sacramento are in the range of <1 to 3.1 μg/l.

Table 5. Mine Drainage With Average Arsenic Concentrations Greater Than 20 μg/l

Mine	Watershed	Average arsenic concentration, μg/l
Rising Star Mine	Lake Shasta	865
Afterthought Mine	Sacramento River	25
Spring Creek Diversion Dam	Sacramento River	44
Greenhorn Mine	Sacramento River	105
Kanaka Creek Mines	Yuba River	20
Brush Creek Mine	Yuba River	62-221[a]
Plumbago Mine	Yuba River	264
Valley View Mine	Bear River	75
Lava Cap Mine	Bear River	57
Empire Mine	Cache Creek	49
Reed Mine	Cache Creek	59

[a]Averages for the main adit and upper adit.

Source: Regional Board (1992).

Loads of Contaminants

The Regional Board (1993b) estimates that 99 percent of the total annual pounds of arsenic, cadmium, copper, lead, and zinc discharged from inactive mines to Central Valley receiving streams is discharged to the Sacramento River Basin upstream of the Delta. The San Joaquin Basin and the Delta receive less than 1 percent of the total Central Valley load.

In 1985, the Regional Board estimated that loads from Iron Mountain Mine alone contributed approximately 76 percent of the cadmium, 80 percent of the zinc, and 67 percent of the copper to the Sacramento River below Keswick Dam (Regional Board, 1989). More recently, the Regional Board estimated that Spring Creek Diversion Dam may contribute approximately 50 percent of the total arsenic load and two mines in the Yuba River watershed (Kanaka Creek Mine and Brush Creek Mine) are estimated to contribute approximately 38 percent of the arsenic load (Regional Board, 1992).

The greatest loads of metals from most inactive mines are typically discharged between October and April when rainfall causes runoff from waste piles and tunnel complexes where water has risen and overflowed. Mine loads are strongly correlated with total annual precipitation. The seasonal loading pattern is different at Iron Mountain Mine due to the Spring Creek Diversion Dam release schedule stipulated in a 1980 Memorandum of Understanding with the Regional Board and several other agencies. Spring Creek Diversion Dam, which was constructed to control releases from the mine to prevent salmon kills, is operated to allow releases to coincide with high summer releases from Shasta Reservoir. Higher releases may also be made during periods of very heavy rainfall to avoid an uncontrolled spill. Total monthly loads from Iron Mountain Mine and Spring Creek Diversion Dam are greatest during late winter and spring.

Mitigation of Mine Drainage Effects

Mine drainage effects are mitigated in several ways. First, as the dissolved metals are transported away from the mine, the pH increases as the mine drainage is diluted from contact with other water. Some percent of the metals then precipitate out and metal concentrations in the receiving stream decrease. Much of the concern with acid mine drainage, therefore is with the threat to aquatic life immediately downstream of the discharge. Twenty-one of 31 mines surveyed by the Regional Board impacted receiving waters immediately downstream of the mine (Regional Board, 1992). Second, some unknown though probably significant percentage of contaminants are entrained in downstream reservoirs. Third, discharges from most mines occur during the rain season when river flows are higher and more dilution is generally available. Fourth, constructed abatement projects (described above) have reduced metals loadings at several of the key mines.

SIGNIFICANCE OF MINES TO THIS STUDY

This discussion addresses three issues: the significance of mine drainage in terms of arsenic concentrations and loads, in terms of drinking water standards for cadmium, copper, and zinc, and in terms of other drinking water issues.

Arsenic Concentrations and Loads

As stated previously, if the arsenic MCL is established at the lower range that is being considered (0.5 to 20 μg/l), Sacramento River water suppliers may have difficulty meeting this standard. Much of the total arsenic load is contributed by Spring Creek Diversion Dam directly to the Sacramento River and by mines in the Yuba River watershed which contribute arsenic, mostly in the dissolved form. Eleven percent of the total arsenic discharged to Central Valley rivers is attributed to mine drainage. The significant sources of arsenic to the Central Valley Basin as a whole are considered by the Regional Board to be urban runoff and agricultural drainage.

The specific sources of arsenic in urban runoff and agricultural drainage are not discussed in detail in the Regional Board's studies except that arsenic is noted to be a component of some agricultural chemicals. The Department of Pesticide Regulation withdrew registration of most arsenical pesticides approximately 10 years ago. There are a few restricted arsenic-containing compounds allowed for treating wood products and potentially a few arsenic-containing herbicides. (Personal communication, Phil Anderson, Department of Pesticide Regulation). The main sources of arsenic in agricultural drainage, therefore, may not be pesticides. Alternatively, mine drainage and/or other sources of arsenic may be more significant than reflected in the Regional Board estimates.

Virtually all mine drainage arsenic concentration and mine drainage flow data are collected by the Regional Board. The Regional Board load estimates, therefore, reflect the universe of available data for calculating arsenic loads from mine drainage. Problems with calculating loads from mine drainage include the extremely inconstant nature of mine discharges and the relatively small number of data points available for analysis, particularly the lack of sufficient flow measurements. Before recommending that arsenic loads from mine drainage be included in the loads evaluation for this study, it may be appropriate to more completely investigate and assess the methodology used by the Regional Board in estimating mine damage as a source of only eleven percent of the total arsenic load to the Sacramento River.

Drinking Water Standards for Other Metals

Metals concentrations were found to be below drinking water standards in both the Sacramento River at the Sacramento Water Treatment Plant intake and Greene's Landing, and the San Joaquin River at Vernalis in the SWP Sanitary Survey. As discussed previously, the City of Redding and the City of Sacramento have historically found all metals concentrations to be below current drinking water standards in their raw and finished water. Unlike many contaminant sources, the effect of mines (located almost entirely in the upper reaches of the

Central Valley watershed) is mitigated by downstream reservoirs and increased pH rather than aggravated by additional sources in the lower reaches of Central Valley rivers. Mine drainage may become of more concern to drinking water agencies in the future if MCLs for these metals are lowered.

Other Drinking Water Issues

Copper concentrations in drinking water are of concern to water suppliers because drinking water is a significant source of copper to wastewater treatment plants. Regional Boards are requiring copper concentrations in wastewater effluent and wastewater sludge be reduced in some areas of California. In Santa Clara, the Regional Board has requested the Santa Clara Valley Water District to conduct studies and participate in copper reduction programs for local wastewater treatment plants who receive wastewater from their service area. The Los Angeles Department of Water and Power (LADWP) is also pressed to limit copper in its finished water because an estimated 25 percent of copper in local wastewater treatment plant sludge is from the drinking water supply.

In addition to wastewater effluent and sludge issues, some metals are a concern due to their concentrations in water treatment plant solid waste products. The LADWP has concerns that arsenic and copper concentrations in their treatment plant residual are at California hazardous waste levels.

A potential future concern regarding mine drainage is the possibility of protecting aquatic life through higher winter releases to dilute mine drainage. This could have an indirect effect on Delta tributary water quality through a corresponding reduction in releases during the summer when seawater intrusion is greatest.

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