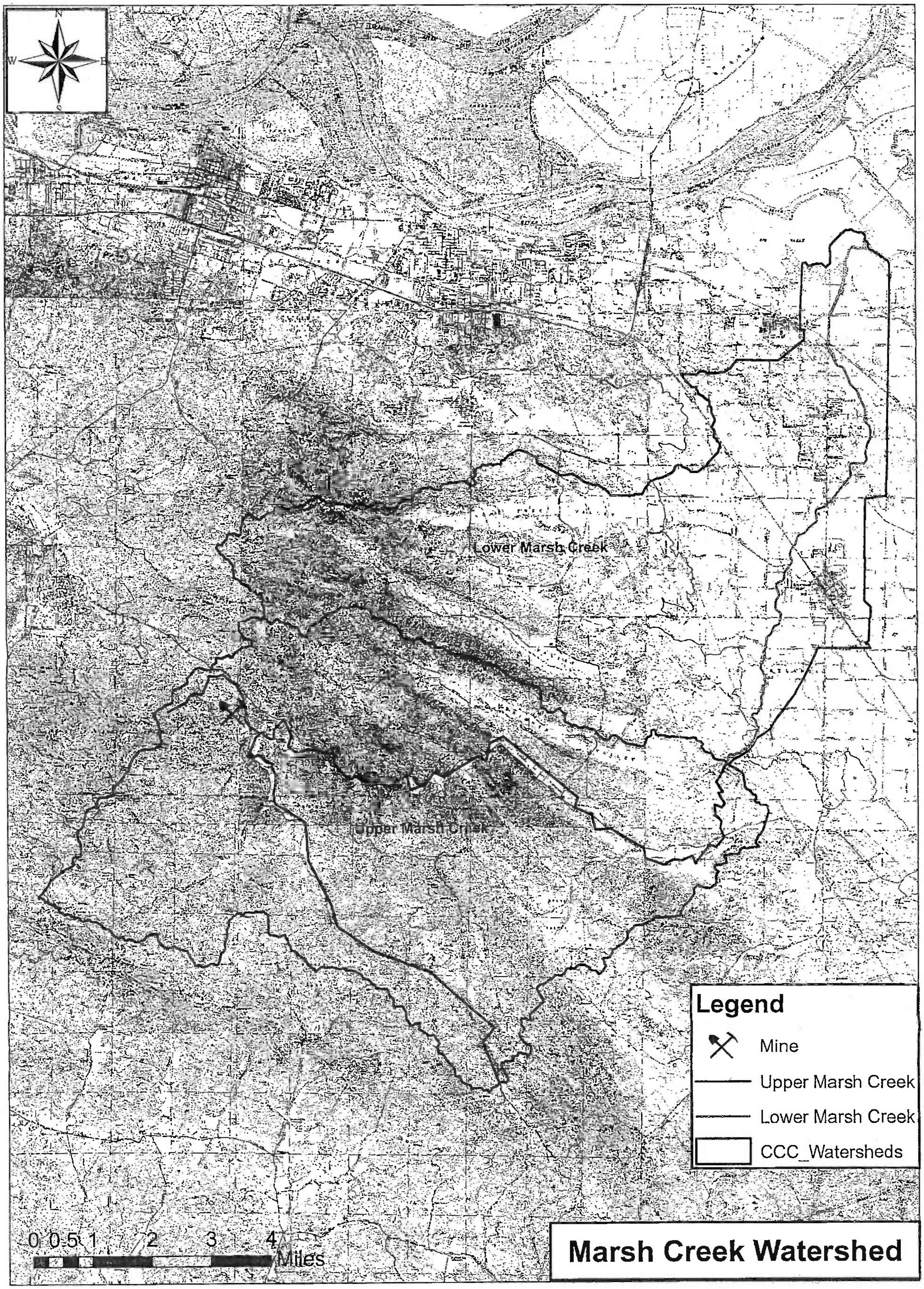
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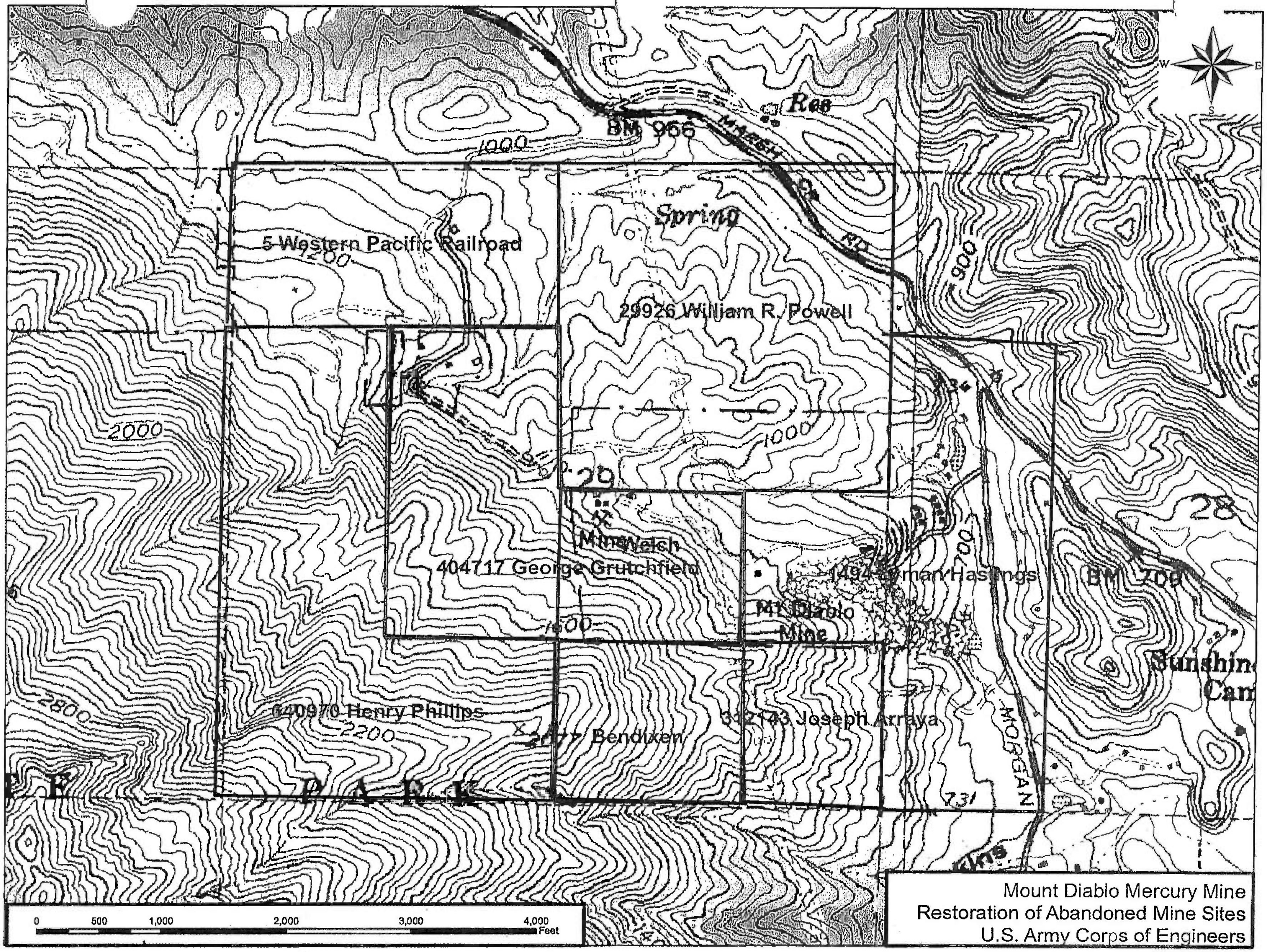
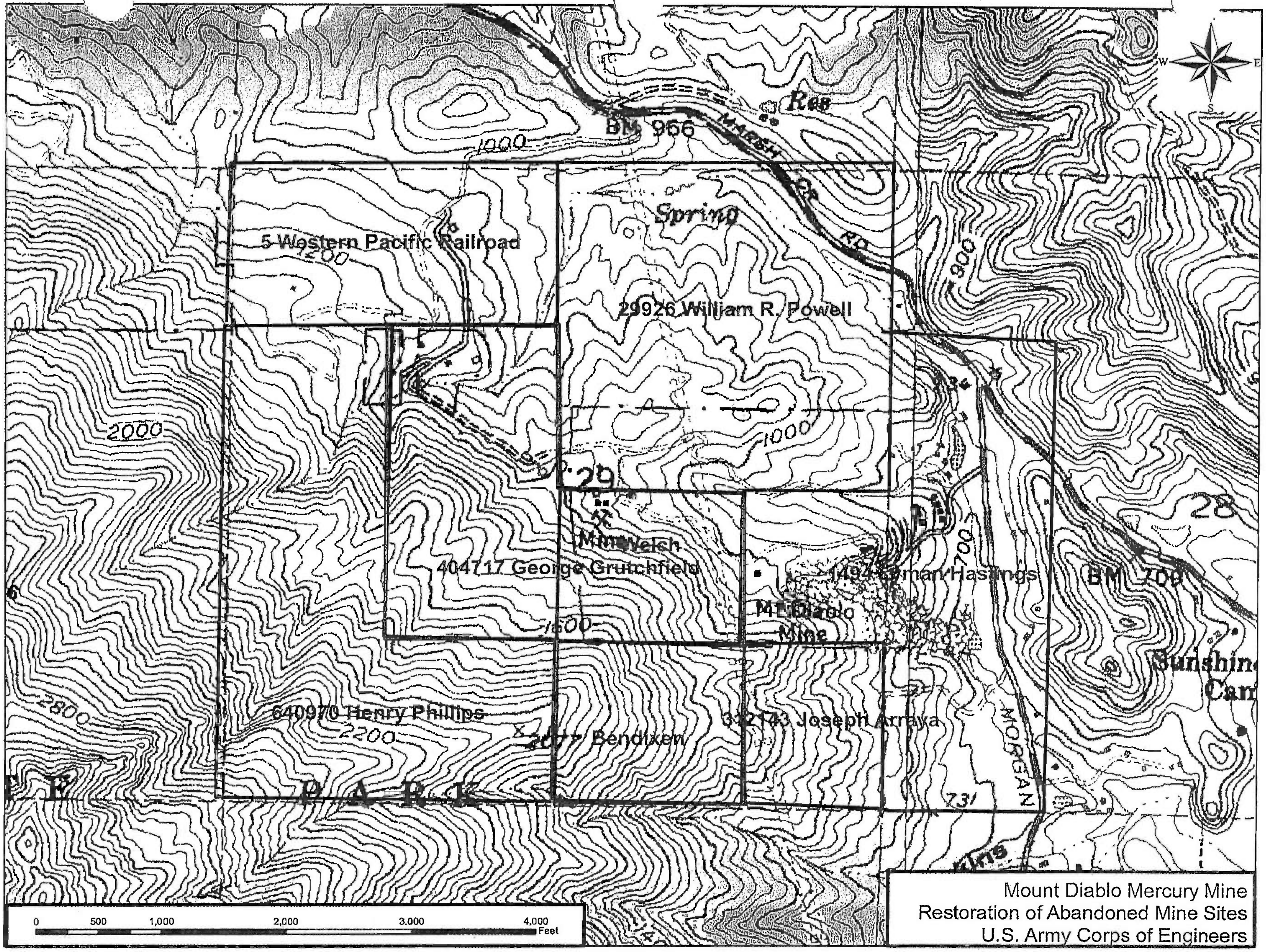
Miles
Marsh Creek Watershed

Figure 1



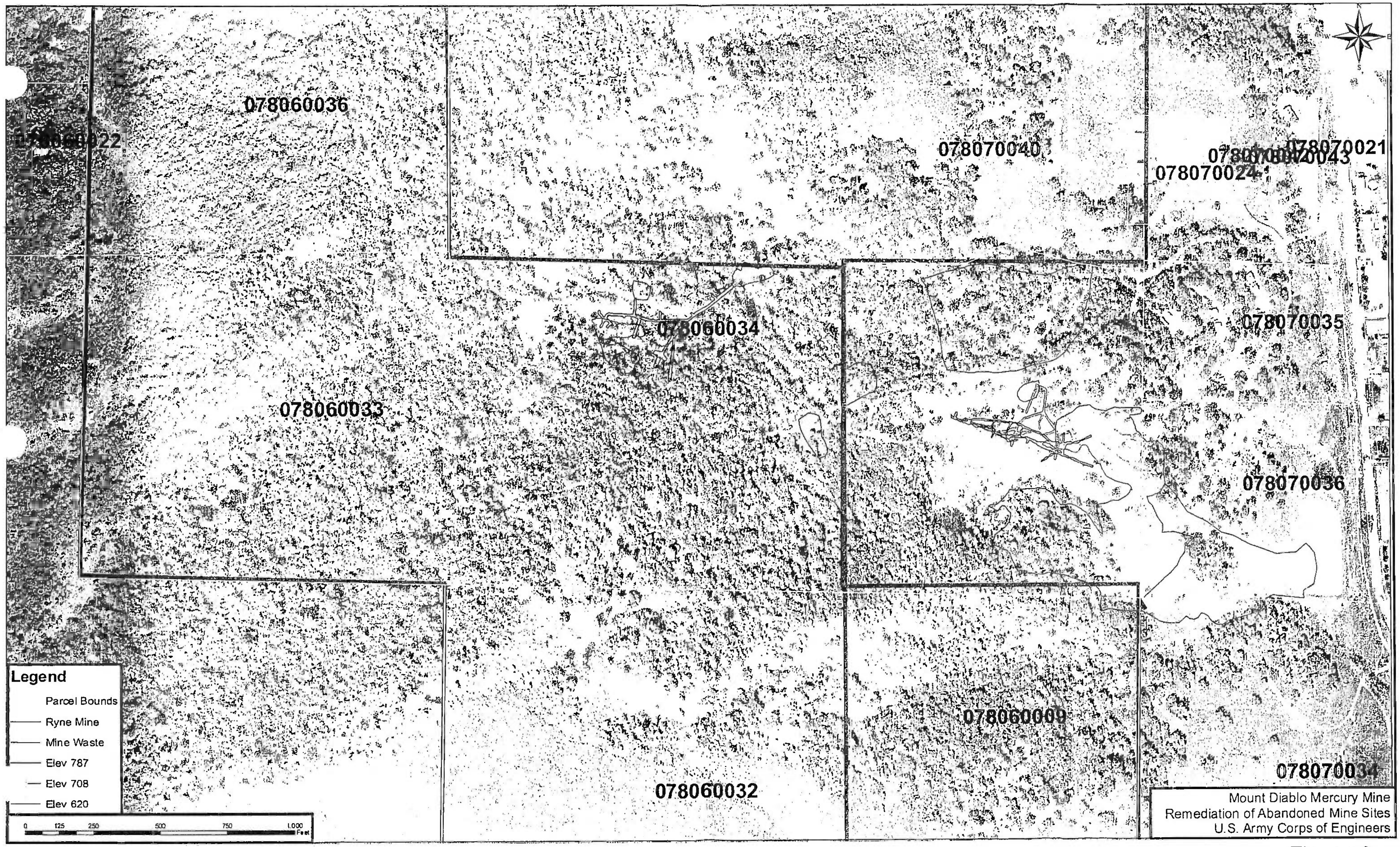
Mount Diablo Mercury Mine
Restoration of Abandoned Mine Sites
U.S. Army Corps of Engineers

Figure 2



Mount Diablo Mercury Mine
Restoration of Abandoned Mine Sites
U.S. Army Corps of Engineers

Figure 2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Parcel Bounds
Ryne Mine
Mine Waste
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Elev 708
Elev 620
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Mount Diablo Mercury Mine
Remediation of Abandoned Mine Sites
U.S. Army Corps of Engineers

Figure 3

APPENDIX A

TIMELINE

TIMELINE: MOUNT DIABL[illegible]ICKSILVER MINE (8/6/2008)

Date	*APN 078-060-034 (West)*	*APN 078-070-034 (East)*	*APN 078-070-036*	*APN 078-070-034*
January 24, 1848	Gold discovered in California			
April 29, 1849	William Ryder Powell files first placer mining claim on Dunn Creek incl. part of -034			Need 3 dates, patent, sale and Park purchase
September 9, 1850	California becomes a State			
1850	Francis Such discovers gold, quicksilver and copper near Mount Diablo (Clayton Historical Society) – placer deposits?			
1857	City of Clayton founded			
April 12,1861	War Between the States begins, demand for mercury fulminate skyrockets			
April 15, 1863	John Welch discovers cinnabar mineral deposit, files mining claim with Contra Costa County, mining operation commences			
April 26, 1865	Civil War ends, mercury demand plummets			
July 26, 1866	US Chaffee Mining Law passes			
May 15, 1869		Lyman Hastings receives federal mineral patent		
May 21, 1870	US Placer mining law passed			
May 10, 1872	US General Mining Act passed			
April 17, 1875	J. Welch receives federal land patent			
June 17, 1874		Lyman H Hastings dies		
1875?		Widow Frances C Hastings Hunsaker discovers metacinnabar		
1875-1877	First production record with US Bureau of Mines, Ryne Mining Co. operates the (western?) mine	Mining must have occurred		
1877	Litigation closes the mines, likely a dispute between the two mining properties			
1878	US Timber & Stone Act passed			
April 4, 1898	US GLO recognizes Powell's placer mining claim (APN 078-070-033, -040, part of -034)			
July 27, 1905	E.A. Howard buys part of property from Powell.			
October 25, 1907		E.A. Howard buys property (Howard Lumber Co.)		
December 10, 1912	US GLO revokes Welch mineral patent			
May 11, 1914	George Grutchfield purchases land from GLO			
July 1914	World War I begins			
April 27, 1915	Agnes Grutchfield granted sole title (widow)			
November 11, 1918	World War I end			
January 14, 1930	Joseph Tonge leases interest to Blomberg, Hardy & Moni?			
March 8,1930	Hardy leases interest to Blomberg & Moni			
April 24, 1930	Joseph Tonge purchases land from Agnes Grutchfield			
1931	Japan invades Manchuria			
1931	Mount Diablo State Park, created in 1921, begins acquiring land			
1933-1936	C.W. Erickson operates the mine			
February 11, 1934		Mt Diablo Quicksilver Mining Co buys property from E.A. Howard (Howard Lumber Co.)		
January 17, 1936	Title transfer from Blomberg & Moni to Mt Diablo Quicksilver Mining Co.			
1936	Bradley Mining Co. operates the mine			
September 3, 1939	World War II begins			
September 2, 1945	World War II ends, Cold War begins			
1946	Public Health Service Drinking Water Standard Amendments			
1947	Bradley Mining Co. ceases operation at the mine			
October 1, 1949	California Dickey Water Pollution Control Act			
June 25, 1950	Korean War begins			
1951	Ronnie B Smith, Producers Refining & Franklin Supply Co. partnership operate mine			
1953	US DoI Defense Minerals Exploration Administration loan contract signed			
February 27, 1953	RWQCB Resolution No. 53-21 (water pollution abatement order)			
July 27, 1953	Korean ceasefire			
1954	Jonas & Johnson operate mine, miner killed, mining operation halted, DMEA contract ends			
1955	Cordero Mining Co. operates mine (Sunoco)			
1956	Nevada Scheelite operates mine (Kennametal)			
1958	John E. Johnson operates mine, Johnson dies, mining halts			
1960	PG&E sues for easement/right-of-way through mine property			
1962	Public Health Service Drinking Water Standard Amendments			
May 11, 1962	Victoria Resources purchases mine from Vic Blomberg			
March 8, 1965	9th Marine Expeditionary Brigade lands at Da Nang, Republic of Vietnam. US involvement escalates through 1968			
1965-1970	Welty & Randall operate mine, rework the calcine mine tailings			
1969	California Porter-Cologne Water Quality Control Act passed			
December 9, 1969	Guadalupe Mining Co. purchases mine from Victoria Resources			
1971	Pace of land purchase by Mount Diablo State Park increases, park boundary approaches mine property			
1974	Safe Drinking Water Act			
July 2, 1974	John and Carolyn Wessman purchase mine property from Guadalupe Mining Co.			
1975	California Surface Mining & Reclamation Act (SMARA)			
February 2, 1976				Mt Diablo State Park purchases from Morgan Territory Investment Co.
August 3, 1977	US Surface Mining Control & Reclamation Act			
September 8, 1978		CRWQCB WDR 78-114		
November 20, 1978		CRWQCB CAO		
August 1, 1979		CRWQCB MRP 78-114		
1984	California real estate disclosure law established (Easton v. Strassburger)			
May 10, 2005	Title transferred to Wessman Family Trust			
December 30, 2005			Title transferred to Mt. Diablo Springs Improvement Society	

APPENDIX B

REFERENCES CD

APPENDIX C

PERMITS & ORDERS

RECEIVED
JUN 9 1952
COUNTY HEALTH DEPARTMENT

Mt. Diablo Mine

Resolution No. 435

Resolved that the following requirements govern the nature of the discharge from the Mt. Diablo Mine to Marsh Creek by way of Dunn Creek:

1. Maximum quantity of settleable solids in the pond effluent shall not exceed 0.5 ml/liter after one hour of quiescent settling in a standard Imhoff cone.

2. The pond effluent shall not produce noticeable color or precipitate after 15 minutes aeration.

3. The pond effluent shall not produce noticeable color or precipitates when pH is adjusted to neutrality (7.0).

4. The pond effluent leaving the mine property shall have a pH between 6.5-8.5.

5. The pond effluent shall not produce excessive color in Marsh Creek.

6. The pond effluent shall not contain any toxic materials in such quantity or of such character as to be hazardous to the public health or to plant or animal life.

If, in the future, there is a change in the conditions or use of the disposal area or in Marsh Creek, it may be necessary for the Central Valley Regional Water Pollution Control Board to revise the requirements to conform to the new conditions or use.

REGIONAL WATER POLLUTION CONTROL BOARD
CENTRAL VALLEY REGION
STATE OF CALIFORNIA
5-15-52

Carl M. Hoskinson
Chairman

Attest:

Joseph S. Gorlinski
Executive Officer

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

ORDER NO. 78-114

WASTE DISCHARGE REQUIREMENTS
FOR
MOUNT DIABLO QUICKSILVER MINE
CONTRA COSTA COUNTY

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

1. The Board on 27 February 1953 adopted Resolution No. 53-21 which prescribed requirements for a discharge from Mount Diablo Quicksilver Mine to Dunn Creek.

2. Surface and mineral rights of the mine are presently owned by Jack and Carolyn Wessman.

3. Present waste discharge requirements established by Resolution No. 53-21 are not adequate nor consistent with present plans and policies of the Board.

4. Mount Diablo Quicksilver Mine discharges mine drainage from the mine tailings and overburden to Dunn Creek near its confluence with Marsh Creek a tributary of the San Joaquin River a water of the State.

5. Mount Diablo Quicksilver Mine is located in the NE 1/4, SE 1/4 of Section 29, T1N, R1E, MDB&M (assors parcel #78060008-6) with surface water drainage to Dunn Creek.

6. The beneficial uses of Marsh Creek and Marsh Creek reservoir are: water-contact recreation, non-water contact recreation, freshwater habitat, wildlife habitat, and the preservation of rare and endangered species.

7. The beneficial uses of the groundwater are: domestic supply, irrigation, and stockwatering.

8. The Board, on 25 July 1975, adopted a Water Quality Control Plan for the Sacramento-San Joaquin Delta Basin.

9. Mining operations ceased in 1971, however, the mine area continues to discharge mineralized water and sediment to Dunn Creek.

10. The action to revise waste discharge requirements for this facility is exempt from an environmental review in accordance with Sections 15101, 15107, and 15108 of the CEQA regulations.

11. The Board has notified the discharger and interested agencies and persons of its intent to prescribe waste discharge requirements for this discharge.

12. The Board in a public meeting heard and considered all comments pertaining to the discharge.

IT IS HEREBY ORDERED, that Resolution No. 53-21, be rescinded and Jack and Carolyn Wessman shall comply with the following:

A. Discharge Prohibitions:

1. The direct discharge of wastes to surface waters or surface water drainage courses is prohibited.

2. Previously deposited sediment in the reservoir shall not be discharged.

B. Discharge Specifications:

1. The discharge shall not cause a pollution or nuisance as defined by the California Water Code.

2. The discharge shall not cause degradation of any water supply.

3. The discharge shall remain within the designated disposal area at all times.

4. The discharger shall implement erosion control practices to minimize erosion of mine overburden and worked areas.

C. Provisions:

1. The discharger may be required to submit technical or monitoring reports as directed by the Executive Officer.

2. The discharger shall follow the following time schedule to comply with discharge prohibition A1:

Action	Compliance Date	Compliance Report Due
Conceptual Plan	1 Nov 1978	15 Nov 1978
Complete Construction Plan	1 Jan 1979	15 Jan 1979
Begin Construction	1 Apr 1979	15 Apr 1979
Progress Construction Report	1 Jun 1979	15 Jun 1979
Full Compliance	1 Jul 1979	15 Jul 1979

3. The discharger shall follow the following time schedule to comply with Provision A.2:

	Due:
Submit Conceptual Plan	15 Sept 1978
Complete Construction	1 Nov 1978

4. The discharger shall report promptly to the Board any material change or proposed change in the character, location, or volume of the discharge.

5. In the event of any change in control or ownership of land or waste discharge facilities presently owned or controlled by the discharger, the discharger shall notify the succeeding owner or operator of the existence of this Order by letter, a copy of which shall be forwarded to this office.

6. Any diversion from or bypass of facilities necessary to maintain compliance with the terms and conditions of this Order is prohibited, except (a) where unavoidable to prevent loss of life or severe property damage, or (b) where excessive storm drainage or runoff from any event having a return frequency greater than one in twenty-five years ($\geq$ 3.9 inches/day [9.9 cm/day]) would damage any facilities necessary for compliance with effluent limitations and prohibitions of this Order. The discharger shall notify the Board in writing within two weeks of each such diversion or bypass including documentation of the storm intensity.

7. The Board will review this Order periodically and may revise requirements when necessary.

I, JAMES A. ROBERTSON, 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 Valley Region, on 8 September 1978.

Original signed by
James A. Robertson

JAMES A. ROBERTSON, Executive Officer

CH/ap 7/25/78

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

MONITORING AND REPORTING PROGRAM NO. 78-114
FOR
MOUNT DIABLO QUICKSILVER MINE
CONTRA COSTA COUNTY

RESERVOIR MONITORING

A grab sample of the impounded water shall be collected during November of each year. The sample shall be collected at a point where a representative sample can be obtained. The sample shall be analyzed for the following:

Constituents	Units
Specific Conductivity	µmhos/cm
pH	units
Copper	mg/l
Iron	mg/l
Manganese	mg/l
Zinc	mg/l

In addition, a monthly report shall be submitted for the months November through March inclusive detailing:

1. The distance from the water surface to the spillway (freeboard).
2. The condition of the containment dikes.
3. The condition of the up watershed diversion berms.

REPORTING

In reporting the monitoring data, the discharger shall arrange the data in tabular form so that the date, the constituents, and the concentrations are readily discernible. The data shall be summarized in such a manner to illustrate clearly the compliance with waste discharge requirements. Monitoring shall commence not later than 30 November 1979, unless otherwise specified.

Monthly monitoring reports shall be submitted to the Regional Board by the 15th day of the following months: December through April.

If the discharger monitors any pollutant at the locations designated herein more frequently than is required by this order, he shall include the results of such monitoring in the calculation and reporting of the values required in the Discharge Monitoring Report Form. Such increased frequency shall be indicated on the Discharge Monitoring Report Form.

Ordered by W. H. Crooks for
JAMES A. ROBERTSON, Executive Officer

1 August 1979
(Date)

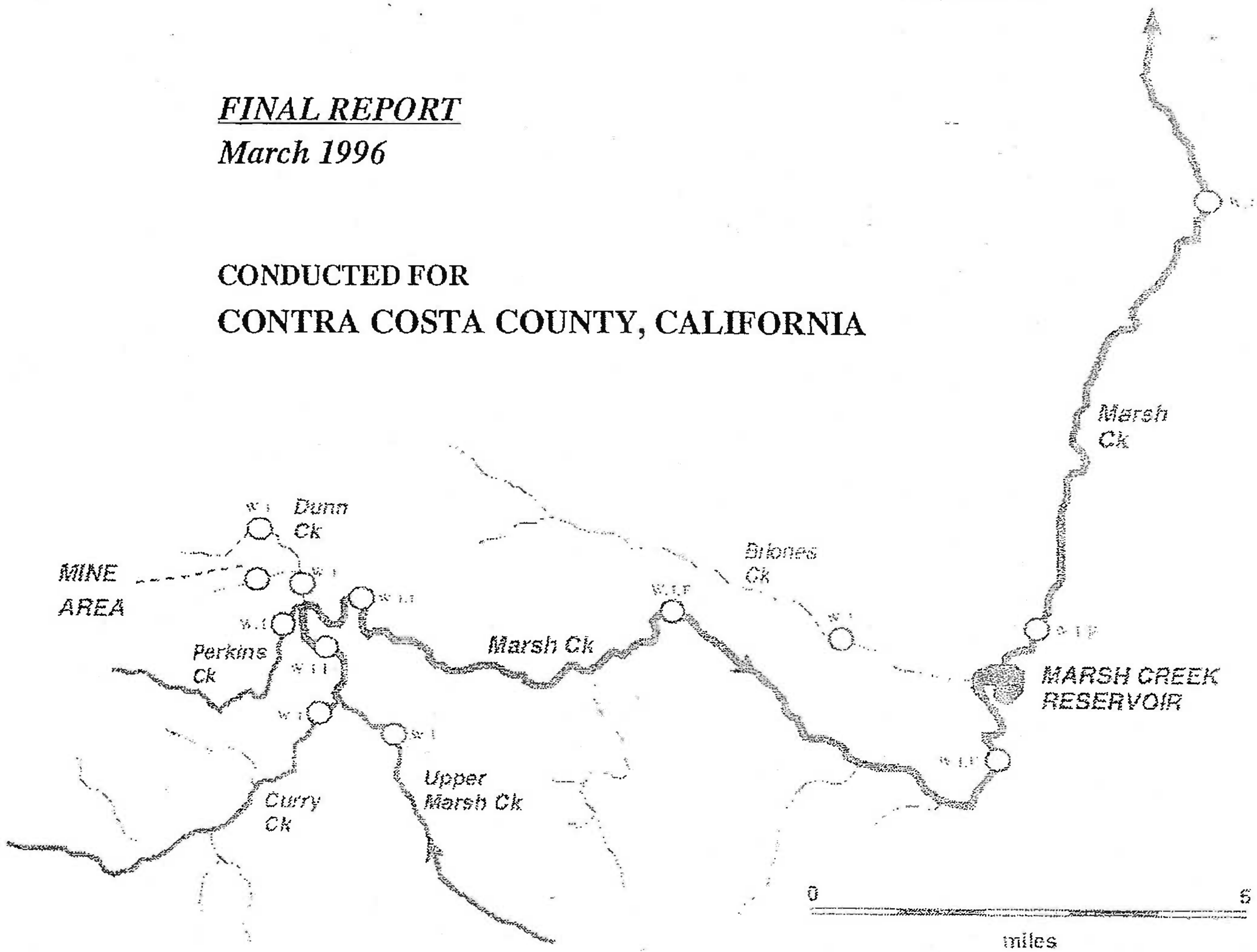
CAH/gs 2/23/79

EXHIBIT 16

MARSH CREEK WATERSHED
1995 MERCURY ASSESSMENT PROJECT

FINAL REPORT
March 1996

CONDUCTED FOR
CONTRA COSTA COUNTY, CALIFORNIA



STUDY AND REPORT BY

Darell G. Slotton, Ph.D.
Shaun M. Ayers
John E. Reuter, Ph.D

MARSH CREEK WATERSHED
1995 MERCURY ASSESSMENT PROJECT

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March 1996

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1624 Pacific Drive, Davis, California 95616
(916) 756-1001 dgslotton@ucdavis.edu

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ACKNOWLEDGEMENTS

I would like to thank Phil Harrington of the Contra Costa County Department of Public Works and Sue Loyd of the County Health Services Department for their help and support throughout this project. The Wessmans graciously provided access to the mine area on their property, provided helpful background information, and consistently exhibited a willingness and desire to help find a solution to the mercury problem on Mt. Diablo. Thanks also to the public and agency participants in the Marsh Creek Watershed Mercury Task Force for helping to move this process along.

DGS

EXECUTIVE SUMMARY

- Before this comprehensive 1995 study, the Mt. Diablo Mercury Mine was generally assumed to be the main source of mercury to the Marsh Creek watershed in Contra Costa County. However, data was not available to quantify this input, rank the mine against other potential mercury sources, or rule out the possibility of a generalized source of mercury in this mercury-enriched watershed.

- In the project reported here, water, suspended sediments, and flow were analyzed at 18 key sites throughout the Marsh Creek watershed during a high flow-period. State-of-the-art collection and analytical procedures were utilized for the 48 individual water mercury analyses, producing above-detection concentration information for each of the major tributaries and potential source regions. Combining concentrations with the flow data, relative mass balances were calculated, ranking each of the tributaries as to mercury contribution to the watershed. This aqueous watershed information was supplemented by mercury analytical collections from multiple groups of aquatic invertebrate indicator species at the 12 stream sites where they were present (41 samples), and stream fish at the 6 sites where they were present (28 samples).

- The 1995 watershed-wide mercury information assembled here establishes that the mine site does indeed represent the overwhelming, ongoing source of mercury to the watershed. Mercury data from water collections and invertebrate bioindicator organisms strongly implicate the mine region as the dominant source of mercury. Mass balance calculations indicate that approximately 95% of the total input of mercury to the upper watershed derives from Dunn Creek, with an estimated 88% traceable specifically to the current exposed tailings piles of the Mt. Diablo Mercury Mine. This is a remarkably high percentage, particularly in light of the geologically mercury-rich nature of the watershed in general, and indicates that the mercury in exposed, processed, cinnabar tailings material is exceptionally available for downstream transport in water.

- The data indicates that the great majority of the mercury load emanating from the tailings is initially mobilized in the dissolved state. This dissolved mercury rapidly partitions onto particles as it moves downstream. The bulk of downstream mercury transport is thus particle-associated.

- Though Dunn Creek carried the bulk of the watershed's source mercury, this small tributary delivered less than 7% of the total water volume and less than 4% of the suspended solids load. With 95% of the mercury originating from the Mt. Diablo Mine area, but 95% of the watershed's suspended sediment load deriving from non-mine, low mercury source regions, any significant decrease in the export of mercury from the immediate mine site should result in a corresponding decline in depositional sediment mercury concentrations downstream and in Marsh Creek Reservoir. This would almost certainly help to drive down the mercury concentrations in water and the flux of mercury into aquatic organisms. With an estimated 88% of the currently exported mercury linked directly to the mine site tailings piles, mercury source mitigation work within the watershed would clearly be best directed toward this localized source.

- Though mitigation recommendations were not a part of our scope of work, we provide input on the subject at the end of this report, based on the data collected in this study, that may help to both clarify the task and direct the planning process.

- Fishes in Marsh Creek Reservoir were found to consist in 1995 of populations of small mosquito fish, native planktivorous hitch, stunted bluegill, and largemouth black bass.

The reservoir was uniformly shallow at this time, with depths averaging 5 feet. The water was organic-stained and very turbid, with heavy growths of aquatic weeds. Lack of oxygen was indicated to be a limiting factor for fish in the bottom waters during the warm season. Adult largemouth bass and possibly bluegill represent the only potential angling opportunities in the reservoir at this time.

- Marsh Creek Reservoir mercury levels were characterized in 1995 with 26 individual sediment mercury samples from surface sediment as well as deep core sections, 25 muscle mercury samples from individual adult fish, 21 muscle and 8 whole composite samples of juvenile fish, and 4 composites of reservoir invertebrates.

- Approximately 5 feet of depositional sediment had accumulated on the reservoir bottom. Reservoir sediment mercury concentrations were found to be quite uniform across the bottom and throughout the reservoir's 30+ year depositional sediment record, with the great majority of samples falling within the range of 0.36-0.80 parts per million mercury, and all sediment samples having less than 1.50 ppm mercury.

- Mercury in Marsh Creek Reservoir edible fish flesh was above the health standard concentration of 0.5 ppm in all samples of "keeper" sized bass and bluegill, with the larger bass ranging up to and slightly over 1.0 ppm muscle mercury. These levels are of concern but are not exceptional for this region of California. They are near enough to the health guidelines that a decline to levels below the guidelines may be realistically attainable, through potential mercury mitigation work in the watershed. Mercury concentrations in adult fish will likely take a number of years to change significantly, even in conjunction with a major reduction in transported watershed mercury. This is because their mercury levels are a composite of accumulations across their multi-year lives. However, mercury levels in a number of the short-lived, alternate indicator organisms utilized in this project should respond to changes in source mercury very quickly.

- With this 1995 watershed mercury assessment, a comprehensive, accurate data base has been initiated for the County, describing mercury conditions throughout the major components of the Marsh Creek watershed. This includes mercury concentration, loading, and relative mass balance data for water and suspended sediment from all major tributaries, mercury levels from aquatic biota throughout the watershed; and depositional sediment and biota mercury concentrations from Marsh Creek Reservoir. The utility of these data for use as a general baseline could be substantially increased with the sampling of selected parameters in the current water year (1996), prior to any mitigation work, to help account for natural inter-annual variability. We note that 1995 was an extremely wet, high-runoff year, while 1996 is more of an average water year. It is our strong recommendation that the County obtain as extensive and varied a baseline data record as possible prior to mitigation, and maintain selective monitoring of key sites and parameters throughout and following mitigation work. Ongoing monitoring of carefully chosen indicator samples will play an integral role in guiding and assessing the effectiveness of any mitigation efforts.

1. INTRODUCTION

The Marsh Creek watershed, in eastern Contra Costa County, is fed primarily by seasonal tributaries from the eastern slope of Mt. Diablo. Flows in the watershed range from zero in many upstream tributaries during the dry season to hundreds of cubic feet per second in downstream Marsh Creek during winter storm runoff. Marsh Creek flows through the towns of Brentwood and Oakley, ultimately emptying into the San Joaquin Delta east of Antioch.

A flood control dam was built on Marsh Creek in 1963, approximately five miles upstream of Brentwood. The resulting Marsh Creek Reservoir is now a shallow water body with extensive riparian, marsh, and aquatic weed growth, providing habitat for a variety of wildlife including resident populations of fish. The surrounding land is currently used for cattle grazing. The primary function of the reservoir is flood control. Operated by the Contra Costa Department of Public Works, it has been closed to the public throughout recent years.

An extensive residential development is planned for the area surrounding Marsh Creek Reservoir. As the existing reservoir may be incorporated into these development plans, information regarding its water quality and that of the watershed in general is of particular current interest. One potential area of concern involves mercury. The California Department of Fish and Game analyzed fish from the reservoir in 1980. These fish were found to be above existing health standards for mercury (Contra Costa County 1994).

A large, abandoned mercury mine site is present on the northeast slope of Mt. Diablo. The Mt. Diablo Mercury Mine is located within the Marsh Creek watershed, adjacent to Dunn Creek, which is a small tributary to Marsh Creek. A substantial area of exposed tailings is present at the site and, while this region contributes only a small fraction of the total flow in the watershed, it has been assumed for many years to be a major contributor to the downstream mercury accumulations. A series of sediment settling ponds were constructed in ~1980 to intercept suspended sediment from the tailings and related springs. Water collections made in the vicinity of the mine by the Central Valley Regional Water Quality Control Board demonstrated significantly elevated mercury concentrations (CVRWQCB 1994). However, these tests did not include the entire watershed and did not have a low enough level of analytical detection to obtain useful data from any but the most extremely contaminated samples. Consequently, this earlier work could not determine the relative loading of mercury to the watershed from the mine on a mass balance basis.

In early 1995, our mercury biogeochemistry research group was contracted by the Contra Costa County Department of Public Works to undertake a comprehensive assessment of mercury throughout the Marsh Creek watershed. It was our strong recommendation that a relatively thorough and up-to-date understanding of mercury dynamics throughout the watershed as a whole be obtained before mitigation plans were made. We felt that it was critical to determine the relative importance of the exposed mine site to the watershed's total mercury loading.

Mercury is naturally enriched throughout extensive areas of the Mt. Diablo region, which is why mercury was historically mined here (Ross 1940). Mercury is similarly enriched throughout much of the California Coast Range. As the majority of the water flow and associated transported material in the Marsh Creek watershed appeared to derive from tributaries other than the one containing the Mt. Diablo mine, it was quite conceivable that a significant proportion of the total mercury budget might come from more generalized watershed sources. Despite the locally contaminated nature of the mine vicinity itself, if the majority of total mercury loading came from elsewhere in the watershed, mitigation work at the mine could be relatively ineffectual.

In the first phase of our mercury assessment, we developed a sampling plan that accounted for all important watershed tributaries, major source flows at the mine site, and included stations along downstream Marsh Creek to the reservoir and well beyond. We waited for a period of high but relatively steady flows following a major storm series, when suspended material was being transported in abundance and the sites could be inter-calibrated. These conditions occurred in late March 1995 and we were able to successfully collect samples throughout the watershed within a short period of consistent flow. At each of the 18 sites, water samples were taken for analysis of mercury in both raw and filtered fractions, as well as for suspended solids concentration. The mercury samples were taken using ultra-clean techniques and were analyzed by the foremost aqueous mercury analytical laboratory in the world, providing above-detection mercury concentration data for all samples. At each site, the water flow was determined as well. With concentration and flow data for each site, it was then possible for us to calculate the total loads of mercury moving through each stretch and to compare the tributaries on a relative basis.

To supplement these water-based mercury measurements, we looked at bioindicator organisms within the watershed. At 12 collection sites, we sampled localized benthic invertebrates of several types. These invertebrates integrate the bioavailable fraction of mercury that they are exposed to over their lifetimes. In-stream fish were collected at the 6 stations where they were present. All of these samples were analyzed for mercury, to provide time-integrated information on the relative mercury trends among the different tributaries.

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A second piece of essential information was the determination of current mercury conditions in Marsh Creek Reservoir, particularly within the fish populations. As the only data to have been collected there had been taken 15 years earlier, in 1980, and the actual data themselves were apparently unavailable (Contra Costa County 1994), a new survey of the reservoir was warranted.

Therefore, in a second phase of our assessment, we conducted a study of mercury in Marsh Creek Reservoir sediments and biota in September 1995. We collected surficial sediments from throughout the reservoir and obtained a record of historical sediment mercury deposition over the 30+ year history of the reservoir through sediment core samples. The reservoir's current fish populations were assessed, with tissue mercury analyses conducted on extensive samples from all types with significant representation at this time.

Table 1 summarizes the mercury analytical samples collected for both phases of this project. A total of 48 aqueous mercury analyses were made, half in raw water and half in corresponding filtered water. Total mercury was analyzed in 170 individual biotic and sediment samples, including 46 individual fish analyzed for muscle mercury from Marsh Creek Reservoir. Additional analytical samples for the project included suspended solids samples from all stream sites (22, including duplicate samples), and moisture and organic percentage analyses in 30 reservoir bottom sediment samples.

Throughout this report, the data for each major watershed parameter is generally presented both in tabular and graphic form. Map figures of each of the major data parameters are included for the watershed as a whole, as well as for the immediate mine vicinity where appropriate.

With the data collected in the two phases of the study, this report provides the County with information on current mercury levels throughout the Marsh Creek watershed and Marsh Creek Reservoir. Further, the relative importance of the various upstream source regions to the overall mercury loading in the system can be estimated. Finally, in the event that new mercury mitigation work is initiated within the watershed, a comprehensive, accurate data base has been initiated, describing mercury conditions throughout the major components of the system, including water, suspended sediment, and aquatic biota from the entire watershed and depositional sediment and biota from Marsh Creek Reservoir. Baseline data, taking into account natural inter-annual variability, can be compared to mercury levels in future collections to guide and assess the effectiveness of mitigation efforts.

Table 1. Summary of all Samples Analyzed for Mercury in This Project

	Raw Water	Filtered
Aqueous Total Mercury:	22	22
Aqueous Methyl Mercury:	2	2
TOTAL AQUEOUS SAMPLES (48 total):	24	24
	Stream	**Reservoir**
Invertebrate Composites:	41	4
Small Fish Whole Fish Composites:	18	8
Individual Fish Muscle Samples:	20	46
Adult Largemouth Bass:		*10*
Juvenile Largemouth Bass:		*10*
Adult Bluegill:		*1*
Juvenile Bluegill:	*4*	*11*
Hitch:	*8*	*14*
Juvenile Salmon:	*5*	
Crayfish Tail Muscle:	*3*	
Individual Fish Liver Samples:		7
Sediment:	—	26
TOTAL SOLID SAMPLES (170 total):	79	91

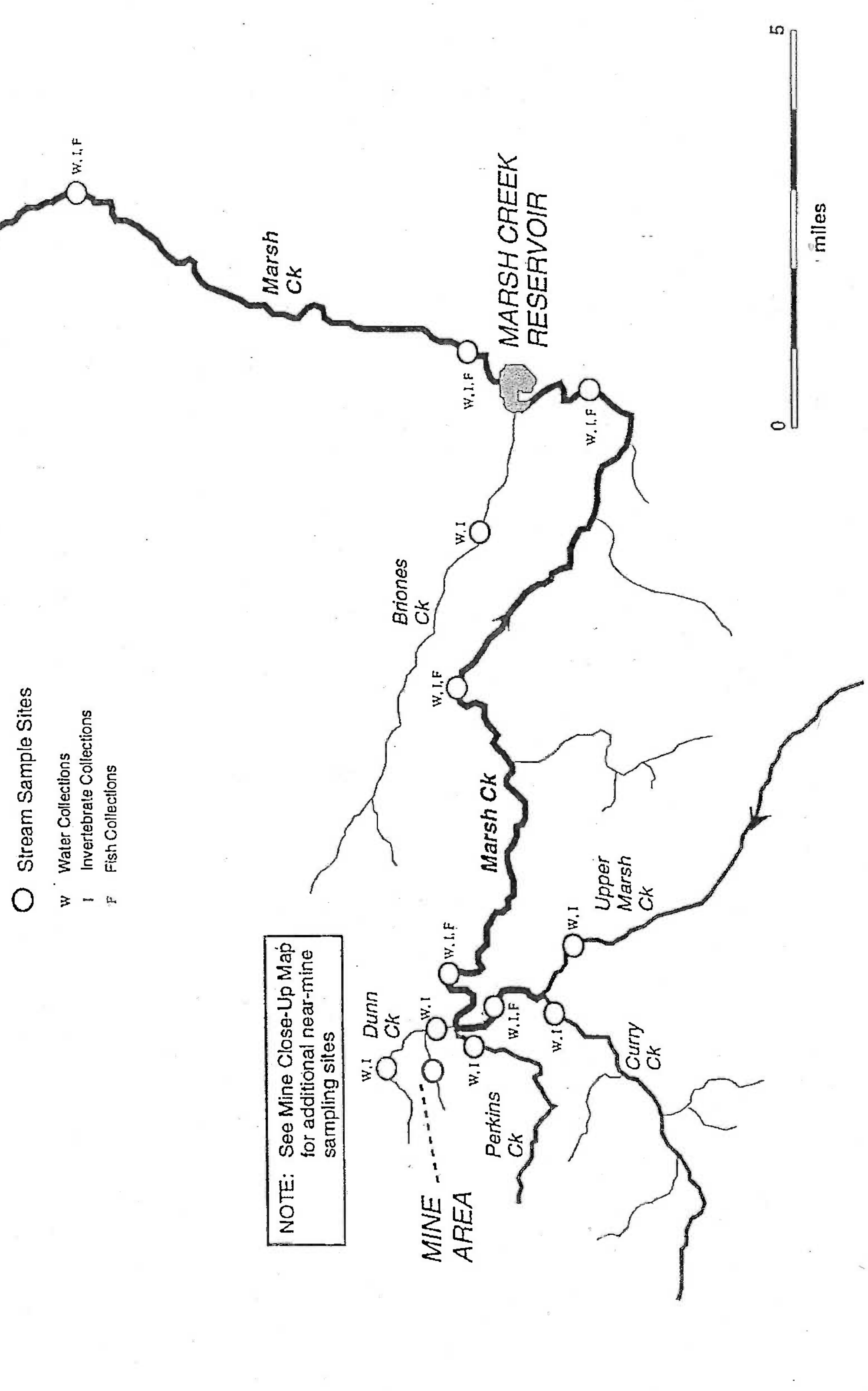
2. METHODS

2.1 Site Selection

The sampling sites utilized for the watershed portion of this project are shown in Figures 1 and 2. Sampling sites within Marsh Creek Reservoir are displayed in section 3.2 (Fig. 18).

In the watershed component of this work, our plan was to sample all significant tributaries of the Marsh Creek watershed, immediately following heavy rains. We sampled water and invertebrates from the upper section of Marsh Creek (above Curry Creek), from Curry Creek, Perkins Creek, Dunn Creek both above and below the Mt. Diablo Mercury Mine area, "My" Creek (a tributary to Dunn Creek that runs along the northern edge of the mine area), and Briones Creek. We were unable to sample two streams which enter Marsh Creek from the south along the mid section of the creek. This was because the landowners repeatedly refused us permission to make collections. However, these were relatively small creeks and their contributions to the downstream mercury load could be estimated by

Figure 1. Marsh Creek Watershed 1995 Mercury Assessment Sampling Sites



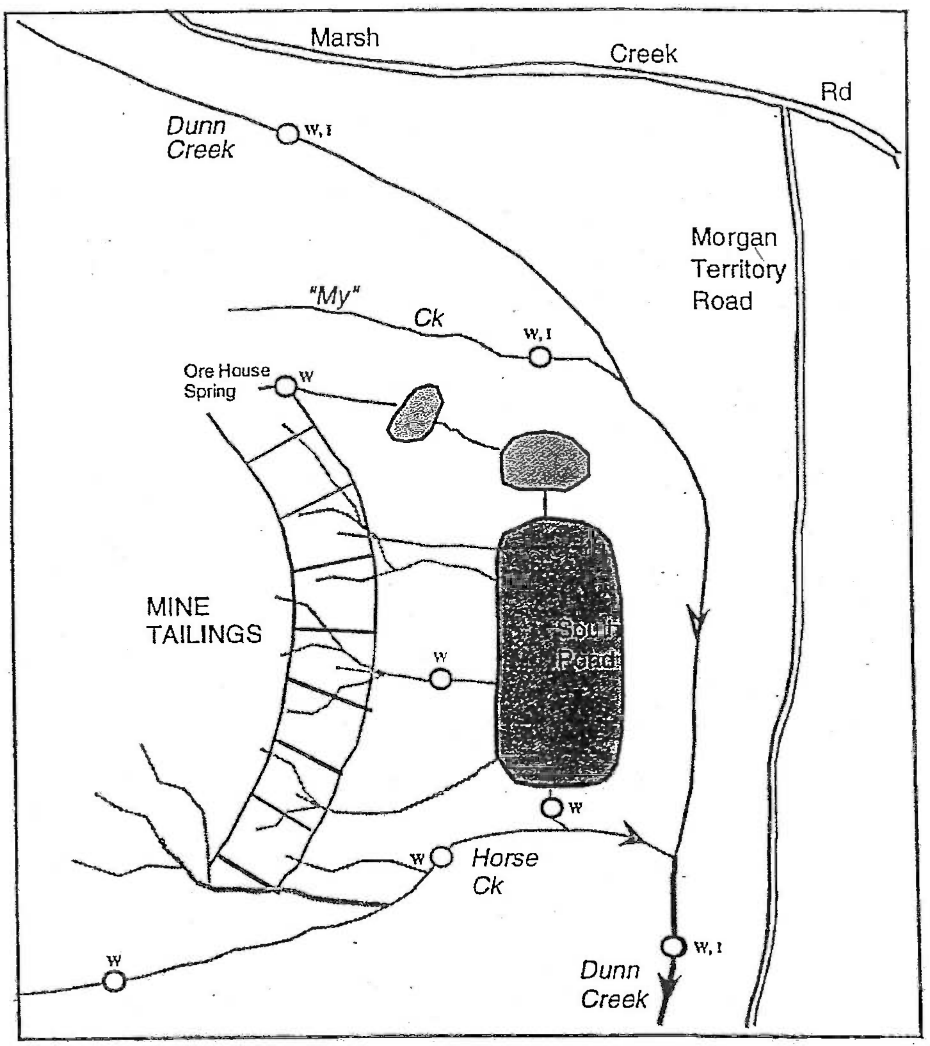


Figure 2. **<u>1995 Mercury Assessment Sampling Sites</u> in the Vicinity of the Mt. Diablo Mine**

O Sample Sites

W Water Collections

I Invertebrate Collections

noting the changes or lack thereof in the various parameters at sites on Marsh Creek both above and below their inflows. As it turned out, they were insignificant to the regional mercury picture.

In addition to the tributaries, we sampled water, invertebrates, and fish from six additional sites along the length of Marsh Creek, including a site between Curry and Perkins Creeks, a site ~1 mile downstream of the Dunn Creek inflow, another ~5 miles downstream, one ~10 miles downstream just above the reservoir, one just below the reservoir, and a final Marsh Creek site well downstream at Delta Rd, between Brentwood and Oakley. In addition to these main stream sites, we collected water from five additional sites in the vicinity of the mine itself. These included samples from Horse Creek, which flows along the south edge of the tailings, both above the tailings influence and below, just before entering Dunn Creek. Other mine area water samples included outflow from the lower settling pond, representative inflow to that pond through the tailings, and the Orehouse spring which flows into the north settling pond.

In summary: at a total of 18 sites, flows were determined and we sampled for suspended solids and for total mercury in raw and filtered water immediately after a major storm cycle. Methyl mercury was additionally analyzed from duplicate samples taken from Marsh Creek directly above the reservoir. Benthic invertebrate bioindicators were sampled at all sites containing sufficient concentrations of organisms for analysis (12 sites) and fish were taken at those stream sites where they were present (6 sites).

In Marsh Creek Reservoir, surficial sediment was collected from 8 different locations in the reservoir (Fig. 16). These were spaced so as to sample all major depositional areas. Sediment cores were taken at the centers of each of the two main basins. Fish were taken from throughout the reservoir.

2.2 Collection Techniques

2.2.1 Water

Water collections for mercury analysis were made in conjunction with Frontier Geosciences Laboratory, which is the most highly esteemed aqueous mercury laboratory in the world. Ultra-clean 250 ml teflon collection bottles were shipped to us, individually packaged in double zip-lock bags. Two person clean collecting protocol was used, in which the actual sample bottle was touched only by one researcher who handled nothing else and wore sterile gloves. Samples were taken in flowing water by standing mid-stream and, facing upstream, submerging the bottle in the middle of the flow. The cap was removed underwater, allowing the bottle to fill without coming into contact with potential surface film material, and then resealed before bringing to the surface. The bottle was then placed into the waiting isolation bags, held by the co-worker. Bagged ice packs kept the bottles cool and samples were shipped by overnight mail to Frontier Geosciences. Water samples were filtered and preserved in a trace metal clean room within 24 hours of collection, and later analyzed within standard holding times.

In conjunction with each set of aqueous mercury samples, we collected identical water into 1 liter bottles for analysis of suspended solids. These bottles were held in a separate ice chest, on ice, and were returned to our laboratory in Davis for processing within 48 hours of collection.

Flow at each of the stream sites was determined by measuring the cross sectional area of the channel along a relatively uniform stretch. A known number of meters was marked off alongside. A current float of near-neutral buoyancy was then passed through this course three to ten times. Time to the nearest 0.01 seconds was recorded for each pass.

2.2.2 Invertebrates

Stream invertebrates were taken from riffle habitat at each of the sites where they were present, i.e. from rapids or cobble bottomed stretches with maximal flow, where aquatic insects tend to be most concentrated among the rock interstices. Stream invertebrates were collected primarily with the use of a research kick screen. At each site, one researcher spread and positioned the screen perpendicular to the flow, bracing the side dowels against the bottom, while the other researcher overturned boulders and cobble directly upstream of the screen. These rocks were hand scrubbed into the flow, dislodging any clinging biota. Following the removal of the larger rocks to the side of the stretch, the underlying cobble/pebble/gravel substrate was disrupted by shuffling the boots repeatedly. Invertebrates were washed into the screen by the current. The screen was then lifted out of the current and taken to the shore, where forceps were used to pick macro-invertebrates from the screen into collection jars. This process was repeated at each site until a sufficient sample size of each taxon of interest was accumulated to permit analysis for mercury. At Marsh Creek Reservoir, samples of adult dragonflies and damselflies were taken with insect nets.

Samples were maintained in their collection jars on ice, and then cleaned in fresh water within 24 hours of collection. Cleaning was accomplished by suspending sample organisms in fresh water and, as necessary, shaking individuals in the water with teflon-coated forceps to remove any significant clinging surficial material. Cleaned organisms were stored in pre-cleaned jars with teflon-lined caps, which were frozen and then dried at 50-60 °C. The dried sample was homogenized to a fine powder with teflon-coated instruments and a glass laboratory mortar and pestle. All of these techniques have been well established and tested in extensive prior mercury research work throughout California (Slotton et al. 1995a).

2.2.3 Fish

Fish were taken from selected stream sites, where present, with baited minnow traps which were left overnight. Stream fish were also taken with seines which were pulled through certain stretches to trap fish. In Marsh Creek Reservoir, fish were collected using a boat with a variety of experimental gillnets, as well as by set line, angling, and with dip nets. Small individuals to be analyzed for mercury from both stream and reservoir were held on ice in sealed bags. They were later weighed and measured in the laboratory and homogenized into appropriate composite samples with a laboratory homogenizer. Larger fish to be analyzed were weighed and measured on site. Tissue samples for mercury analysis were excised directly in the field, using clean technique, with stainless steel scalpels. Muscle samples were taken from the dorso-lateral ("shoulder") region, as done by the California Department of Fish and Game. Tissue samples were placed directly into pre-weighed laboratory digestion tubes, which were capped with teflon liners and maintained in sealed bags. The precise weight of each tissue sample was determined by weighing the tubes containing samples (together with pre-weighed blanks) and subtracting the initial empty weights. We have utilized these techniques with great success in similar work over the past 11 years (Reuter et al. 1989, Slotton 1991, Slotton et al. 1995a, Slotton et al. 1995b)

2.2.4 Sediment

Sediment samples were taken in Marsh Creek Reservoir both from the surficial sediment at the sediment/water interface and in extended cores which penetrated deep into the sediment. Surficial sediment samples were collected with an Ekman dredge and were spooned into pre-cleaned glass jars with teflon-lined caps. Sediment cores were taken by hand with a custom-made non-metallic coring device which was driven into the bottom from the boat and then carefully pulled out and transported to shore. There, the core was extruded and sectioned, with samples retained in pre-cleaned glass jars with teflon-lined caps. Sediment samples were maintained refrigerated but unfrozen (so as to not alter mineral structure) until they were analyzed for mercury within 18 days of collection.

2.3 Analytical Methodology

2.3.1 Water

Total mercury in water was analyzed by dual amalgamation/cold vapor atomic fluorescence spectrometry, as developed by Bloom and Crecelius (1983). Methyl mercury was analyzed utilizing aqueous phase ethylation, followed by cryogenic gas chromatography with cold vapor atomic fluorescence detection, as developed by Bloom (1989). The detection levels for these extremely sensitive analyses are approximately 0.01 ng L^{-1} (parts per trillion), well below any environmental aqueous mercury levels present throughout Northern California.

Current speed was estimated by taking the average time of the near-neutral buoyancy current float to traverse the uniform test stretch of stream and dividing by the length of the stretch. The speed of the flow was then multiplied by the cross sectional area to obtain the flow volume per second.

The bulk load of total mercury moving through each stream site per day was determined by multiplying the measured aqueous mercury concentration by the corresponding measured flow (volume per second) and finally by the number of seconds in a day.

The relative mass balance contributions of bulk mercury from individual upstream source areas to downstream receiving waters were determined by assessing the proportional contributions of bulk mercury among the source flows immediately upstream at each major fork in the sampled streams. This was done by working upstream from the Marsh Creek site 1 mile below the Dunn Creek inflow. Based on the data, all significant mercury inputs occurred above this point. The calculated bulk flows of mercury of the streams contributing to this portion of Marsh Creek (Marsh Creek above Perkins Creek, Perkins Creek, and Dunn Creek) were assessed relative percentage contributions by dividing each mercury load value by the sum of the three. The total mercury input at this point was considered to be 100%. The relative contributions of tributaries upstream of these 3 stem flows were determined by successively following this procedure and multiplying the percentage bulk mercury load proportions of contributing flows by the previously calculated percent contribution of the stem flow immediately downstream (Table 6).

2.3.2 Suspended Solids

Suspended solids concentration at each site was determined by filtering a given volume of well mixed sample water through a pre-weighed glass fiber filter. The solids were retained on the filter, which was then dried at 105 °C for 24 hours. After cooling the filter in a dessicator, it was re-weighed to the nearest 0.0001 g. The weight of solids was obtained by subtracting the initial, clean weight of the filter from the weight with solids. This amount was divided by the volume of water filtered to derive the solids concentration on a milligram per liter basis. To obtain bulk loading quantities of suspended solids, the concentration data were weighted by the accompanying flows, as described for aqueous mercury.

Dry weight mercury concentration of the particulates themselves was estimated by first determining the aqueous mercury concentration attributable to the suspended solids. This was done by subtracting the aqueous mercury concentration in filtered water from the corresponding mercury concentration in raw water. This aqueous concentration, attributable to the entrained particulates, was then divided by the concentration of suspended solids in the water.

2.3.3 Fish, Invertebrate, and Sediment Total Mercury

Solid samples for mercury were analyzed using homogeneous portions. Sediment was subsampled from homogenized, wet (liquefied) samples. Identical subsamples were used to determine moisture content for dry weight conversions. Fish tissue was also analyzed on wet (fresh) samples, as is the standard procedure for governmental agencies. Mercury analyses of invertebrate samples were conducted with dried and powdered samples for uniformity, as described in Slotton et al. (1995a).

Solid samples of all types were processed by first digesting in concentrated sulfuric and nitric acids and potassium permanganate, under pressure, at 80-100 °C for three hours. They were subsequently analyzed for total mercury using a well-established modified cold vapor atomic absorption (CVAA) micro-technique, described in Slotton et al. (1995b). The level of detection for this technique is approximately 0.01 mg kg^{-1} (ppm), sufficient to provide above-detection results for nearly all aquatic sediment and biota samples in this region.

2.3.4 Sediment Water and Organic Content

Moisture content of sediment samples was determined by weight difference between fresh, homogenized sample (10-2560 g) and the sample after drying at 105 °C to constant weight (generally 24 hours), subtracting out the weight of the weighing container. Weights were accurate to ± 0.001 g. To obtain the Loss On Ignition (LOI) estimate of organic content, the dried sample was subsequently placed in a 475 °C muffle furnace for 2 hours in order to burn off any organic matter. After cooling, the mineral moisture of hydration was returned by re-wetting the sample. The sample was again dried at 105 °C to constant weight, cooled in a dessicator, and weighed again to ± 0.001 g. The loss in weight between the initial dry sample and the sample after the muffle furnace treatment is attributed to organic matter.

2.4 Quality Assurance/Quality Control (QA/QC)

2.4.1 Water

The water samples for mercury were analyzed at Frontier Geosciences Laboratory in a single, large analytical run, accompanied by a good number of QA/QC samples. QA/QC was excellent, as summarized below in Table 2.

Table 2. Frontier Geosciences Laboratory Aqueous Mercury QA/QC (from 1 analytical run)

	Spike Recoveries (%)	Duplicate RPD (%)	Reagent Blanks (ng/L)	Filter Blanks (ng/L)	NRCC Dogfish (ppm)
Certified Level					4.57
Ideal Recovery	(100%)	(0%)	(0.00)	(0.00)	(100%)
Control Range (%)	75-125%	≤25%			75-125%
Control Range (concentration)			≤0.20 ng/L	≤0.20 ng/L	3.43 - 5.71
Recoveries (%)	100-113%	1-20%			97-107%
Recoveries (concentration)			0.10	0.12	4.42 - 4.89
(n)	n=3	n=11	n=1	n=1	n=7
Mean Recoveries (%)	105%	8%			101%
Mean Recoveries (concentration)			0.10	0.12	4.63

2.4.2 Fish, Invertebrates, and Sediment

Extensive QA/QC accompanied all of our total mercury analyses of aquatic biota and sediment samples. For each sample batch of approximately 24 samples, a large number of QA/QC samples were included through all phases of the digestion and analysis procedures (16 total). These included 1 blank and 7 aqueous mercury standards, 2 pairs of samples of standard reference materials (4 total) with known mercury concentrations, 2 duplicates of analytical samples, and 2 spiked analytical samples. These 16 additional samples per analytical run were used, as always, to ensure the reliability of the data generated. The QA/QC results for this portion of the work are summarized in Table 3.

Table 3. D.G. Slotton Laboratory Total Mercury QA/QC Summary (from 8 analytical runs)

	Std Curve R^2	Spike Recoveries	Duplicate RPD	NBS Tuna	IAEA Tuna	NBS Sediment	BCR Sediment
Certified Level (ppm)				0.95	4.70	1.47	0.67
Ideal Recovery	1.000	(100%)	(0%)	(100%)	(100%)	(100%)	(100%)
Control Range (%)	≥0.975	75-125%	≤25%	75-125%	75-125%	75-125%	75-125%
Control Range (ppm)				0.71-1.19	3.60-6.00	1.10-1.84	0.50-0.84
Recoveries (%)	0.998-1.000	87-108%	0.2-18.8%	88-120%	93-104%	97%	90-100%
Recoveries (ppm)				0.84-1.14	4.37-4.87	1.42-1.43	0.60-0.67
(n)	n=8	n=18	n=21	n=16	n=15	n=2	n=6
Mean Recoveries (%)	0.999	98%	5%	106%	98%	97%	96%
Mean Recoveries (ppm)				1.01	4.61	1.43	0.64

The extensive set of aqueous standards was used to construct an accurate curve of mercury concentration vs atomic absorbence for each analytical run. The standard curve R^2 values for the mercury runs utilized in this project all fell between 0.998 and 1.000, well above the control range of ≥ 0.975. The standard reference material samples included two fish standards and two sediment standards. All recoveries were within the 75% - 125% control levels, at 88-120%. Sample duplication was excellent, with relative % difference (RPD) having a mean value of 5% among 21 total paired samples. Spike recoveries were also consistently good, with recoveries of 87% - 108%, as compared to the 75% - 125% control levels.

3. RESULTS

3.1 Watershed

3.1.1 Water

We determined flows and collected water samples for mercury and suspended solids at 18 individual sampling sites distributed throughout the Marsh Creek watershed. These collections were made within a 48 hour period during high runoff flow conditions in late March 1995, following an extensive series of storms. A considerable effort was made to obtain these samples within as close a time period as possible, during high but relatively stabilized flow conditions. Flow values are presented in Table 4 and Figures 3 and 4. Concentration data for suspended solids and aqueous mercury are presented in Table 4 and Figures 5 and 6. Calculated bulk mercury loads, on a grams per day basis for each site, can be found in Table 5 and Figures 7 and 8. Mass balance data quantifying the overall proportional mercury contributions of the various source tributaries to downstream receiving waters are presented in Table 6 and Figures 9 and 10.

Table 4. Watershed Flow; Aqueous Mercury and Suspended Solids Concentration Data

Site	Flow (cfs)	*Aqueous Total Mercury* Raw (ng/L)	Filtered (ng/L)	*Suspended Solids* All (TSS) (mg/L)	Solids Hg (dry ppm)
Upper Marsh Creek	28.30	3.24	1.29	16.10	0.10
Curry Creek	33.70	5.18	1.49	32.00	0.12
Marsh Ck above Perkins Ck	65.60	4.69	1.34	32.10	0.10
Perkins Creek	13.90	8.89	4.11	3.00	1.59
Upper Dunn Creek	5.20	3.60	2.73	1.50	0.60
Upper Horse Creek	0.08	25.50	16.00	1.10	8.64
"My" Creek	2.10	381.00	28.40	10.90	32.41
OreHouse Spring	0.01	1,940.00	71.00	11.40	164.00
Trickle coming from tailings	0.03	58,400.00	54,100.00	77.20	56.37
South Pond outlet	0.05	59,100.00	59,100.00	26.10	0.00
Horse Creek @ tailings	0.32	25,000.00	21,900.00	104.00	29.8
Dunn Ck below mine confluence	7.80	949.00	226.00	13.50	53.60
Marsh Ck below Dunn Ck conf.	83.60	79.30	21.40	19.40	2.99
Mid Marsh Ck @ rd. crossing	101.00	52.80	10.10	24.60	1.74
Marsh Ck above Reservoir	111.00	37.67	8.80	23.10	1.25
Briones Ck @ Deer Valley Rd.	4.10	5.84	2.03	61.20	0.06
Marsh Ck below Reservoir	116.00	43.70	7.47	34.60	1.05
Marsh Ck @ Delta Rd.	107.00	37.80	6.44	53.80	0.58
		Aqueous Methyl Mercury Raw (ng/L)	Filtered (ng/L)		
Marsh Ck above Reservoir		0.204	0.112		

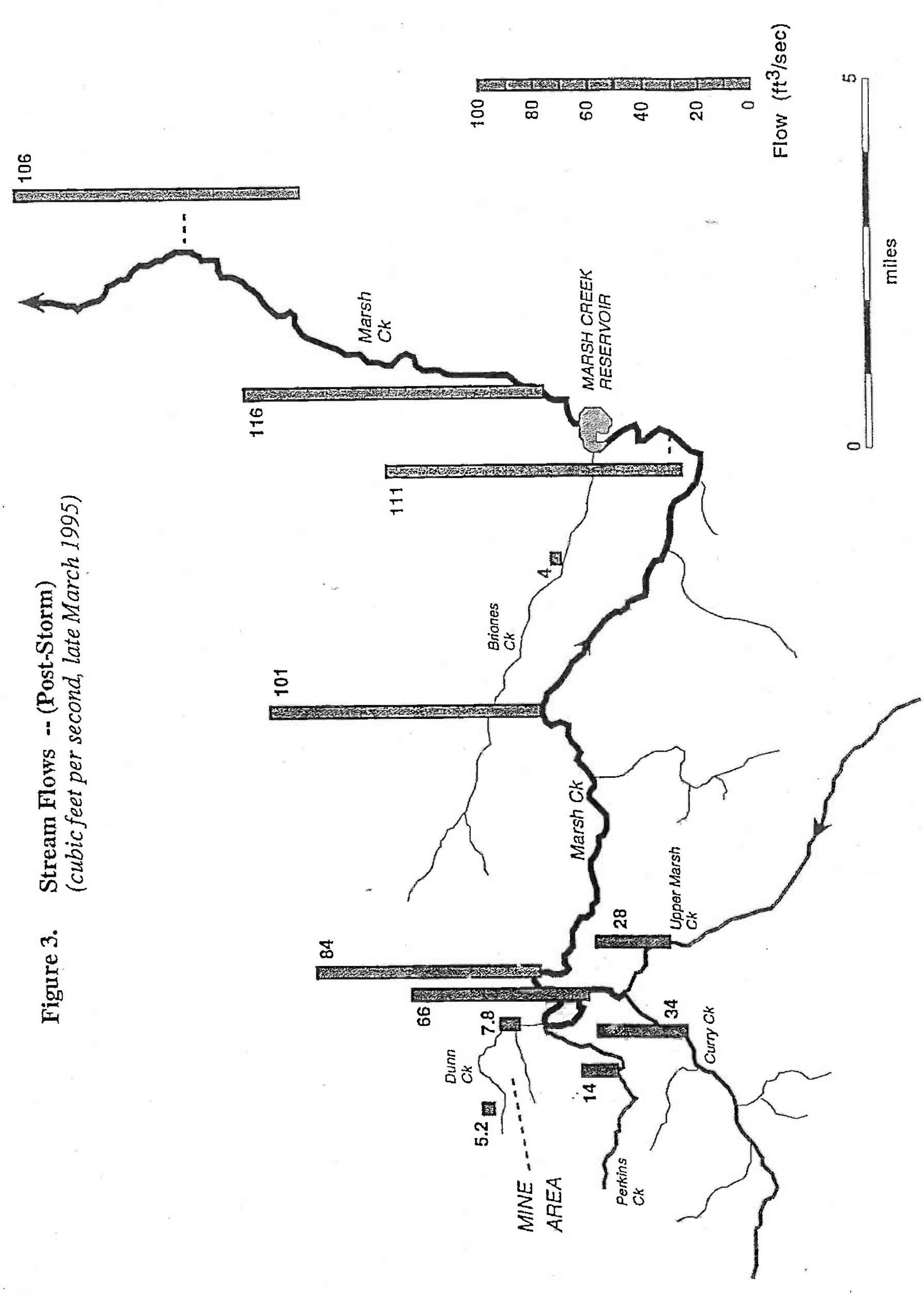
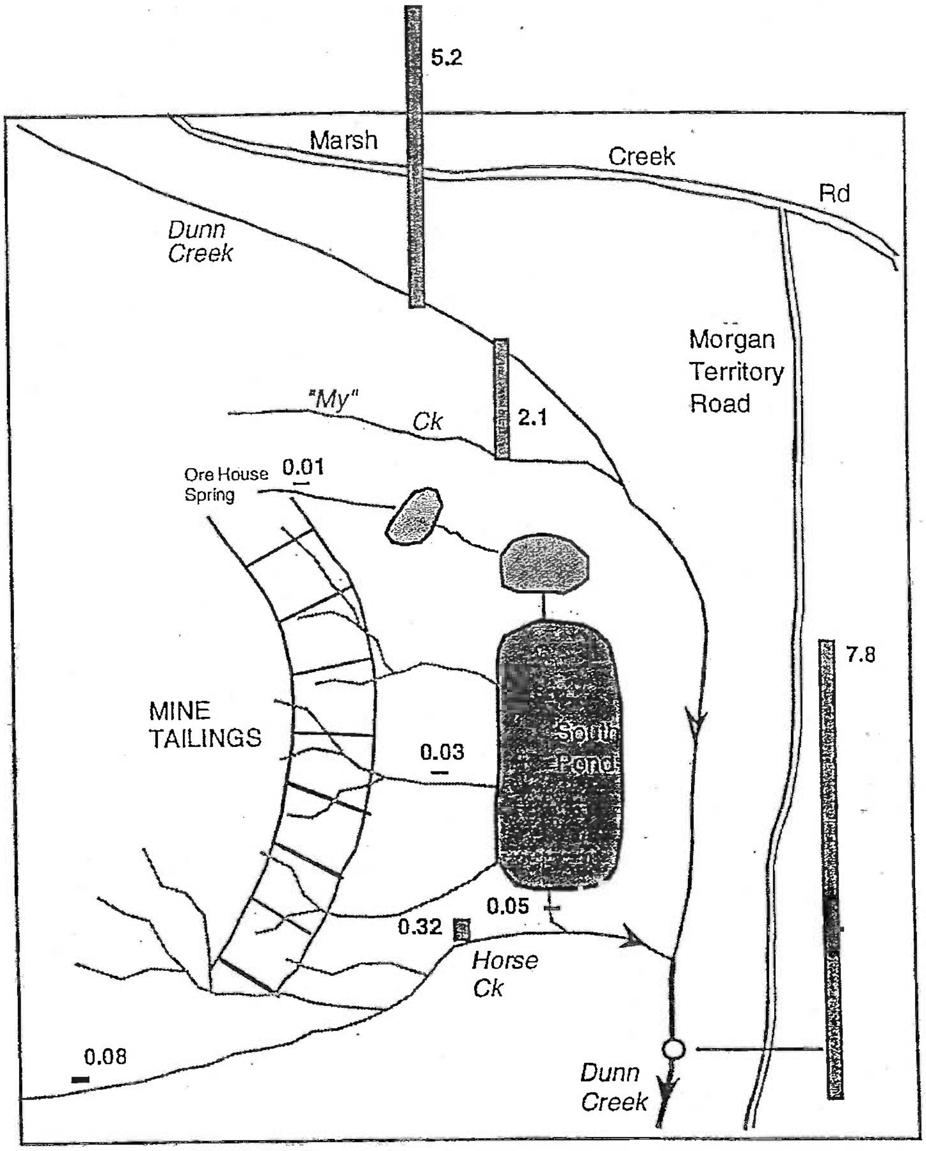


Figure 3. Stream Flows -- (Post-Storm)
(cubic feet per second, late March 1995)



Flow (ft^3/sec)

Note scale (vs 100 ft^3/sec scale used in whole watershed map)

Figure 4. **<u>Stream Flows</u> in the Vicinity of the Mt. Diablo Mine**
(Late March 1995)

3.1.1.1 *Relative Flows*

Flow values, in units of cubic feet per second (cfs), are presented in Table 4 and Figures 3 and 4. Flow data were collected as a key parameter for bulk load and mass balance calculations. At the time of these samplings, major tributary streams in the Marsh Creek watershed each contributed flows of between 4 and 34 cubic feet per second to Marsh Creek. The flows measured in Marsh Creek itself demonstrated a characteristic, steady increase moving downstream, incorporating the inputs of the various tributaries as well as groundwater inflows. Flow was estimated at approximately 100 cfs at a site halfway between the Dunn Creek confluence with Marsh Creek and the downstream reservoir. Flows at and below the reservoir were an additional 5-15% higher.

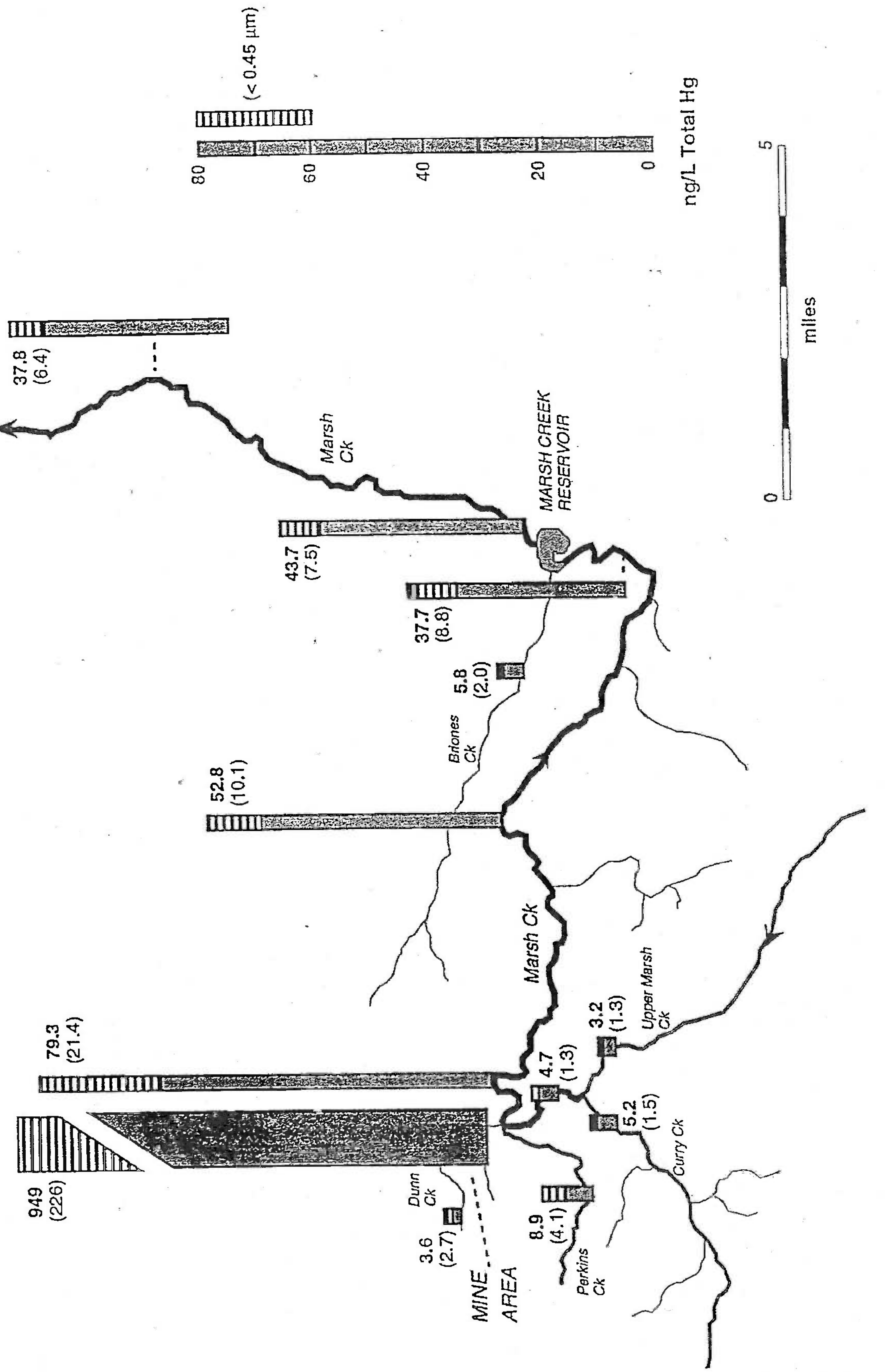
Of the ~115 cfs flow noted immediately above and below the reservoir in this sampling, three major upstream tributaries together accounted for 69% (~80 cfs) of the total. These were upper Marsh Creek, Curry Creek, and Perkins Creek. The water volume measured in Dunn Creek (7.8 cfs), which includes all flows derived from the Mt. Diablo mine area, amounted to less than 7% of the downstream flow. Further, the great majority of this water was derived from regions away from the mine, including the upper portions of Dunn Creek (5.2 cfs) and Horse Creek (0.08 cfs). "My" Creek, which is north of and relatively peripheral to the main tailings region, accounted for a further 2.1 cfs. Flows emanating specifically from the area of exposed tailings were estimated at only 0.28 cfs at the time of this sampling (lower Horse Creek minus upper Horse Creek, South Pond outflow minus Orehouse spring flow). This tailings-specific flow, at 0.24%, was less than one quarter of 1% of the total downstream water flow noted at the reservoir.

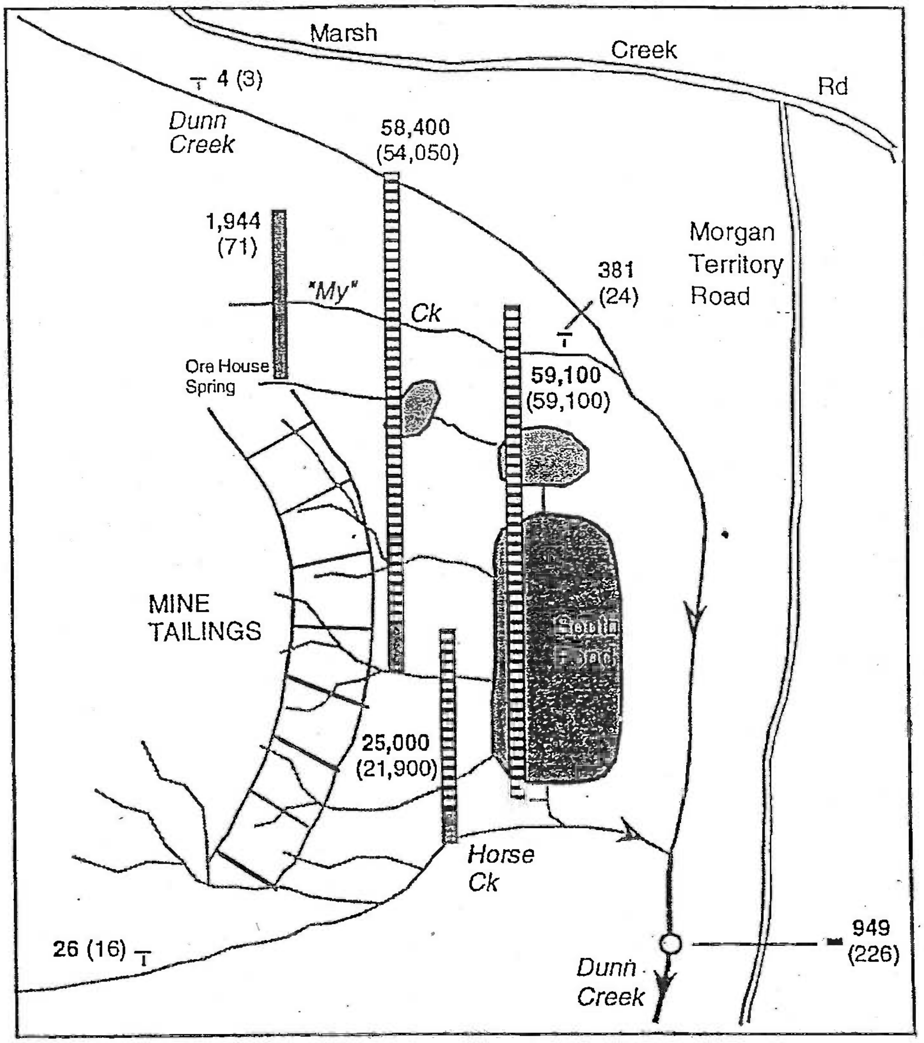
3.1.1.2 *Aqueous Mercury Concentrations*

Mercury was analyzed in homogenized, representative water samples taken from each of the 18 sites throughout the Marsh Creek watershed. Each sample was further divided into a filtered (≤ 0.45 µm) and raw water sample, each of which was analyzed for total mercury. Duplicate samples taken at the inflow to Marsh Creek Reservoir were also analyzed for methyl mercury. Aqueous mercury concentrations, in units of nanograms per liter (ng L^{-1}, = parts per trillion), are presented in Table 4 and Figures 5 and 6 Mercury measured in the filtered fraction is displayed superimposed on the total mercury data bars in the figures, and in parentheses in the figure data.

It is apparent in Figure 5 that; on a concentration basis, aqueous mercury levels in Dunn Creek downstream of the Mt. Diablo mine were significantly higher than the concentrations seen in all other tributaries to Marsh Creek, as well as upstream of the mine.

Figure 5. Marsh Creek Watershed
Aqueous Mercury Concentrations
(ng/L, late March 1995)





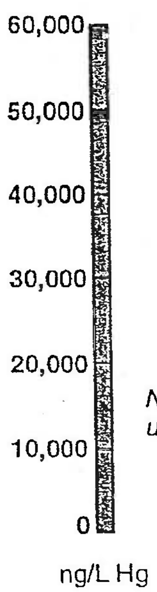
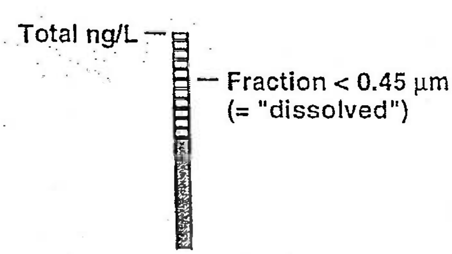


Figure 6. Aqueous Mercury Concentrations in the Vicinity of the Mt. Diablo Mine
(Late March 1995)

Note scale (vs 0-80 ng/L scale used in whole watershed map)



The mercury concentrations found in the other main tributaries, at 3.2-8.9 ng L^{-1}, were two orders of magnitude lower than the 949 ng L^{-1} concentration found in Dunn Creek below the mine. The great impact of the mine-region Dunn Creek flows to Marsh Creek is apparent in the large increase in Marsh Creek aqueous mercury concentrations below the Dunn Creek confluence. Upstream levels of 3.2-8.9 ng L^{-1} increased to 79.3 ng L^{-1}, measured one mile below the confluence. Aqueous mercury concentrations remained elevated below this point in the watershed, at > 37 ng L^{-1} as far downstream as the town of Oakley.

The close-up map of aqueous mercury concentrations in the immediate vicinity of the Mt. Diablo mine (Fig. 6) demonstrates that the very high mercury levels seen in Dunn Creek are clearly derived from the mine itself. The stream "My" Creek, which borders the north extent of the tailings region, was quite high in mercury at 381 ng L^{-1}, while flows emanating from the tailings themselves were massively contaminated, with levels ranging from 25,000 - 60,000 ng L^{-1}. The Orehouse spring was also quite high, though far lower in mercury than the downslope tailings flows, at 1,944 ng L^{-1}. This small spring, however, contributed very little to the overall water volume from the site, with its flow at this time measured at just 0.01 cubic feet per second (Fig. 4).

Previous water sampling in the region by the Central Valley Regional Water Quality Control Board utilized less sensitive analytical techniques that placed most watershed samples below the 0.00002 mg L^{-1} (20 ng L^{-1}) level of detection (CVRWQCB 1994). However, above detection results were obtained from 4 of the earlier samples, including a Dunn Creek sample directly below the mine inflows (600 ng L^{-1}) and 3 sites in the direct vicinity of the tailings and settling pond (16,000 - 70,000 ng L^{-1}). These December 1994 levels were quite similar to the corresponding concentrations we found in our 1995 work.

In addition to the maximally contaminated flows from the mine tailings themselves, it is notable that all of the Marsh Creek watershed tributaries which showed any significant elevation in mercury concentration, relative to the entire data base, derived from the same slope of Mt. Diablo; i.e. the region between Perkins Creek and "My" Creek.

It is a very important observation that nearly all of the mercury detected in the heavily contaminated, near-tailings flows was found to be in the *filtered* fraction; i.e. the "dissolved" state. The sample of representative tailings seepage moving into the settling pond was found to contain 58,400 ng L^{-1} total mercury, with 54,050 ng L^{-1} (93%) measured in the filtered fraction. Water leaving the settling pond had 59,100 ng L^{-1} total mercury, with an identical concentration (a full 100%) measured in the filtered fraction. The somewhat diluted but higher volume flow in Horse Creek had a total mercury concentration of 25,000 ng L^{-1}, with 21,900 ng L^{-1} (88%) accounted for by the filtered fraction. These collections were in marked contrast to samples from all other sites throughout the watershed, where the majority of the total aqueous mercury was in the particulate fraction. In downstream Dunn Creek and Marsh Creek, the filtered fraction accounted for only 17-27% of the total aqueous mercury. Further, it is likely that much of the downstream "filtered" mercury fraction was not truly "dissolved", but was associated with particulates and colloids that were simply smaller than the 0.45 µm standard pore size used in filtration. In contrast, the filtered mercury fraction that constituted virtually the entire mercury load in flows sampled at the tailings themselves likely originated from truly dissolved mercury, as suggested by the acidity (low pH) in the immediate vicinity of the ore body and settling pond.

This data indicates that the extremely high mercury concentrations in the tailings flows are derived specifically from the dissolution of mercury from the tailings. The tailings of this historic mercury mine are by definition rich in mercury. Once in the dissolved state, this mercury can become highly mobile. Mercury presumably dissolves readily into water in the immediate vicinity of the tailings due to the characteristic presence of sulfides in the ore. This sulfur, when exposed to rainwater, promotes the formation of sulfuric acid. The acid dissolves ore constituents that would otherwise remain in solid form, including the metals iron and mercury. The iron creates the orange stain characteristic of much acid mine drainage. This happens as the low pH is subsequently neutralized by dilution with other water and the dissolved metal begins to precipitate out of solution. Mercury likely precipitates fairly rapidly as well, as evidenced by the decline in the proportion of filtered mercury seen downstream of the immediate mine area. However, we note that the freshly formed, tiny, flocculent particles that result from the precipitation of formerly dissolved metals are themselves extremely susceptible to downstream transport, if exposed to significant flow energy. Therefore, it is our interpretation that this process of the tailings mercury dissolving into runoff seepage water is, either directly or indirectly, supplying much of the greatly elevated mercury concentrations seen in the downstream watershed.

The downstream shift in aqueous mercury partitioning, from dissolved mercury in the immediate vicinity of the tailings to particulate mercury dominating the remainder of the downstream watershed, indicates that the tailings-based dissolved mercury rapidly adsorbs to particulate material upon leaving the mine site.

An additional finding brought out by this data involves the main settling pond at the mine site, which captures much of the overland and through-flow from the tailings. The mercury measured in the outflow from this pond was entirely in the dissolved state. It was also essentially identical to representative tailings seepage that was flowing *into* the pond, both in character and mercury concentration. We conclude that, in its current configuration and pH, the settling basin may not be effectively "settling out" a significant proportion, if any, of the aqueous mercury flowing into it. This is particularly the case under storm-related, elevated flow conditions, when the great majority of overall transport in the watershed occurs.

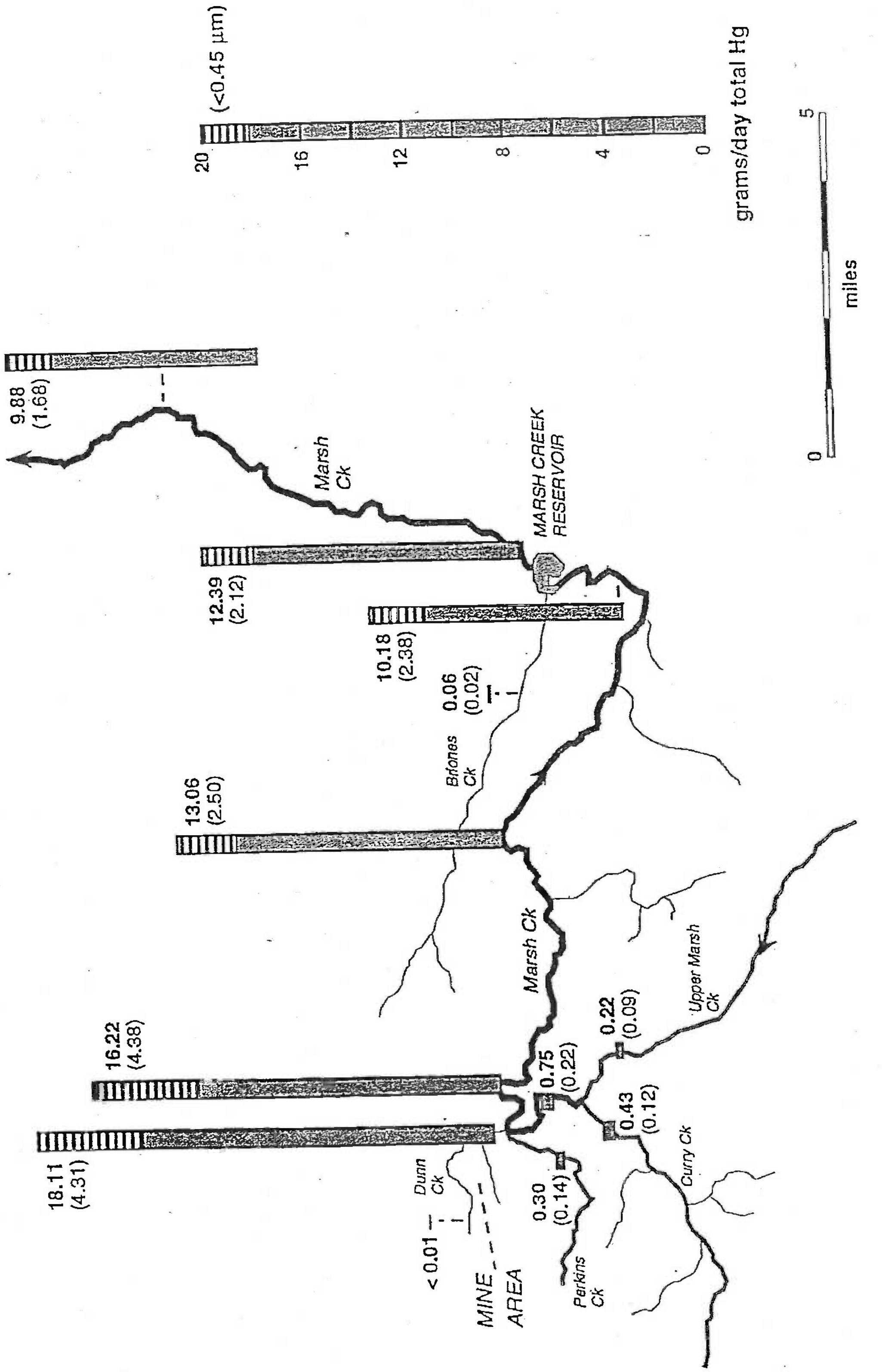
3.1.1.3 *Bulk Loads*

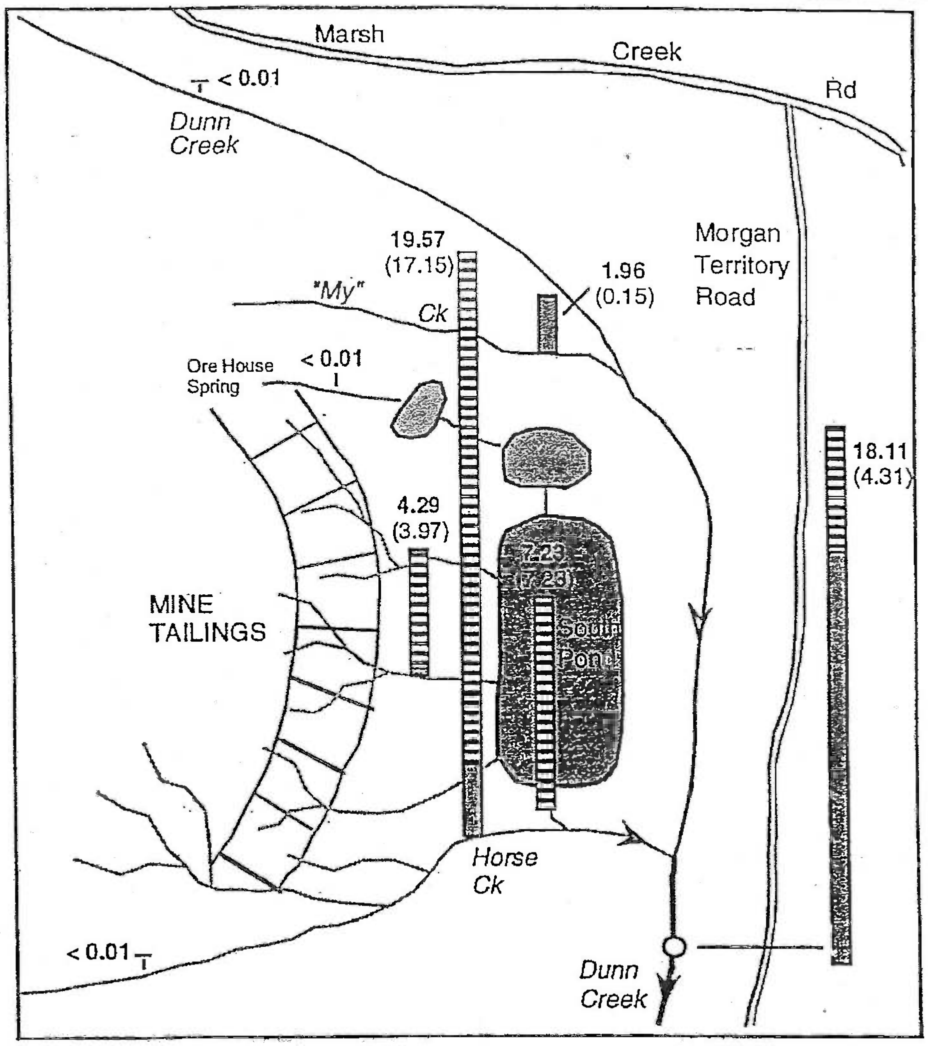
The mercury concentration data describe the local water quality conditions present at each of the sampling sites at the time of these collections. Aqueous mercury concentration is also a critical parameter with regard to localized biological uptake in the stream ecosystem. However, for considerations of overall mercury loading from the watershed to the downstream reservoir and beyond, we needed to determine the actual quantities of mercury that move through each of the stretches. This was accomplished by weighting the concentration information at each of the sites by the corresponding flow values that we determined at the time of sampling. In this way, we have been able to estimate the mercury *loads* deriving from the various tributaries, on a grams mercury per day basis. This data is presented in Table 5 and in Figures 7 and 8.

Clearly, Dunn Creek below the mine region is contributing the vast majority of mercury to the downstream reaches of Marsh Creek. All of the other tributaries, combined, accounted for approximately 1 gram of daily high flow mercury load at the time of this assessment, as compared to over 18 grams per day calculated to be moving concurrently through lower Dunn Creek toward Marsh Creek. Loads in Marsh Creek below the Dunn Creek confluence, at 10-16 grams per day as far downstream as Oakley, were dramatically greater than levels seen upstream of this confluence and in other tributaries away from mine influence. The mine inset map (Fig. 8) demonstrates that the great majority of the Dunn Creek mercury load derives specifically from the tailings piles. The greater proportion of this tailings-derived load enters lower Horse Creek without moving through the settling pond. A load of 19.6 grams of mercury per day was calculated for lower Horse Creek above the settling pond outlet, while the corresponding mercury load moving out of that pond was calculated at 7.2 grams per day.

At the time of this sampling, the data indicates that a portion of the upstream mercury load was actively sedimenting out of the water column in the course of moving downstream. Total aqueous mercury loads generally declined, moving downstream from the mine area. This occurred near the mine (Fig. 8) as well as along the length of Marsh Creek below the Dunn Creek confluence (Fig. 7). The combined mercury loads from Horse Creek (19.6 g/day), the settling pond (7.2 g/day), "My" Creek (2.0 g/day), and

Figure 7. Marsh Creek Watershed
Aqueous Mercury Bulk Loads
(grams mercury per day, late March 1995)





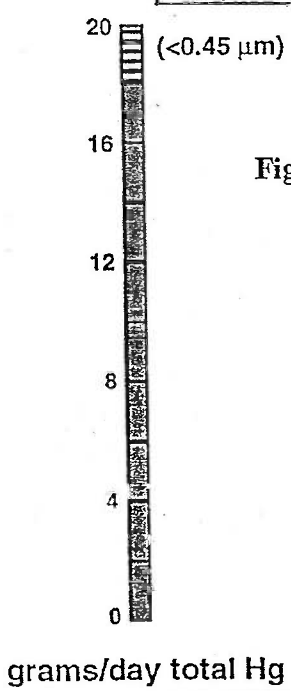


Figure 8. **Aqueous Mercury <u>Bulk Loads</u> in the Vicinity of the Mt. Diablo Mine**
(Measured Concentrations x Measured Flows)
(Late March 1995)

Table 5. Watershed Aqueous Mercury and Suspended Solids Bulk Loading Data

Site	*Aqueous Total Hg* Raw (*grams/day*)	*Aqueous Total Hg* Filtered (*grams/day*)	*Suspended Solids* (TSS) (*kilograms/day*)
Upper Marsh Creek	0.224	0.089	1,110.0
Curry Creek	0.427	0.123	2,640.0
Marsh Ck above Perkins Ck	0.753	0.215	5,160.0
Perkins Creek	0.302	0.140	102.0
Upper Dunn Creek	0.046	0.035	18.4
Upper Horse Creek	0.005	0.003	0.2
"My" Creek	1.960	0.146	55.9
OreHouse Spring	0.048	0.002	0.3
Trickle coming from tailings	4.290	3.970	5.7
South Pond outlet	7.230	7.230	3.2
Horse Creek @ tailings	19.600	17.100	81.2
Dunn Ck below mine confluence	18.100	4.310	257.0
Marsh Ck below Dunn Ck conf.	16.200	4.380	3,960.0
Mid Marsh Ck @ rd. crossing	13.100	2.500	6,070.0
Marsh Ck above Reservoir	10.200	2.380	6,250.0
Briones Ck @ Deer Valley Rd.	0.059	0.020	614.0
Marsh Ck below Reservoir	12.390	2.120	9,800.0
Marsh Ck @ Delta Rd.	9.880	1.680	14,100.0
	Aqueous Methyl Hg Raw (*grams/day*)	*Aqueous Methyl Hg* Filtered (*grams/day*)	
Marsh Ck above Reservoir	0.055	0.030	

upper Dunn Creek (0.05 g/day) totaled 28.8 grams per day, while the load measured in Dunn Creek just below the mine site was considerably lower at 18.1 grams per day. The load in downstream Marsh Creek one mile below the Dunn Creek confluence was still lower at 16.2 grams per day. The decline in the mercury load suspended in the water column continued, moving downstream, with 13.1 g/day measured at the site halfway down to the reservoir and 10.2 g/day measured just above the reservoir. This consistent pattern indicates that a portion of the mercury load was falling out of the current along with sedimenting particulates. However, we note that much or all of the previously suspended sediment that settles out within the channel itself during post-storm and lower flow conditions may ultimately be transported downstream to the reservoir and beyond under higher flow conditions, particularly with the spike increases in flow typical during large storm events.

The bulk load data additionally indicates that all significant mercury loading to the Marsh Creek watershed is accounted for by the upper watershed tributaries. The steady drop in aqueous mercury loads measured in Marsh Creek, from the Dunn Creek confluence down to the reservoir, precludes the possibility of any important additional inputs of mercury from other sources along that stretch.

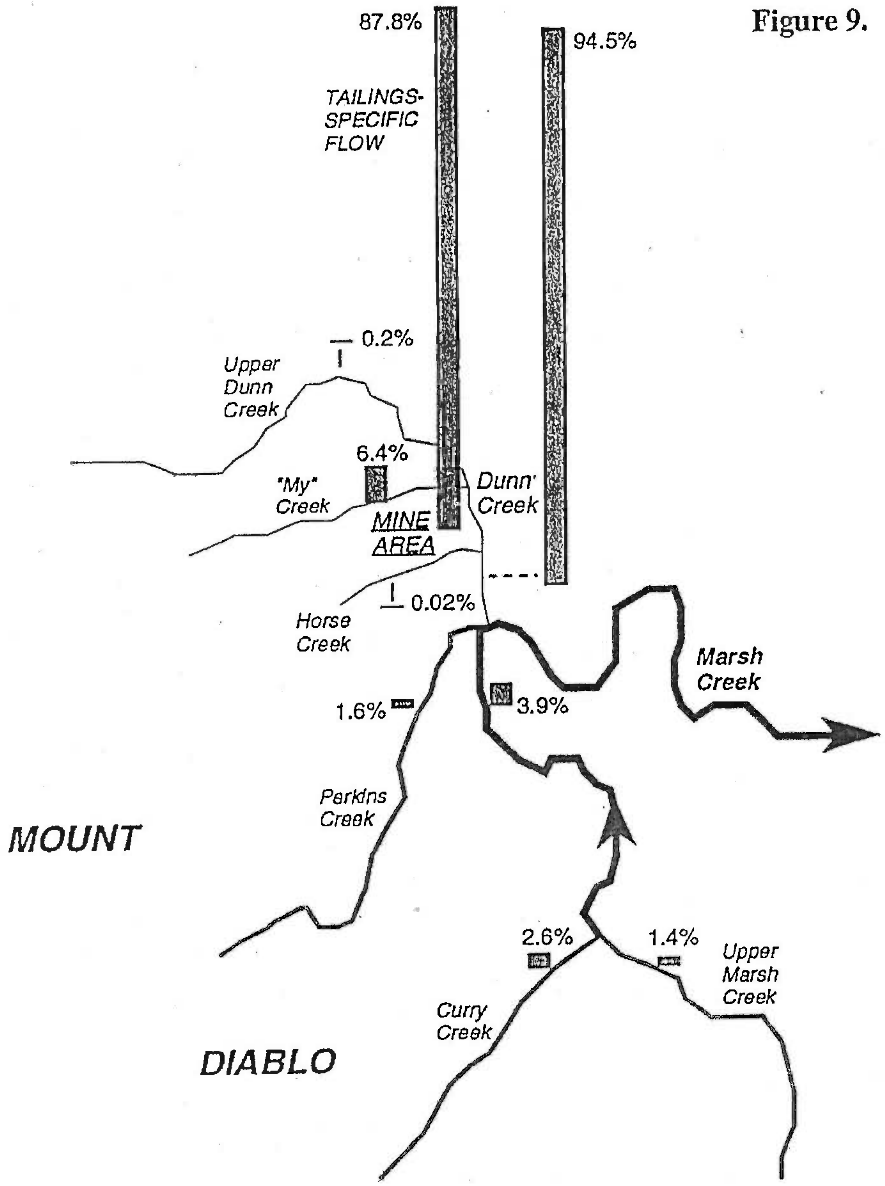
3.1.1.4 *Mercury Mass Balance*

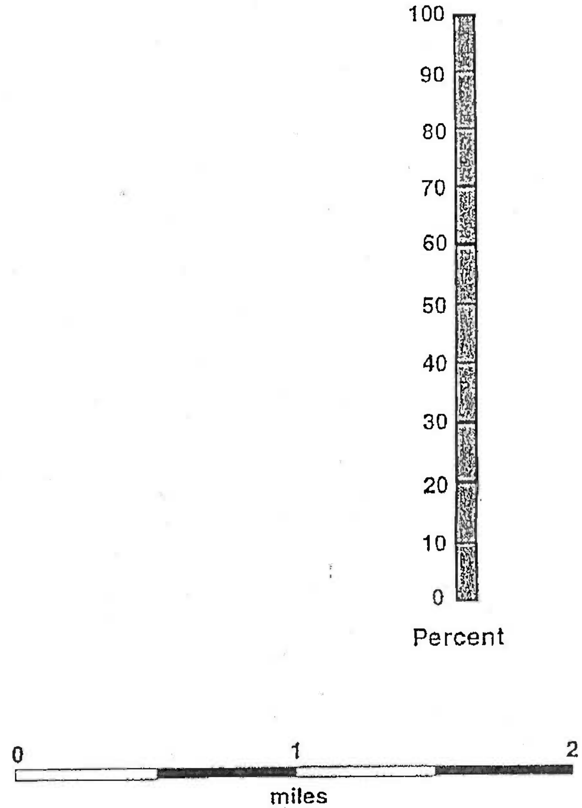
Table 6. Calculated Relative Mercury Mass Balance Contributions of Upper Watershed Sources

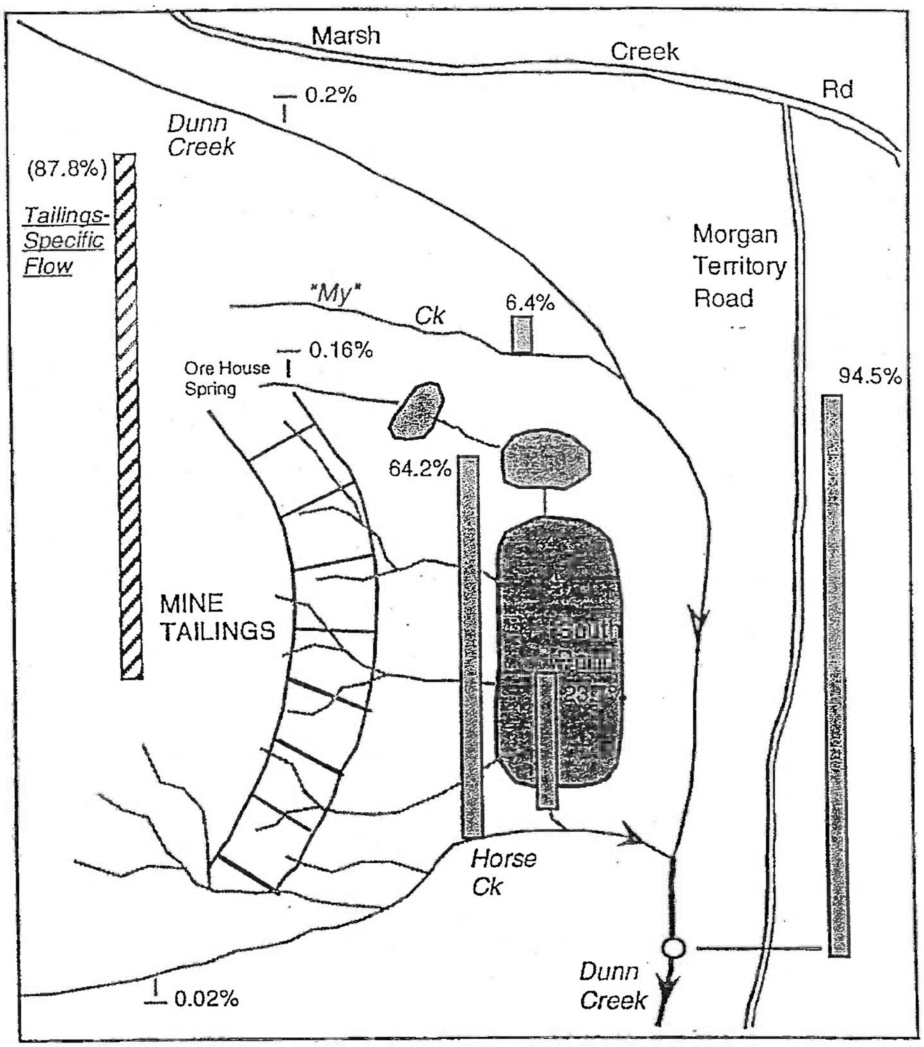
Site	Raw Total Hg (grams/day)	%	Filtered Total Hg (grams/day)	%
Perkins Creek	0.30	1.6%	0.14	3.0%
Marsh Creek above Perkins Creek	0.75	3.9%	0.22	4.6%
Dunn Creek below mine confluence	18.11	94.5%	4.31	92.4%
	(19.17)	(100.0%)	(4.67)	(100.0%)
Marsh Creek above Perkins Creek	0.75	(3.9%)	0.22	(4.6%)
Upper Marsh Creek	0.22	1.4%	0.09	1.9%
Curry Creek	0.43	2.6%	0.12	2.7%
	(0.65)	(3.9%)	(0.21)	(4.6%)
Dunn Creek below mine confluence	18.11	(94.5%)	4.31	(92.4%)
Upper Dunn Creek	0.05	0.2%	0.03	0.1%
"My" Creek	1.96	6.4%	0.15	0.5%
South Pond Outlet	7.23	23.7%	7.23	27.2%
Horse Creek at Tailings	19.57	64.2%	17.15	64.5%
	(28.81)	(94.5%)	(24.56)	(92.4%)
TAILINGS ALONE				
Horse Creek at Tailings	19.573	64.21%	17.146	64.51%
(- Upper Horse Creek)	- 0.005	- 0.02%	- 0.003	- 0.01%
	19.568	64.19%	17.143	64.50%
	(+)		(+)	
South Pond Outlet	7.230	23.72%	7.230	27.20%
(- OreHouse Spring)	- 0.048	- 0.16%	- 0.002	- 0.01%
	7.182	23.56%	7.228	27.20%
TAILINGS ALONE	26.75	87.8%	24.37	91.7%

Based on the data collected during this representative post-storm, elevated flow sampling, we have constructed a mass balance of the relative contributions of mercury to the watershed from the various upstream tributaries. These tributaries have been

Figure 9. Upper Marsh Creek Watershed: Calculated, Relative Aqueous Mercury Bulk Load / Mass Balance Percentages







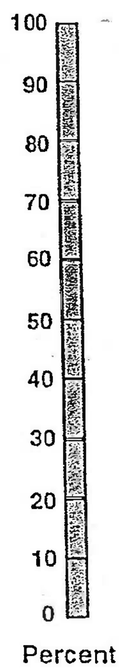


Figure 10. **Calculated, Relative Aqueous Mercury Bulk Load / Mass Balance Percentages In the Vicinity of the Mt. Diablo Mine**
(Relative to total mercury loads throughout the entire upper watershed of Marsh Creek; late March 1995)

demonstrated to provide essentially all of the watershed's mercury loading. The data are presented in Table 6 and in Figures 9 and 10. The technique used to arrive at these values is described in section 2.3.1. These are our best estimates of the true proportional inputs of mercury from the different source regions to the Marsh Creek watershed.

In this analysis, the Dunn Creek inflow to Marsh Creek represents 94.5% of the total mercury loading to the upper watershed. Though the bulk of the water and transported sediment derive from upper Marsh Creek, Curry Creek, and Perkins Creek, these major tributaries accounted for only 5.5% of the watershed's mercury.

Of the 94.5% of the watershed mercury estimated to derive from Dunn Creek, it is apparent that the overwhelming majority comes from the Mt. Diablo mine. The upper stretches of Dunn Creek and Horse Creek, above the influence of the mine, together with the Orehouse spring flow, accounted for less than 0.4% of the total mercury (Fig. 10). "My" Creek contributed a moderate load of 6.4%. We are not clear at this time whether this particular stream is amenable to straightforward mitigation options.

Our major interest is in the flows emanating from the tailings themselves, as they are a very localized source that represent the County's best and most cost-effective mitigation focus for watershed mercury cleanup, if they in fact constitute the majority of the source. The data indicate that this is indeed the case. Subtracting out the small mercury loads of the Orehouse spring and upper Horse Creek, the relative mercury loading to the entire watershed derived specifically from this comparatively small region of mine tailings is estimated to be approximately 88%. The majority of this tailings-based load (64.2% in this analysis) enters lower Horse Creek without passing through the settling basin.

This information suggests that mitigation work directed specifically at the mine tailings, in order to lessen the export of mercury, may be a very sensible and cost-effective approach.

3.1.1.5 *Suspended Solids*

Suspended solids (TSS) data for the 18 stream sites are presented on a concentration basis (mg L^{-1}, = parts per million) in Table 4. This is a measure of particulate matter, primarily sediment, in the water. Suspended solids are of importance to mercury dynamics as they generally constitute the major vector of downstream mercury transport in running water. Mercury can be incorporated into the mineral matrix of particles as well as surface-adsorbed. Upon loosing velocity in the downstream reservoir and delta, these particulates deposit at the bottom as sediments and constitute the bulk of the total mercury in those systems.

Highest concentrations of TSS were seen in the flows on and around the tailings (to 104 mg L^{-1}), where iron and other metals were actively precipitating. The small Briones Creek, which drains farmland, was relatively very turbid as well (61 mg L^{-1}). Upper Marsh Creek and Curry Creek (~32 mg L^{-1}), the dominant sources of flow to the watershed, were quite turbid with suspended solids during this post-storm sampling period, while Perkins Creek (3 mg L^{-1}), "My" Creek (11 mg L^{-1}), upper Horse Creek (1 mg L^{-1}), and upper Dunn Creek (1.5 mg L^{-1}) were flowing quite clear. Below the Dunn Creek confluence, suspended solids concentrations in Marsh Creek generally increased steadily, moving downstream toward the reservoir and below (19 mg L^{-1} below the Dunn Creek confluence, increasing to 54 mg L^{-1} near Oakley).

As described above for mercury, the actual bulk loads of suspended solids moving through the different stream sections at the time of this sampling can be calculated by weighting the measured concentrations of TSS by the corresponding flows. These data are presented in Table 5 in units of kilograms per day and, Figure 11, as metric tons (1,000 kilograms, = 2,200 pounds) per day. The pattern is in sharp contrast to the mercury findings. Whereas the Dunn Creek mercury load overwhelmingly dominated that of the entire watershed, the suspended solids entering Marsh Creek from Dunn Creek represented only a very small fraction of the overall suspended solids load measured in downstream Marsh Creek. The Dunn Creek suspended solids load was calculated to be 0.26 metric tons/day, as compared to a combined 6.86 metric tons/day measured at the reservoir inflows. The Dunn Creek contribution of suspended solids therefore represented less than 4% of the total load measured entering the reservoir. While approximately 88% of the watershed's mercury was calculated to derive from the tailings piles at the Mt. Diablo mine, these suspended solids data indicate that an estimated 95% of the drainage's suspended solids load comes from tributaries which were found to be relatively very low in mercury--i.e. those tributaries other than Dunn Creek (including "My" Creek) and Perkins Creek.

In Table 4 and Figure 12 we have estimated the mercury concentration of the suspended particulates at the different sites, in consistent units of dry weight milligrams of mercury per kilogram suspended sediment (mg kg^{-1}, = parts per million). We note that the dominant sources of suspended sediment to the watershed--upper Marsh Creek, Curry Creek, and the small tributaries entering Marsh Creek along its lower length--were measured or demonstrated to be very low in suspended sediment mercury concentration, on the order of 0.1 ppm. This is in comparison with Marsh Creek TSS mercury levels between the Dunn Creek confluence and the reservoir of 1.3-3.0 ppm. Clearly, if the load of mercury emanating from the Mt. Diablo mine site can be significantly lessened, the natural suspended sediment loads transported through the Marsh Creek watershed in future

Figure 11. Suspended Solids Loads During High Runoff
(March 1995; metric tons/day)

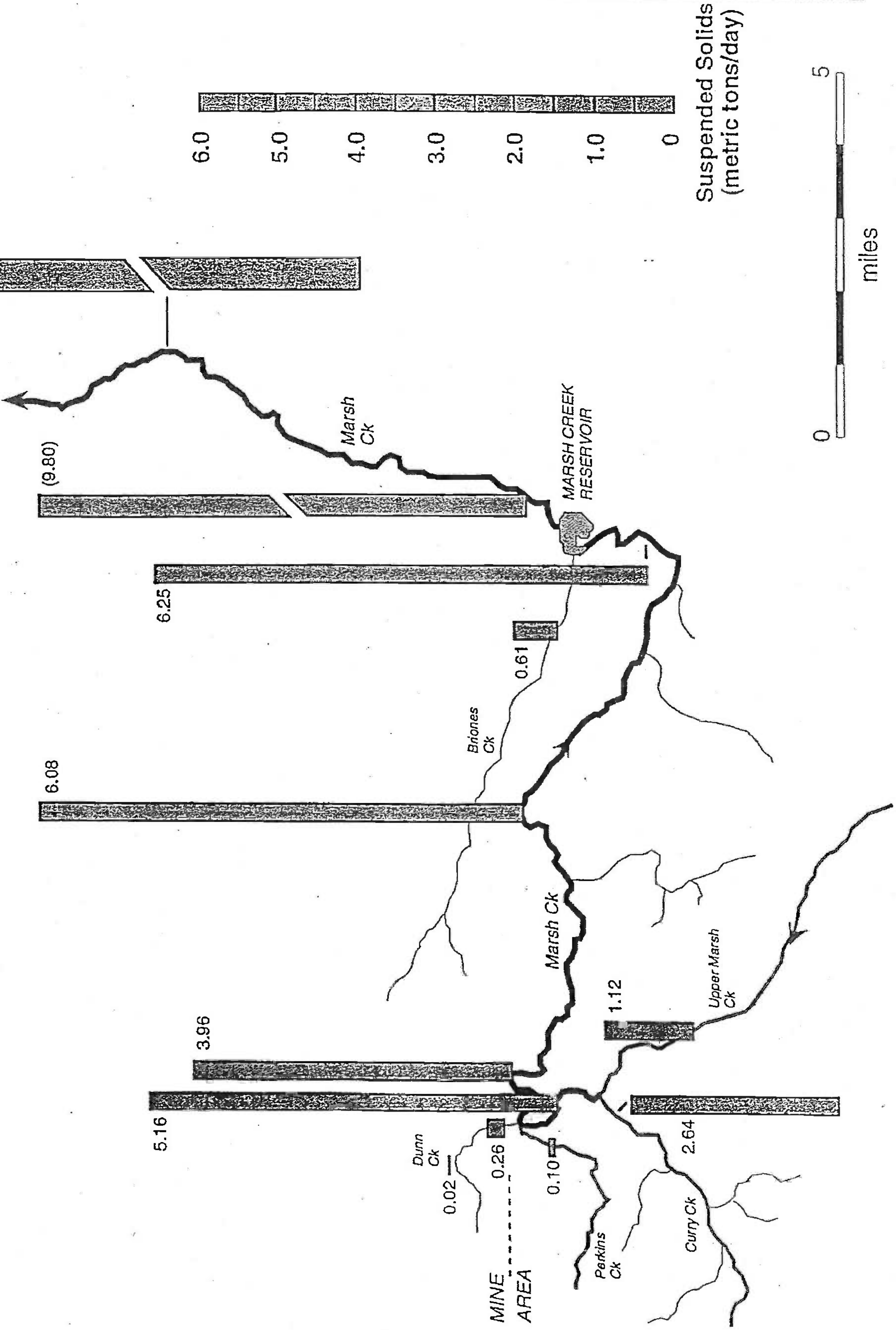
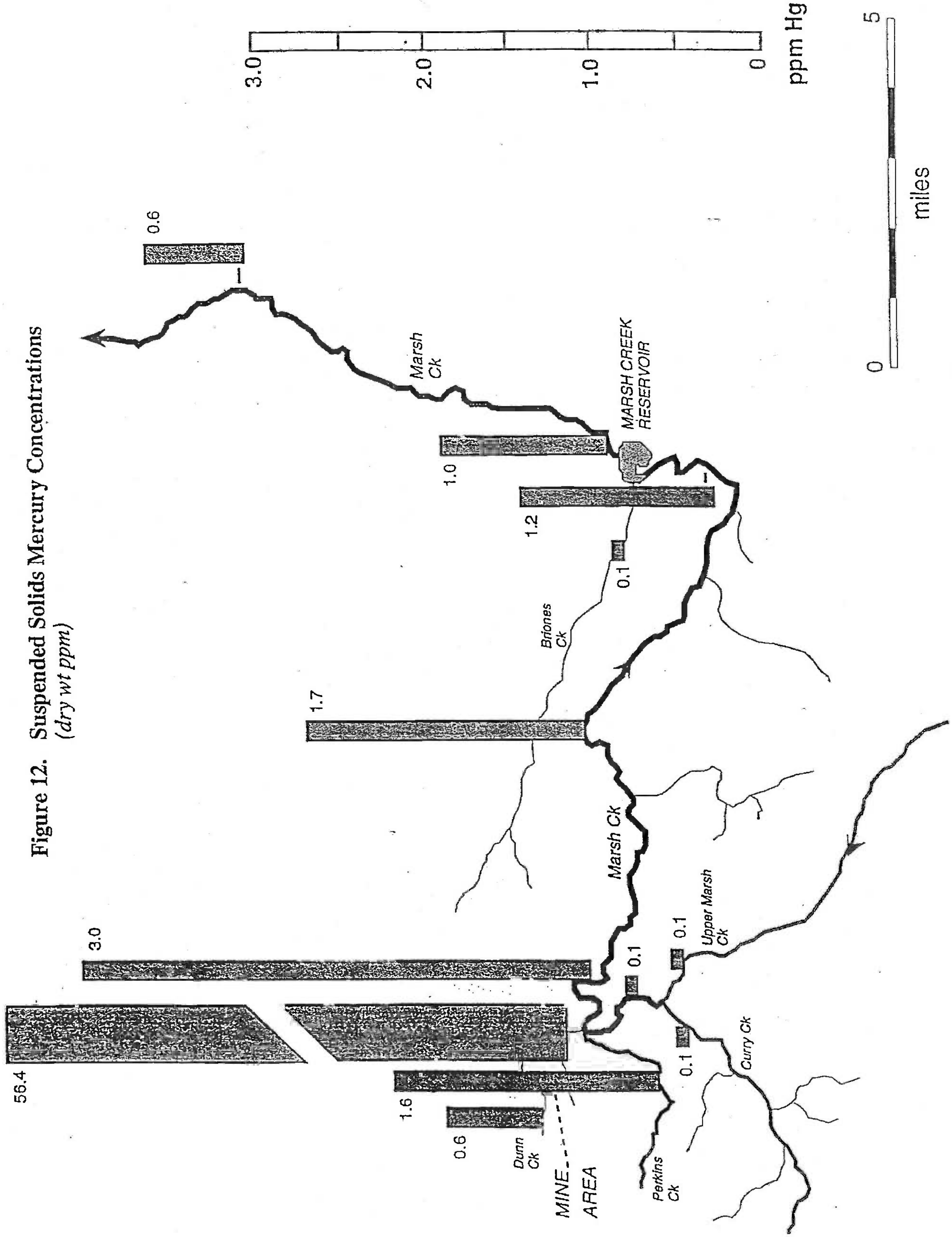


Figure 12. Suspended Solids Mercury Concentrations
(dry wt ppm)



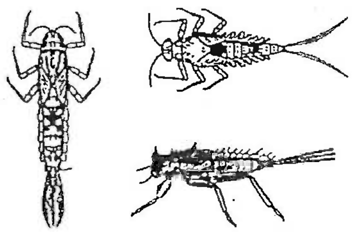
storm seasons should plummet in average mercury concentration, as the great majority of sediment transported in this drainage has been shown to be quite low in mercury content. This material can then form a natural, lower mercury "treatment" for the Marsh Creek Reservoir bottom sediments in future years.

3.1.2 Stream Invertebrates

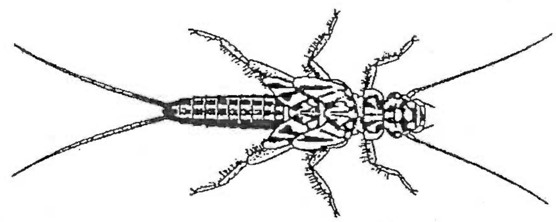
Stream invertebrates that were analyzed for this project are illustrated in Figure 13. The mercury data for the watershed invertebrate samples are presented in Table 7 and in Figures 14 and 15. Native in-stream invertebrate species have proven to be excellent monitors of mercury bioavailability in California streams and rivers (Slotton et al. 1995a). Because they incorporate mercury into their bodies throughout their lives, they can provide a time-integrated measure of stream conditions, as compared to standard "point-in-time" grab sampling for water. The mercury incorporated into local aquatic biota is, by definition, specifically the bioavailable fraction, which can be of paramount importance for management considerations. Additionally, many of these species are ideal indicators of highly localized conditions, as compared to fish which can and often do migrate extensively. The benthic invertebrate species we focused on in this work typically remain within a very limited area throughout their lives. They thus function as relatively static biological probes of the fraction of mercury in the water that is bioavailable.

At the majority of sampling stations, we were able to collect specimens from three distinct trophic feeding levels of invertebrates in sufficient quantity for mercury analysis. Macro-invertebrates were not present in the smaller, more ephemeral flows in the immediate mine region. Near the base of the aquatic food chain were mayfly nymphs (Ephemeroptera) from several herbivorous genera. Perlodid stoneflies were also taken at most of the sites. These are medium-sized invertebrate predators which feed on small to medium invertebrates. At the top of the invertebrate food chain in the upper watershed are the large-jawed hellgrammites (Corydalidae), which can reach several inches in length and are voracious predators of all other co-occurring species. We additionally took samples of aquatic "hair worms" of the order Nematomorpha. These organisms have a complex life cycle, deriving from the terrestrial ecosystem, and do not feed while in the stream. They thus provide limited information, presumably linked to direct uptake of mercury from the water. The majority of biotic mercury is typically accumulated through the food chain in the diet, particularly in the higher trophic levels (Lindberg et al. 1987, Gill and Bruland 1990).

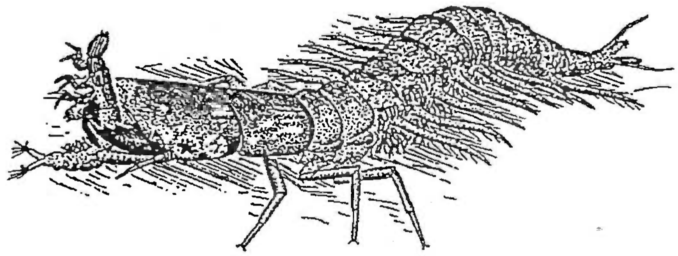
Figure 13. **Stream Invertebrates Analyzed in This Project**
(illustrations taken from McCafferty 1981, Goldman 1981)



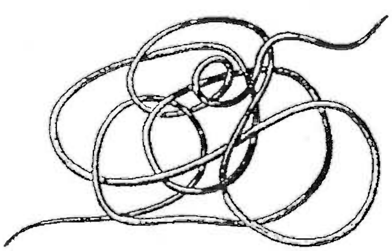
Mayflies (Ephemeroptera)
(~1/2 inch)
Siphloneuridae
Baetidae
Ephemerellidae



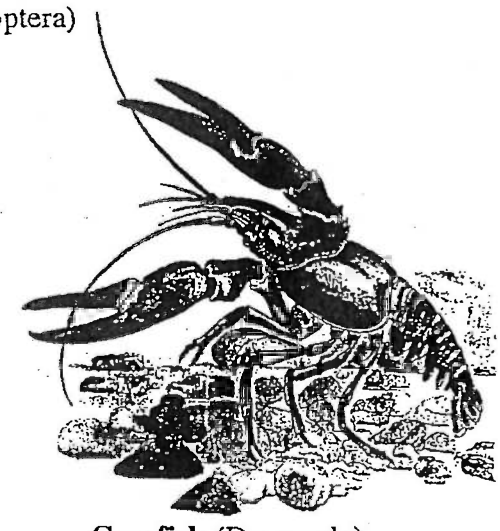
Stoneflies (Plecoptera)
Perlodidae (~1 inch)



Hellgrammites (Megaloptera)
Corydalidae (2-4 inches)



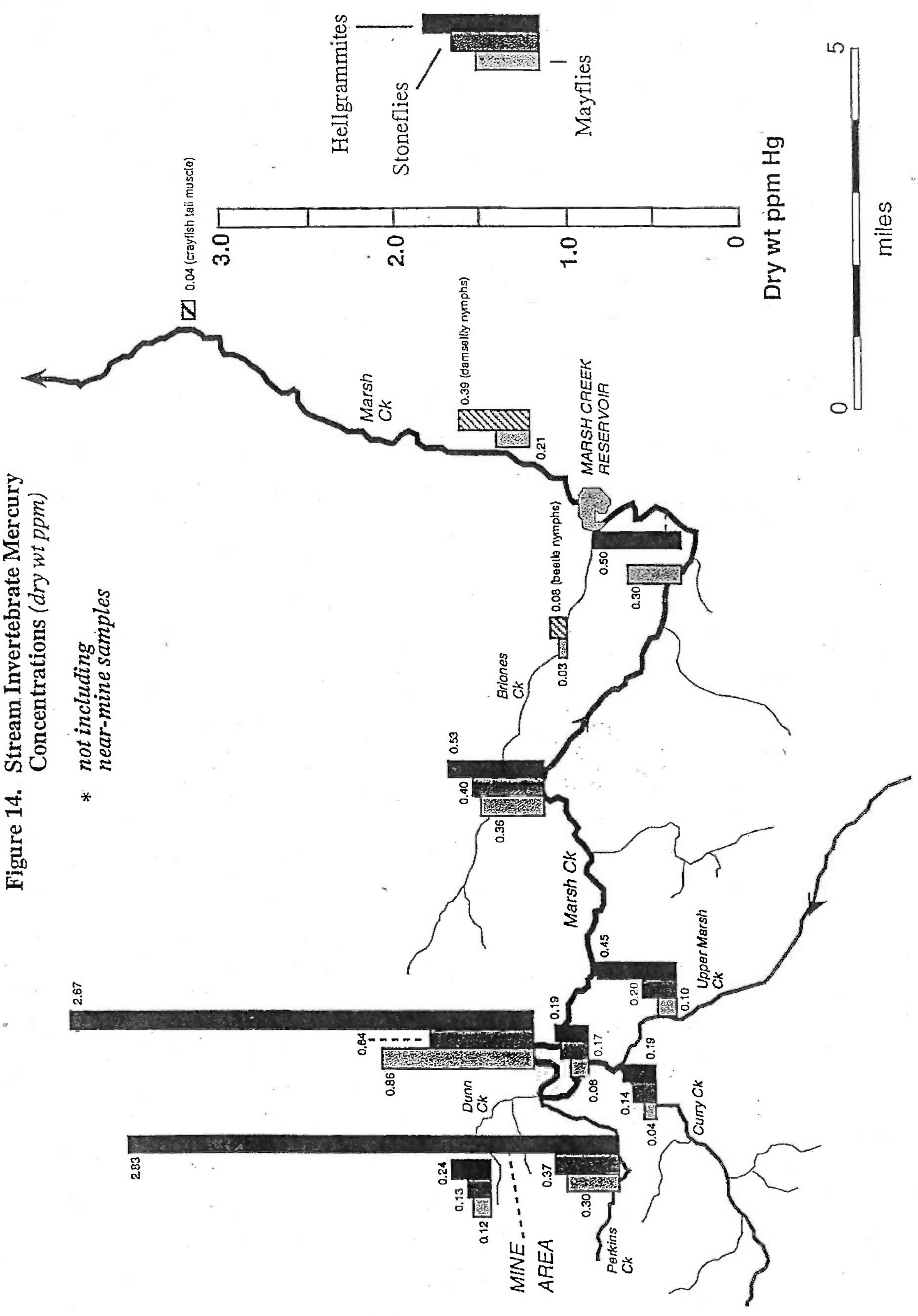
Horsehair Worms
(Nematomorpha)

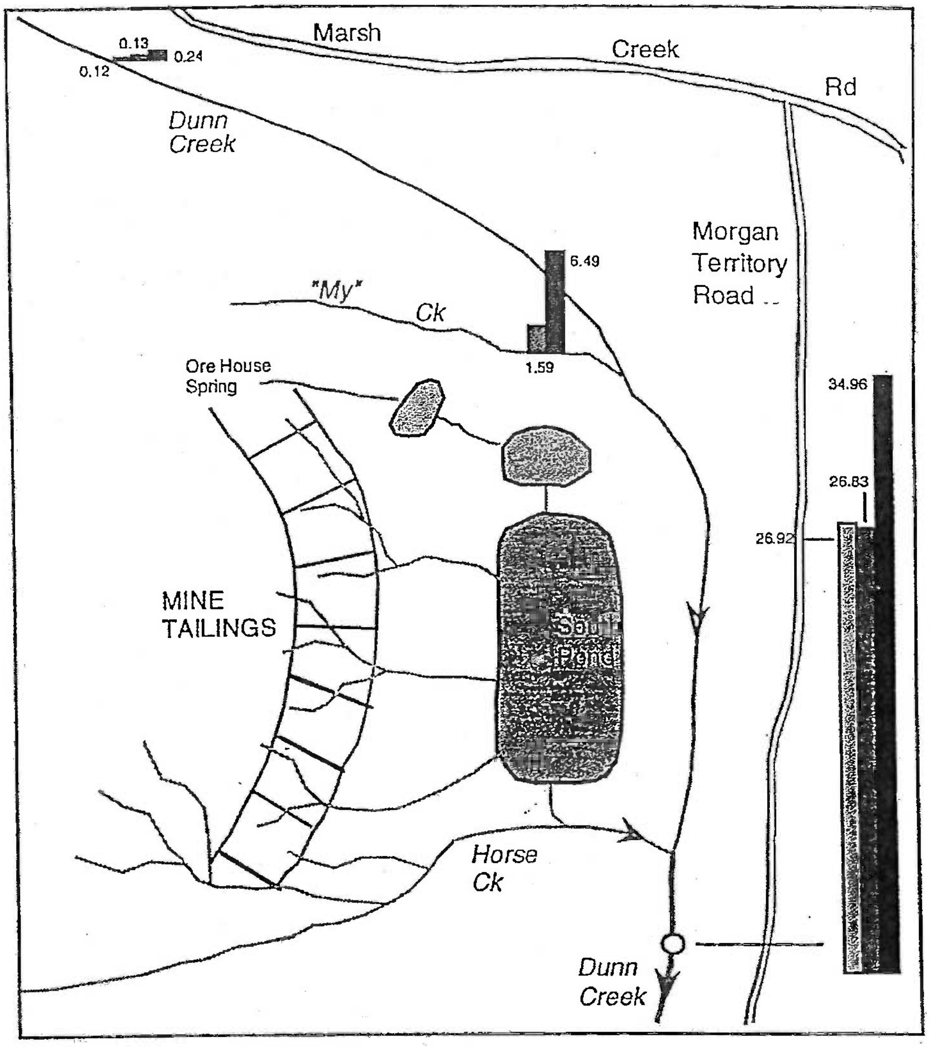


Crayfish (Decapoda)
Pacifasticus

Figure 14. Stream Invertebrate Mercury Concentrations *(dry wt ppm)*

* *not including near-mine samples*





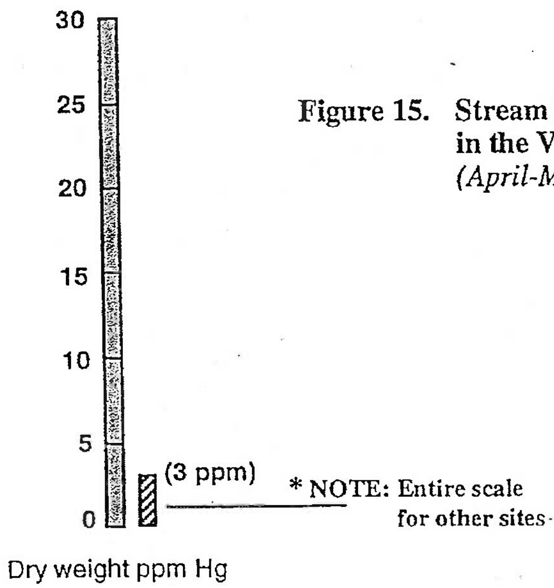


Figure 15. Stream Invertebrate Mercury in the Vicinity of the Mt. Diablo Mine
(April-May, 1995)

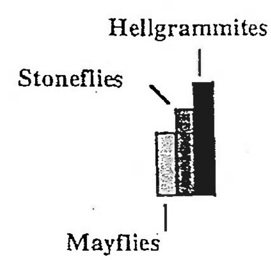


Table 7. Stream Invertebrate Mercury Concentrations *(dry weight ppm)*

SITE	Nematomorpha Horsehair Worms *Water Uptake Only*	Ephemeroptera Mixed Mayflies *Herbivores*	Plecoptera Perlodid Stoneflies *First Order Predators*	Megaloptera Medium Hellgrammites *Second Order Predators*
Upper Marsh Creek	0.06	0.10	0.20	0.45
Curry Creek	0.10	0.04	0.14	0.19
Marsh Ck above Dunn Ck	0.06	0.08	0.17	0.19
Perkins Creek	0.38	0.30	0.37	2.83
Upper (clean) Dunn Creek	0.06	0.12	0.13	0.24
"My" Creek	0.32		1.59 §	6.49
Dunn Creek below Mine		13.80	16.00	23.80
Marsh Ck below Dunn Ck	0.29	0.52	0.64	2.67
Middle Marsh Creek	0.09	0.36	0.40	0.53
Briones Creek		0.05	0.08 ¥	
Marsh Ck above Reservoir		0.30		0.50
Marsh Ck below Reservoir		0.21	0.39 †	

Alternate 1° predators: § Rhyacophyllid caddis larvae
¥ Predaceous beetle nymphs
† Damselfly nymphs

The invertebrate mercury data indicate that the trend within the watershed for bioavailable mercury generally parallels that seen for aqueous mercury concentrations (section 3.1.1). Massive spike concentrations were apparent in Dunn Creek invertebrates immediately below the inflows from the mine site (27-35 ppm, dry weight). Biota from "My" Creek and Perkins Creek were also relatively elevated, though to a lesser degree, as were aqueous mercury concentrations in these streams. In particular, the hellgrammite samples from Perkins Creek (2.83 ppm) and "My" Creek (6.49 ppm) were significantly elevated. Concentrations were low throughout the invertebrate food chain at most sites upstream and away from the mine influence. Samples from upper Dunn Creek, above the mine, were two orders of magnitude lower in accumulated mercury than near-mine samples, at 0.06-0.24 ppm. Levels from upper Marsh Creek, Curry Creek, and Briones Creek were in a similar low range.

Along Marsh Creek, invertebrate mercury concentrations were dramatically higher downstream of the Dunn Creek confluence as compared to the relative "control" levels seen upstream of this point. Concentrations generally declined with increasing distance downstream from the mine. Comparable samples were not available at the downstream site near Oakley, though we were able to take several crayfish, which we analyzed for tail muscle mercury (Table 9, Fig. 14). These were quite low at ~0.04 ppm wet wt, ~0.18 ppm dry wt.

Within each site, mercury concentrations in the various trophic groups generally increased with feeding level, with predatory stoneflies typically containing higher levels than herbivorous mayflies, and the large predatory hellgrammites generally having the greatest concentrations.

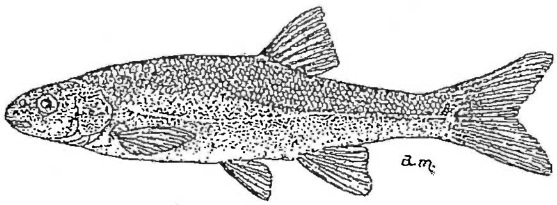
We again point out that both the aqueous concentration data and these data from bioindicator stream organisms provide information on relative localized water quality in the various tributaries. For questions of absolute, bulk contributions of mercury from each of the streams to the entire watershed, the bulk loading/mass balance types of information are more relevant (section 3.1.1.4 - 3.1.1.5). Both approaches provide important, though potentially very different, information.

3.1.3 Stream Fish

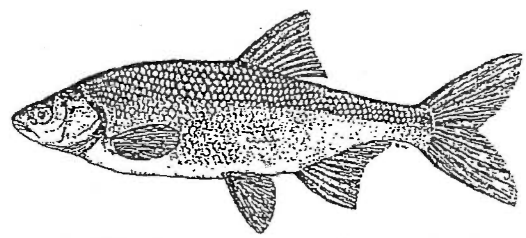
Illustrations of the stream fishes collected in this project can be found in Figure 16. Data collected from the in-stream fish samples are presented in Tables 8 and 9 and Figure 17. Fish were present at a subset of the sampling sites, primarily in the main channel of Marsh Creek downstream of Dunn Creek. Fish were not present in smaller upstream tributaries, presumably due to annual dry-season losses of water. While larger fish were found in Marsh Creek within a mile above the reservoir, upstream fish were limited to "minnows". These small species consisted of California roach (*Hesperoleucus symmetricus*), mixed with juvenile hitch (*Lavinia exilicauda*) closer to the reservoir. Below the reservoir, the character of the creek changes such that roach and hitch are no longer present. Fish taken downstream of the reservoir consisted of small bluegill (*Lepomis macrochirus*), together with a collection of juvenile (parr) Chinook salmon (*Oncorhynchus tshawytscha*) taken near Oakley.

The California roach and juvenile hitch were prepared for mercury analysis in the form of whole fish, multiple individual composites (Table 8). This is the technique typically used for roach in other metals biomonitoring work in California (Hellawell 1986, Reuter et al. 1989,1995, Bodega Research Associates 1995). Composites were made of similar sized individuals, with up to five different size classes composited separately for each site, depending on the range of sizes taken. The much larger hitch individuals taken just upstream of the reservoir were analyzed for muscle mercury rather than whole body composite concentrations. A subset of the fish taken downstream of the reservoir were also analyzed for muscle mercury, in addition to whole fish composite mercury. Muscle

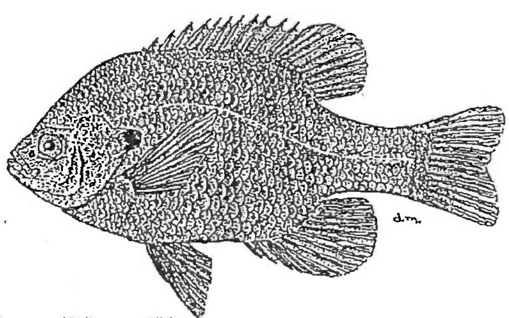
Figure 16. Stream Fish Species Sampled in This Project
(illustrations taken from Moyle 1976)



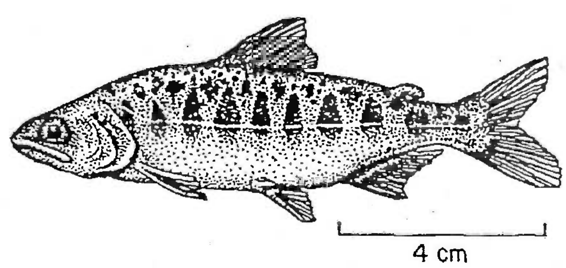
California Roach
Hesperoleucus symmetricus
(2-5 inches)



Hitch
Lavinia exilicauda
(juveniles 2-5 inches + 7-8")



Bluegill
Lepomis macrochirus
(2-5 inches)



juvenile (parr) Chinook Salmon
Oncorhynchus tshawytscha
(juveniles 2-4 inches)

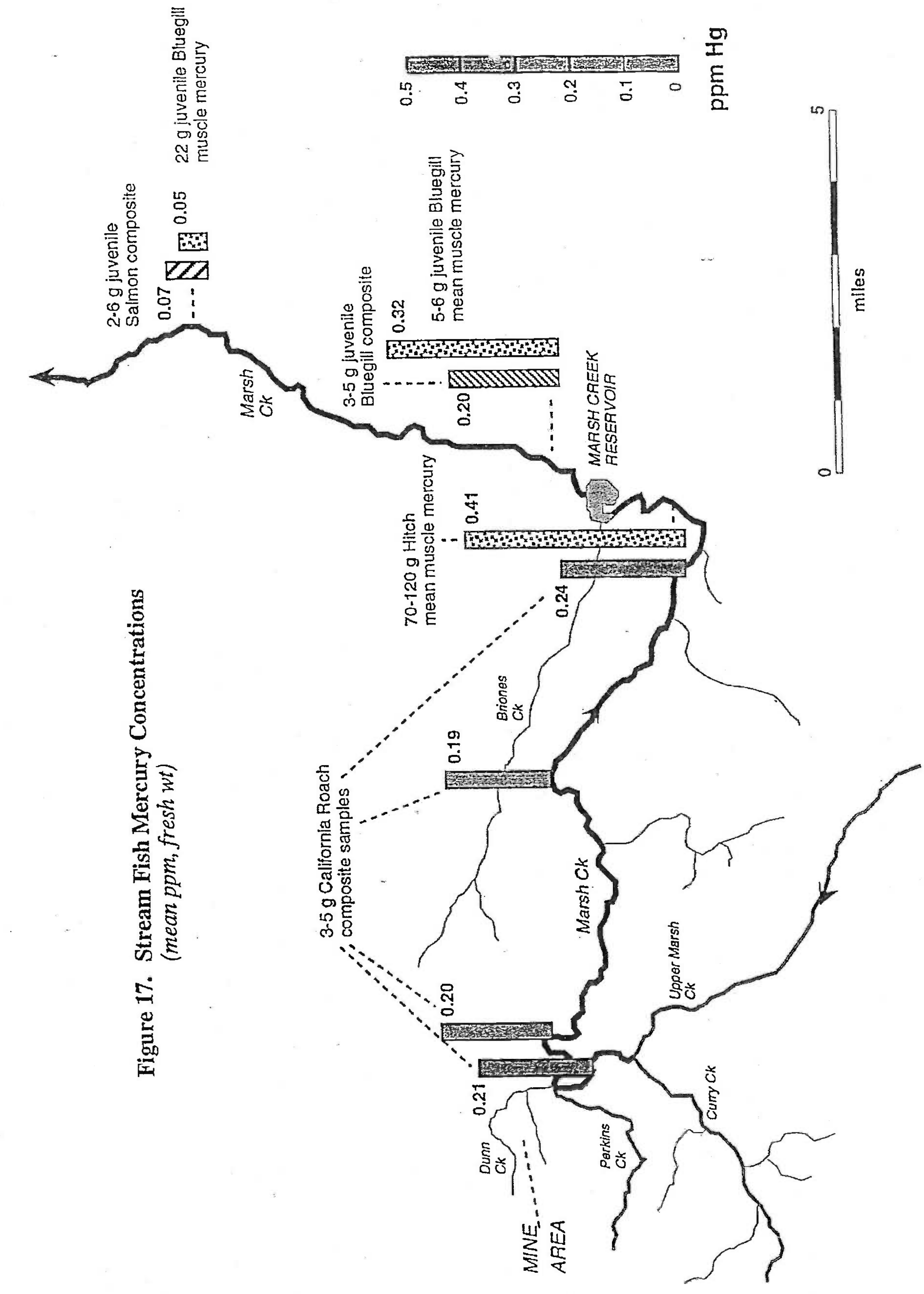


Figure 17. Stream Fish Mercury Concentrations
(mean ppm, fresh wt)

mercury analyses (Table 9) were conducted on those fish for which the majority of comparative information exists in the form of muscle mercury concentrations.

Because fish were basically absent in the watershed upstream of the Dunn Creek confluence, it was not possible to use them as indicators of water quality differences between mine-impacted and control waters. Also, because fish are free to migrate up and down the creeks on each side of the reservoir, their accumulated mercury cannot be definitively linked with the location of capture. Additionally, the presence of different fish species above as compared to below the reservoir introduces a level of uncertainty to comparisons of fish mercury levels between these two areas. Consequently, the information provided by the stream fish data is somewhat limited. Because of these considerations, we supplemented fish collections with the invertebrate mercury work, described in section 3.1.2. However, some useful conclusions may be drawn from the stream fish data.

Mercury concentrations in the composite fish samples from spring 1995 (Table 8) were quite similar among the Marsh Creek sites between upper Marsh Creek and just below the reservoir. Among similar sized fish (2-5 g) including California roach, juvenile hitch, and juvenile bluegill, mercury concentrations were within the comparatively narrow range of 0.13-0.25 ppm. Except for a single, anomalously higher mercury individual roach from upper Marsh Creek, composites of all sizes (2-19 g) from these sites had mercury concentrations that fell within this range. There is no indication of a size vs mercury trend in this small-fish composite data.

Only a single individual roach was collected upstream of the Dunn Creek confluence, approximately one half mile upstream of Perkins Creek in Marsh Creek, despite repeated sampling efforts over several days. The similar mercury level in this fish (0.21 ppm) as compared to the range of levels seen downstream (0.13-0.25 ppm) suggests that this fish may have been a migrant from downstream. The lack of additional fish here indicates that the site was above the normal range of fish in the creek, a function of the annual disappearance of surface water each dry season. Therefore, it is likely that the individual roach taken here may have been a relatively recent migrant--and its mercury content may not reflect local conditions. Based on the aqueous mercury concentration data and the stream invertebrate findings, fish residing throughout the year in Marsh Creek above the Dunn Creek confluence would be expected to have significantly lower mercury than downstream fish.

Of the minnow composite samples, only a single individual roach exhibited a mercury concentration greater than 0.25 ppm. This 9 g individual had anomalously higher mercury concentration, at 0.71 ppm, nearly three-fold greater than the next highest values. As this