Golder Associates Inc.

200 Union Boulevard, Suite 500
Lakewood, CO USA 80228
Telephone (303) 980-0540
Fax (303) 985-2080

Golder Associates

SURFACE WATER
REMEDIAL INVESTIGATION REPORT
CALIFORNIA GULCH SITE
LEADVILLE, COLORADO
VOLUME I

Prepared For:

Asarco, Inc.
495 East 51st Avenue
Denver, Colorado 80216-2098

Prepared By:

Golder Associates Inc.
200 Union Blvd., Suite 500
Lakewood, Colorado 80228

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Executive Summary

EXECUTIVE SUMMARY

A Remedial Investigation (RI) for the surface water in and around the California Gulch Site was conducted during the Ice-off (April 29 to May 3), Spring (June 11-13), Summer (July 23-25), and Fall (September 16-18) of 1991; and Winter (March 23-25) of 1992, in accordance with the Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Work Plan (Res-Asarco 1991a). Surface water quality and flow data were collected at 31 sampling stations located within several drainages near the site including the Arkansas River and California Gulch. A total of five complete sampling events were performed in addition to sampling during three Summer Storm events at selected stations on August 24, August 30, and September 11, 1991. Water quality samples were collected by several organizations on behalf of Asarco and samples were analyzed by ACZ Laboratories in Steamboat Springs, Colorado. Quality Assurance and Quality Control (QA/QC) was maintained throughout the sample handling and analysis. Data was input into a database managed by Asarco, Inc.

Interpretation of the data was performed to evaluate the extent of metals and the fate and transport of metals within the surface water systems. A human health risk evaluation was also performed based on fish tissue data collected, and is provided under separate cover. Aquatics and Terrestrial Ecosystem Evaluations and the Sitewide Baseline Risk Assessment are being prepared separately.

The nature and extent of metals was evaluated using the chemical data collected. Based on frequency of detection, concentrations, and toxicity, aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc were identified as the metals of concern. California Gulch appears to contribute significant amounts of iron, lead, manganese, and zinc to both Arkansas River concentrations and loads immediately downstream of the confluence with California Gulch. Total antimony, barium, cadmium, chromium, mercury, nickel, selenium, and silver were reported below the Contract Required Detection Limit (CRDL) in surface water for all Arkansas River sampling stations and events. Total antimony, chromium, mercury, and

selenium were not detected or were detected at very low concentrations in California Gulch and its tributaries.

Concentrations of arsenic in stream bed sediments in the Arkansas River were within estimated background concentrations in soils at the site. Concentrations of antimony, barium, chromium, copper, manganese, mercury, and nickel in Arkansas River sediment were within published background ranges for soils in the Western United States. Concentrations of aluminum, cadmium, iron, lead, and zinc in sediment were elevated in California Gulch, California Gulch tributaries, the Arkansas River, and Arkansas River tributaries.

Results of the RI indicate that metals concentrations and movement within the system vary seasonally. Areas with the greatest potential to degrade water quality within California Gulch appear to be Stray Horse Gulch/Starr Ditch and Oregon Gulch. Other potential point sources identified in the Tailings and Mine Waste RI include Colorado Zinc Lead Tailings, Fluvial Tailings Site No. 2, Fluvial Tailings Site No. 3, Fluvial Tailings Site No. 4, Fluvial Tailings Site No. 6 and Fluvial Tailings Site No. 8. Sediment transport is believed to be an important mechanism by which certain analytes are transported along California Gulch. However, the majority of the total concentrations of some metals, particularly cadmium, manganese, and zinc, appear in the dissolved phase.

Metals loading and mass balance calculations were performed for total aluminum, cadmium, copper, iron, lead, and zinc. Metals loading represents the total mass loading rate in the surface water column only, and does not account for material being deposited in sediments. Based on this analysis, California Gulch contributed metals to the Arkansas River surface water during the Winter event, which was a period of relatively low flow. During the higher flow Spring event, loading of total metals from California Gulch to the Arkansas River does not appear to be significant. Summer storms, particularly the September 11, 1991 storm, contributed to metal loadings in the Arkansas River immediately downstream of the confluence with California Gulch.

The RI presents several methods for determining background metals concentrations at the site including the analog method, the analytical approach, direct measurement, the empirical (iron bog) approach, and a historical records review. Background water quality in the California Gulch basin is difficult to accurately predict with the data collected to date. Given the geological conditions in California Gulch, it is probable that elevated levels of lead, zinc, copper, cadmium, aluminum, and iron existed during pre-mining times. A preliminary review of the existing surface water quality data in California Gulch and the Arkansas River was presented. Zinc was selected as an indicator for metal for this review. It was assumed that the baseflow zinc concentration could be used as a likely maximum background for comparison with zinc concentrations in the Arkansas River. Based on this assumption, it was determined that the background water contribution from California Gulch could range from 2.5 to 98 percent of the total zinc concentration in the Arkansas River at AR-3. The average background contribution occurring at AR-3 from California Gulch was estimated at approximately 10 percent.

Section 1

1.0 INTRODUCTION

The Surface Water Remedial Investigation Report is one component of the Phase II Remedial Investigation (RI) of a California Gulch CERCLA site located in and near Leadville, Colorado. The report describes results of the investigation of several surface water drainages located within and near the populated area of the site. Streams studied include California Gulch and its tributaries; and, the Arkansas River and its tributaries, Evans Gulch, Empire Gulch, Iowa Gulch, Lake Fork, Halfmoon Creek, and Tennessee Creek. Field investigations and sampling were performed by Woodward-Clyde Consultants (WCC) Water, Waste, and Land, Inc. (WWL) and Asarco Inc. Field investigations and sampling were performed during the Ice-off, Spring, Summer, August Summer Storms of 1991, and during the Winter of 1992. Work was performed in accordance with the Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Work Plan (WCC, 1991)(Surface Water Work Plan), as directed by Administrative Order for Certain Remedial Investigation Studies, EPA Docket No. CERCLA VIII 91-19.

1.1 Purpose of Investigation

The data quality objective (DQO) for the surface water data collection program was to collect data of sufficient quality to utilize for evaluation of the physical and chemical characteristics of surface water associated with the California Gulch site. The primary purposes of the RI were: (1) to characterize water quality in the California Gulch drainages and other drainages which may contribute contaminant loading to the Arkansas River, (2) evaluate whether contributions of subdrainages within California Gulch are significant contributors to contaminant loading in California Gulch, (3) evaluate the seasonal variations in contaminant loading, and (4) make recommendations for remedial options to be discussed in the Feasibility Study (FS).

A review of existing data was made prior to the preparation of a Surface Water Work Plan. A remedial investigation scoping document (Res-Asarco, 1991b) was prepared as an initial planning portion of the RI. Identification of DQOs, data gaps and needs, and applicable or relevant and appropriate requirements (ARAR's) were identified in the scoping document, based on a review of existing data. The review of existing data included the following considerations:

- analytical methods,
- detection limits,
- quality assurance/quality control procedures and documentation,
- seasonality of the data,
- analytes sampled,
- existing gauging stations with longer-term periods of record near the study area to assist in determining flow ratings during high-flow periods,

The scoping document was the basis for preparation of the Surface Water Work Plan. The procedures utilized in implementing the field sampling plan are included in the Field Sampling Plan and the Quality Assurance Project Plan, which together, constitute the Sampling and Analysis Plan, Revision 3.0, for the Yak Tunnel Operable Unit (Res-Asarco, 1991a).

1.2 Site Description

The California Gulch site is located in Lake County, Colorado in the upper Arkansas River watershed, approximately 100 miles southwest of Denver (Figure 1-1). The site encompasses approximately 16.5 square miles and includes the towns of Leadville and Stringtown, and the confluence of the Arkansas River and California Gulch. Elevations range from approximately 9,515 feet above mean sea level (MSL) at the confluence to approximately 10,330 feet above MSL at the Yak Tunnel portal in upper California Gulch.

The California Gulch site is located in a highly mineralized area of the Colorado Rocky Mountains. Mining, mineral processing, and smelting activities have produced gold, silver, lead, and zinc for more than 130 years. Over 2,000 mine waste rock piles have been identified at the site. A few of these piles are located within the residential area in Leadville. Seven major tailing impoundments exist, as well as fluvial tailings deposited directly into California Gulch and Malta Gulch. Three major slag piles and several smaller piles remain. Soils within the site contain elevated concentrations of metals, both from natural erosion processes and mining activities. Surface water in the California Gulch drainage area also contains elevated concentrations of metals.

1.3 History of the Leadville Mining District

Mining in the Leadville area began in 1859, when gold was discovered at the mouth of California Gulch by prospectors working the channels of Arkansas River tributaries. Initial activities consisted of only small scale placer mining until 1868, when the first gold ore veins were discovered along California Gulch. By 1872, however, problems with water, transportation, and labor made ore removal so difficult that most miners had left the area.

In 1874, W.H. Stevens and A.B. Wood investigated the composition of a "heavy sand" that interfered with the recovery of gold in placer sluice boxes. The material proved to be a silver-bearing lead carbonate. Mining in the Leadville district boomed as news of this discovery spread and sources of carbonate ore were discovered.

As the search for ore became widespread, extensive replacement deposits of lead and silver and, later on, rich gold ores associated with fissure veins were found. Copper, usually associated with the gold ore, assumed minor importance. Zinc and manganese minerals occurred with the lead-silver ores; they were of little value in the early days, but were later mined extensively.

As surface veins diminished, miners tunneled deeper into the mountains. Underground mines were developed east and southeast of Leadville. As mines were developed, waste rock was excavated along with the ore. The waste rock was placed near the mine entrance and the ore was transported to a mill.

At the mill, ores were crushed and physical processes were used to separate the ores into metallic concentrates and waste products. The metallic concentrates were shipped elsewhere or further processed at local smelters. The waste products (mill tailings) were generally placed in a tailings pond near the mill.

In the smelter, the high-grade ores were refined and concentrated into higher-grade products. Waste products from the smelters included slag, dust, and off-gases. Forty-four known smelters were in the district (Res-Asarco, 1987).

Groundwater which began flooding into the mines had to be pumped out continuously. As a result, mining costs became prohibitive. In 1889, the Yak Tunnel was constructed as an extension of the Silver Cord Tunnel to drain the Iron Hill area (Luke, 1978). With the portal at an elevation of 10,330 above MSL, the Yak Tunnel was driven eastward to penetrate the Iron-Mikado fault system. The venture proved so successful that the tunnel was extended at various times, successively penetrating the Breece Hill, Ibex, and Resurrection areas. In 1912, the tunnel was terminated at the Resurrection No. 2 Mine (Luke, 1978).

A surge of mining activity in the early 1920s in the Carbonate Hill and Iron Hill areas sparked new interest in using the Yak Tunnel for dewatering purposes. In May 1923, the Yak Tunnel was again extended to a total length of more than 3.5 miles. By that time, the tunnel drained a complex area of massive sulfide and carbonate mineralization through a maze of underground mine workings.

With the advent of World War II, operating properties in the district increased production as a result of the federal support-premium price paid for copper, lead, and zinc. During the war, a major portion of the recorded production came from processing old dumps by the Ore and Chemical Company and John Hamm Milling Company; however, production increases were recorded from the Resurrection No. 2, Fortune, Eclipse, and Hellena shafts, as well. Ore output practically ceased after 1957 when the Irene shaft was closed due to low metal prices.

In 1965, a joint venture between Asarco and Resurrection Mining Company reopened the Irene workings and substantial ore reserves were proven in the down-dropped block in the eastern portion of the Leadville district bordered by the Ball Mountain, Weston, and Barbutt faults. In 1969, a new shaft, the Black Cloud, was sunk in Iowa Gulch to access the newly found ore reserves. The Black Cloud mine and mill went into production in April 1971 and has operated continuously since that time. The other significant mine operating in the district since the Resurrection Mill shut down in 1957 is the Sherman Mine at the head of Iowa Gulch. This mine, now owned by the Leadville Corporation, was operated by Day Mines and the Hecla Mining Company between 1976 and 1984, after which it was shut down for economic reasons. An estimated 26 million tons of ore were produced in the Leadville Mining District from 1859 through 1986 (Res-Asarco, 1987).

Historically, the primary point source of California Gulch surface water contamination was water discharged from the Yak Tunnel. Remediation of the Yak Tunnel Operable Unit is currently in progress. In November, 1989, a surge pond and drainage ditches were constructed below the Yak Tunnel portal to contain surges emanating from the Yak Tunnel and to divert rainfall around the surge pond. The Yak Tunnel Water Treatment Plant (WTP) became operational in February, 1992 and is currently treating the Yak Tunnel discharge. Water from the Yak Tunnel now discharges above the surge pond after being treated by the WTP, rather than being discharged directly into California Gulch. The City of Leadville Waste Water Treatment Plant (WWTP) and stormwater from Leadville also discharge into California Gulch.

1.4 Previous Investigations

Major previous studies have been completed to evaluate surface waters of the upper Arkansas River. The documents are listed below, and a summary of each report is presented in Section 1.5. The sample locations for these investigations are summarized in Figures 1-2 and 1-3.

Ecology and Environmental (E&E). Interpretive Report, Surface and Groundwater Investigation California Gulch, Leadville, Colorado. Prepared for the EPA. 1983.

Engineering-Science, Inc. (ESI). Yak Tunnel/California Gulch Remedial Investigation. Prepared for the State of Colorado Department of Law. 1986.

Moran and Wentz. Effects of Metal-Mine Drainage on Water Quality in Selected Areas of Colorado, 1972-73. Colorado Water Resources Circular No. 25, Colorado Water Conservation Board, Denver, Colorado. 1974.

Res-Asarco. Draft Remedial Investigation Scoping Document, California Gulch Site, Leadville, Colorado. Prepared by Woodward-Clyde. 1991.

Roy F. Weston, Inc. Data and Sampling Analysis Plan. Prepared for the EPA. 1990.

Turk and Taylor. Appraisal of Ground Water in the Vicinity of the Leadville Drainage Tunnel, Lake County, Colorado. U.S.G.S. 1979.

U.S. Bureau Of Reclamation (USBR). Assessment of Heavy Metals Pollution in the Upper Arkansas River of Colorado. REC-ERC-75-5. Engineering and Research Center, September, 1975.

U.S. Bureau of Reclamation (USBR). Heavy Metals Pollution of the Upper Arkansas River, Colorado, and Its Effects on the Distribution of the Aquatic Macrofauna, 1981.

U.S. Environmental Protection Agency (EPA). Phase I California Gulch Remedial Investigation, Leadville, Colorado. 1987.

U.S. Environmental Protection Agency (EPA). Phase II California Gulch Remedial Investigation, Leadville, Colorado. 1989.

Water, Waste and Land (WWL). California Gulch Hydrologic Investigation, Leadville, Colorado. Prepared for the Resurrection Mining Corporation. 1990.

Wentz, D.A. Effect of Mine Drainage on the Quality of Streams in Colorado, 1971-72. Colorado Water Resources Circular No. 21, Colorado Water Conservation Board, Denver, Colorado. 1974.

1.5 Summary of Previous Investigations

In 1974, two reports published by the Colorado Water Conservation Board (CWCB) (Moran and Wentz 1974; Wentz 1974) analyzed various watersheds in Colorado with significant mine drainages. Major water constituents and heavy metals were analyzed as part of the study.

Historical water quality and discharge data have been collected from January, 1967 through June, 1978 at two United States Geologic Servey (USGS) gauge locations on the Arkansas River near the confluence of the California Gulch. Turk and Taylor (1979) collected water quality samples from the Leadville Tunnel to determine metals loadings to the East Fork of the Arkansas River. Although it was not an objective of the Turk and Taylor study to identify specific loading sources in the California Gulch watershed, the study provided long-term data at some sampling locations in the proximity of the study area.

In 1975 and 1981, two studies by the U.S. Bureau of Reclamation (USBR) were performed for several sites along the Arkansas River. Major constituents and several metals were analyzed in surface water, sediments and fish tissue for several sampling events. The main purpose of these reports was to determine the effects on the aquatic life in the Arkansas River from the Leadville Tunnel, owned by the USBR.

In 1983, Ecology and Environmental (EE) published a report for the EPA concerning the California Gulch, Leadville Tunnel, and regional Arkansas River watershed. The EE investigation included sampling to identify potential sources of contaminant loading. The report identified the Yak Tunnel as a source of contaminants in California Gulch surface water.

In 1984, CH2M Hill and the EPA conducted field investigations into potential sources of contamination in California Gulch, Starr Ditch, and the Yak Tunnel. The recommendation in the report, published in 1987, was to investigate potential sources of contaminants other than the Yak Tunnel. The report suggested that the Yak Tunnel was not the only source of contamination and that more data were needed to identify diffuse sources of contamination. The report also suggested that mine wastes, tailing impoundments, and slag piles contribute metals to California Gulch waters.

In 1985, the Colorado Department of Law (CDL), with Engineering-Science, collected additional samples. The investigation was conducted in conjunction with the 1984 EPA sampling. The investigation used many of the same sampling locations as the 1984 EPA study, with some additional locations to identify other sources of contamination within the Arkansas River basin. CDL sampled locations in the Arkansas River, Iowa Gulch, Empire Gulch, and the Lake Creek watersheds.

In 1987, CH2M Hill and the EPA conducted a Phase II investigation to supplement the 1984 field investigation. The objective of the 1987 investigation was to better define the sources of contamination by shortening the distance between sample locations. Additional surface water samples were taken at five locations within the Starr Ditch/Stray Horse Gulch. The report was published in 1989.

In 1989, the Resurrection Mining Company, with WWL, conducted a field investigation to identify additional sources of contaminant loading to California Gulch waters. The investigation supplemented the 1984 EPA field investigations with additional sampling. The investigation included sampling California Gulch, Malta Gulch, Airport Gulch, Pawnee Gulch, Georgia Gulch, Oregon Gulch, Nugget Gulch, Whites Gulch, Garibaldi Gulch, and Starr Ditch/Stray Horse Gulch. In addition, ten seeps were sampled in an attempt to identify diffuse loadings. The report was published in 1989.

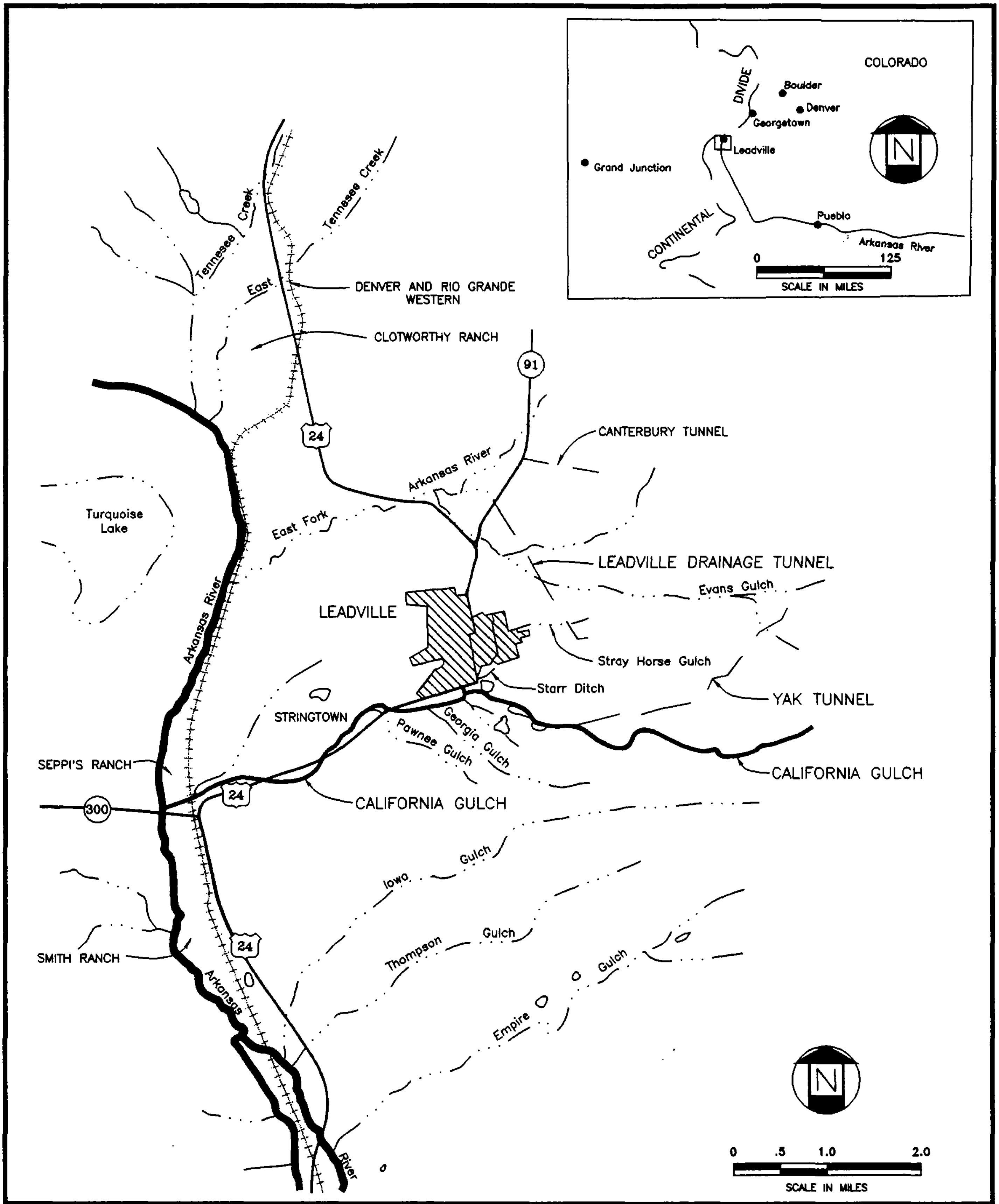
The CDL, EPA Phase II, and the Resurrection Mining Corporation investigations were all guided by the objectives of building an additional database from the 1984 EPA field investigations and identifying additional sources of contamination within the California Gulch watershed. These investigations appear to be independent of the previous investigations.

In 1990, the EPA, with Weston, produced a Sampling and Analysis Plan in an attempt to identify additional sources of contamination. The plan proposed a site visit to identify sources, including sampling surface water in other gulches and mine tailing areas. The final report, with site locations, has not been published.

1.6 Report Organization

In general, the format of this Surface Water RI report follows the format outline described in the EPA's document "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988). The Surface Water RI report is organized into eight major sections plus appendices. Section 1.0, describes the purpose of the investigation, background information and report organization. Section 2.0 describes the surface features, hydrogeologic and hydrologic setting, and ecology and aquatics of the site. Section 3.0 presents an overview of the field activities and data analysis. Section 4.0 presents the site water balance. Section 5.0 presents a discussion of the analytical data, seasonal variations in contamination, and potential routes of migration, and contribution of California Gulch to Arkansas River loadings. Section 6.0 discusses methods for determining background concentrations. Section 7.0 summarizes the nature and extent of contamination, fate and transport, and presents recommended remedial action objectives for the FS. References are provided in Section 8.0. A human health risk assessment for exposure to surface water was performed and is provided under separate cover. It includes a discussion of exposure assessment, data analysis, toxicity assessment, risk characterization, uncertainties and limitations, and summarizes the results of the risk assessment evaluation. Technical memoranda on field activities are included in Appendix A. Appendix B includes information on field activities, including chain-of-custody forms, a staff gauge summary, discharge rating curve and summaries of QA/QC sampling.

Appendix C includes water balance calculations. Appendix D includes analytical data, chemical data quality assurance procedures a discussion of data usability and data gaps, and data correspondence. Appendix E includes sediment transport calculations. Figure 1-4 is a flow diagram of the technical approach used in the preparation of this RI report. Additional reports regarding the aquatic life and terrestrial ecosystem evaluations were completed in 1993.



Golder Associates Denver, Colorado

TITLE	**GENERAL SITE LOCATION MAP**				
CLIENT/PROJECT	**ASARCO SURFACE WATER RI REPORT**				
DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
CHECKED	MAY	SCALE	AS SHOWN	DWG NO./REV. NO.	A159
REVIEWED	JJ	FILE NO.	2819A159	FIGURE NO.	**1-1**

TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1077124

SITE NAME: CALIFORNIA GULCH

DOCUMENT DATE: 05-01-1996

DOCUMENT NOT SCANNED

Due to one of the following reasons:

☐ PHOTOGRAPHS

☐ 3-DIMENSIONAL

☑ OVERSIZED

☐ AUDIO/VISUAL

☐ PERMANENTLY BOUND DOCUMENTS

☐ POOR LEGIBILITY

☐ OTHER

☐ NOT AVAILABLE

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DOCUMENT DESCRIPTION:

Map ASARCO Surface Water RI Report; Locations of Surface Water Data Collection By Previous Investigations.

Contact the Superfund Records Center to view available document.
(303) 312-6473

TARGET SHEET

EPA REGION VIII

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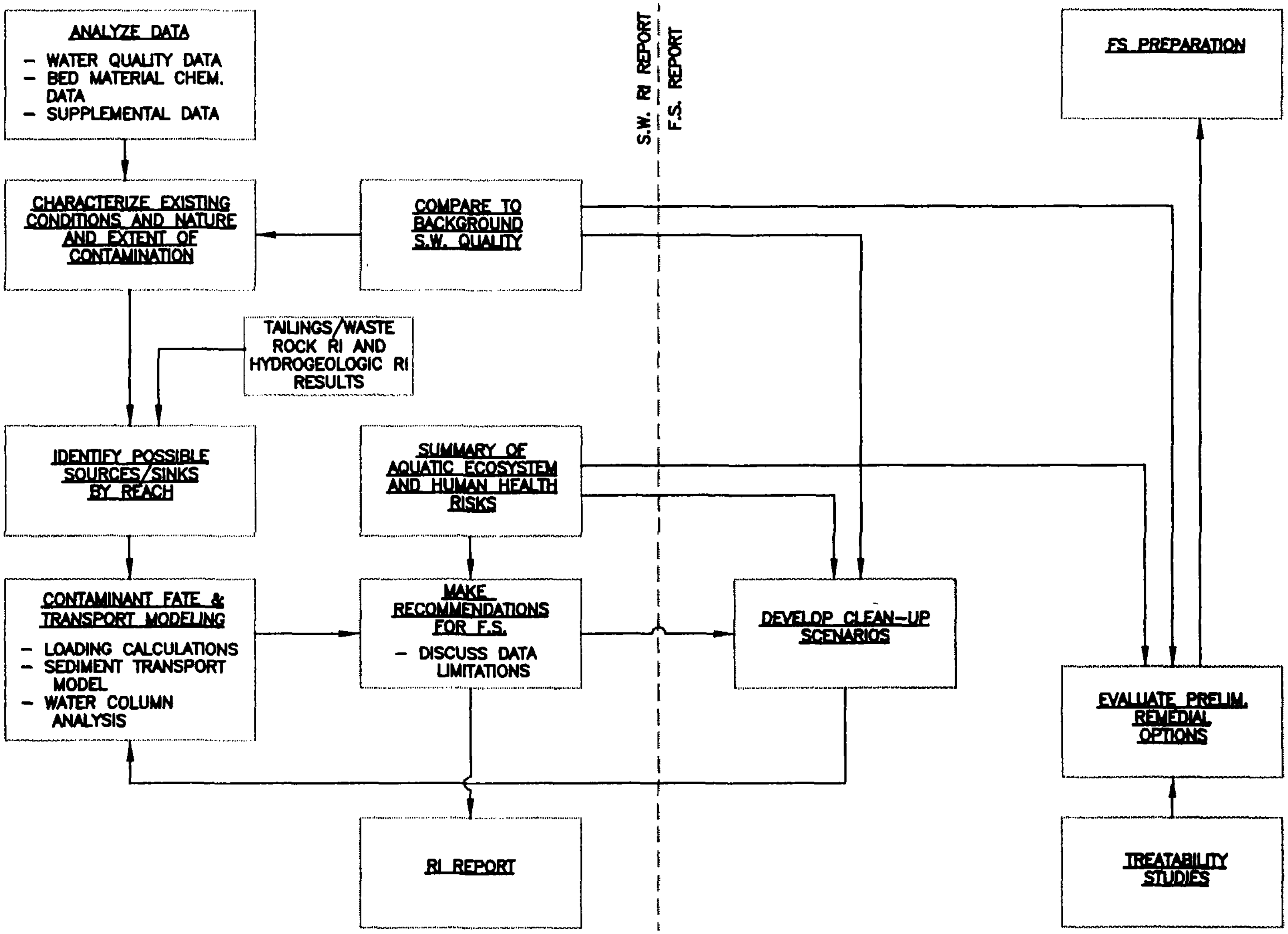


SOURCE: WOODWARD-CLYDE CONSULTANTS, DRAFT SURFACE WATER RI (MARCH, 1993)

CLIENT/PROJECT **ASARCO** **SURFACE WATER RI REPORT**			Golder Associates Denver, Colorado			TITLE **SURFACE WATER RI REPORT** **TECHNICAL APPROACH**		
DRAWN RB	CHECKED AR	REVIEWED BDP	DATE MAY 1996	SCALE NO SCALE	FILE NO. 2819A063	JOB NO. 943-2819	DWG NO./REV.NO.	FIGURE **1-4**

Section 2

2.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

Physical characteristics of the study area are discussed in this section as it pertains to surface water quality. Included in this section is a discussion of the geologic setting, demographics and land use, hydrogeologic setting, hydrologic setting, vegetation, wildlife, aquatic life and climate of the area.

2.1 Geologic Setting

Bedrock in the California Gulch area consists of Precambrian granite and metamorphic rocks overlain by Paleozoic sedimentary dolostone, limestone, sandstone, siltstone, and shale. The sedimentary formations, in order of oldest to youngest, are the Sawatch Quartzite, Peerless Formation, Manitou Dolomite, Chaffee Formation (containing the Parting Quartzite and Dyer Dolomite members), Leadville Dolomite, Belden Formation, and Minturn Formation (Tweto, 1968). The total thickness of sedimentary rocks exposed in the area ranges from 0 to 1600 feet (Emmons et al., 1927).

The Precambrian and Paleozoic rocks were intruded by porphyritic igneous rocks during the late Cretaceous and Tertiary periods. These porphyritic rock forms sheets several feet thick (sills) between sedimentary beds and a large deep-rooted irregularly-shaped mass (the Breece Hill stock). Ore-forming fluids have chemically altered the porphyry throughout most of the area. Subsequent to porphyry emplacement, vertical pipe-like masses of rhyolite agglomerate breccia were intruded, cross-cutting all other rock types. Bedrock is generally exposed east of the town of Leadville, including the upper California Gulch area.

The western portion of the study area, including the town of Leadville and the areas west and south of Leadville, is underlain by thick deposits of unconsolidated glacial outwash materials of Pleistocene age. These unconsolidated sediments are derived from various types of lithologies in the Mosquito Range east of Leadville, and include varieties of porphyry, rhyolite, granite, and other igneous rocks, quartzite, dolomite, limestone, and sandstone. The sediments were transported and redeposited by glacial and fluvial processes and are poorly sorted, loose, and porous. The Arkansas River valley, in the extreme western portion of the study area, is composed of Holocene stream terrace, stream channel, and floodplain deposits.

Terrace deposits are located parallel and adjacent to active stream channels in Evans Gulch and California Gulch and along the Arkansas River. Floodplain deposits, low terrace remnants, marshy areas, and active stream channel deposits are located throughout the study area.

A complex system of major and minor faults causes significant displacement and fracturing of the bedrock units. Major faults in the bedrock are generally high-angle, northerly-striking fracture zones, with displacements ranging from about 100 feet to more than 1,000 feet. Major faults separate the strata into a stair-step arrangement of fault blocks with decreasing elevations toward the west. Fracture zones associated with the major faults range from tens to hundreds of feet wide. Relatively impermeable layers of clay-rich fault gouge commonly exist within the fracture zones. Blocks of bedrock between major faults are commonly broken by numerous minor faults and fissures (Emmons et al., 1927). The Pendery Fault marks the boundary between upper and lower California Gulch. Upstream (east) from the Pendery Fault, California Gulch is incised into bedrock; just west of the fault, the unconsolidated sediments are more than 250 feet thick, and increase in thickness toward the Arkansas River (EPA, 1989a).

The majority of economic mineral deposits in the Leadville district occur east of Leadville and are in the form of tabular dolostone or limestone replacement deposits with horizontal dimensions hundreds to several thousands of feet thick. Mineral veins hosted in minor faults and fissures are also locally important sources of ore. Major mineralized areas include Iron Hill, White Cap-Cord, Ibex-Irene, and Resurrection-Diamond. Ore minerals in unoxidized areas are primarily sulfides and carbonates of iron, lead, and zinc, which contain small amounts of silver, gold, and other trace metals. Sulfide minerals in near-surface ore bodies have been naturally oxidized to carbonate, sulfate, silicate, and oxide minerals. Depths to unoxidized ore range from 100 to 800 feet below the ground surface (Emmons et al., 1927).

2.2 Demographics and Land Use

The California Gulch site, including the town of Leadville, is located in Lake County. Lake County is a relatively small (380 square miles), predominantly rural county. Persons residing within the Leadville city limits account for approximately half of the county's total population. The population of Lake County has fluctuated with the mining industry. Population peaked in 1900 at 18,054, declined to below 7,000 in 1920, and remained generally at that level until 1960. During the years between 1960 and 1981, population gradually increased to approximately 9,000, and then declined throughout the 1980s. The 1990 population was 6,007 (U.S. Bureau of the Census, 1990). Closure of AMAX's Climax molybdenum mine in 1981, and its lower level of operations upon reopening, were major factors contributing to the population decline. Leadville's population trends have been similar to those of Lake County.

Approximately two-thirds of the land in Lake County is federally owned. Most of the federal land is within the San Isabel National Forest, with the Bureau of Land Management managing most of the remainder.

Land uses surrounding California Gulch are predominantly mining, commercial, and residential. A small area of rangeland in the Leadville area is directly upstream from the confluence of California Gulch and the Arkansas River.

Along the Arkansas River valley, land uses include irrigated pastures and haylands, rangeland, and residential and recreation areas. Several wetlands support sport fishing and hunting in the county. In addition, several large lakes are located just west and southwest of Leadville (Turquoise, Twin, and Clear Lakes). Lodges, private homes, and campgrounds have been developed in the vicinity of these lakes.

2.3 Hydrogeologic Setting

Groundwater in the California and Evans Gulch areas occurs in both bedrock and alluvial aquifers. In the upper portions of the California Gulch, particularly above the Pendery Fault, groundwater occurs primarily in the various fractured bedrock formations.

2.3.1 Bedrock Aquifer

Groundwater moves within bedrock through permeable highly-fractured zones adjacent to the major faults and by numerous interconnecting minor faults, fractures and joints within the blocks. Before the bedrock system was disturbed by mining, the low-permeability gouge zones along the major faults apparently restricted lateral flow between the fault blocks (Emmons et al., 1927). Groundwater flows across the fault traces but appears to follow circuitous routes, eventually flowing through the fault.

The bedrock aquifer has three types of porosity that contribute to storage and flow: primary (intergranular rock porosity); secondary (faults, fractures, joints, and karsts); and mine workings. The primary porosity and permeability of most of the rock types in the area are low; thus the primary porosity and permeability are generally insignificant compared to secondary porosity and permeability and the influence of mine workings.

The effects of mining and mine drainage have dramatically changed the natural hydrogeologic system. Mine workings in the area consist of a network of interconnected shafts, winzes, drifts, and stopes. The stopes (ore body excavations) commonly extend hundreds to thousands of feet in horizontal dimensions and are generally tens of feet high (Res-Asarco, 1990; Emmons et al., 1927). Stopes are generally filled with broken waste rock and/or rubble from roof collapse. These mine workings allow flow toward the topographically lower Yak Drainage Tunnel. Connected mine workings distant from the Yak Tunnel appear to capture groundwater from neighboring drainage basins, such as Evans Gulch. The Yak Tunnel and the associated network of mine workings penetrate fault gouge zones, increasing direct hydraulic connections between groundwater-bearing fault blocks. Natural permeability within the aquifers is short-circuited by the free-flowing mine workings. New fractures caused by mine subsidence may further increase bedrock permeability.

Karst (cave formation) dissolution and collapse features occur locally in the Leadville and Dyer Dolomite units. Karst breccias commonly host ore deposits in the Leadville mining district and surrounding area (DeVoto, 1982; Johansing, 1982), and an open fissure of probable karst origin was encountered in the Leadville Tunnel (Salsbury, 1976). Karst features probably have local influence on groundwater flow because these features have greater porosity and permeability than the primary porosity and permeability of the surrounding rock.

2.3.2 Alluvial Aquifer

Groundwater in the unconsolidated (alluvial) aquifer is contained in lake bed, glacial deposits, and alluvial deposits. Little is known about the thickness and hydraulic characteristics of the lake bed deposits in California Gulch. Geologic interpretation from Emmons et al. (1927) and EPA (1987a) suggest that the lake bed deposits generally occur at depths greater than 200 feet below ground surface (bgs) in lower California Gulch.

The remainder of the unconsolidated deposits, composed of glacial till and outwash, and recent alluvial deposits, are being characterized in the Hydrogeologic RI. The EPA considered the groundwater in alluvial formations to occur in two distinctly separate aquifers based on aquifer pump testing, observed hydraulic gradients, and water quality (EPA, 1987a). Although some of the pump test data may suggest the existence of two distinct aquifers, lithologic information from geologic drill logs does not support this hypothesis.

2.3.3 Aquifer Recharge

Recharge to the bedrock and alluvial aquifers in the California Gulch area results from direct infiltration of precipitation and surface water, including snowmelt. Local bedrock recharge may also occur where mine workings constructed below stream channels intercept some of the surface water (EPA, 1987b). Observed fluctuations in the water table indicate that recharge occurs principally during snowmelt, and that short-duration summer thunderstorms are of little consequence (Turk and Taylor, 1979).

The nature of groundwater and surface water interaction in the top 10 feet of the alluvial aquifer was investigated by installing 40 shallow mini-piezometers (EPA, 1987a). The distribution and extent of gaining or losing reaches of California Gulch appear to vary over time. Figure 4-2 shows the gaining and losing reaches, based on measurements made during the RI. The groundwater/surface water interaction is discussed in the Hydrogeologic RI Report (Asarco, 1996a).

2.4 Hydrologic Setting

California Gulch drains approximately 11.5 square miles and discharges into the Arkansas River. The Arkansas River is formed by the merging of Tennessee Creek and the East Fork of the Arkansas River northwest of Leadville. The mainstream of California Gulch receives water from several ephemeral drainages, including Starr Ditch, upper California Gulch, Oregon Gulch, Georgia Gulch, Pawnee Gulch, Airport Gulch, and Malta Gulch. It also receives discharges from the Yak Tunnel Water Treatment Plant (WTP) and the Leadville Waste Water Treatment Plant (WWTP) as well as inflows from groundwater along reaches of the gulch. Figure 2-1 shows the drainage areas associated with the sampling locations.

A surge pond associated with the Yak Tunnel is approximately 7 acres, and collects runoff from the adjacent hillsides. During the Spring through Fall 1991 sampling events, the Yak Tunnel discharge was filtered, and discharged into California Gulch between stations CG-2 and CG-3 below the surge pond. The Yak Tunnel WTP began operating on February 26, 1992, and discharges between Stations CG-1 and CG-2. It should be noted that the WWTP discharges between Stations CG-5 and CG-6. In the past, metals loading was generated primarily by Yak Tunnel discharge to California Gulch. The water is now treated to meet

New Source Performance Standards (40 CFR 440, Subpart J) for metals as required by the EPA.

Average flow of the Arkansas River at the confluence of Tennessee Creek and East Fork Arkansas (USGS Gauge #07081200 - Sampling Station AR-1) based on 16 years of record is 72 cubic feet per second (cfs) with high spring runoff and infrequent flood flows. The average flow of the Arkansas River at the Highway 24 crossing 3.5 miles downstream of Lake Fork (USGS Gauge #07083700 - Sampling Station AR-5) based on 10 years of record is 248 cfs. Annual flooding usually occurs as a result of rapid snowmelt in May and June. Analysis of snowmelt and rainfall/runoff events indicates that the lower frequency, larger floods result from short duration, high-intensity thunderstorms during the summer months. Floods with a frequency of less than approximately 10 years are typically generated by snowmelt. Figure 2-2 presents typical hydrographs for the Arkansas River above and below the California Gulch confluence.

The period of record for stream flow measurements in California Gulch is limited to less than five years. However, records for stream flow in the Arkansas River include data collected for over ten years. Arkansas River flow records indicate that peak flows occur in response to summer storm events and snow melt during the spring. Review of data presented in Figure 2-2, show average Arkansas River stream flow for the period of record, and Tables 3-3 through 3-7 which indicate that Arkansas River flow from April through June 1991 was near average. From July through September 1991, the flow was slightly below the average for the Arkansas River but was again average during the March 1992 measurement. Similar streamflow conditions would be expected for the California Gulch watershed. Therefore, data collected in California Gulch during 1991 and 1992 would be typical and representative for the watershed.

Evans Gulch, an ephemeral drainage, drains the area to the north of California Gulch. The Leadville Mine Drainage Tunnel (LMDT), constructed to dewater mines in the Stray Horse Gulch area, discharges into the East Fork of the Arkansas River north of Leadville.

2.5 Ecology and Aquatic Life

The ecology and aquatic life of the study area including vegetation, wildlife, aquatic life and climate are discussed in this section. Further characterization of the vegetation and wildlife in the area are presented in the Final Terrestrial Ecosystem Evaluation (TEE) (Asarco, 1996b). Further characterization of the aquatic life in the area is presented in the Final Aquatic Ecosystem Characterization (AEC) (Asarco, 1995).

2.5.1 Vegetation

Natural vegetation in the study area before European-American settlement was primarily subalpine forest and associated non-forest types including willow shrub and emergent wetlands and sagebrush-grass meadows. The natural pattern of vegetation primarily resulted from the influence of elevation, soils, hydrology, and fire history. All original vegetation types are still present, but most of the area has been modified to a greater or lesser extent by human activities. The modifications resulted from timber cutting, fire, agriculture, mining, erosion and deposition of sediments, construction of towns, changes in surface and groundwater hydrology, changes in water quality, and smelter emissions.

About half of the 10,500-acre study area is occupied by upper montane or sub-alpine forest. The predominant species is lodgepole pine, which forms monotypic stands in most forested areas. Several hundred acres of spruce-fir occur at higher elevations (10,600 to 11,800 feet above MSL) in the eastern portion of the study area, and small areas of aspen forest occur along California Gulch. Lodgepole pine forests have a characteristically sparse understory of common juniper, kinnikinnick, heartleaf arnica, and other species. Understory cover in spruce-fir forests varies from dense to sparse, depending on shade and moisture, and is dominated by broom huckleberry, myrtle blueberry, mosses, and lichens. Aspen forests typically have a diverse and highly productive understory of shrubs and herbs.

Non-wetland meadows and shrublands cover about 1,150 acres, and successional or mosaic meadow/forest mixtures cover an additional 781 acres. Relatively level sites in valleys and flats at lower elevations (up to 11,000 feet MSL) are occupied by a sagebrush-grass community. The dominant shrub is mountain big sagebrush. A diverse and productive community of forbs and grasses is also present, including sulfur flower, yarrow, lupine, geranium, agoseris, American vetch, Idaho fescue, junegrass, muttongrass, and many other species. Mixtures of sagebrush-grass with young lodgepole pine occur in a number of areas on uplands and slopes adjacent to developed lodgepole pine forest. Subalpine meadows lacking sagebrush occur from 11,000 to 11,800 feet MSL in the higher eastern end of the study area, often mixed in a mosaic with young conifers, open woodlands, and small groves of conifers. Many of the areas of subalpine meadow appear to be former subalpine forest where the trees have only partially reoccupied the area after past timber-cutting or burning. A small area of alpine tundra occurs from 11,800 to 12,200 feet above MSL on the slope of Ball Mountain at the eastern edge of the study area.

Wetlands cover approximately 350 acres primarily in the Arkansas River valley, Upper Evans Gulch, and South Evans Gulch. They consist mainly of tall willow shrub, with various emergent herbs, grasses, and sedges occupying open areas and wetland margins. California Gulch has limited wetland vegetation, and much of the valley floor is occupied by mining facilities or fluvial tailing.

About 2,100 acres in the study area consist of disturbed or unvegetated areas. These include residential and commercial areas in the city of Leadville and smaller communities; disturbed land associated with mines, mills, smelters, tailing impoundments, waste ponds, unvegetated slag, a landfill, other industrial waste land, and other barren areas. Residential areas mixed with lodgepole pine forest cover an additional 300 acres. Irrigated and sub-irrigated hay meadows occupy about 45 acres on the floor of the Arkansas River valley.

Vegetation types representing a transition or mosaic of disturbed land with natural vegetation types occupy about 550 acres. In most cases they appear to represent natural succession in former disturbed areas. The dominant species include sagebrush, lodgepole pine, and aspen. Due to the elevation and harsh climate, successional stages are dominated by native plant species, and relatively little invasion of non-native species has occurred.

2.5.2 Wildlife

The mountain forests and meadows around Leadville support deer, elk, and bighorn sheep. However, the immediate vicinity of Leadville and the California Gulch area supports relatively small numbers of big game species due to elevation, climate, lack of habitat, and habitat disturbance. Much of the area along the Arkansas River valley is important winter range for deer and elk. Elk calving grounds are found in several locations in Lake County, including Twin Lakes, several miles downstream from Leadville (Colorado Department of Wildlife [CDW], 1991).

Numerous small animals are present, including fur bearers such as beaver, mink, raccoon, weasels, and muskrats; small game such as white-tailed jackrabbits; and rodents such as mice, voles, least chipmunks, red squirrels, and marmots. Coyotes are very common in the upper Arkansas basin, and bobcat, red fox, and mountain lion are seen occasionally. Pika are common on the talus slopes near timberline (Topielec et al., 1977).

Waterfowl such as mallards, teal, and coots use the wetland areas along the river as resting areas, and Turquoise Lake west of Leadville may support breeding populations of several species of ducks. American kestrel (sparrow hawk) are common in the area, and there are a few nesting red-tailed hawks and golden eagles are in the mountains along the river valleys. Bald eagles and ferruginous hawks are sometimes present as transients. There is a wide variety of small birds in the Leadville area, including American robins, dark-eyed juncos, and chickadees. Upland game birds are uncommon, but include blue grouse and mountain ptarmigan (Topielec et al., 1977).

2.5.3 Aquatic Life

Studies conducted in 1991 by Asarco found that the aquatic macroinvertebrate community of the East Fork of the Arkansas River was typical for Colorado montane streams. Major macroinvertebrate families found included mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and Diptera (true flies). Diversity values for macroinvertebrates were obtained during several seasonal sampling events in 1991 at sampling locations all along the Arkansas River and major tributaries above and below California Gulch. Evaluation of Rapid Bioassessment Protocol III (EPA, 1989b) matrices, both above and below the confluence with Big Evans Gulch (Leadville Drainage Tunnel), indicates that the benthic macroinvertebrate community is slightly impaired directly downstream of Evans Gulch.

Studies conducted along the main stem of the Arkansas River during 1991 found that the macroinvertebrate community was largely composed of various life stages of mayflies, caddisflies, stoneflies, Diptera, and occasional flatworms (Turbellarnia) and aquatic earthworms (Oligochaeta). A rich and diverse benthic fauna was found at sites upstream of California Gulch. However, the benthic community was moderately to slightly affected by adverse water quality conditions associated with the California Gulch discharge. The number of metals-sensitive benthic macroinvertebrate increased at sampling sites downstream of California Gulch, indicating recovery from the effects of elevated metals concentrations.

In 1991, brown, brook, cutthroat, and rainbow trout were found at sites on the East Fork of the Arkansas River. Population density and biomass estimates were high and similar at sites both above and below Evans Gulch. Although several age classes were present, two-and three-year old brown trout were most numerous and most trout were less than 15 cm in length.

During studies conducted in 1991, brown trout were abundant in the upper reaches of the Arkansas River upstream from the confluence with California Gulch. The population was comprised of several age classes with strong two- and three-year age classes. The CDW reported that population estimates were high for brown and brook trout upstream from

California Gulch in October 1989 and April 1990 (Woodling, 1990). However, trout populations were impacted by elevated metals concentrations in areas downstream from California Gulch where decreases in density and biomass were reported in 1989 and 1990 (Woodling, 1990). Sampling in August 1991 showed comparatively similar decreases in trout density and biomass at sites located downstream from California Gulch.

2.6 Climate

The climate in the California Gulch area is typical for the mountainous areas of central Colorado. Severe local topographic features strongly influence local climatic variations in Lake County. The City of Leadville is at an elevation of approximately 10,000 feet above MSL. Weather conditions are recorded at the National Weather Service's Leadville Airport Station located 2 miles southwest of Leadville, and the Yak Tunnel meteorological station located near the Yak Tunnel Water Treatment Plant.

The normal temperature extremes range from 86°F to -30°F, with an average minimum temperature of 21.9°F (Topielec et al., 1977). The average frost-free season is 79 days. The wind is predominantly from the northwest and ranges from calm to 30 miles per hour (Gilgulin, 1985).

Average annual precipitation is 18 inches. July and August have the most precipitation, while the months of lowest precipitation are December and January (USDA, SCS, 1965). Summertime precipitation is usually associated with convective showers (Topielec et al., 1977). Figure 2-3 presents average monthly precipitation and total monthly precipitation during the sampling events. Annual snowfall depths for mountains in the area are between 200 and 300 inches. During winter months, the depth of snow on the ground in Leadville is commonly 6 inches (Gilgulin, 1985). The annual peak snowmelt usually occurs in June.

TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1077124

SITE NAME: CALIFORNIA GULCH

DOCUMENT DATE: 05-01-1996

DOCUMENT NOT SCANNED

Due to one of the following reasons:

☐ PHOTOGRAPHS

☐ 3-DIMENSIONAL

☑ OVERSIZED

☐ AUDIO/VISUAL

☐ PERMANENTLY BOUND DOCUMENTS

☐ POOR LEGIBILITY

☐ OTHER

☐ NOT AVAILABLE

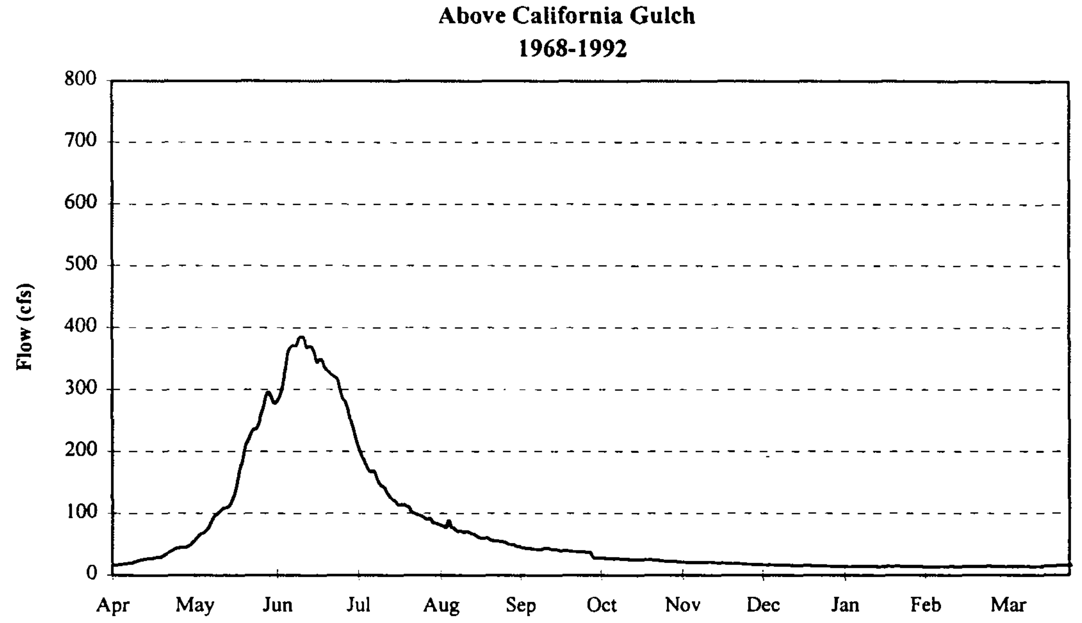
☐ TYPES OF DOCUMENTS NOT TO BE SCANNED
(Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

DOCUMENT DESCRIPTION:

Map ASARCO Surface Water RI Report;ASARCO Surface Water RI Study Drainage Basin Map.

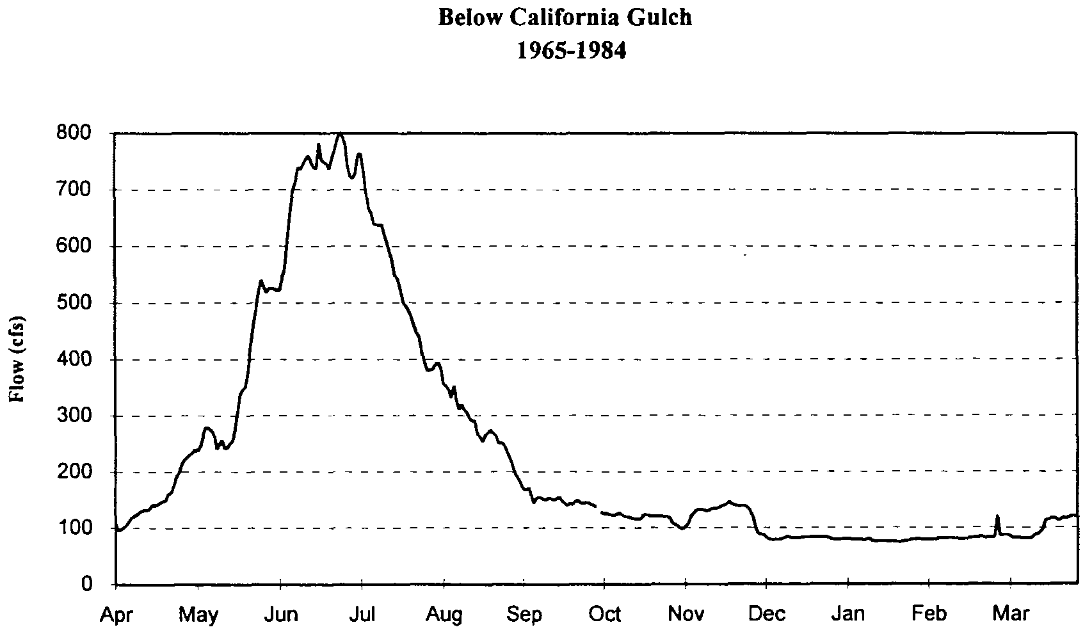
Contact the Superfund Records Center to view available document.
(303) 312-6473

FIGURE 2-2
Average Daily Arkansas River Discharge



Above California Gulch
1968-1992

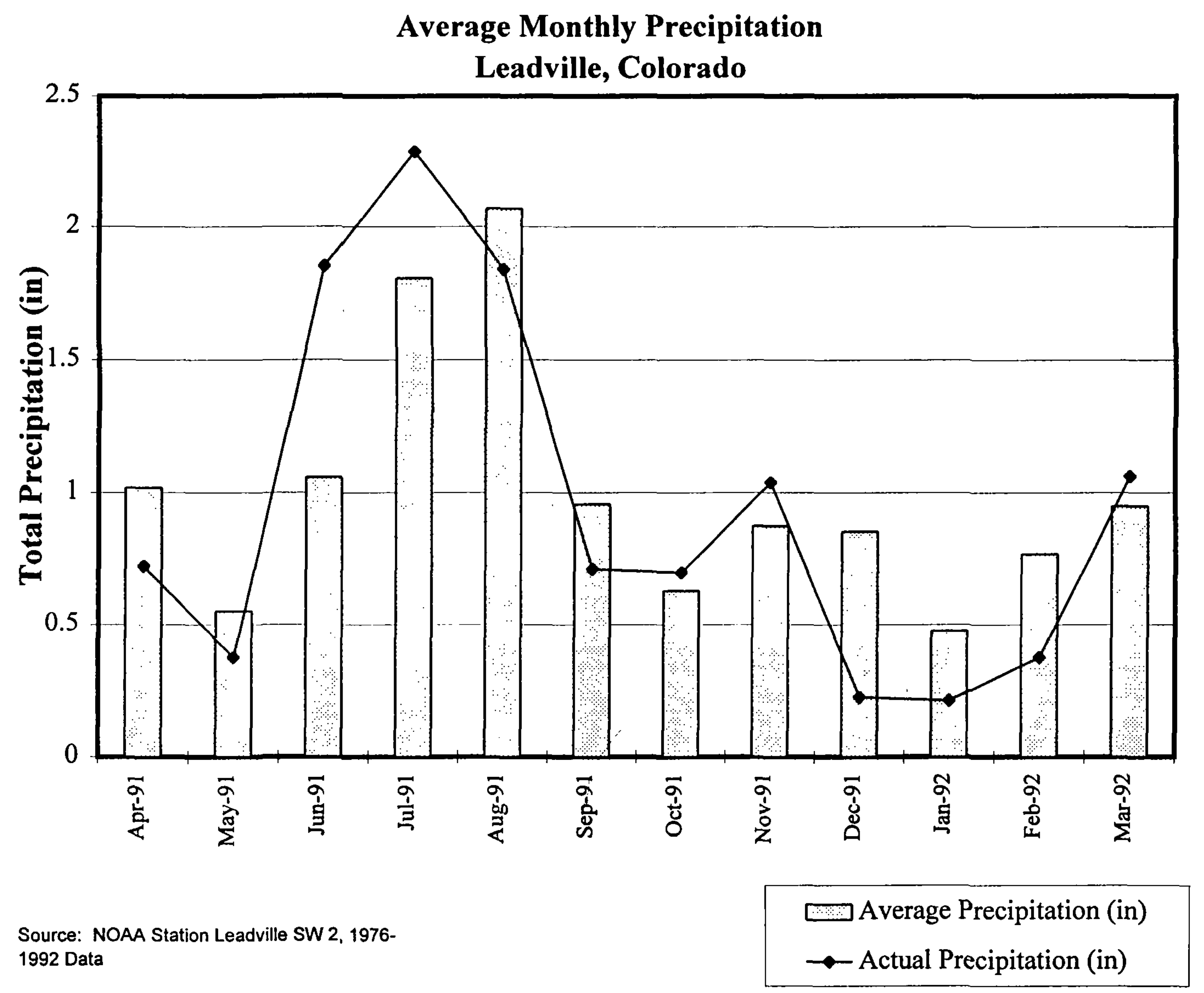
Source: USGS gauge station at
Arkansas River near Leadville



Below California Gulch
1965-1984

Source: USGS gauge station at
Halfmoon Creek near Malta

Figure 2-3



Source: NOAA Station Leadville SW 2, 1976-1992 Data

943-2819 (*, avg precip Chart 2)

Section 3

3.0 SURFACE WATER AND BED MATERIAL FIELD INVESTIGATION

A description of sampling stations and an overview of the field activities is presented in this section. Data were collected according to the Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Workplan. Soil and surface water samples were collected from locations up- and down-gradient from known metals sources and at locations throughout the study area (Table 3-1). The samples were analyzed for several physical parameters, for metals known to exist in the ore body, and for constituents commonly affected by mining activities. A summary of sampling events is shown in Table 3-2 and is discussed in the following sections.

Analytical results were used to characterize surface water within the California Gulch drainage basin, confirm expected metals source areas, and identify unanticipated sources of metals concentrations. Interaction between surface water and groundwater was evaluated to calculate the drainage basin water balance, assist in understanding the nature and extent of metals distribution, and assess fate and transport of metals through the environment. Results of the evaluations also were used to calculate possible human health risks.

3.1 Sampling Stations

Samples of soil/sediment, surface water and groundwater were collected from locations throughout the RI site. Potential source areas were evaluated for metals types and concentrations contributed to the system. Potential source areas of metals identified during the RI were sampled upgradient and downgradient of the potential sources. Similar data were collected from the Arkansas River. Chemical analytical results are presented in Tables 5-1 through 5-8.

Sampling stations were generally established at locations having either a permanent flow measuring device (flume) or permanently installed staff gauge. Selection of surface water and sediment sampling stations for the RI was based on several criteria. The criteria were not applied rigidly but were used as guidelines in selecting sampling locations that were expected to provide data representative of the California Gulch drainage. The location selection criteria were:

- Even distribution throughout the drainage basin;
- Upgradient from anticipated metals source areas; and,
- Down gradient from anticipated metals source areas.

Sampling locations were planned to identify metals transport pathways through the surface water system and to evaluate the effects of water quality from several tributary sub-basins discharging into the California Gulch surface stream.

Table 3-1 presents sampling station location descriptions, northings, eastings, elevations, and approximate drainage areas. Figure 3-1 illustrates the sampling station locations, and Figure 3-2 presents a schematic of the sampling stations. It should be noted that the sample identifications were changed after the Spring, 1991 sampling event at the request of the EPA. The original station numbering generally increased upstream. This was revised so the station numbers increased downstream.

A site reconnaissance was performed to verify the suitability of the sample locations prior to implementation of sample collection. The general locations of the sites were based on the proximity to potential sources.

The sampling station on the Arkansas River just downstream of the confluence with California Gulch (AR-3) was subdivided into east and west stations (AR-3E and AR-3W) after the Spring 1991 sampling event and the two stations were utilized in all subsequent sampling events. AR-3 was subdivided to account for a visible sediment plume emanating from California Gulch. AR-3E is the east 1/3 of the Arkansas River in the water and sediment mixing zone with California Gulch water, and AR-3W is the west 2/3 of the Arkansas River in a zone limited to water mixing with California Gulch water.

All phases of sample processing were supervised by Asarco, and included oversight by EPA's consultant. Technical memoranda regarding sampling are included in Appendix A. Chain of custody forms were maintained throughout the sample processing and are included in Appendix B-1.

3.2 Overview of Field Activities

Field activities occurred during seven sampling events: Ice-Off 1991, Spring 1991, Summer 1991, August 1991, Summer Storms 1991, Fall 1991, and Winter 1992. Field activities generally consisted of gathering flow data, field water quality data, surface water samples, and bed material samples. Table 3-2 presents a summary of the sampling events.

3.2.1 Flow Measurements

Discharge measured during the sampling events and calculated discharge for California Gulch and the Arkansas River are shown in Figures 3-3 and 3-4. The calculated discharges are the sum of the upstream discharge and any tributary inflows. Discrepancies between measured and calculated discharge not accounted for by measurement error represent gains to the stream from surface water runoff or groundwater, or losses to groundwater. Section 4.0 presents a discussion of the California Gulch water balance. A schematic of discharge is presented in Figure 3-5.

It should be noted that the WWTP discharges into California Gulch between Stations CG-5 and CG-6. During the Spring through Fall 1991 sampling events, the Yak Tunnel discharge was filtered, and discharged into California Gulch between stations CG-2 and CG-3 below the surge pond. The Yak Tunnel WTP began operating on February 26, 1992, and discharges between Stations CG-1 and CG-2. Together, the WWTP and the Yak Tunnel discharges contribute a significant portion of the surface water in California Gulch, particularly during periods of low flow.

Flow rates at sites CG-1 and CG-6 were measured with existing Parshall flumes. At other sites, discharge was calculated from current-meter measurements, portable cutthroat flume measurements, or by a volumetric method. The field technician rated the quality (% error) of flow measurements based on the cross-section of the stream (e.g., straight and rectangular) for velocity-area calculations, and/or on the type of flow (e.g., highly turbulent). Possible ratings were excellent (estimated 2% error), good (estimated 5% error), fair (estimated 8% error, and poor (estimated error > 8%). All current-meter measurements were performed by methods described in Standard Operating Procedures (SOP) No. 1A, Surface Water Flow Measurement as outlined in the Surface Water Data Collection Work Plan. Flow measurements and field data for each sampling event are presented in Tables 3-3 through 3-9.

Staff gauges were installed at sites where it was expected that direct flow measurements might not be possible due to high flows. Staff gauges were not installed at sites that were expected to be dry most of the year. Staff gauge readings were taken as an adjunct to flow measurements to develop ratings curves. Rating curves and staff gauge measurements were used to estimate streamflows in the Arkansas River at sites AR-3, AR-2, and AR-3A during the Summer Storms, 1991 analysis. Staff gauge locations and discharge ratings curves are included in Appendix B-2.

3.2.2 Field Water Quality Data

During the sampling events, field water quality data were collected, and specific conductivity, pH, dissolved oxygen, and water temperatures were measured. Climatic data, including air temperature and barometric pressure, were noted. Tables 3-3 through 3-9 summarize field water quality data.

3.2.3 Surface Water and Bed Material Sample Collection

Surface water and bed material samples were collected according to the Surface Water Data Collection Work Plan. The surface water sampling method utilized at a specific site depended on the width and depth of flow within the channel. In general, two methods were used to sample surface water:

- If the stream depth was less than 1 foot and the width less than 3 feet, samples were collected near the center of flow. A beaker was used to collect water into a churn splitter. Samples were distributed from the churn splitter to sample bottles.
- If the stream depth was greater than 1 foot and the width greater than 3 feet, a horizontal composite sample collection method was used. A beaker was used to collect water from several equally spaced stations within the stream into the churn splitter. Samples were distributed from a churn splitter into sample bottles.

Samples to be tested for alkalinity, chloride, fluoride and dissolved metals were filtered using a 0.45 micrometer membrane filter apparatus and peristaltic pump. Unfiltered samples were collected for total metals analyses and filtered samples were collected for dissolved metals analyses.

Bed material was sampled with a stainless steel scoop. Bed material samples were collected at the same stations as surface water samples. Sub-samples were collected from the entire stream width and mixed in a stainless steel bowl to obtain a composite sample. Samples were collected from the top layer of bed material whenever possible.

3.3 Laboratory Analysis

ACZ Laboratories, Inc. (ACZ) of Steamboat Springs, Colorado, performed laboratory analyses of surface water and bed material samples. Surface water samples were generally analyzed for total and dissolved metals and major constituents. Table 3-10 presents surface water analytes, EPA test methods, Contract Required Detection Limits (CRDL's), Instrument

Detection Limits (IDL's) and reporting units. Bed material samples were analyzed for total metals, and sulfate, chloride and cyanide. Table 3-11 presents bed material analytes, EPA test methods, CRDL's and reporting units. Results of laboratory analyses are presented in Section 5.0. QA/QC sample summaries are presented in Appendix B-3.

3.4 Data Analysis

Chemical data were validated by Weston and Asarco. After validation, these data were entered into a database managed by Weston.

TABLE 3-1
SAMPLING STATION LOCATIONS

Sampling Station						
New Sampling Station ID[1]	Old Sampling Station ID[2]	Location	Approximate Northing (ft)	Approximate Easting (ft)	Approximate Elevation (ft)	Approximate Drainage Area (mi^2)[4]
AR-1	AR05	Arkansas River below confluence with Tennessee Creek	519,341	1,761,296	9,720	97.2
AR-2	AR04	Arkansas River above confluence with California Gulch	506,899	1,757,599	9,520	99.8
AR-3A	DNE	Arkansas River below confluence with California Gulch	503,885	1,758,269	9,485	111.8
AR-3E	AR03	East 1/3 Arkansas River in mixing zone with California Gulch water	506,353	1,757,760	9,515	110.9[3]
AR-3W	AR03	West 2/3 Arkansas River in mixing zone with California Gulch water	506,382	1,757,722	9,515	110.9[3]
AR-4	AR02	Arkansas River below confluence with Halfmoon Creek - Lake Fork	497,295	1,759,591	9,400	201.5
AR-5	AR01	Arkansas River above confluence with Empire Gulch	486,417	1,767,086	9,285	220.8
TC-1	TC01	Tennessee Creek above confluence with Arkansas River	522,736	1,762,374	9,760	44.7
EF-1	EF02	East Fork above confluence with Evans Gulch	529,641	1,779,584	9,980	34.1
EF-2	EF01	East Fork below confluence with Evans Gulch	524,885	1,771,874	9,895	48.2
EM-1	EM04	Empire Gulch at old boiler	502,136	1,793,027	10,900	3.6
EM-2	EM03	Empire Gulch above Beaver Lakes subdivision	498,578	1,786,152	10,590	5.9
EM-3	EM02	Empire Gulch about 1 3/4 mi. above EM04	491,453	1,773,713	9,555	9.0
EM-4	EM01	Empire Gulch above confluence with Arkansas River	486,222	1,767,678	9,285	10.0
IG-1	IG01	Iowa Gulch above confluence with Arkansas River	494,789	1,764,585	9,400	9.6
HC-1	HC01	Halfmoon Creek above confluence with Arkansas River	500,260	1,755,652	9,465	24.2
LF-1	LF01	Lake Fork above confluence with Arkansas River	501,666	1,756,214	9,465	60.8
CG-1	CG06	California Gulch above confluence with Yak Tunnel	511,666	1,781,959	10,330	2.1
CG-2	CG05	California Gulch below Resurrection Tailings	513,027	1,778,433	10,185	2.7
CG-3	CG04	California Gulch above confluence with Starr Ditch	513,820	1,775,550	10,045	3.1
CG-4	CG03	California Gulch below confluence with Oregon Gulch	513,075	1,773,785	9,970	6.0
CG-5	CG02	California Gulch below confluence with Airport Gulch	509,781	1,766,944	9,755	8.4
CG-6	CG01	California Gulch above confluence with Arkansas River	506,882	1,757,836	9,530	11.1
MG-1	MG01	Malta Gulch above confluence with California Gulch	508,044	1,759,443	9,570	2.7
AG-1	AG01	Airport Gulch above confluence with California Gulch	509,984	1,768,265	9,825	0.3
PG-1	PG01	Pawnee Gulch above confluence with California Gulch	512,556	1,770,430	9,885	0.4
GG-1	GG01	Georgia Gulch above confluence with California Gulch	512,892	1,772,976	9,955	0.7
OG-1	OG01	Oregon Gulch above confluence with California Gulch	513,476	1,775,294	10,025	0.4
SD-1	SD01	Starr Ditch above confluence with California Gulch	514,106	1,775,431	10,050	1.2
SG-1	SG01	Stray Horse Gulch above culvert inlet at 5th St.	517,219	1,779,663	10,330	1.1
EG-1	EG02	Evans Gulch above confluence with Little Evans Gulch	520,539	1,779,040	10,260	7.7
EG-2	EG01	Evans Gulch below confluence with Little Evans Gulch	522,622	1,776,198	10,100	11.1
LE-1	LE01	Little Evans Gulch above confluence with Evans Gulch	NA	NA	NA	2.9

[1] Summer 1991, Fall 1991, and Winter, 1992 sampling events

[2] Ice-Off and Spring, 1991 sampling events

[3] AR-3E and AR-3W have the same drainage area. Samples were split at this location.

[4] Some of the sampling station locations have changed over time. The drainage areas estimated to each sampling location are approximate and are used to estimate areal loading rates only.

NA = Not available

DNE = Did not exist

Source: Water, Waste and Land, Inc./Weston (northings, eastings, elevations)

TABLE 3-2
SUMMARY OF SAMPLING EVENTS

Sampling Event	Dates	Sampling Firm	Total Metals Analyzed?	Dissolved Metals Analyzed?	Major Constituents Analyzed?	Discharge Measured ?	Bed Material Samples Analyzed?	Other
ICE-OFF, 1991	4/29/91-5/3/91	WCC	Yes	Yes	Yes	Yes	Yes	
SPRING, 1991	6/11/91-6/13/91	WWL	Yes	Yes	Yes	Yes	No	
SUMMER, 1991	7/23/91-7/25/91	WWL	Yes	Yes	Yes	Yes	Yes	
AUGUST, 1991	8/13/91-8/14/91	WWL				Yes	No	Automatic sampling equipment installed at Stations AR-3A, AR-3E, AR-2, and CG-6. Staff gauges installed and surveyed.
SUMMER STORMS, 1991[1]	8/24/91 8/30/91 9/11/91	WWL	Yes[2]	No	Yes[3]	Yes	No	
FALL, 1991	9/16/91-9/18/91	WWL	Yes	Yes	Yes	Yes	Yes	
WINTER, 1992	3/23/91-3/25/91	WWL	Yes	Yes	Yes	Yes	Yes	

Notes

1. Summer Storms Sampling at Stations AR-2, AR-3, AR-3A, AR-3E, AR-4, and CG-6 only.
2. Reduced set of total metals analyzed: Ag, As, Cd, Cu, Fe, Mn, Pb, and Zn only.
3. Reduced set of major constituents analyzed: Calcium, Magnesium, pH, Specific Conductivity, and Total Suspended Solids only.

WCC - Woodward Clyde Consultants, Inc.
WWL - Water, Waste and Land

TABLE 3-3
SUMMARY OF FIELD DATA
ICE-OFF, 1991

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/ cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
AR-1	4-30-91	--	20[3]	--	9.0	240	7.00	7.5	7.0	--
AR-2	4-30-91	CM	17	--	8.5	250	7.01	8.6	8.5	--
AR-3	4-30-91	CM	24	--	3.0	240	8.00	9.2	1.0	--
AR-4	4-29-91	CM	64	--	8.0	200	7.74	8.4	-1.5	.65
AR-5	4-29-91	CM	87	--	7.0	210	7.71	9.0	5.0	.68
TC-1	5-01-91	CM	10	--	8.5	107	7.69	8.8	14.0	--
EM-1	NM	--	NM	--	--	--	--	--	--	--
EM-2	5-03-91	CM	0.5	--	4.0	214	7.75	10.4	8.0	--
EM-3	4-30-91	CM	0.9	--	7.0	246	7.57	11.6	8.0	--
EM-4	4-29-91	CM	0.5	--	3.5	219	7.57	13.6	2.0	29.87
IG-1	4-29-91	CM	0.4	--	3.0	703	7.41	11.4	2.0	--
LF-1	5-1-91	CM	45	--	11.0	93	7.35	7.5	14.0	--
HC-1	4-30-91	CM	1.7	--	8.0	93	7.80	13.5	7.0	--
CG-1	5-03-91	--	0.0	--	1.0	311	4.93	8.6	11.0	--
CG-2	5-03-91	CM	<0.1	--	0.0	1580	7.65	8.9	11.0	--
CG-3	5-03-91	CM	0.7	--	7.0	680	7.57	8.4	11.0	--
CG-4	5-02-91	CM	2.2	--	7.0	1666	2.89	7.8	14.0	--
CG-5	5-02-91	CM	2.6	--	10.0	1270	10.14	8.4	15.0	--
CG-6	5-01-91	CM	3.5	--	7.0	560	8.12	7.9	19.5	--
OG-1	5-02-91	CM	0.5	--	0.0	468	3.33	9.3	10.0	--
SD-1	5-02-91	PF	0.6	--	7.0	508	6.45	8.4	11.0	--

TABLE 3-3
(Concluded)

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
SG-1	5-02-91	CM	<0.1	--	1.0	406	4.23	11.5	7.0	--
EF-1	5-01-91	CM	21.4	--	9.0	230	7.94	7.7	13.5	--
EF-2	5-01-91	CM	14.4	--	9.0	230	7.94	7.7	13.5	--
EG-1	--	--	Frozen	--	--	--	--	--	--	--
EG-2	--	--	Frozen	--	--	--	--	--	--	--
AG-1	5-02-91	CM	0.4	--	9.0	26	6.07	8.2	14.5	--
PG-1	5-02-91	CM	0.3	--	10.0	110	8.32	7.6	14.8	--
GG-1	5-02-91	CM	<0.1	--	10.0	700	8.46	7.6	14.5	--
LE-1	--	--	Frozen	--	--	--	--	--	--	--
MG-1	5-01-91	V	0.8	--	10.0	96	3.36	6.8	14.0	--
Yak Tunnel[4]	4-29 to 5-3-91	--	0.58	--						
Leadville WWTP[5]	5-91	--	0.71	--						

Notes: Daily precipitation data show that precipitation did not occur on the 1st, 2nd or 3rd of May, 1991 (NOAA, 1991).
NM - No flow measurement taken due to excessive depth and/or velocity.
PF - Parshall Flume
PCF - Portable Cutthroat Flume
CM - Current Meter
V - Volumetric
[1] Site identification based on revised Station ID.
[2] Discharge Error Estimate from field notes.
[3] Discharge estimated from field notes.
[4] Yak Tunnel Discharge provided by ASARCO.
[5] Leadville WWTP Discharge provided by the City of Leadville.

Source: Woodward Clyde Consultants

TABLE 3-4
SUMMARY OF FIELD DATA
SPRING, 1991

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp (°C)	Barometric Pressure (in. Hg)
AR-1	6-13-91	USGS Station	297[3]	--	6.0	77	7.54	8.5	29.0	21.5
AR-2	6-12-91	--	298[3]	--	8.0	82	7.58	8.1	22.0	21.5
AR-3	6-12-91	--	289[3]	--	6.0	94	7.58	8.9	11.0	21.5
AR-4	6-11-91	--	470[3]	--	10.0	90	7.84	8.6	22.0	21.5
AR-5	6-11-91	USGS Station	511[3]	--	7.0	112	7.88	9.1	25.0	21.5
TC-1	6-13-91	NM	--	--	7.0	29	6.60	8.4	24.0	21.0
EM-1	6-11-91	CM	13	5%	7.5	111	7.68	7.6	19.5	20.25
EM-2	6-11-91	CM	9.3	8%	12.5	153	8.07	7.0	26.0	20.5
EM-3	6-11-91	CM	10	8%	13.5	169	8.16	7.3	23.0	21.25
EM-4	6-11-91	CM	7.7[4]	>8%	12.0	191	7.84	7.7	22.5	21.5
IG-1	6-11-91	CM	11	8%	9.5	518	8.12	8.1	22.0	21.5
LF-1	6-11-91	CM	79	5%	15.0	50	8.07	7.4	22.0	21.5
CG-1	6-12-91	PF	0.3	2%	11.0	777	3.47	7.1	12.0	21.0
CG-2	6-12-91	PCF	<0.1	2%	13.0	895	4.61	6.8	15.0	20.75
CG-3	6-12-91	PCF	1.4	2%	15.0	1,107	5.69	6.7	20.0	20.75
CG-4	6-12-91	PCF	0.9	2%	15.0	1,318	3.99	6.1	15.0	21.0
CG-5	6-12-91	PCF	1.2	2%	15.0	1,200	5.62	6.8	23.0	21.0
CG-6	6-12-91	PF	1.7	2%	12.0	934	7.45	7.8	27.0	21.25
OG-1	6-12-91	V	<0.1	--	10.0	15,540	2.32	10.0	17.0	21.0
SD-1	6-12-91	PCF	<0.1	2%	21.0	900	3.62	5.8	21.0	21.0
SG-1	6-12-91	PCF	0.1	2%	15.0	880	3.22	6.8	17.0	20.5

TABLE 3-4
(Concluded)

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/ cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp (°C)	Barometric Pressure (in. Hg)
EF-1	6-13-91	--	103[3]	--	5.0	77	7.61	8.6	17.5	20.75
EF-2	6-13-91	NM	--	--	5.0	109	7.93	8.5	17.5	21.5
EG-1	6-13-91	CM	28	8%	7.0	135	8.32	8.3	20.0	21.0
EG-2	6-13-91	CM	29	>8%	7.0	116	7.76	8.2	18.0	20.75
AG-1	6-12-91	--	DRY	--						
PG-1	6-12-91	--	DRY	--						
GG-1	6-12-91	--	DRY	--						
LE-1	6-13-91	--	DRY	--						
MG-1	6-11-91	--	DRY	--						
Yak Tunnel[5]	6-11 to 6-13-91	--	1.15	--						
Leadville WWTP[6]	6-91	--	0.65	--						

Notes:
NM - No flow measurement taken due to excessive depth and/or velocity.
PF - Parshall Flume
PCF - Portable Cutthroat Flume
CM - Current Meter
V - Volumetric

[1] Site identification based on revised Station ID.

[2] Discharge Error Estimate from field notes.

[3] Discharge is estimated from field notes.

[4] Split Flow, discharge is the sum of multiple flow measurements.

[5] Yak Tunnel Discharge is provided by ASARCO, and is the average discharge during the sampling period.

[6] Leadville WWTP Discharge provided by the City of Leadville.

Source: Water, Waste and Land

TABLE 3-5
SUMMARY OF FIELD DATA
SUMMER, 1991

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
AR-1	7-25-91	CM	105	8%	9.0	119	7.87	8.0	19.0	22.0
AR-1	7-23-91	CM	83	8%	15.0	127	8.14	7.6	21	21.5
AR-2	7-24-91	CM	70	2%	10.0	154	7.87	8.1	11.0	22.0
AR-3W	7-24-91	CM	47[4]	--	10.5	146	8.18	7.6	11.0	21.5
AR-3E	7-24-91	CM	31[4]	--	11.0	236	8.15	7.2	21.0	21.5
AR-3A	7-24-91	CM	71	2%	12.0	207	8.08	7.5	25.0	22.0
AR-4	7-23-91	NM	162[3]		15.0	132	8.14	8.4	22.0	22.0
AR-5	7-23-91	NM	204[3]		12.0	195	8.23	8.0	25.0	22.0
TC-1	7-23-91	CM	34	8%	16.5	54	7.81	6.8	14	21.0
TC-1	7-25-91	CM	48	8%	10.0	56	7.57	7.6	14.0	21.0
EM-1	7-23-91	CM	9.7	--	9.0	131	8.33	7.7	15.0	20.5
EM-2	7-23-91	CM	10	5%	12.0	152	8.29	7.3	20.0	20.5
EM-3	7-23-91	CM	12	8%	14.0	180	8.40	6.9	21.0	21.5
EM-4	7-23-91	CM	9.7	5%	10.5	207	8.07	7.4	16.0	21.5
IG-1	7-23-91	CM	14	--	12.0	431	8.16	7.5	28.0	22.0
LF-1	7-23-91	CM	51	2%	17.0	69	7.48	7.5	16.0	21.5
HC-1	7-23-91	CM	2	2%	20.0	63	8.61	6.7	23.0	22.0
CG-1	7-24-91	--	DRY	--						
CG-2	7-24-91	--	DRY	--						
CG-3	7-24-91	PCF	1.1	--	13.5	1,680	11.61	6.5	13.0	21.0
CG-4	7-24-91	CM	0.7	5%	15.0	1,290	7.43	7.4	13.0	21.5
CG-5	7-24-91	CM	2.6	8%	14.0	1,240	6.76	6.6	16.0	21.0
CG-6	7-24-91	PF	2.7	8%	14.5	1,030	8.00	6.4	13.0	21.5
OG-1	7-24-91	V	< 0.1	--	13.0	15,480	2.55	5.1	15.0	21.5

TABLE 3-5
(Concluded)

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/ cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
SD-1	7-24-91	PCF	0.2	--	11.0	207	8.14	7.2	10.0	21.0
SG-1	7-24-91	V	< 0.1	--	11.0	4,800	2.52	6.4	11.0	21.5
EF-1	7-25-91	CM	51	2%	8.5	132	8.17	7.8	16.5	21.0
EF-2	7-25-91	CM	57	2%	9.0	167	8.08	8.0	20.0	21.5
EG-1	7-25-91	CM	3.9	8%	10.0	176	8.48	7.1	15.0	20.5
EG-2	7-25-91	CM	2.8	5%	11.0	174	8.21	7.6	15.0	21.5
AG-1	7-24-91	--	DRY	--						
PG-1	7-24-91	--	DRY	--						
GG-1	7-24-91	--	DRY	--						
LE-1	7-25-91	--	DRY	--						
MG-1	7-24-91	--	DRY	--						
Yak Tunnel[5]	7-23 to 7-25-91	--	0.97	--						
Leadville WWTP[6]	7-91	--	0.68	--						

Notes:
NM - No flow measurement taken due to excessive depth and/or velocity.
PF - Parshall Flume
PCF - Portable Cutthroat Flume
CM - Current Meter
V - Volumetric

[1] Site identification based on revised Station ID.

[2] Discharge Error Estimate from field notes.

[3] Discharge was estimated from total discharge measured at the location of stations AR-3E and AR-3W. AR-3E discharge was estimated to be approximately 1/3 of the total distance on the east side of the Arkansas River and AR-3W discharge was estimated to be approximately 2/3 of the total distance on the west side of the Arkansas River.

[4] Discharge estimated from field notes.

[5] Yak Tunnel Discharge provided by ASARCO.

[6] Leadville WWTP Discharge provided by the City of Leadville.

Source: Water, Waste and Land, Inc.

TABLE 3-6
SUMMARY OF FIELD DATA
FALL, 1991

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (μmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
AR-1	9-18-91	CM	32	5%	11.0	182	8.30	6.9	25	20.5
AR-2	9-17-91	CM	30	--	7.0	201	7.21	7.9	21	21.0
AR-3A	9-16-91	CM	29	--	11.7	207	8.13	7.0	NM	21.0
AR-3E	9-17-91	CM	9.8[3]	5%	4.7	215	8.25	8.3	13	21.0
AR-3W	9-17-91	CM	15[3]	5%	6.0	199	8.02	8.6	21	21.0
AR-4	9-16-91	CM	73	2%	15.0	164	8.50	9.0	24	21.0
AR-5	9-16-91	CM	80	8%	6.3	213	7.87	8.9	23	21.5
TC-1[4]	9-18-91	CM	9.6	>8%	8.0	75.5	7.56	8.1	22	20.5
EF-1	9-18-91	CM	20	2%	11.5	164	8.70	8.0	20	20.5
EF-2	9-18-91	CM	28	--	7.5	230	8.37	7.8	13	20.5
EM-1	9-16-91	CM	1.9	8%	7.0	147	8.38	7.5	12	19.75
EM-2	9-16-91	CM	2.6	>8%	10.0	198	8.48	7.4	16	20.0
EM-3	9-16-91	CM	2.4	>8%	7.0	204	8.49	8.4	15	21
EM-4	9-16-91	CM	1.6	5%	4.5	237	7.94	8.5	11	21.5
IG-1	9-16-91	CM	0.3	8%	9.0	734	8.49	8.1	21	21.0
LF-1	9-16-91	CM	29	2%	12.5	97	8.42	9.3	17	21.0
HC-1	9-16-91	CM	4.4	2%	14.4	84	8.48	7.0	19	21.0
CG-1	9-17-91	--	DRY	--						
CG-2	9-17-91	--	DRY	--						
CG-3	9-17-91	PCF	< 0.1	--	17.0	1,205	7.50	5.1	19	20.0
CG-4	9-17-91	PCF	< 0.1	--	18.0	1,863	5.23	5.1	24	20.5
CG-5	9-17-91	PCF	0.1	--	12.0	984	7.69	7.1	15	20.5
CG-6	9-17-91	PF	1.1	--	8.5	664	8.26	8.1	18	20.5
OG-1	9-17-91	--	DRY	--						

TABLE 3-6
(Concluded)

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (μmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
SD-1	9-17-91	--	DRY	--						
SG-1	9-17-91	--	DRY	--						
EG-1	9-18-91	PCF	< 0.1	--	10.5	202	8.46	5.7	19	20.0
EG-2	9-18-91	--	DRY	--						
AG-1	9-17-91	--	DRY	--						
PG-1	9-17-91	--	DRY	--						
GG-1	9-17-91	--	DRY	--						
LE-1	9-18-91	--	DRY	--						
MG-1	9-17-91	--	DRY	--						
Yak Tunnel[5]	9-16 to 9-18-91	--	0.76	--						
Leadville WWTP[6]	9-91	--	0.55	--						

Notes: NM - No flow measurement taken due to excessive depth and/or velocity.
PF - Parshall Flume
PCF - Portable Cutthroat Flume
CM - Current Meter
V - Volumetric
NA - Not Available

[1] Site identification based on revised Station ID.

[2] Discharge Error Estimate from field notes.

[3] Discharge was estimated from the total discharge measured at location of stations AR-3E and AR-3W. AR-3E discharge was estimated to be approximately 1/3 of the total distance on the east side of the Arkansas River and AR-3W discharge was estimated to be approximately 2/3 of the total distance on the west side of the Arkansas River.

[4] Due to access problems TC-1 was sampled upstream of the established sampling location.

[5] Yak Tunnel Discharge provided by ASARCO.

[6] Leadville WWTP Discharge provided by the City of Leadville.

Source: Water, Waste and Land

TABLE 3-7
SUMMARY OF FIELD DATA
WINTER, 1992

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/ cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
AR-1	3-25-92	CM	15	8%	1.5	285	8.32	9.9	-1	21.0
AR-2	3-24-92	CM	10	>8%	1.0	294	8.19	9.6	0	21.25
AR-3A	3-23-92	CM	11	>8%	2.0	323	8.78	8.8	-4	21.25
AR-3E	3-23-92	CM	4.0[3]	>8%	2.2	341	8.29	9.6	-4	21.25
AR-3W	3-23-92	CM	8.1[3]	>8%	2.0	287	8.37	9.1	-4	21.25
AR-4	3-23-92	CM	41	>8%	5.2	204	8.35	8.9	-1	21.25
AR-5	3-23-92	CM	51	>8%	4.1	213	8.57	8.7	-1	21.25
TC-1	3-25-92	CM	5.9	5%	1.1	137	7.72	10.3	3	22.5
EF-1	3-24-92	--	Frozen	--	-	-	-	-	-	-
EF-2	3-25-92	CM	8.8	8%	3.0	449	8.30	8.8	2	21.0
EM-1	3-23-92	--	Inaccessible	--	-	-	-	-	-	-
EM-2	3-23-92	CM	1.0	8%	2.1	210	8.55	9.0	6	20.3
EM-3	3-23-92	--	Frozen	--	-	-	-	-	-	-
EM-4	3-23-92	CM	0.8	2%	3.0	267	7.83	9.2	11	21.4
IG-1	3-23-92	--	Frozen	--	-	-	-	-	-	-
LF-1	3-23-92	CM	26	5%	6.0	102	7.60	8.7	3	21.3
HC-1	3-23-92	--	Frozen	--	-	-	-	-	-	-
CG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
CG-2	3-24-92	CM	0.4	>8%	8.0	838	7.35	7.2	-4	20.75
CG-3	3-24-92	CM	0.5	8%	4.5	536	7.97	8.2	-2	20.75
CG-4	3-24-92	PCF	0.6	--	2.9	876	7.32	8.9	5	21.3
CG-5	3-24-92	PCF	0.5	8%	1.0	913	7.65	9.5	-1	21.0
CG-6	3-24-92	PF	1.4	--	1.6	597	7.77	9.4	2	21.6
OG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
SD-1	3-24-92	PCF	< 0.1	--	0.5	313	8.49	9.4	3	21.7
SG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
EG-1	3-24-92	--	Inaccessible	--	-	-	-	-	-	-

TABLE 3-7
(Concluded)

Sampling Station[1]	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate[2] (%)	Water Temp. (°C)	Specific Cond. (µmhos/cm^2)	pH (std. units)	Dissolved Oxygen (mg/l)	Air Temp. (°C)	Barometric Pressure (in. Hg)
EG-2	3-24-92	--	DRY	--	-	-	-	-	-	-
AG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
PG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
GG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
LE-1	3-24-92	--	Inaccessible	--	-	-	-	-	-	-
MG-1	3-24-92	--	DRY	--	-	-	-	-	-	-
Yak Tunnel[4]	3-23 to 3-25-92	--	0.59	--						
Leadville WWTP[5]	5-92	--	0.66	--						

Notes:
NM - No flow measurement taken due to excessive depth and/or velocity.
PF - Parshall Flume
PCF - Portable Cutthroat Flume
CM - Current Meter
V - Volumetric
NA - Not Available

[1] Site identification based on revised Station ID.

[2] Discharge Error Estimate from field notes.

[3] Discharge was estimated from the total discharge measured at location of stations AR-3E and AR-3W. AR-3E discharge was estimated to be approximately 1/3 of the total distance on the east side of the Arkansas River and AR-3W discharge was estimated to be approximately 2/3 of the total distance on the west side of the Arkansas River.

[4] Yak Tunnel Discharge provided by ASARCO.

[5] Leadville WWTP Discharge provided by the City of Leadville.

Source: Water, Waste and Land, Inc.

TABLE 3-8
SUMMARY OF FIELD DATA
SUMMER STORMS

Site	Sample Number	Date	Time	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate (%)	Water Temp. (deg. C)	Specific Cond.	pH (std. units)	Dissolved Oxygen (mg/L)
AR-2	1	8/24/91	15:33	SG	39.3	--	11.1	252	7.50	6.1
AR-2	2	8/24/91	15:55	SG	41.5	--	11.3	204	7.89	6.4
AR-2	3	8/24/91	16:18	SG	41.3	--	11.2	210	8.07	6.3
AR-2	4	8/24/91	17:03	SG		--	11.2	203	8.03	6.2
AR-2	1	8/30/91	16:57	SG	38.8	--	15.7	217	7.50	5.7
AR-2	2	8/30/91	17:24	SG	36.8	--	15.2	193	8.00	
AR-2	3	8/30/91	17:52	SG	36.5	--	14.6	198	8.04	6.1
AR-2	4	8/30/91	18:19	SG	36.0	--	14.8	192	8.06	
AR-2	5	8/30/91	18:47	SG	35.7	--	14.6	194	8.14	6.7
AR-2	6	8/30/91	19:14	SG	36.9	--	15.1	194	8.09	
AR-2	7	8/30/91	19:42	SG	37.9	--	15.3	193	7.94	5.5
AR-2	8	8/30/91	20:09	SG	37.6	--	15.0	194	7.94	
AR-2	9	8/30/91	20:37	SG	38.0	--	14.3	196	8.01	5.4
AR-2	10	8/30/91	21:04	SG	35.9	--	15.0	195	7.98	
AR-2	11	8/30/91	21:32	SG	35.1	--	15.7	197	7.94	4.9
AR-2	12	8/30/91	22:27	SG	34.8	--	15.9	197	7.94	6.0
AR-2	1	9/11/91	18:59	SG	29.9	--	10.1	195	7.01	
AR-2	2	9/11/91	19:26	SG	28.2	--	10.7	196	7.34	6.2
AR-2	3	9/11/91	19:54	SG	28.6	--	10.3	194	7.58	
AR-2	4	9/11/91	20:21	SG	29.7	--	10.3	195	7.79	6.2
AR-2	5	9/11/91	20:49	SG	27.7	--	10.2	196	7.87	
AR-2	6	9/11/91	21:16	SG	27.3	--	10.1	196	7.91	6.1
AR-2	7	9/11/91	21:44	SG	28.5	--	10.0	197	7.96	
AR-2	8	9/11/91	22:11	SG	29.0	--	10.2	197	8.01	6.2
AR-2	9	9/11/91	22:39	SG	29.9	--	10.0	198	8.03	
AR-2	10	9/11/91	23:06	SG	30.0	--	10.2	201	8.10	6.1
AR-2	11	9/11/91	23:34	SG	29.3	--	10.2	203	8.05	
AR-2	12	9/12/91	0:29	SG		--	10.4	201	8.10	
AR-3E	1	8/24/91	15:35	SG	32.0	--	12.0	247	7.97	6.9
AR-3E	2	8/24/91	15:57	SG	31.3	--	12.2	237	8.02	6.1
AR-3E	3	8/24/91	16:20	SG	31.3	--	12.4	236	8.03	6.4
AR-3E	4	8/24/91	17:05	SG	31.5	--	12.1	234	8.09	6.4
AR-3E	1	8/30/91	16:59	SG	36.4	--	15.0	250	7.23	5.7
AR-3E	2	8/30/91	17:26	SG	35.8	--	14.9	261	7.66	
AR-3E	3	8/30/91	17:54	SG	36.2	--	14.5	261	7.56	4.8
AR-3E	4	8/30/91	18:21	SG	36.1	--	14.6	258	7.56	
AR-3E	5	8/30/91	18:49	SG	36.0	--	15.8	259	7.64	4.5
AR-3E	6	8/30/91	19:16	SG	36.4	--	14.9	263	7.60	
AR-3E	7	8/30/91	19:44	SG	36.4	--	14.8	271	7.58	4.9
AR-3E	8	8/30/91	20:11	SG	36.8	--	14.9	282	7.60	
AR-3E	9	8/30/91	20:39	SG	36.8	--	15.2	275	7.64	5.1
AR3E	10	8/30/91	21:06	SG	36.9	--	14.9	271	7.72	
AR-3E	11	8/30/91	21:34	SG	36.5	--	15.5	271	7.78	4.7
AR-3E	12	8/30/91	22:29	SG	36.3	--	14.7	271	7.80	
AR-3E	1	9/11/91	19:01	SG	27.7	--	10.7	225	7.91	6.3
AR-3E	2	9/11/91	19:28	SG	27.5	--	10.6	227	7.86	
AR-3E	3	9/11/91	19:56	SG	27.8	--	10.5	228	7.85	6.2
AR-3E	4	9/11/91	20:23	SG	28.4	--	10.6	224	7.94	
AR-3E	5	9/11/91	20:51	SG	29.8	--	10.9	223	7.78	6.4
AR-3E	6	9/11/91	21:18	SG	29.8	--	10.8	236	7.81	
AR-3E	7	9/11/91	21:46	SG	30.5	--	11.0	229	7.87	6.7
AR-3E	8	9/11/91	22:13	SG	31.4	--	10.6	241	7.92	
AR-3E	9	9/11/91	22:41	SG	30.8	--	10.6	252	8.01	6.2
AR-3E	10	9/11/91	23:08	SG	31.2	--	10.5	574	6.48	
AR-3E	11	9/11/91	23:36	SG		--	10.7	388	6.39	6.1
AR-3E	12	9/12/91	0:31	SG		--	11.3	309	6.95	
AR-3A	1	8/24/91	15:32	SG	34.8	--	12.6	328	8.04	6.3
AR-3A	2	8/24/91	15:54	SG	34.5	--	12.8	231	8.00	6.2
AR-3A	3	8/24/91	16:17	SG	34.5	--	12.5	226	7.97	6.2
AR-3A	4	8/24/91	17:02	SG	34.5	--	12.3	224	8.04	6.0
AR-3A	1	8/30/91	16:57	SG	38.3	--	15.4	229	7.68	5.2
AR-3A	2	8/30/91	17:24	SG	38.1	--	14.8	226	7.72	
AR-3A	3	8/30/91	17:52	SG	37.9	--	14.8	230	7.72	4.4
AR-3A	4	8/30/91	18:19	SG	37.8	--	14.2	233	7.82	

TABLE 3-8
(Concluded)

Site	Sample Number	Date	Time	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate (%)	Water Temp. (deg. C)	Specific Cond.	pH (std. units)	Dissolved Oxygen (mg/L)
AR-3A	5	8/30/91	18:47	SG	37.8	--	14.0	233	7.88	4.3
AR-3A	6	8/30/91	19:14	SG	37.8	--	14.2	232	7.89	
AR-3A	7	8/30/91	19:42	SG	37.8	--	13.8	235	7.94	4.3
AR-3A	8	8/30/91	20:09	SG	38.1	--	13.8	239	7.98	
AR-3A	9	8/30/91	20:37	SG	38.2	--	12.7	246	7.87	4.3
AR-3A	10	8/30/91	21:04	SG	38.5	--	12.9	239	7.79	
AR-3A	11	8/30/91	21:32	SG	38.4	--	13.1	239	7.55	5.0
AR-3A	12	8/30/91	22:27	SG	38.2	--	13.4	240	7.73	
AR-3A	1	9/11/91	18:58	SG		--	11.7	219	7.88	8.2
AR-3A	2	9/11/91	19:25	SG		--	11.5	223	7.82	
AR-3A	3	9/11/91	19:53	SG		--	11.3	215	7.90	8.0
AR-3A	4	9/11/91	20:20	SG		--	11.4	220	8.01	
AR-3A	5	9/11/91	20:48	SG		--	11.4	216	8.00	6.8
AR-3A	6	9/11/91	21:15	SG		--	11.8	214	8.20	
AR-3A	7	9/11/91	21:43	SG		--	10.8	220	8.16	7.0
AR-3A	8	9/11/91	22:10	SG		--	10.5	219	8.20	
AR-3A	9	9/11/91	22:38	SG		--	10.4	224	8.17	6.7
AR-3A	10	9/11/91	23:05	SG		--	10.6	226	8.13	
AR-3A	11	9/11/91	23:33	SG		--	10.5	393	7.22	5.2
AR-3A	12	9/12/91	0:28	SG		--	10.7	336	7.29	
CG-6	1	8/24/91	15:30	PF	1.1	--	17.2	884	7.98	6.1
CG-6	2	8/24/91	15:52	PF	1.0	--	16.7	852	8.02	6.0
CG-6	3	8/24/91	16:15	PF	1.0	--	16.5	791	8.07	5.5
CG-6	4	8/24/91	17:00	PF	1.0	--	16.0	727	8.09	5.8
CG-6	1	8/30/91	16:55	PF	1.6	--	17.1	860	7.14	5.3
CG-6	2	8/30/91	17:22	PF	1.7	--	17.3	865	7.46	
CG-6	3	8/30/91	17:50	PF	1.7	--	17.2	916	7.58	3.7
CG-6	4	8/30/91	18:17	PF	1.5	--	17.3	904	7.61	
CG-6	5	8/30/91	18:45	PF	1.7	--	17.0	913	7.61	
CG-6	6	8/30/91	19:12	PF	1.7	--	13.8	930	7.37	5.7
CG-6	7	8/30/91	19:40	PF	1.7	--	14.2	920	7.45	
CG-6	8	8/30/91	20:07	PF	1.7	--	14.2	993	7.23	
CG06	9	8/30/91	20:35	PF	1.7	--	14.1	1008	7.31	4.5
CG-6	10	8/30/91	21:02	PF	1.7	--	14.4	943	7.34	
CG-6	11	8/30/91	21:30	PF	2.0	--	14.9	954	7.23	
CG-6	12	8/30/91	22:25	PF	2.1	--	15.0	935	7.30	4.4
CG-6	1	9/11/91	18:56	PF	1.2	--	11.4	769	7.05	5.7
CG-6	2	9/11/91	19:23	PF	1.1	--	12.0	739	7.43	
CG-6	3	9/11/91	19:51	PF	1.0	--	11.4	719	7.57	5.9
CG-6	4	9/11/91	20:18	PF	0.9	--	11.8	704	7.80	
CG-6	5	9/11/91	20:46	PF	0.9	--	11.6	692	7.87	6.8
CG-6	6	9/11/91	21:13	PF	0.9	--	11.7	693	7.73	
CG-6	7	9/11/91	21:41	PF	1.0	--	11.5	689	7.88	6.6
CG-6	8	9/11/91	22:08	PF	1.0	--	11.1	814	7.76	
CG-6	9	9/11/91	22:36	PF	1.0	--	11.2	779	7.78	6.3
CG-6	10	9/11/91	23:03	PF	1.3	--	11.1	211	2.98	
CG-6	11	9/11/91	23:31	PF	1.2	--	11.1	211	3.21	6.0
CG-6	12	9/12/91	0:26	PF	1.2	--	11.5	140	4.26	

PF = Parshall Flume
SG = Discharge estimated from staff gauge readings and rating curves

TABLE 3-9
SUMMARY OF FIELD DATA
AUGUST, 1991

Site	Date	Flow Measurement Device	Discharge (cfs)	Discharge Error Estimate (%)	Water Temp. (deg. C)	Specific Cond.	pH (std. units)	Dissolved Oxygen (mg/L)
AR-1	8/14/91	CM	57	5%	NM	NM	NM	NM
AR-2	8/9/91	CM	54	5%	NM	NM	NM	NM
AR-2	8/13/91	CM	49		NM	NM	NM	NM
AR-2	8/27/91	CM	43	5%	NM	NM	NM	NM
AR-3E/W	8/9/91	CM	52	5%	NM	NM	NM	NM
AR-3E/W	8/13/91	CM	56	5%	NM	NM	NM	NM
AR-3E/W	8/27/91	CM	46	5%	NM	NM	NM	NM
AR-3A	8/9/91	CM	55	5%	NM	NM	NM	NM
AR-3A	8/13/91	CM	57	5%	NM	NM	NM	NM
AR-3A	8/27/91	CM	46	5%	NM	NM	NM	NM
AR-4	8/13/91	CM	120	5%	NM	NM	NM	NM
AR-5	8/13/91	CM	132	5%	NM	NM	NM	NM
TC-1	8/14/91	CM	13		NM	NM	NM	NM
EF-1	8/14/91	CM	34	5%	NM	NM	NM	NM
EF-2	8/14/91	CM	36	5%	NM	NM	NM	NM
EM-1	8/13/91	CM	6.3	>8%	NM	NM	NM	NM
EM-2	8/13/91	CM	6.1	>8%	NM	NM	NM	NM
EM-3	8/13/91	CM	7.2	>8%	NM	NM	NM	NM
EM-4	8/13/91	CM	4.1		NM	NM	NM	NM
IG-1	8/13/91	CM	3.1	5-8%	NM	NM	NM	NM
HC-1	8/13/91	CM	1.9	5%	NM	NM	NM	NM
LF-1	8/13/91	CM	50		NM	NM	NM	NM
EG-1	8/14/91	PCF	0.8		NM	NM	NM	NM
EG-2	8/14/91	PCF	0.4		NM	NM	NM	NM
LE-1		--	DRY	--	--	--	--	--
CG-1		--	DRY	--	--	--	--	--
CG-2		--	DRY	--	--	--	--	--
CG-3	8/14/91	PCF	1.1		NM	NM	NM	NM
CG-4	8/14/91	CM	1.3	2%	NM	NM	NM	NM
CG-5	8/14/91	CM	1.1		NM	NM	NM	NM
CG-6	8/27/91	PF	2.3		NM	NM	NM	NM
MG-1		--	DRY	--	--	--	--	--
AG-1		--	DRY	--	--	--	--	--
PG-1		--	DRY	--	--	--	--	--
GG-1		--	DRY	--	--	--	--	--
OG-1		--	DRY	--	--	--	--	--
SD-1	8/14/91	PCF	0.2		NM	NM	NM	NM
SG-1		--	DRY	--	--	--	--	--
Yak Tunnel[1]	8/9-27/91	--	0.85	--	--	--	--	--
Leadville WWTP[2]	8/91	--	0.66	--	--	--	--	--

NM-NOT MEASURED
CM - Current Meter
PCF - Portable Cutthroat Flume
PF - Parshall Flume
NM - Not Measured

[1] Yak Tunnel discharge is the average flow of the referenced dates, and was provided by Asarco.

[2] Leadville WWTP discharge provided by City of Leadville.

TABLE 3-10
SURFACE WATER SAMPLES - PARAMETERS ANALYZED, ANALYTICAL METHODS AND DETECTION LIMITS

Parameter	EPA Method	CRDL	IDL	Reporting Units
FIELD ANALYSIS				
pH	N/A			
Specific conductivity (SC)	N/A			µmhos/cm
Dissolved Oxygen (DO)	N/A			mg/l
Water temperature	N/A			°C
Alkalinity as CaCO$_3$[1]	N/A			mg/l
Chlorine[1]	N/A			mg/l
LABORATORY ANALYSIS				
Major Constituents				
pH[2]	150.1			
Specific conductivity[2]	120.1			µmhos/cm
Total suspended solids[2]	160.2	N/A	2[7]	mg/l
Total dissolved solids[2]	160.1	N/A	2[7]	mg/l
Dissolved Organic Carbon[2]	ASTM D 4129-82	N/A	1[7]	mg/l
Alkalinity[3]	310.1	N/A	1[7]	mg/l
Calcium (Ca)[3,4]	200.7 CLP-M	5	1	mg/l
Magnesium (Mg)[3,4]	200.7 CLP-M	5	1	mg/l
Sodium (Na)[3,4]	200.7 CLP-M	5	1	mg/l
Potassium (K)[3,4]	200.7 CLP-M	5	1	mg/l
Chloride (Cl$^-$)[2,3]	325.3	N/A	1[7]	mg/l
Sulfate ($SO^{2-}{}_4$)[2,3]	375.4	N/A	4[7]	mg/l
Silica (SiO_2)[2,3]	200.7	N/A	1[7]	mg/l
Total phosphorus as P[2,3]	365.1	N/A	0.01[7]	mg/l
Fluoride (F)[2,3]	340.2	N/A	0.1[7]	mg/l
Nitrate + Nitrite as N[2,3]	353.2	N/A	0.02[7]	mg/l
Cyanide	335.3 CLP-M	10	10	mg/l
Metals (Total and Dissolved)				
Aluminum (Al)[4]	200.7 CLP-M	200	50	µg/l
Antimony (Sb)[4]	200.7 CLP-M	60	40	µg/l
Arsenic (As)[4]	206.2 CLP-M	10	1	µg/l
Barium (Ba)[4]	200.7 CLP-M	200	10	µg/l
Cadmium (Cd)[4]	200.7 CLP-M	5 (0.1)[6]	0.1	µg/l
Chromium (Cr)[4]	200.7 CLP-M	10	10	µg/l
Copper (Cu)[4]	200.7 CLP-M	25 (1)[6]	1	µg/l
Iron (Fe)[4]	200.7 CLP-M	100	20	µg/l

TABLE 3-10
(Concluded)

Parameter	EPA Method	CRDL	IDL	Reporting Units
Lead (Pb)[4]	239.2 CLP-M	3	1.1	µg/l
Manganese (Mn)[4]	200.7 CLP-M	15	10	µg/l
Mercury (Hg)[4]	245.2 CLP-M	0.2	0.2	µg/l
Nickel (Ni)[4]	200.7 CLP-M	40	20	µg/l
Selenium (Se)[4]	270.2 CLP-M	5	1.1	µg/l
Silver (Ag)[4]	200.7 CLP-M	10 (0.1)[6]	0.55/0.5	µg/l
Zinc (Zn)[4]	200.7 CLP-M	20	10	µg/l

N/A - Not applicable
CRDL - Contract Required Detection Limit
IDL - Instrument Detection Limit

[1] Parameter measured only for water collected at one station downstream of the Leadville WTP.

[2] USEPA, 1983.

[3] Sample was not filtered.

[4] USEPA, 1990.

[5] Detection limit listed for CLP methodology is the CRDL. Data above the instrument detection limit (IDL) and below the CRDL are reported as estimated. Instrument detection limits are laboratory dependent and are updated periodically. All detection limits are given for pure water and may not be achievable on environmental sample matrices.

[6] Parameter analyzed to a lower detection limit only in aquatic sampling events in which biota are also sampled.

[7] Contract Laboratory Reporting Limits

Source: Woodward Clyde Consultants

TABLE 3-11
BED MATERIAL SAMPLES - PARAMETERS ANALYZED, ANALYTICAL METHODS AND DETECTION LIMITS

Parameter	EPA Method	CRDL	Reporting Units
Major Constituents			
Sulfate	375.3	N/A	mg/kg
Calcium	200.7 CLP-M	1000	mg/kg
Chloride	325.3	N/A	mg/kg
Cyanide	335.2 CLP-M	2	mg/kg
Magnesium	200.7 CLP-M	1000	mg/kg
Potassium	270.2 CLP-M	1000	mg/kg
Sodium	200.7 CLP-M	1000	mg/kg
Metals (Total Only)			
Aluminum	200.7 CLP-M	40	mg/kg
Antimony	204.2 CLP-M	12	mg/kg
Arsenic	206.2 CLP-M	2	mg/kg
Barium	200.7 CLP-M	40	mg/kg
Cadmium	200.7 CLP-M	1	mg/kg
Chromium	200.7 CLP-M	2	mg/kg
Copper	200.7 CLP-M	5	mg/kg
Iron	239.9 CLP-M	20	mg/kg
Lead	200.7 CLP-M	0.6	mg/kg
Manganese	245.5 CLP-M	3	mg/kg
Mercury	200.7 CLP-M	0.1	mg/kg
Nickel	200.7 CLP-M	8	mg/kg
Selenium	200.7 CLP-M	1	mg/kg
Silver	200.7 CLP-M	2	mg/kg
Zinc	200.7 CLP-M	4	mg/kg

N/A - Not applicable

Method 200.7 CLP-M is ICP analysis

Methods 206.2 CLP-M, 239.9 CLP-M, and 270.2 CLP-M are Furnace AA analysis

Method 245.5 CLP-M is for Cold Vapor AA analysis

Method 335.2 CLP-M is Spectrophotometric

All analyses following CLP methodologies are from EPA, 1990.

Sample specific CRDL's for solid samples are adjusted for percent moisture and any dilutions, and will be higher than those listed above.

Source: Woodward Clyde Consultants

TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1077124

SITE NAME: CALIFORNIA GULCH

DOCUMENT DATE: 05-01-1996

DOCUMENT NOT SCANNED

Due to one of the following reasons:

☐ PHOTOGRAPHS

☐ 3-DIMENSIONAL

☑ OVERSIZED

☐ AUDIO/VISUAL

☐ PERMANENTLY BOUND DOCUMENTS

☐ POOR LEGIBILITY

☐ OTHER

☐ NOT AVAILABLE

☐ TYPES OF DOCUMENTS NOT TO BE SCANNED
(Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

DOCUMENT DESCRIPTION:

Map ASARCO Surface Water RI Report; Surface Water RI Sampling Locations.

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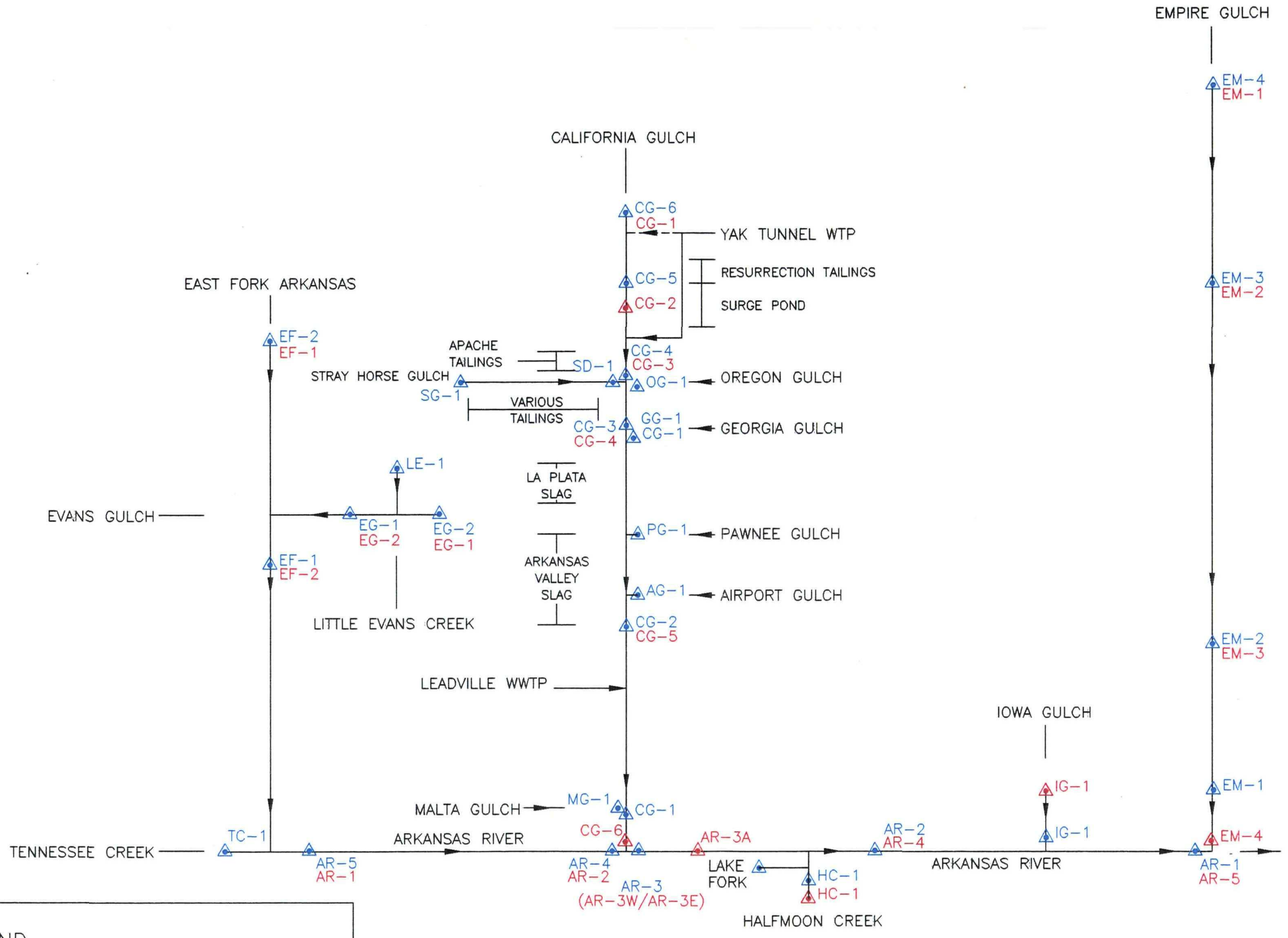


LEGEND

△ AR-1 ICE-OFF/SPRING, 1991 SAMPLING

▲ AR-1 FALL/SUMMER, 1991 AND WINTER, 1992 SAMPLING

→ DIRECTION OF FLOW

------ YAK TUNNEL WTP OUTFALL AFTER FEBRUARY, 1992

MODIFIED FROM: WOODWARD-CLYDE CONSULTANTS, DRAFT SURFACE WATER RI REPORT

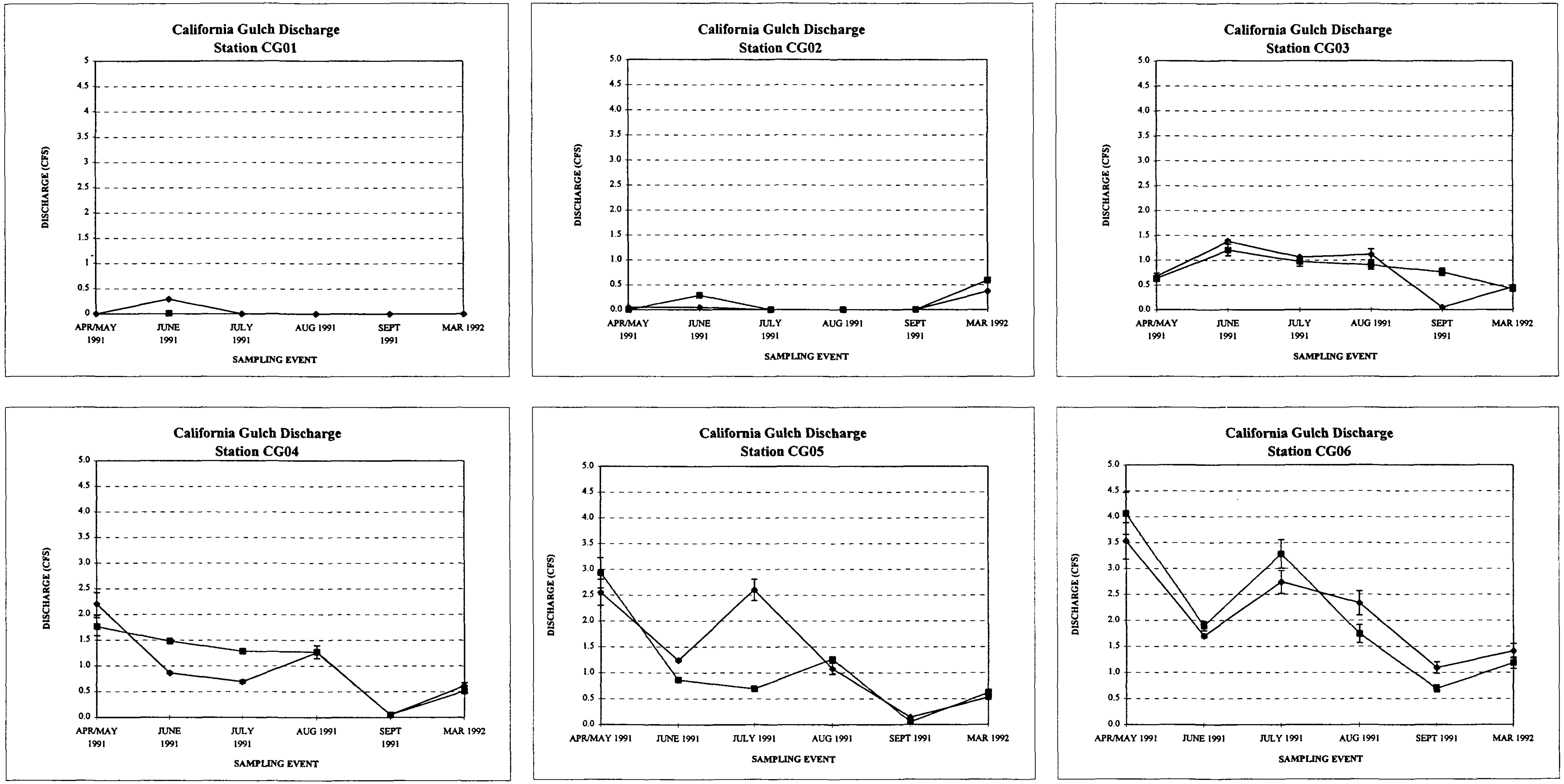
Golder Associates
Denver, Colorado

CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF
WATER QUALITY SAMPLING SITES

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
CHECKED	ABR	SCALE	NO SCALE	DWG. NO./REV. NO.	
REVIEWED	BDP	FILE NO.	2819B008	FIGURE NO.	3-2

FIGURE 3-3
CALIFORNIA GULCH DISCHARGE
MEASURED AND CALCULATED



LEGEND

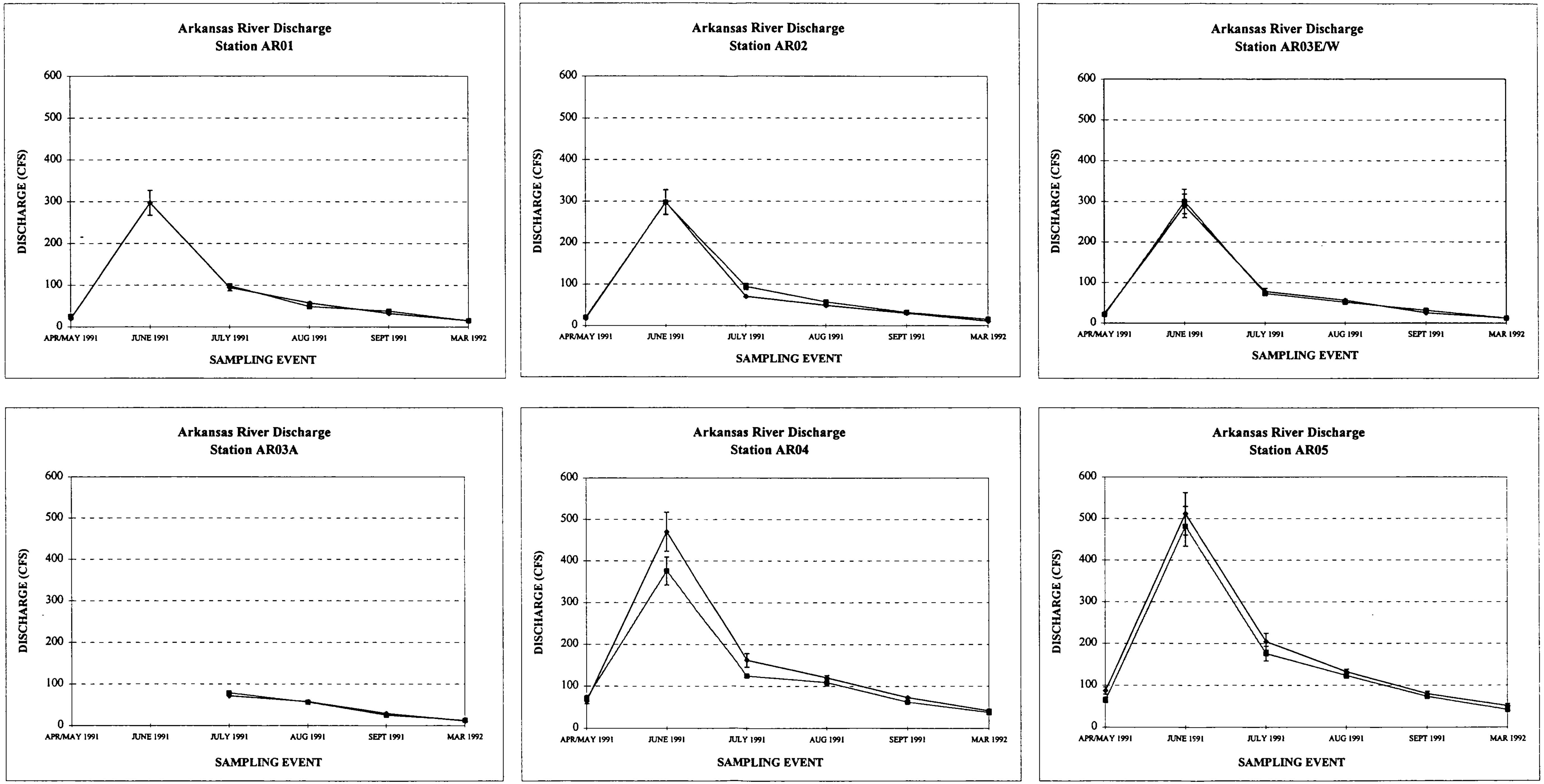
◆ = Measured Discharge
■ = Discharge Calculated from Measured Upstream Surface Water Discharges (See Note 1)
I = Estimated Range of Error (See Note 2)

Note 1: The discharge (Q) at each station was calculated as follows:

Q[CG02] = Q[CQ01] (for all sampling events except March 1992)
Q[CG02] = Q[CG01] + Q[Yak WWTP] (March 1992 sampling only)
Q[CG03] = Q[CG02] + Q[Yak WWTP] (for all sampling events except March 1992)
Q[CG03] = Q[CG02] (March 1992 sampling only)
Q[CG04] = Q[CG03] + Q[OG01] + Q[SD01]
Q[CG05] = Q[CG04] + Q[GG01] + Q[PG01] + Q[AG01]
Q[CG06] = Q[CG05] + Q[MG01] + Q[Leadville WWTP]

Note 2: Error in measured discharge was estimated from field conditions. Error in calculated discharge was estimated as the sum of the errors in the individual flow measurements comprising the calculated discharge.

FIGURE 3-4
ARKANSAS RIVER DISCHARGE
MEASURED AND CALCULATED

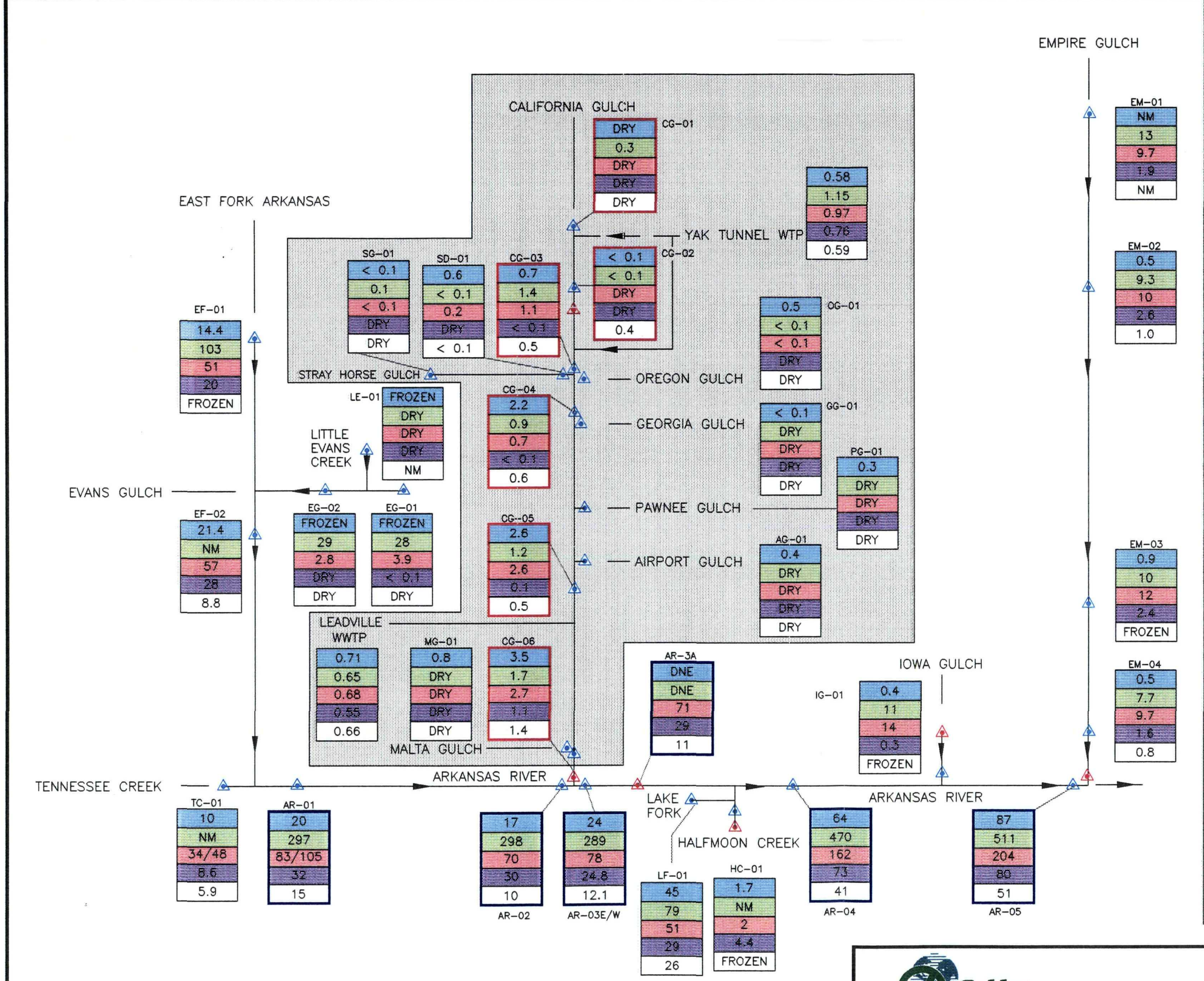


LEGEND

◆ = Measured Discharge
■ = Discharge Calculated from Measured Upstream Surface Water Discharges (See Note 1)
I = Estimated Range of Error (See Note 2)

Note 1: The discharge (Q) at each station was calculated as follows:
Q[AR01] = Q[TC01] + Q[EF02]
Q[AR02] = Q[AR01]
Q[AR3E/W] = Q[AR02] + Q[CG06]
Q[AR3A] = Q[AR03E/W]
Q[AR04] = Q[AR3A] + Q[HC01] + Q[LF01]
Q[AR05] = Q[AR04] + Q[IG01]

Note 2: Error in measured discharge was estimated from field conditions.
Error in calculated discharge was estimated as the sum of the errors in the individual flow measurements comprising the calculated discharge.



LEGEND

△ SAMPLING SITE ICE-OFF/SPRING 1991 SEE NOTE # 2.

▲ FALL/SUMMER, 1991 AND WINTER, 1992

TOTAL METAL CONCENTRATION (ug/L)	🟦 1.0 🟩 1.0 🟥 1.0 🟪 1.0 ⬜ 1.0	SAMPLING EVENT ICE-OFF (APR/MAY, 1991) SPRING (JUNE, 1991) SUMMER (JULY, 1991) FALL (SEPT, 1991) WINTER (MARCH, 1992)
TOTAL METAL CONCENTRATION (ug/L)	🟦 1.0 🟩 1.0 🟥 1.0 🟪 1.0 ⬜ 1.0	CALIFORNIA GULCH SAMPLING SITES
TOTAL METAL CONCENTRATION (ug/L)	🟦 1.0 🟩 1.0 🟥 1.0 🟪 1.0 ⬜ 1.0	ARKANSAS RIVER SAMPLING SITES
	▨	CALIFORNIA GULCH DRAINAGE BASIN
	U	ANALYTE NOT DETECTED
	NA	NOT ANALYZED
	DNE	SAMPLING SITE DID NOT EXIST
	— —	YAK TUNNEL WTP OUTFALL DURING WINTER, 1992 SAMPLING
	——►	FLOW DIRECTION

1.0/1.0

RESULTS AT AR-3E / RESULTS AT AR-3W

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY △ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.
3. TOTAL METAL CONCENTRATION IS DISSOLVED PLUS PARTICULATE METALS CONCENTRATION.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates Denver, Colorado

CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF DISCHARGE

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
CHECKED	ABR	SCALE	NO SCALE	DWG. NO./REV. NO.	
REVIEWED	BDP	FILE NO.	2819B013	FIGURE NO.	3-5

Section 4

4.0 WATER BALANCE

The surface water balance (gaining and losing reaches) along California Gulch was estimated to provide a description of surface water/groundwater interactions. California Gulch gains water from groundwater, surface runoff, springs, stormwater discharge from the City of Leadville, the Yak Tunnel Water Treatment Plant (WTP) and the Leadville Waste Water Treatment Plant (WWTP). California Gulch loses water to groundwater and evaporation. The losses and gains often vary seasonally, and interactions between surface water and groundwater can be complex. Further discussion of groundwater/surface water interaction is presented in the Hydrogeologic RI report.

The surface water balance was calculated using both estimates and direct measurements of discharge from the various water sources (e.g. groundwater, stormwater discharge). Data used in the calculations were collected for the Hydrogeologic RI with the exception of surface runoff (stormwater) data and WTP and WWTP discharges. Surface runoff calculations are described in this section. Yak Tunnel discharge was provided by Asarco, and Leadville WWTP discharge was provided by the City of Leadville. Hydrogeologic data collected were used to evaluate the nature of groundwater/surface water interactions along lower California Gulch, particularly to identify gaining stream reaches (groundwater discharges to surface water) and losing stream reaches (surface water discharges to groundwater) (Figure 4-2). Surface water flow measurements used in the calculations were collected at monitoring locations CG-3, CG-4, CG-5, and CG-6, on July 21, August 18, September 22 and October 27, 1992. Mini-piezometer water level measurements from 35 mini-piezometers installed along lower California Gulch were taken on the same dates. The mini-piezometer installation locations are shown on Figure 4-2.

A water balance was calculated by comparing measured stream discharges with predicted discharges. For the purposes of analysis, California Gulch was divided into segments with each segment beginning and ending at the midpoint between two mini-piezometers (Figure 4-1). The flow at a point A was determined as the flow at point B, which is upstream of A, plus any gains to the stream and minus any losses from the stream. Losses from evaporation of stream water were assumed to be negligible.

Surface runoff from the City of Leadville was calculated as:

$$Q_r = cPA$$

Where Q_r = surface runoff (ft^3/sec)

c = Runoff coefficient

P = average Precipitation (ft/sec)

A = Surface Area (ft^2)

Precipitation data was from the National Weather Service Station Leadville SW2. Surface runoff (stormwater) from the City of Leadville discharges between CG-3 and CG-5. Appendix C includes the calculations for stormwater runoff, including a description of area calculations.

Groundwater discharge was calculated as:

$$Q_g = K\, i\, A$$

Where Q_g = groundwater discharge (ft^3/sec)

K = hydraulic conductivity of alluvial materials through which groundwater flows (ft/sec)

i = hydraulic gradient (dimensionless)

A = surface area of the stream bed/groundwater contact (wetted surface area) (ft^2)

The hydraulic conductivity (K) for the shallow alluvial material within the gulch was estimated from slug tests. As discussed in the Hydrogeologic RI, slug tests were performed in July and August 1992 in mini-piezometers located within apparent gaining stream reaches of lower California Gulch. For stream segments with multiple slug tests, a mean value of K was used.

Additionally, it was assumed that the horizontal hydraulic conductivity was an order of magnitude greater than vertical hydraulic conductivity.

The hydraulic gradient (i) was determined using water level data gathered during the Hydrogeologic RI, as follows:

$$i = \frac{\Delta h}{\Delta L}$$

where:

Δh = head difference between surface water and groundwater (ft)

ΔL = distance from the edge of the stream to center of the screen interval on the mini-piezometer (ft)

Figure 4-1 illustrates the calculation of ΔL.

The wetted surface area (groundwater/surface water contact) of California Gulch was determined by assuming that the cross-sectional shape of the gulch was elliptical. The wetted surface water area was calculated as:

$$A = \left(\Pi * \sqrt{\left(b^2 + h^2\right)/2}\right) * L$$

Where A = wetted surface area (ft^2)

Π = pi

b = half of the stream width measured from centerline of stream at each mini-piezometer station (ft)

h = depth of flow at each mini-piezometer station (ft)

L = distance between two flow points (ft)

There were no stream width data for September and October. For purposes of calculation, it was assumed that stream width and depth of flow had a constant proportional relationship. July stream width and flow depth were used to calculated September and October stream widths at known flow depths as follows:

$$\frac{w_1}{h_1} = \frac{w_2}{h_2} \rightarrow w_1 = \frac{h_1 w_2}{h_2}$$

where: w_1 = September/October stream width

h_1 = September/October depth of flow (ft)

w_2 = July stream width (ft)

h_2 = July depth of flow (ft)

Water balance calculations are shown in Tables 4-1a through 4-1d.

Discrepancies between measured and predicted discharge may be due to the following:

- Stream discharge at CG-3 and CG-6 were estimated from a rating curve rather than directly measured.
- Hydraulic conductivity may vary along the gulch. The settlement of fine grained sediments in the stream bed may have decreased permeability. Additional measurements of hydraulic conductivity within the streambed sediments are needed to characterize vertical hydraulic conductivity.
- Predicted flows were consistently lower than the actual flows for the two segments below Leadville (CG-4 to CG-5, and CG-5 to CG-6). This may be attributed to surface flow entering California Gulch from un-metered tributaries, and/or underestimation of surface (stormwater) runoff from the City of Leadville.

TABLE 4-1a
Water Balance Calculations for California Gulch
July, 1992

Mini-peizometers	dH/dL (i)	AREA CALCULATIONS Segment Length (L) (ft)	Stream Width (ft)	Wetted Perimeter (ft)	Area of flow (A) (ft^2)	K (ft/min)	q=kiA (cfs)	Total Groundwater Flow for Mini-piezometers (cfs)	Water Balance Results Predicted flow vs. Measured flow (cfs)
P-1	-0.48	900.00	1.50	2.00	1802.09	0.00030	-0.0042	CG-6	**Predicted flow at CG-6 = 1.42** Measured flow at CG-5(0.7) + Malta Gulch(0.1) + Leadville WWTP (0.7) + Total Groundwater flow (-0.08) **Measured at CG-6 = 1.8**
P-2	-0.66	875.00	3.00	3.78	3304.30	0.00030	-0.0108		
P-3	-0.43	950.00	2.50	2.92	2769.65	0.00030	-0.0058		
P-4	-0.77	1875.00	2.00	3.64	6831.24	0.00030	-0.0257		
P-7	-0.50	1800.00	4.60	5.15	9274.40	0.00030	-0.0229		
P-8	-0.32	900.00	3.00	3.40	3058.25	0.00030	-0.0048		
P-9	-0.46	900.00	3.50	3.91	3521.44	0.00030	-0.0080	Sum P-1 through P-10 = -0.08 CG-5	**Predicted flow at CG-5 = 0.66** Measured flow at CG-4(0.3) + Total Groundwater flow (-0.02) + + Leadville runoff (0.38) **Measured at CG-5 = 0.7**
P-10	0.05	625.00	3.00	3.52	2199.62	0.00030	0.0006		
P-11	-0.12	475.00	3.00	3.38	1604.56	0.00010	-0.0003		
P-12	0.04	800.00	4.00	4.55	3643.06	0.00010	0.0002		
P-13	-0.64	850.00	4.80	5.36	4556.13	0.00010	-0.0050		
P-14	-0.09	550.00	3.00	3.51	1931.77	0.00010	-0.0003		
P-15	-0.13	500.00	3.00	3.45	1724.25	0.00010	-0.0004		
P-16	-0.02	425.00	6.60	7.35	3124.41	0.00010	-0.0001		
P-17	-0.05	425.00	4.60	5.15	2189.79	0.00010	-0.0002		
P-18	0.00	575.00	2.60	2.92	1680.01	0.00010	0.0000		
P-19	-0.32	500.00	4.50	5.08	2538.23	0.00010	-0.0014		
P-20	0.01	475.00	2.60	3.03	1441.51	0.00010	0.0000		
P-21	-0.13	600.00	1.60	1.99	1192.12	0.00010	-0.0003		
P-22	-0.28	475.00	2.50	3.30	1565.93	0.00010	-0.0008		
P-23	-0.14	425.00	2.20	2.60	1105.02	0.00010	-0.0003		
P-24	0.02	525.00	2.50	2.79	1462.44	0.00010	0.0001		
P-25	0.05	550.00	1.00	2.64	1454.04	0.00010	0.0001		
P-26	-0.74	525.00	7.50	8.35	4383.04	0.00010	-0.0056		
P-28	-0.77	475.00	5.50	6.16	2925.08	0.00010	-0.0039	Sum P-11 through P-29 = -0.02 CG-4	**Predicted flow at CG-4 = 0.7** Measured flow at CG-3(0.7) + Total Groundwater flow (-0.002) + **Measured at CG-4 = 0.3**
P-29	-0.34	475.00	0.00	0.00	0.00	0.00010	0.0000		
P-30	0.04	575.00	7.00	7.84	4508.96	0.00031	0.0008		
P-31	-0.17	525.00	5.00	5.57	2924.87	0.00031	-0.0026		
P-31A	0.03	600.00	4.00	4.54	2726.57	0.00031	0.0004		
P-32	-0.01	450.00	2.00	2.27	1019.42	0.00031	-0.0001		
P-33	-0.84		2.00	2.22	0.00	0.00031	0.0000		
P-34					0.00	0.00031		Sum P-30 through P-35 = -0.002 CG-3 -0.03	**Predicted flow at CG-3 = 0.85** Measured flow at CG-2(0.0) + Total Groundwater flow (-0.03) + Yak Water Treatment Plant (.882) **Measured at CG-3 = 0.7**
P-35	-0.02	875.00	7.80	8.71	7620.21	0.00031	-0.0007		
P-36	-0.79	825.00	3.00	3.45	2845.01	0.00031	-0.0116		
P-37	-0.59	400.00	12.60	14.01	5604.21	0.00031	-0.0170		
		200.00	0.00	0.00	0.00				

Notes:

- q indicates losing reaches (surface water discharges to groundwater)

Water Balance was done using actual measured flows (Asarco, 1996a).

TABLE 4-1b
Water Balance Calculations for California Gulch
August, 1992

Mini-peizometers	dH/dL (i)	AREA CALCULATIONS Segment Length (L) (ft)	Stream Width (ft)	Wetted Perimeter (ft)	Area of flow (A) (ft^2)	K (ft/min)	q=kiA (cfs)	Total Groundwater Flow for Mini-piezometers (cfs)	Water Balance Results Predicted flow vs. Measured flow (cfs)
P-1	-0.53	900.00	2.00	3.14	2827.35	0.00030	-0.007	CG-6	**Predicted flow at CG-6 = 1.27**
P-2	-0.67	875.00	4.00	4.97	4346.25	0.00030	-0.014		Measured flow at CG5-(0.7) + Malta
P-3	-0.43	950.00	2.40	2.98	2831.27	0.00030	-0.006		Gulch(0.1) + Leadville WWTP (0.7) +
P-4	-0.85	1875.00	4.20	5.73	10748.81	0.00030	-0.045		Total Groundwater flow (-0.13)
P-7	-0.52	1800.00	6.00	6.76	12160.89	0.00030	-0.031		**Measured at CG-6 = 1.8**
P-8	-0.41	900.00	5.80	6.48	5828.73	0.00030	-0.012		
P-9	-0.52	900.00	6.00	6.70	6027.63	0.00030	-0.016	Sum P-1 through P-10 =	**Predicted flow at CG-5 = 1.46**
P-10	0.09	625.00	3.40	4.33	2703.74	0.00030	0.001	-0.13	Measured flow at CG-4(0.6) +
P-11	-0.11	475.00	3.00	3.68	1746.59	0.00010	0.000	CG-5	Total Groundwater flow (-0.02)
P-12	-0.03	800.00	3.00	3.40	2718.44	0.00010	0.000		*+ Leadville runoff (0.88)*
P-13	-0.60	850.00	6.40	7.16	6089.16	0.00010	-0.006		**Measured at CG-5 = 0.7**
P-14	-0.10	550.00	1.00	2.29	1257.88	0.00010	0.000		
P-15	-0.16	500.00	2.60	3.28	1639.91	0.00010	0.000		
P-16	-0.02	425.00	6.00	6.76	2871.32	0.00010	0.000		
P-17	-0.06	425.00	7.00	7.77	3304.30	0.00010	0.000		
P-18	-0.06	575.00	3.00	3.45	1982.89	0.00010	0.000		
P-19	-1.06	500.00	4.50	5.00	2499.05	0.00010	-0.005		
P-20	0.00	475.00	2.80	3.23	1536.33	0.00010	0.000		
P-21	-0.12	600.00	4.40	5.20	3120.06	0.00010	-0.001		
P-22	-0.33	475.00	2.80	3.82	1815.35	0.00010	-0.001		
P-23	-0.26	425.00	2.60	3.28	1393.92	0.00010	-0.001		
P-24	-0.03	525.00	3.00	4.00	2102.44	0.00010	0.000		
P-25	0.04	550.00	3.00	4.13	2272.60	0.00010	0.000		
P-26	-0.72	525.00	4.40	4.92	2582.20	0.00010	-0.003		
P-28	-0.78	475.00	6.00	6.76	3209.12	0.00010	-0.004	Sum P-11 through P-29 =	**Predicted flow at CG-4 = 1.29**
P-29	-0.37	475.00	6.40	7.23	3435.33	0.00010	-0.002	-0.02	Measured flow at CG-3(1.3) +
P-30	0.03	575.00	5.00	5.68	3266.87	0.00031	0.001	CG-4	Total Groundwater flow (-0.01) +
P-31	-0.35	525.00	3.60	4.02	2112.12	0.00031	-0.004		**Measured at CG-4 = 0.3**
P-31A	-0.02	600.00	3.00	3.51	2107.38	0.00031	-0.0002		
P-32	-0.03	450.00	4.00	4.49	2021.60	0.00031	-0.0003		
P-33						0.00031			
P-34			0.00			0.00031		Sum P-30 through P-35 =	**Predicted flow at CG-3 = 0.62**
P-35	-0.05	875.00	6.00	6.76	5911.54	0.00031	-0.002	-0.01	Measured flow at CG-2(0.0) +
P-36	-0.84	825.00	4.00	4.58	3778.07	0.00031	-0.016	CG-3	Total Groundwater flow (-0.03) +
P-37	-0.92	200.00	8.60	9.55	1910.38	0.00031	-0.009	-0.03	Yak Water Treatment Plant (.64)
									Actual flow at CG-3 = 0.7

Notes:

- q indicates losing reaches (surface water discharges to groundwater)

Water Balance was done using actual measured flows (Asarco, 1996a).

TABLE 4-1c
Water Balance Calculations for California Gulch
September, 1992

		AREA CALCULATIONS						Total Groundwater Flow for Mini-piezometers (cfs)	Water Balance Results Predicted flow vs. Measured flow (cfs)
Mini-peizometers	dH/dL (i)	Segment Length (L) (ft)	Stream Width (ft)	Wetted Perimeter (ft)	Area of flow (A) (ft^2)	K (ft/min)	q=kiA (cfs)		
P-1	-0.43	900.00	3.03	4.04	3640.22	0.00030	-0.0077	CG-6	**Predicted flow at CG-6 = 2.73**
P-2	-0.64	875.00	4.58	5.76	5039.05	0.00030	-0.0158		Measured flow at CG-5(2.2) + Malta
P-3	-0.41	950.00	4.50	5.25	4985.37	0.00030	-0.0101		*Gulch(0.1) + Leadville WWTP (0.7) +*
P-4	-0.79	1875.00	2.89	5.27	9879.02	0.00030	-0.0387		Total Groundwater flow (-0.17)
P-7	-0.52	1800.00	11.65	13.05	23495.14	0.00030	-0.0600		**Measured at CG-6 = 1.8**
P-8	-0.37	900.00	7.40	8.38	7543.67	0.00030	-0.0138	↓	
P-9	-0.49	900.00	11.38	12.72	11444.68	0.00030	-0.0277	Sum P-1 through P-10 =	**Predicted flow at CG-5 = 0.84**
P-10	0.06	625.00	7.00	8.06	5035.08	0.00030	0.0015	-0.17	*Measured flow at CG-4(0.74) +*
P-11	-0.13	475.00	9.24	10.40	4942.05	0.00010	-0.0011	CG-5	Total Groundwater flow (-0.04) +
P-12	-0.02	800.00	10.08	11.28	9026.29	0.00010	-0.0002		+ Leadville runoff (0.14)
P-13	-0.59	850.00	12.10	13.51	11481.44	0.00010	-0.0117		**Measured at CG-5 = 0.7**
P-14	-0.10	550.00	5.94	6.95	3824.90	0.00010	-0.0007		
P-15	-0.11	500.00	5.93	6.81	3405.40	0.00010	-0.0006		
P-16	-0.07	425.00	16.37	18.23	7748.53	0.00010	-0.0009		
P-17	-0.07	425.00	11.65	13.05	5547.46	0.00010	-0.0006		
P-18	-0.03	575.00	8.32	9.35	5376.05	0.00010	-0.0003		
P-19	0.00	500.00				0.00010			
P-20	-0.03	475.00	5.79	6.66	3165.78	0.00010	-0.0002		
P-21	-0.10	600.00	3.32	4.12	2473.64	0.00010	-0.0004		
P-22	-0.35	475.00	3.75	4.95	2348.90	0.00010	-0.0014		
P-23	-0.23	425.00	4.57	5.40	2292.92	0.00010	-0.0009		
P-24	0.03	525.00				0.00010			
P-25	0.08	550.00	1.36	3.76	2069.10	0.00010	0.0003		
P-26	-0.87	525.00	17.70	19.70	10343.98	0.00010	-0.0155	↓	
P-28	-0.72	475.00	12.89	14.43	6853.04	0.00010	-0.0085	Sum P-11 through P-29 =	**Predicted flow at CG-4 = 0.79**
P-29	-0.40	475.00		0.78	369.30	0.00010		-0.04	Measured flow at CG-3(0.8) +
P-30	0.03	575.00	16.57	18.49	10633.21	0.00031	0.0014	CG-4	Total Groundwater flow (-0.01) +
P-31	-0.04	525.00	4.50	5.01	2632.38	0.00031	-0.0006		**Measured at CG-4 = 0.3**
P-31A	0.00	600.00	8.40	9.43	5660.49	0.00031	0.0000		
P-32	-0.02	450.00	5.50	6.23	2803.39	0.00031	-0.0004		
P-33	0.00					0.00031		↓	
P-34						0.00031		Sum P-30 through P-35 =	**Predicted flow at CG-3 = 0.57**
P-35	-0.15	875.00	11.51	12.85	11239.81	0.00031	-0.0088	-0.01	Measured flow at CG-2(0.0) +
P-36	-1.11	825.00	3.45	3.97	3271.77	0.00031	-0.0186	CG-3	Total Groundwater flow (-0.05) +
P-37	-0.95	400.00	15.54	17.28	6911.86	0.00031	-0.0337	-0.05	Yak Water Treatment Plant (.62)
									Measured at CG-3 = 0.7

Notes:

- q indicates losing reaches (surface water discharges to groundwater)

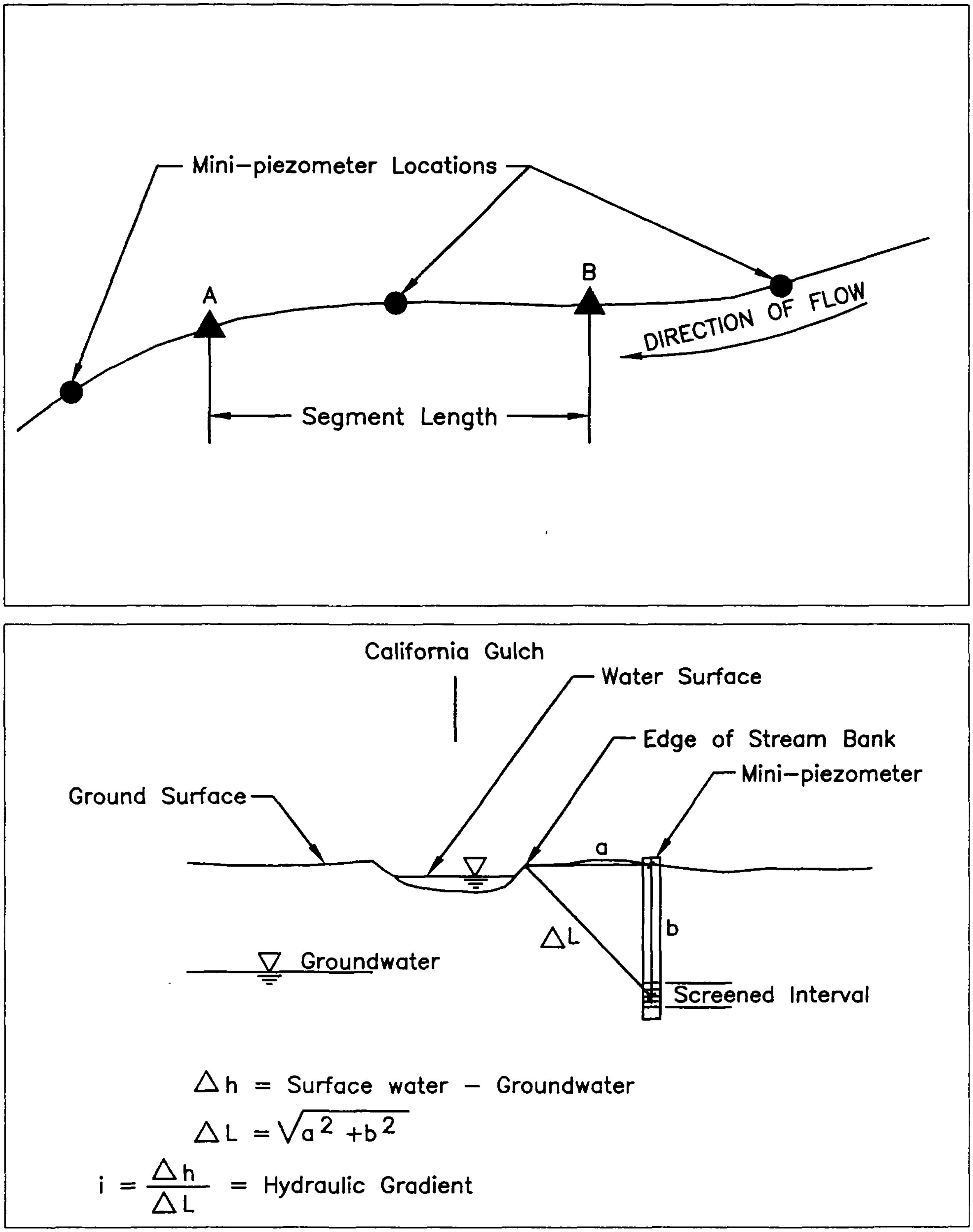
Water Balance was done using actual measured flows (Asarco, 1996a).

TABLE 4-1d
Water Balance Calculations for California Gulch
October, 1992

Minipeizometers	dH/dL (i)	AREA CALCULATIONS				K (ft/min)	q=kiA (cfs)	Total Groundwater Flow for Mini-piezometers (cfs)	**Water Balance Results** Predicted flow vs. Measured flow (cfs)
		Segment Length (L) (ft)	Stream Width (ft)	Wetted Perimeter (ft)	Area of flow (A) (ft²)				
P-1	-0.45	900.00	2.73	3.64	3279.80	0.00030	-0.007	CG-6 ↓	**Predicted flow at CG-6 = 1.66** *Measured flow at CG-5(1.1)* + Malta Gulch(0.1) + Leadville WWTP (0.7) + Total Groundwater flow (-0.14) **Measured at CG-6 = 1.8**
P-2	-0.64	875.00	4.39	5.52	4832.53	0.00030	-0.015		
P-3	-0.41	950.00	4.81	5.61	5331.58	0.00030	-0.011		
P-4	-0.80	1875.00	2.75	5.02	9406.09	0.00030	-0.037		
P-7	-0.39	1800.00	9.81	10.99	19785.38	0.00030	-0.038		
P-8	-0.31	900.00	6.90	7.82	7033.97	0.00030	-0.011		
P-9	-0.39	900.00	10.50	11.74	10564.32	0.00030	-0.020	*Sum P-1 through P-10 =* -0.14 CG-5 ↓	**Predicted flow at CG-5 = 0.58** Measured flow at CG-4(0.5) + Total Groundwater flow (-0.04) + + Leadville runoff (0.12) **Measured at CG-5 = 0.7**
P-10	0.08	625.00	9.60	10.87	6796.10	0.00030	0.003		
P-11	-0.09	475.00	7.92	8.92	4236.04	0.00010	-0.001		
P-12	0.00	800.00	9.76	10.92	8739.74	0.00010	0.000		
P-13	-0.57	850.00	11.52	12.86	10934.70	0.00010	-0.011		
P-14	-0.13	550.00	5.82	6.81	3747.63	0.00010	-0.001		
P-15	-0.11	500.00	5.33	6.12	3060.55	0.00010	-0.001		
P-16	-0.02	425.00	15.31	17.06	7248.62	0.00010	0.000		
P-17	-0.04	425.00	11.19	12.54	5328.48	0.00010	0.000		
P-18	0.01	575.00	8.32	9.35	5376.05	0.00010	0.000		
P-19	0.00	500.00	10.46	11.80	5901.39	0.00010	0.000		
P-20	-0.03	475.00	5.65	6.49	3084.61	0.00010	0.000		
P-21	-0.10	600.00	3.04	3.78	2265.02	0.00010	0.000		
P-22	-0.47	475.00	3.56	4.70	2231.46	0.00010	-0.002		
P-23	-0.78	425.00	4.02	4.75	2016.67	0.00010	-0.003		
P-24	0.04	525.00				0.00010			
P-25	0.08	550.00	1.73	3.79	2083.67	0.00010	0.000		
P-26	-0.75	525.00	16.80	18.70	9818.01	0.00010	-0.013		
P-28	-0.81	475.00	11.79	13.20	6268.03	0.00010	-0.009	Sum P-11 through P-29 = -0.04 CG-4 ↓	**Predicted flow at CG-4 = 0.45** Measured flow at CG-3(0.45) + Total Groundwater flow (0.003) + **Measured at CG-4 = 0.3**
P-29	-0.38	475.00				0.00010			
P-30	0.03	575.00	17.73	19.77	11366.84	0.00031	0.002		
P-31	0.00	525.00	3.50	3.90	2047.41	0.00031	0.000		
P-31A	0.00	600.00	7.87	8.84	5301.10	0.00031	0.000		
P-32	0.06	450.00	8.20	9.29	4179.60	0.00031	0.001		
P-33						0.00031			
P-34						0.00031		Sum P-30 through P-35 = 0.003 CG-3 -0.04	**Predicted flow at CG-3 = 0.30** Measured flow at CG-2(0.0) + Total Groundwater flow (-0.04) + Yak Water Treatment Plant (.331) **Measured at CG-3 = 0.7**
P-35	-0.96	875.00				0.00031			
P-36	-1.08	825.00	3.98	4.57	3769.64	0.00031	-0.021		
P-37	-0.72	200.00	23.94	26.62	5324.00	0.00031	-0.020		

Notes:
- q indicates losing reaches (surface water discharges to groundwater)

Water Balance was done using actual measured flows (Asarco, 1996a).



Δh = Surface water − Groundwater

$$\Delta L = \sqrt{a^2 + b^2}$$

$$i = \frac{\Delta h}{\Delta L} = \text{Hydraulic Gradient}$$

Golder Associates Denver, Colorado

TITLE	**WATER BALANCE CALCULATIONS**				
CLIENT/PROJECT	**ASARCO SURFACE WATER RI REPORT**				
DRAWN	RLB	DATE	MAY 1996	JOB NO.	943–2819
CHECKED	AR	SCALE	NO SCALE	DWG NO./REV. NO.	
REVIEWED	BDP	FILE NO.	2819A073	FIGURE NO.	**4–1**

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TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1077124

SITE NAME: CALIFORNIA GULCH

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Section 5

5.0 SURFACE WATER QUALITY

Surface water and stream bed sediments were analyzed for a variety of constituents during several sampling events to evaluate the nature and extent of contamination in the RI Study area (Section 3.0). A summary of the laboratory tests results is presented in this section with a discussion of potential metal sources and modes of transport in California Gulch. This section also includes a summary of the behavior of the metals of concern during each sampling event, the contribution of California Gulch to Arkansas River metals concentrations and loads, and a discussion of the potential for acid mine drainage at the site.

5.1 Summary of Laboratory Test Results

Surface water laboratory test results are presented in Tables 5-1 through 5-8 for all sampling stations for the Ice-Off, Spring, Summer, Summer Storms, and Fall, 1991, and Winter, 1992 sampling events. Water quality reported for the 1991 Ice-off sampling, the Summer, Summer Storms, Fall samples of 1991 and the Winter 1992 samples were collected prior to the Yak Tunnel Water Treatment Plant being in operation. Tables 5-9 through 5-12 include stream sediment laboratory test results for all sampling stations for the Ice-Off, Summer, Fall and Winter sampling events.

Laboratory test results are summarized by surface water system (e.g., California Gulch and tributaries, and Arkansas River and tributaries) for the major sampling events in Tables 5-13 through 5-16. The percentage of analyte detections in surface water are shown in Table 5-13, including the percentage of detections greater than the contract required detection limit (CRDL). Table 5-14 is a list of concentration ranges for the analytes detected in surface water, and Tables 5-15 and 5-16 show data for stream sediment samples. When numerical comparisons are made, values identified as non-detect are reported as one-half the instrument detection limit (IDL), and rejected values are not included in the analysis.

The data set of laboratory test results for surface water and sediments was provided by Roy F. Weston, Inc. (Weston). The data are presented in Appendix D-1, with a sample identification key in Table D-1 and a summary of data qualifier notation in Table D-2. Appendix D-2 provides a discussion of data gaps, including a discussion of discrepancies between dissolved and total metals concentrations. Appendix D-3 includes correspondence with Weston regarding the data set.

Surface water and sediment samples were analyzed for total and dissolved metals and other major constituents, as discussed in Section 3 and summarized in Tables 3-10 and 3-11.

5.1.1 Surface Water

Laboratory test result of surface water samples are summarized in this section. General trends exhibited by metals and major constituents are discussed, and the metals of concern in surface water are identified.

5.1.1.1 Metals

California Gulch and its tributaries exhibit concentrations of metals greater than those found in the Arkansas River and the Arkansas River tributaries. Movement of metals within California Gulch is discussed in Section 5.2. Seasonal variations of metals within California Gulch are discussed in Section 5.3. Contributions of California Gulch to Arkansas River metal concentrations and loads are discussed in Section 5.4. The following sections discuss the form of metals (dissolved and total) found in surface water and the metals of concern in the study area.

Dissolved and Total Metals

Metals in surface water appear both in suspended and dissolved (<45 micrometer particle size) form. Analysis of unfiltered samples indicates total metals (both suspended and dissolved) found in a surface water sample. Analysis of filtered samples indicates the portion of metals in the sample that are in the dissolved form. Surface water samples were analyzed for both total and dissolved metals to investigate how the form of the metals in the water changes seasonally. Analytical results for total and dissolved metals are listed in Appendix D. Dissolved metals content is discussed in the Aquatic Ecosystems Characterization (Asarco, 1995).

The ratio of dissolved to total metals concentrations varied during the sampling events. Metals adsorbed to, or precipitated on stream sediment particles may redissolve into stream water due to changes in water chemistry. Metals adsorbed to, or precipitated on stream sediments may be suspended and transported during high flow, fall out of suspension, and be deposited in the bed material during periods of low flow. Table 5-17 shows the ratio of dissolved to total metals during the major sampling events in California Gulch and the Arkansas River. Figure 5-1 shows the seasonal variation of the dissolved to total metal concentration ratio along California Gulch. The dissolved metal concentrations in California Gulch appear to be seasonally influenced, with the Spring, Fall and Winter samples generally having more than half of the metals in the dissolved form. In general, as pH decreases, a greater portion of the metals are dissolved rather than suspended. Dissolved to total metal ratios in the Arkansas River do not appear to show seasonal variation (Tables 5-1 through 5-3, 5-7 and 5-8).

Metals of Concern

Metals of concern in surface water from California Gulch and its tributaries were determined by the frequency of occurrence (percentage detections), the relative level of concentrations, and the toxicity to humans of the metals. Based on analysis of the laboratory test results, aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc are considered the primary metals of concern. Although barium exceeded CRDL values at several monitoring stations, it is not included in the metals of concern because it is listed in neither EPA nor Colorado Water Quality standards as a human or fresh water aquatic life health risk. Metals concentrations exceeding the CRDL are shown in Table 5-15 as a percentage of total samples tested and the concentration values are shown in Table 5-16. Except for silver, all metals were found at levels exceeding the CRDL in the Arkansas River and its tributaries.

In the Arkansas River and its tributaries other than California Gulch, the majority of the metals analyzed were not detected or were detected only at levels below the CRDL, as indicated in Table 5-13. Antimony, arsenic, barium, chromium, nickel, selenium, and silver were detected above the instrument detection limit (IDL) but below the CRDL. Copper was detected below the CRDL in the Arkansas River tributaries, and above the CRDL in the Arkansas River at only one station (AR-4) during one event (Ice-Off). In California Gulch and its tributaries, antimony, chromium, mercury, nickel, selenium, and silver were not detected, were detected only at levels below the CRDL, or were detected at relatively low levels.

5.1.1.2 Major Constituents

The major constituents of interest that appear to correlate with metals form and concentration are pH and total suspended solids (TSS). Other major constituents analyzed did not correlate with concentrations of concern.

Field pH

Field pH values in California Gulch ranged from 2.9 to 11.6, and generally decreased during the Spring sampling event. A pH of 11.6 was recorded at Station CG-3 during Summer sampling, and a pH of 2.6 was measured at Station CG-4 during the Ice-Off sampling. Spatial information is presented in Tables 5-1 through 5-8.

Total Suspended Solids

Some dissolved and total metal concentrations, notable lead and copper, show a strong correlation with total suspended solids (TSS) as shown in Figures 5-2 through 5-10 and described in Section 5.3. This correlation may be due to adsorbed metals adhering to small suspended particles, or colloids. Work conducted by the USGS (Kimball and Wetherbee, 1989; Kimball, et. al., 1994) suggests transport of metals by colloids is significant in Leadville area surface waters. The studies also suggest that some elevated dissolved metal concentrations are the result of small colloids (<0.45 micrometers) passing through filters.

From the trends illustrated in Figures 5-2, 5-6, and 5-8, lead and copper are strongly associated with colloidal transport, as indicated by the lack of any increases in these metals without an associated increase in TSS. Zinc (Figure 5-10) and cadmium (Figure 5-5) appear to be partially associated with colloidal transport. Zinc and cadmium show increases associated with TSS peaks, but also show increases not associated with TSS. Since iron (Figure 5-7) and aluminum (Figure 5-3) are probably the primary components of most colloidal particles, they also show a strong correlation with TSS. According to a study performed by the USGS on the Arkansas River below California Gulch (Kimball and Wetherbee, 1989), zinc and cadmium occurred as both a dissolved constituent and adsorbed onto colloids, while copper was primarily adsorbed.

The most likely sources of TSS in the form of colloids in California Gulch are surface water runoff such as overland flow, sheet flow or urban stormwater runoff. Other potential sources of colloids are re-suspension of sediments and direct formation from chemical precipitation of dissolved metals such as iron or aluminum. Colloids can form in surface waters as pH or dissolved oxygen increase. Although groundwater is not likely a direct source of colloids because aquifer material can efficiently filter most colloidal material, dissolved iron in groundwater discharging into surface water may precipitate to form colloids.

Metals adsorbed to colloidal material can come from the same source area as the colloid material, or can be acquired from other waters after mixing. Since California Gulch is a small drainage basin, characterized by steep slopes and rapid flow rates, it is likely that both the colloids and the adsorbed metals are derived from the same source areas. Therefore, the source of adsorbed metals on colloids, derived from surface flow is probably a surface source such as runoff directly from a tailings pile or metals enriched ground. Metals adsorbed to colloids that have formed by direct precipitation are probably derived from bedload materials.

5.1.2 Stream Bed Sediment

Results for sediment sampling for all stations and events are shown in Tables 5-9 to 5-12. Summaries of the results are shown in Tables 5-15 and 5-16. For purposes of comparison, Table 5-18 summarizes estimated study background metals in soils, and literature reported background metal values.

Concentrations of arsenic in stream bed sediments in the Arkansas River were within estimated background concentrations in soils at the site. Concentrations of antimony, barium, chromium, copper, manganese, mercury and nickel in Arkansas River sediments were within published background ranges for soils in the Western United States. Concentrations of aluminum, arsenic, cadmium, iron, lead, manganese, and zinc in sediment were elevated in California Gulch, California Gulch tributaries, the Arkansas River, and Arkansas River tributaries.

The results for sediment sampling generally do not correlate with surface water metal concentrations, TSS, pH or other parameters, as shown in Figures 5-3 through 5-9. Appendix F presents supporting data for background water quality review, including a calibration factor for predicting zinc values. A possible explanation for this can be related to the average grain size of the sediment samples. Samples with a small grain size will have a large surface area relative to total volume. Most of the metals in a sediment sample are concentrated on the surface area of the individual particles. Therefore, the grain size distribution of a sediment sample can greatly affect the concentrations of metals measured.

In accordance with the Surface Water RI Work Plan, sediment samples were collected with a hand scoop and uniformly mixed. Samples were not sieved or otherwise sorted by grain size before analysis, nor were the grain size distributions determined. As a result, variations in sediment sample metal concentrations may reflect grain size heterogeneitities.

5.2 Metal Sources and Transport

Possible sources of metals in California Gulch, the movement of metals within California Gulch, and the contribution of California Gulch to Arkansas River concentrations and loads are discussed in this section.

5.2.1 Sources of Metals in California Gulch

Sources of metals in California Gulch basin are both disturbed and undisturbed. Disturbed point sources in the California Gulch area include tailings piles, waste rock piles, and slag piles. Undisturbed sources can be termed "background" sources and include natural weathering of metaliferous primary minerals such pyrite and sphalerite, and sorption reactions with secondary minerals, organics and clays. A discussion of background metal concentrations is presented in Section 6.0, and Section 5.3 includes a discussion of potential sources of the metals of concern for each sampling event.

Contaminant migration from the source areas to California Gulch surface water is complex due to the numerous potential sources in the watershed. Metals in California Gulch may originate from several potential sources including:

- Surface water runoff from waste rock piles, slag piles, smelter sites, tailings impoundments and/or other mineralized-fill areas;
- Seeps created by infiltration through tailings impoundments;
- Surface water runoff from naturally mineralized areas within the watershed;
- Metals attached to stream sediments which become suspended or dissolved due to high flow rates or significant pH changes;

- Springs or seeps discharging groundwater that has been in contact with highly mineralized areas;

- Fluvial tailings or piles that come in direct contract with surface water flows;

- Discharge from mine drainages or portals;

- Runoff adjacent to major roads where slag or other highly-mineralized material has been used to "sand" roadways; and,

- Airborne transport of metals adsorbed to or in dust particles.

Evaluation of some of these sources (e.g., mine waste, tailings, slag piles, and groundwater) and their potential for contributing metals to California Gulch surface waters is discussed as part of the RI reports. Sediment transport is discussed in the following section of this RI. Areal loading of metals at various locations along California Gulch reflects source areas topographically upgradient from the gulch. Metals concentrations measured at the California Gulch monitoring stations reflect the distribution of source areas within the study area.

5.2.2 Transport of Metals in California Gulch

Sediment transport is one of the major metals transport mechanisms within California Gulch. The significance of sediment-movement is critical in understanding how metals move through the system. The erosion of waste piles is important in evaluating metals source areas contributing to the system, not necessarily the movement of metals through the area. Metals may attach themselves to sediment and be transported downstream with suspended sediment load. Stream bed material can be aggraded or degraded within the system, depending on the hydraulics of natural streams. Sediment transport calculations were made to estimate aggrading/degrading reaches within the stream system. Aggradation or degradation in a stream system depends on many variables, including:

- Stream flow rates and volumes;

- Natural or man-made obstructions such as bridges and culverts within the waterway;

- Changes in stream geomorphology due to relocation, diversion, dredging, placer, mining, channelization; and

- Amount of erodible material available in the watershed.

The primary mode of sediment transport in California Gulch is as suspended sediment. This is indicated by the ratio of the shear velocity on the streambed to the fall velocity of particular sediment particles. For ratios less than 0.5, most of the sediment will be transported as bed load; for ratios between 0.5 to 2.0, the transport sediment will be bed load with some suspended load, and for ratios greater than 2.0, the mode of transport will primarily be suspended load (Laursen, 1960).

The Bagnold Equation was used to estimate the sediment transport potential of California Gulch. By comparing the ability of the upstream reach to carry sediment to the ability of the downstream reach, a relationship between aggrading (sediment accumulation) and degrading (sediment erosion) reaches can be estimated. A reach is assumed to be aggrading if the upstream reach has a greater ability to carry sediment than the downstream reach. A reach is assumed to be degrading if the upstream reach has less ability to carry sediment than the downstream reach. This equation should be calibrated with suspended sediment and bedload data from low and high flow events to achieve a more accurate quantitative result. Calibration of the equation was not done as part of the RI report.

The Bagnold equation is based on the following factors:

$$q_T = 43.2\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)\tau_o\, U\left(\frac{e_b}{\tan\alpha} + 0.01\frac{U}{W}\right)$$

γ_w = Specific weight of water (62.4 lbs/ft^3)

γ_s = Specific weight of solids (167.9 lbs/ft^3 based on a specific gravity of 2.69

τ_o = Average shear stress on channel boundary (0.21-5.75 lbs/ft^2)

U = Average flow velocity (0.627-7.68 ft/sec.)

e_b = Efficiency factor (0.14-0.15)

tan α = Dynamic solid friction (0.375-0.51)

w = Fall velocity (0.35 ft/sec.)

The equation estimates transport of contaminants attached to sediment that have a specific gravity or approximately 2.69. The approach was used to quantify sediment transport; it does not quantify contaminated material transport. The assumption is made that metals have adsorbed or will adsorb to sediment particles.

The average weighted velocity and shear stress for the 2-yr., 10-yr. and 100-yr. events was estimated, using the U.S. Army Corps of Engineers, HEC-2 computer program (Asarco, 1992). Based on information contained in the Floodplain Information Report, the 2-yr. and 10-yr. peak flows were assumed to result from a snowmelt flood and the 100-yr. peak flows were assumed to result from a rainfall event. A detailed discussion of the hydrology of the California Gulch watershed can be found in the Floodplain Information Report. Snowmelt events were assumed to last 8 hours. This corresponds to the warmest part of the day which was assumed to be 9:00 a.m. to 5:00 p.m. The duration of the rainfall event was estimated from the HEC-1 runoff simulation model and was assumed to be a 6-hour storm.

The ability of a reach to transport sediment was quantified and the results of the analysis are shown in Table 5-19. The supporting calculations are included in Appendix E. It is assumed that stream reaches with sediment transport changes of less than 20 percent are in transition, these reaches may be aggrading or degrading. Results indicate that sediment transport potentials are not drastically different from reach to reach during the lower flow events, however, sediment transport potential varies from reach to reach during higher flow events.

Assuming that the average annual sediment yield of the watershed is approximately equal to the average 2-year transport in California Gulch, the estimated annual sediment yield from California Gulch to the Arkansas River is 1,700 tons/year. Further assuming a unit weight of sediment of 100 pounds per cubic foot, the amount of sediment discharged annually to the Arkansas River is estimated to be 1,260 cubic yards.

5.3 Seasonal Variation of Metals of Concern in California Gulch

Figures 5-11 through 5-18 are schematic depictions of total metal concentrations for aluminum, cadmium, copper, iron, lead, manganese, and zinc. Tables 5-1 through 5-8 summarize total metal concentrations for different sampling events. Figure 5-2 presents discharge, pH, and TSS for California Gulch. Figures 5-3 through 5-10 present total metal concentrations in surface water and sediment, and total metal loads of the metals of concern in California Gulch.

Concentrations of total and dissolved metals in surface water and sediments generally varied throughout the year at Stations CG-1, CG-2, CG-3 and CG-6. However, concentrations of aluminum, cadmium, copper, iron, and lead in surface water at Station CG-4 increased by an order of magnitude during the ice-off sampling event (Figures 5-3 through 5-10). The increase occurred in both total and dissolved concentrations (except for dissolved aluminum) for these metals in water compared to average concentrations measured at the same station during other times of the year. The increase was not apparent in the sediments at Station CG-4 during the ice-off sampling event. Total suspended solids in surface water also increased by an order of magnitude at CG-4 during the ice-off sampling event, compared to average values measured during other times of the year (Figure 5-2).

A similar increase in total and dissolved concentrations in the surface water occurred for aluminum, copper, iron, and lead at CG-5 during the summer sampling event. A peak in concentration of cadmium was not appearant at CG-5 during the summer sampling event, although the concentration level increased at CG-5, it remained high downstream to Station

CG-6 and did not return to the low-average levels measured in CG-1, CG-2, and CG-3. Samples measured during the summer event at CG-5 had concentrations for the four metals that were 1.3 to 5 times greater than values measured during the ice-off event. Total suspended solids at CG-5 also were three times greater during hte summer sampling event than total suspended solids values measured during the ice-off sampling event (Figure 5-2). Other trends in concentration values are not apparent in the data presented in Figures 5-3 through 5-10. A more detailed dixcussion of the metals concentration variations is presented in the following sections.

Seasonal changes in surface water metals concentrations may result from re-introduction of metals from temporarily suspended sediments during periods of high flow. The ice-off (April/May) and summer (July) flow rates reflect peak flow periods in California Gulch (Figure 5-2). Another factor influencing higher concentrations may be a slight decrease in pH at Station CG-4 during the ice-off sampling event and increased pH at Station CG-5 (Figure 5-2). The pH also decreased slightly at Station CG-4 during the summer sampling event (compared to the upstream CG-3 station). However the pH at CG-5 was slightly lower than the pH at Station CG-4 during the summer sampling event.

Figures 5-11 through 5-18 present schematic diagrams of metals concentrations for samples from California Gulch and its tributaries and the Arkansas River and its tributaries, including Tennessee Creek, Halfmoon Creek, Iowa Gulch, and Empire Gulch. Data presented in the schematic diagrams indicate that tributaries to California Gulch contain metals concentrations at significantly higher levels than tributaries to the Arkansas River. However, Stray Horse, Oregon, Georgia, Pawnee, Airport, and Malta Gulch (California Gulch tributaries) periodically go dry, during which time they contribute nothing to the metals load in California Gulch. Flow from the California Gulch tributaries is generally minor, compared to the surface stream in California Gulch and several tributaries to the Arkansas River, other than California Gulch, go dry during portions of the year. A discussion of metals loads in California Gulch and the Arkansas River is presented in the following sections.

Total lead concentrations are highest during the Ice-Off and Summer sampling event. The maximum total lead value of 38,800 μg/l during mobilized during periods of high surface water runoff. (Dissolved lead levels are low to not-detect during the same high Summer values for total lead.) Low surface water pH values during the Ice-off and Spring events do not seem to correlate with total lead concentrations.

High lead values during the Ice-Off and Summer events may be related to total suspended solids values which appear to correlate with high total lead values. The tendency for lead to sorb onto solid surfaces, such as clay- or silt-sized suspended sediments may account for corresponding total lead values.

A slight increase in discharge occurred between Stations CG-5 and CG-6 during all seasonal sampling events. A similar increase in pH occurred between Stations CG-5 and CG-6, except for the ice-off sampling event (Figure 5-2). A corresponding order of magnitude increase in aluminum, cadmium, copper, and zinc concentrations in sediments occurred between Stations CG-5 and CG-6 during the ice-off sampling event. Iron and lead sediment concentrations also increased significantly between Stations CG-5 and CG-6 during the ice-off sampling event. Section 5.4 discusses metals loading from California Gulch into the Arkansas River.

5.3.1 Ice-Off Sampling Event

A peak of total metal concentrations and loads of zinc, copper, lead, aluminum, cadmium, and iron in surface water at Station CG-4 during the Ice-Off event. This peak corresponds to a peak in total suspended solids (TSS), increased discharge, and a decrease in pH. High metal concentrations, high suspended solids, low pH and increased discharge suggest that this peak is related to a surface metals source between CG-3 and CG-4, possibly Oregon Gulch and Starr Ditch. OG-1 had a discharge of 0.5 cfs and elevated concentrations of zinc, lead, copper, and aluminum. The Starr Ditch had a flow of 0.6 cfs and similarly elevated metal concentrations.

Metal loading during the Ice-Off sampling event showed a peak load at CG-4 and a subsequent decrease at CG-5 and CG-6. Loading to California Gulch during the Ice-Off sampling event appeared to come primarily from Malta Gulch (Station MG-01), Oregon Gulch (OG-01), and Starr Ditch (SD-01). Malta Gulch appears to have contributed significant amounts of aluminum, cadmium and lead to California Gulch during the Ice-Off event. Malta Gulch was dry during the other sampling events. Oregon Gulch contributed significant amounts of aluminum, copper, iron, lead, manganese and zinc during the Ice-Off event. Starr Ditch contributed significant amounts of aluminum, cadmium, copper, lead, and zinc during the Ice-off event. Metals loading from the tributaries to California Gulch were not significant during the Spring, Summer, Fall, and Winter events.

Since total load is representative of total mass of metal moving downstream at a give sampling point, a decrease in load indicates a loss in metals. Two possible mechanisms that could cause metals to be removed form the California Gulch are: 1) loss of metals to groundwater along losing stream reaches, and 2) precipitation or adsorption of metals to stream bed material. Refer to section 5.2.1 for how metals may originate in sediments. As metals precipitate onto sediments, the relative concentrations of metals in sediments increase. Seasonal changes in sediment concentrations includes changes in pH of surface water with corresponding precipitation or dissolution of metals in the sediments. While dilution of surface water by purer water will result in a reduction in overall concentration, it will not change the total load carried by the stream.

5.3.2 Spring Sampling Event

An increase in zinc, copper and cadmium loads and concentrations were noted between CG-2 and CG-3 during the Spring sampling event. Total suspended solids did not increase but pH did increase slightly with the increase in metals at CG-3. Discharge also increased at CG-3, which appears to be as fast or, one possible source between these two locations is the Apache tailings impoundment. Another possible source for these contaminants is groundwater moving in the vicinity of Starr Ditch. The confluence of both Starr Ditch and the Yak Tunnel surge pond discharge with California Gulch are in close proximity to CG-3. Although Starr Ditch discharges into California Gulch below CG-3, groundwater in the vicinity of the ditch may intersect the California Gulch above CG-3.

Metals loading during the spring sampling event show a sharp increase at CG-3 for zinc and cadmium and a subsequent downstream decrease and leveling off. A decrease in metals loads is indicative of a loss of metals, either to the sediment via precipitation or adsorption, or as a loss to groundwater.

5.3.3 Summer Sampling Event

A peak in concentration and load relative to other sampling stations and sampling events of total aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc, occurred at CG-5 during the Summer sampling event. This peak in concentration correlates with a peak in total suspended solids. Total metal concentrations at the other surface water sampling points were lower than Ice-Off and Spring sampling event concentrations.

Possible metal sources for the peak at CG-5 include the Colorado Zinc-Lead Tailings impoundment, the La Plata slag, the Arkansas Valley slag, and several other smaller waste rock or tailings impoundments. Groundwater in the vicinity of the Colorado Zinc-Lead tailings pile has elevated concentrations of zinc, cadmium, lead and aluminum. Stormwater run-off from the City of Leadville is another potential source of metals in the gulch. The sampling period corresponded with the highest monthly precipitation during the year. As shown in Figure 3-3, a discrepancy exists between measured and calculated discharge at CG-5 during the Summer event, indicating a surface water or groundwater source entering California Gulch surface water, other than upstream flow. Stormwater from the City of Leadville discharges between CG-4 and CG-5.

The total loads for all metals shows an increase at CG-5 and a decrease at CG-6, suggesting a loss of metals to either groundwater or to the steam bed material.

An anomolously high pH value of 11.61 was recorded at CG-3 during the Summer event. A pH this high is unlikely to occur naturally, particularly in an alpine riparian environment such as California Gulch. The high pH value could also be the result of a discharge from the yak Tunnel surge pond Filter Unit which is immediately upstream of CG-3. During the summer of 1991, lime adjustments were made to the surge pond.

5.3.4 Summer Storms Sampling Events

As discussed in Section 3, surface water samples were taken during three summer storm events. Samples were taken at stations AR-2, AR-3E, and CG-6 only. Analysis indicates that runoff from California Gulch greatly influences metals concentrations and loading rates in the Arkansas River. Figures 5-19 through 5-25 present Summer Storm loading hydrographs for cadmium, copper, iron, lead and zinc. Aluminum was not sampled during the Summer Storm events. A slight increase in cadmium and zinc load in California Gulch during the August 30 storm in seen in Figures 5-19 and 5-25. This may result from a gradual increase in inflow of relatively low pH rain water and increasing discharge during the storm, prior to the peak discharge at 20:09. Section 5.4.2 presents analysis of the contribution of California Gulch to Arkansas River metals loading.

August 24, 1991 Summer Storm

During the August 24 storm event, samples were taken at ninety minute intervals. This time interval was determined to be too long to capture typical storm event data. Total metal concentrations at CG-6 were within ranges reported for other sampling events along California Gulch (Stations CG-1 through CG-6).

August 30, 1991 Summer Storm

Total metal concentrations at CG-6 were within ranges reported for other sampling events along California Gulch (Stations CG-1 through CG-6). Peaks in total metal concentrations and loads generally correlated with peaks in discharge.

September 11, 1991 Summer Storm

Peak concentrations of the metals of concern at CG-6 were above the ranges reported for other sampling events along California Gulch (Stations CG-1 through CG-6). Peak total concentrations of cadmium and zinc were approximately five times greater than the highest concentrations recorded during all other sampling events. Peak total concentrations of copper, iron, and lead were approximately two times greater than the highest concentration recorded during all other sampling events. Peaks in total metal concentrations were correlated with sharp decreases in pH and increases in TSS. The pH decreased from 7.8 to 3.0 during the same 1/2 hour that concentrations increased. Due to the lack of sampling at other stations along California Gulch, specific sources of metal loading to the gulch during this event cannot be readily determined.

5.3.5 Fall Sampling Event

The fall sampling event was characterized by very low flows along California Gulch. Total zinc and cadmium were elevated in surface water, showing a high initial concentration at CG-3 and an increase at CG-4. Total lead, copper, aluminum, and iron had low concentrations. The increase in zinc and cadmium at CG-4 did not correlate with TSS, but did correlate with a slight decrease in pH. Concentrations generally decreased at CG-5 and CG-6.

Since California Gulch was in a "baseflow" condition during this period, and all other tributaries were dry, the source of the zinc increase is likely to be either groundwater inputs or desorption/dissolution from stream bed sediments. Groundwater along the reach from CG-3 to

CG-4 is elevated in metals and fluctuates between losing and gaining as described in Section 3 of the Hydrogeologic RI. Groundwater near the Apache Tailings deposit is high in zinc and cadmium but relatively low in lead and copper, which is similar to the Fall CG-4 surface water.

5.3.6 Winter Sampling Event

The Winter sampling event was characterized by low flows and low metal concentrations. Concentrations for total zinc and cadmium showed a slight increase between CG-3 and CG-4. Total lead, copper, iron and aluminum did not show a significant increase in this reach. During the Winter sampling event California Gulch appeared to be in "baseflow" conditions, similar to the fall sampling event. All tributaries to California Gulch were dry during the Winter event with the exception of Starr Ditch. However, the volume of flow and metals concentrations in the Starr Ditch were too low to account for any of the observed changes in California Gulch.

During the Winter event, the Yak Tunnel WTP contributed most of the flow to California Gulch from CG-2 to CG-5. The Yak Tunnel WTP came on-line in February, 1992, after the Fall Sampling event and prior to the Winter sampling event. After coming on-line, the Yak Tunnel WTP discharged between stations CG-1 and CG-2. Prior to the WTP operation, the Yak Tunnel Filter Plant discharged below the surge pond between CG-2 and CG-3. Relatively low metals concentrations in California Gulch during the Winter sampling event can be attributed to the fact that the majority of discharge to the gulch was treated water from the Yak Tunnel WTP and the Leadville WWTP. As during the Fall event, surface water discharge did not change much along the length of the stream, suggesting that the input of groundwater to the stream was small.

5.4 Contribution of California Gulch Metals to the Arkansas River

Contribution of metals in California Gulch to the Arkansas River were evaluated based on both concentrations and loads. Metals loading rates were determined by multiplying the surface water discharge by the concentration of metals and a conversion factor as follows:

$$Q_m = Q_w \text{ X } C_m \text{ X } k$$

where:

Q_m = metal loading rate (pounds per day) (lbs/day)
Q_w = water discharge (cubic feet per second) (cfs)
C_m = concentration of metal (micrograms per liter) (μg/l)
k = conversion factor to lbs/day = .0054

Section 3.2.1 presents a discussion of discharge measurement and errors.

Total metal loading rates were calculated from measured concentrations for the metals of concern. For purposes of numerical comparisons, values which were non-detect were assumed to have a value of half the instrument detection limit. Total metals concentrations were used in the calculations because they represent all forms (suspended and dissolved) of the metal analyzed, variations in the dissolved/total metal ratio is discussed in Section 5.1.1. Total metal loads in California Gulch are presented in Figures 5-3 through 5-10. Summer storm loading hydrographs are presented in Figures 5-19 through 5-25.

Evaluation of the data presented in Figures 5-19 through 5-25 indicates that total loads of cadmium, copper, iron, lead, and zinc are generally higher at the AR-3E sampling station than at Station CG-6 during peak summer storm events. This is because the AR-3E load includes both the load in the Arkansas River above the confluence with California Gulch (AR-2) plus the load contributed from California (CG-6).

5.4.1 Ice-Off, Spring, Summer, Fall and Winter Loading

Table 5-20 presents a comparison of µg/l of total metal concentrations in the Arkansas River above and below the confluence with California gulch for the Ice-Off, Spring, Summer, Fall and Winter sampling events. Surface water data from Station AR-3 were used for the Ice-Off and Spring Sampling events. The data from AR-3E were used for all other sampling events. Data from Station AR-3E had higher metal concentrations than AR-3W.

Table 5-21 is a comparison of lbs/day of total metal as calculated loads in the Arkansas River above and below the confluence with California Gulch. California Gulch metals loading contributions to the Arkansas River correlate with high metal concentrations in California Gulch, rather than to periods of high flow. California Gulch generally contributed significantly to the lead, manganese, iron and zinc loads to the Arkansas River. Contributions were particularly high during the Winter sampling event. Although California Gulch surface waters also contributed to the total metal concentrations and loads of other metals in the Arkansas River, concentrations both upstream and downstream of California Gulch were below the CRDL.

The increased total metal concentrations and loads measured in the Arkansas River immediately below California Gulch do not persist further down the river. Downstream of Station AR-3E/W, total metals concentrations generally decrease and discharge increases, resulting in a decrease in total metal loads.

5.4.2 Summer Storm Loading

As discused in Section 5.3.4, analysis indicates that storm discharge from California Gulch greatly influences metal concentrations and loading rates in the Arkansas River. Figures 5-19 through 5-25 present Summer Storm loading hydrographs for cadmium, copper, iron, lead and zinc. Total metal concentrations in the Arkansas River upstream of California Gulch at Station AR-2 were within ranges observed during other sampling events. However, significant increases in total metal concentrations and loads were observed in the Arkansas River below the confluence with California Gulch at Station AR-3E during the August 30 and September 11 summer storms. These peaks correlate in time with peaks in total metal loads at Station CG-6.

In general, peak total metal loads observed during the September 11 summer storm event were approximately one order of magnitude greater than peaks during the August 30 storm. These variations appear to correlate with trends in pH and TSS during the two events. The pH and TSS at Station AR-3E remained relatively constant during the August 30 storm. During the September 11 storm, pH dropped from 8.0 to 6.5 and TSS increased from 4 to 172 mg/l during the same 1/2 hour period that total metal concentrations increased at least one order of magnitude.

5.5 Potential for Acid Mine Drainage

Acid mine drainage (AMD) produces waters of low acidity (often with pH values of 3 or lower) and elevated metals and sulfate concentrations. AMD results from a sequence of events which can be catalyzed by bacteria capable of living in very acidic waters. Once initiated, the AMD-generating cycle can continue and intensify. The sequence can be represented by the following series of equations describing the oxidation of pyrite (FeS_2), the most common iron sulfide (Stumm and Morgan, 1981):

$$FeS_{2(s)} + 7/2O_2\ H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$$

$$Fe^{2+} + 1/4O_2 + H^+ = Fe^{3+} + 1/2H_2O$$

$$Fe^{3+} + 3H_2O = Fe(OH)_{3(s)} + 3H^+$$

$$FeS_{2(s)} + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

Once the oxidation of pyrite is well established, it can continue even as oxygen is depleted, since the Fe(III) precipitated in ferric hydroxide ($Fe[OH]_3$) can be redissolved and participate in oxidation of further pyrite (Stumm and Morgan, 1981). In the series of reaction in acidic environments, the rate-limiting step is the oxidation of ferrous (Fe[II]) to ferric (Fe[III]) iron (second reaction above). This step is catalyzed by bacteria such as Thiobacillus and Ferrobacillus ferrooxidans which thrive in acidic conditions. As emphasized by several authors, the decomposition of iron pyrite is among the most acidic of all weathering reactions (Stumm and Morgan, 1981; Wentz, 1974).

The series of reactions essentially describes the acid production process with pyrite that occurs at coal mines, but additional reactions occur at metal mines due to the mix of sulfide minerals (Ferguson and Erickson, 1987). The oxidation of sulfide ore minerals adds trace metal ions to solution but does not increase acidity. As an example, the oxidation of sphalerite (ZnS) liberates zinc and sulfate ions (Wentz, 1974):

$$Zn\ S_{(s)} = 20_2 = Zn^{2+} + SO_4^{2-}$$

In production of AMD, the key biochemical parameters affecting acid generation include temperature, pH, oxygen concentration, carbon dioxide concentration, the presence of nutrients, moisture content, and mass and surface area of pyrite present (Knapp, 1987). Even in the presence of favorable biochemical factors, AMD may not be a problem at a mining site if the acidity is neutralized by carbonates in the mine tailings or waste. Carbonates such as calcite ($CaCO_3$) and dolomite ($CaMg[CO]_2$) are effective neutralizers of acid, while metal carbonates such as siderite ($FeCO_3$) are less effective. In addition, in a specific mine waste or tailings, the rate of oxidation of pyrite and release of oxidation products may be less than or greater than the rate of dissolution of neutralizing carbonates.

The geochemical signature of AMD may be altered by further reactions, such as ion exchange on clay surfaces, gypsum or jarosite precipitation, and acid-induced dissolution of other minerals (Ferguson and Erickson, 1987). AMD is affected by the physical characteristics of a mine waste, slag, or tailings pile, the spatial relationship between wastes, and other hydrologic cycle. Important physical characteristics of mine waste or tailings include mineralogy, particle size (fine grained sulfides are more reactive), physical weathering tendency, and waste or tailings permeability (Ferguson and Erickson, 1987).

The pH values measured in California Gulch at Stations CG-1 through CG-6 varied seasonally, typically between about 5 and 8, with the lowest values generally occurring during the Spring (Figure 5-2). A minimum seasonal pH value of 3.5 occurred during the Spring sampling event at Station CG-4. The minimum pH value measured in California Gulch surface water during the RI was 2.8 at Station CG-6. This value was measured at the peak of a Summer storm event on September 11, 1991. During the storm, pH values in California Gulch dropped from 7.1 to 2.8 over a period of 27 minutes (Appendix D). The rapid drop in pH appears to have occurred as storm runoff flowed into the California Gulch surface stream. As the storm peak receded, pH values increased at CG-6 to 3.7 during less than 1 1/2 hours.

Based on Tailing and Mine Waste RI reports, it appears that Apache Tailings, Colorado Zinc Tailings, Oregon Gulch Tailings, Fluvial Site No. 2, Fluvial Site No. 3, Fluvial Site No. 4, Fluvial Site No. 6, fluvial Site No. 8 (Arkansas River portion), and the Mine Waste in the Stray Horse Gulch area all have the potential for generating AMD.

The data utilized in the Tailings and Mine Waste RI reports were derived from samples taken during the Fall typically a low flow rate season. Some areas proposed to be sampled were actually dry and did not contribute to surface water flows in California Gulch. Increased flow rates and erosion associated with runoff from the tailings and mine waste areas may affect the water quality within California Gulch. This is apparent from the Summer storms analysis loading hydrographs. During periods of rainfall-runoff/snowmelt, metals loading rates may increase due to erosional processes occurring within the watershed which tend to release contaminated materials to surface waters.

TABLE 5-1
Surface Water Laboratory Test Results
Ice-Off, 1991 Sampling

	California Gulch						California Gulch Tributaries							Arkansas River					Arkansas River Tributaries							
STATION	**CG-1**	**CG-2**	**CG-3**	**CG-4**	**CG-5**	**CG-6**	**AG-1**	**GG-1**	**MG-1**	**OG-1**	**PG-1**	**SD-1**	**SG-1**	**AR-1**	**AR-2**	**AR-3**	**AR-4**	**AR-5**	**EF-2**	**EM-2**	**EM-3**	**EM-4**	**HC-1**	**IG-1**	**LF-1**	**TC-01**
TOTAL METALS (ug/L)																										
Aluminum	2010	5350	490	30500	7290	6600	23800	2790	55300	381000	8470	52800	1660	53	U	U	319	161	U	360	86.4	1620	U	U	83.1	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	24.5	263	3.3	253	19.6	122	574	40.6	28.8	245	54	581	18.2	U	U	U	1.6	2.1	U	1.2	U	5.7	U	U	U	U
Barium	71.7	127	48.2	488	65.4	228	812	109	1310	2610	369	2300	98.2	60.9	63.9	61.6	47.2	46.6	100	105	0	0	22	57.8	18.7	24.4
Cadmium	97.5	154	67.5	151	87.7	57.3	52.8	4.6	170	89.5	33.4	772	163	0.6	0.62	0.88	3.6	1.9	1.6	1.1	0.28	2.6	0.27	0.32	0.25	0.44
Chromium	U	U	U	U	U	U	17.1	U	55.8	U	U	50	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	94	208	51.9	2420	404	494	1050	80.8	1100	10200	180	12900	145	2.8	4.7	5.3	36.1	9.5	2.8	3.3	17	10.9	2.1	U	3.2	3.7
Iron	8710	40900	2920	211000	39500	42000	25600	4000	99900	8130000	17700	290000	10800	563	493	561	1680	815	270	1090	220	2520	56.5	79.3	690	909
Lead	2960	3190	96.7	10500	1180	3550	11100	932	16500	25500	2750	55900	2490	U	U	4.5	27.5	19.2	1.5	15.8	4.5	103	U	5.6	U	U
Manganese	1810	13300	6460	61900	34800	9770	973	325	3720	2510000	2060	33100	4160	97.4	89.6	0	540	228	410	104	14.8	179	U	U	88.8	52.2
Mercury	U	0.3	U	2.3	0.5	1.3	1.9	U	2.9	0.3	0.6	9	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	24.4	22.2	65.2	47.9	U	21.8	U	45.9	1600	U	113	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	U	U	U	U	8.5	11.8	U	U	U	U	U	U	U	U	U	1.9	U	4.1	4.5	U	U	U	U	U	U	U
Silver	7.1	11.7	U	74	3.3	20.5	43.4	2.3	85.8	12.9	14.8	381	8.8	U	U	0.55	U	U	U	U	U	U	U	U	U	U
Zinc	10300	17900	20200	51100	32700	15700	1190	1180	14100	1110000	4360	106000	15600	0	198	276	0	0	689	37.5	17.2	81.4	11.7	14.4	25	94
DISSOLVED METALS (ug/L)																										
Aluminum	701	202	U	8920	6110	U	93.8	85.8	77.3	33500	88.1	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	U	1.3	U	U	8.4	11.2	1.2	15.8	3.8	U	U	U	U	U	U	23	U	U	U	1.4	U	U	U	U
Barium	31	28.2	44.2	65.7	34	20	U	U	143	45.8	35.4	33	42.6	U	65.8	60.1	24.9	24.6	U	96	111	95.3	21.7	59.3	U	U
Cadmium	122	163	66.1	146	88.4	47.8	5.2	1.9	63.2	110	2.9	136	165	0.32	0.72	1.2	1.5	2.7	0.88	U	0.12	0.12	0.1	0.1	0.14	0.56
Chromium	U	31.9	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	31.1	10.6	3.8	888	333	8.7	38.4	9.7	43.4	893	13.2	16.8	38.9	2	3	5.1	13.1	33.4	2.5	2.9	2.1	25	23.8	1.2	3.4	6.1
Iron	200	8700	229	90600	22900	U	121	61	48.8	728000	105	71.5	49.7	381	340	310	254	202	U	98.1	U	U	63.2	63.2	292	720
Lead	687	35.1	1	2240	433	U	55.8	15.5	226	47.3	12.9	8.6	313	U	U	U	1.2	18.6	U	U	U	U	U	3.5	U	U
Manganese	2130	13800	6660	57400	36400	9680	113	U	448	257000	57.9	1940	3560	93.9	92.6	190	493	142	425	33.5	U	U	10.3	U	70	52.1
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	U	50.1	38.6	U	U	U	U	192	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	10	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	11.6	U	U	U	U	U	U	U	U
Silver	0.5	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	3.2	U	U	U	U	U	U	U	U
Zinc	12400	17900	21100	42100	35100	11800	171	34	3280	114000	177	6140	15300	18.6	30	140	0	0	U	U	U	U	U	2.4	U	52
MAJOR CONSTITUENTS																										
pH (Field)	4.93	7.65	7.57	2.89	10.14	8.12	6.07	8.46	3.36	3.33	8.32	6.45	4.23	7	7.01	8	7.74	7.71	7.94	7.75	7.57	7.57	7.8	7.41	7.35	7.69
Alkalinity (mg/L)	U	U	45	U	U	23	3	19	2	U	16	23	U	U	84	72	33	66	109	119	111	107	37	124	27	39
Calcium (mg/L)	37	242	68	87	92	57	2	5	4	77	10	68	47	27	28	30	19	22	52	27	32	30	10	92	9	11
Chloride (mg/L)	U	U	U	U	3	5	U	U	U	2	U	U	U	U	U	2	2	2	U	U	U	U	U	2	U	U
Cyanide	U	U	U	38	U	U	U	U	U	3	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Dissolved Organic Carbon (mg/L)	U	U	U	U	U	11	U	U	7	U	U	4	U	7	6	8	14	14	50	U	54	7	15	7	7	14
Fluoride (mg/L)	U	0.5	0.2	0.2	0.2	U	U	U	U	U	U	0.2	U	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.3	0.3	0.1	U	0.2	U
Magnesium (mg/L)	6	74	34	98	75	28	U	U	U	350	2	15	10	10	11	11	8	8	21	11	10	10	4	34	3	4
Nitrate + Nitrite (mg/L) as N	0.62	1.16	0.1	0.82	0.61	0.29	0.32	0.02	5.36	0.39	U	0.43	2.02	0.37	4.14	U	3.9	0.14	0.22	0.99	0.29	0.43	1.35	0.31	U	0.65
Potassium (mg/L)	U	4	2	2	2	3	1	U	2	U	3	3	U	2	2	2	1	2	U	U	1	1	1	1	U	2
Silica (mg/L)	2	6	8	11	14	8	2	3	3	15	4	3	2	8	8	8	7	8	7	7	7	7	6	7	7	9
Sodium (mg/L)	U	6	3	3	5	8	U	U	U	6	U	2	U	2	3	5	4	5	2	2	2	2	2	3	4	3
Specific Conductivity (umhos/cm)	307	1390	617	1530	1130	562	21	35	89	4230	76	435	350	218	222	238	177	195	386	205	226	196	86	603	87	95
Sulfate (mg/L)	70	984	200	1020	729	296	4	U	6	3300	23	214	187	51	43	51	58	49	117	8	10	14	8	243	12	16
Total Dissolved Solids (mg/L)	208	1470	502	1640	1110	464	48	50	84	6010	78	354	290	156	176	146	116	126	276	138	132	128	60	492	60	88
Total Suspended Solids (mg/L)	152	334	12	868	114	446	1300	138	2480	522	250	1680	126	U	U	U	U	U	U	22	U	14	U	8	U	U
Total Phosphorus (mg/L) as P	0.18	0.28	0.05	0.73	0.09	1.23	1.2	0.26	2.49	0.32	0.95	2.96	0.19	0.02	U	0.09	0.07	0.06	U	0.05	0.02	0.14	U	U	0.03	0.02

U = Not detected
NA = Not analyzed
R = Data rejected

TABLE 5-2
Surface Water Laboratory Test Results
Spring, 1991 Sampling

	California Gulch						C. G. Tributaries			Arkansas River					Arkansas River Tributaries											
STATION	**CG-1**	**CG-2**	**CG-3**	**CG-4**	**CG-5**	**CG-6**	**OG-1**	**SD-1**	**SG-1**	**AR-1**	**AR-2**	**AR-3**	**AR-4**	**AR-5**	**EF-1**	**EF-2**	**EG-1**	**EG-2**	**EM-1**	**EM-2**	**EM-3**	**EM-4**	**HC-1**	**IG-1**	**LF-1**	**TC-01**
TOTAL METALS (ug/L)																										
Aluminum	20100	7440	1320	3140	2500	1430	312000	11800	10800	408	1010	934	306	451	374	357	58.6	80.7	159	96.2	268	387	72.9	191	180	179
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	13.8	U	U	U	U	33.6	20.7	2.1	1.4	U	U	U	1.1	1.8	1.4	2.7	1.3	U	U	U	1.3	U	1.2	U	1.3
Barium	14	25.5	33.4	33.9	31.6	34.8	U	76.3	31.8	35.2	46	47.3	32.4	U	44.7	48.6	52.1	50.6	73.5	81.7	97.3	115	14	45.6	12.8	12.5
Cadmium	198	236	290	276	217	138	557	357	344	0.59	0.94	3	1.7	2.7	0.66	0.56	0.87	0.8	0.2	0.19	0.16	0.34	0.22	0.64	0.32	0.67
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	639	330	822	772	557	300	7800	838	709	8	8	8.8	6.8	U	5.4	5.2	8.1	7.5	3.6	1.2	2.9	5.7	4.4	5.1	4.9	6.3
Iron	3100	4160	2550	8560	8250	4940	2760000	31200	18200	624	1230	1520	567	879	525	574	86.1	94.2	292	237	548	769	65.6	391	494	270
Lead	942	618	62.2	167	212	123	0	1170	203	6.5	12.2	16.6	12	25.8	4.6	6	8.2	8.6	2.7	2	4.7	12.3	1.3	27.9	1.2	2
Manganese	6050	7450	15600	24900	20700	13600	1490000	14200	13400	83.7	150	322	162	201	49.2	88	13.8	U	16.4	15.5	88.8	80.2	U	122	66.4	51.7
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	U	U	0	39.4	28.4	U	726	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	0	0	0	0	0	0	0	0	0	U	0	0	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	1.2	1.5	U	U	U	U	1.9	5.2	0.81	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	26100	31000	61200	61200	50700	32500	634000	44600	43500	115	166	570	344	385	29.2	101	101	113	14.8	U	U	19.8	10.2	117	25	88.8
DISSOLVED METALS (ug/L)																										
Aluminum	22500	7800	300	2880	323	U	331000	11400	12300	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	66.2
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	U	1	U	U	0	1.4	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Barium	13.7	17.7	37.2	35.5	32.8	29.9	U	46.5	34.7	16.6	19.4	23.6	26.9	28.1	33.6	32.8	49.6	50.8	66.3	77	86.6	108	13.6	37	10.4	10
Cadmium	225	257	327	313	254	137	555	410	393	0.31	3.9	1.6	1.5	1.8	U	0.29	0.46	0.54	U	U	U	U	U	0.19	1.5	0.41
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	713	355	874	863	580	20.7	8420	910	801	4.3	8.2	5.5	8.7	10.2	2.6	3.8	3.6	4	1.4	1.4	3	1.2	4.1	7.5	4.5	8.6
Iron	2340	1200	2320	6400	4800	U	2800000	10500	17600	72.4	85.2	89.1	91.5	89.6	43.1	40.1	U	U	45	28.4	99.4	58.2	U	U	202	119
Lead	997	492	37.8	171	107	5	0	899	208	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	6570	7850	17300	27800	23200	15100	1530000	15600	14800	26.2	23.8	202	115	97.5	U	36.5	U	U	U	U	10.3	U	U	11.1	54.7	33.3
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	29.5	26.8	0	47.9	43	28.6	916	20.4	27.1	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	U	U	U	1.5	U	1.2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	0.65	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	30500	34100	71400	71900	59400	33400	644000	52400	50700	45.8	43.7	376	202	189	U	19.9	U	U	U	U	U	U	U	U	U	64.9
MAJOR CONSTITUENTS																										
pH (Field)	3.47	4.61	5.69	3.99	5.62	7.45	2.32	3.62	3.22	7.54	7.58	7.58	7.84	7.88	7.61	7.93	8.32	7.76	7.68	8.07	8.16	7.84	8.07	8.12	8	6.6
Alkalinity (mg/L)	U	U	2	U	2	25	U	U	U	29	27	28	29	31	37	41	56	58	50	72	81	90	22	75	24	14
Calcium (mg/L)	47	125	124	131	124	91	70	60	45	9	9	11	10	13	12	14	16	17	14	19	22	26	6	80	7	4
Chloride (mg/L)	U	U	U	U	6	10	3	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Cyanide	U	U	U	U	U	U	0	0	0	U	U	U	11	11	U	U	U	U	U	U	U	U	6	6	7	U
Dissolved Organic Carbon (mg/L)	8	7	U	U	7	14	24	8	7	13	19	16	13	12	11	14	16	15	14	10	11	9	7	9	15	13
Fluoride (mg/L)	0.5	0.7	0.4	0.4	0.3	0.2	U	0.4	0.33	U	0.3	0.2	0.3	0.4	0.2	0.2	U	U	0.3	0.3	0.3	0.3	0.4	0.4	0.2	U
Magnesium (mg/L)	19	37	62	75	68	50	395	41	34	4	4	4	4	5	4	6	8	8	6	8	9	10	2	19	2	U
Nitrate + Nitrite (mg/L) as N	0.4	0.32	0.29	0.27	0.39	0.44	0.21	0.12	0.09	U	U	U	U	U	0.05	0.05	0.05	0.04	0.18	0.03	U	U	0.04	0.27	U	U
Potassium (mg/L)	2	3	2	3	3	5	U	2	2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	2	U	U
Silica (mg/L)	55	41	19	21	21	17	28	30	28	5	5	5	6	6	4	4	3	3	4	5	7	7	4	5	7	5
Sodium (mg/L)	4	4	5	6	7	16	5	2	2	U	U	U	2	2	U	U	U	U	U	U	U	U	U	3	3	U
Specific Conductivity (umhos/cm)	637	885	986	1120	1000	777	13300	828	937	77	62	74	75	99	90	106	136	137	91	126	140	158	41	438	50	32
Sulfate (mg/L)	403	613	739	815	761	508	7480	539	504	31	35	37	33	41	35	45	35	54	14	14	39	35	29	214	31	41
Total Dissolved Solids (mg/L)	630	876	1050	1210	1170	768	29600	802	802	60	80	76	86	88	76	82	82	96	60	106	114	114	38	380	68	42
Total Suspended Solids (mg/L)	U	12	U	14	U	10	80	126	12	U	18	44	4	16	U	4	4	4	4	U	U	14	2	2	U	6
Total Phosphorus (mg/L) as P	U	0.02	U	0.03	0.02	1.36	0.38	0.56	0.14	0.02	0.05	0.07	0.03	0.04	0.02	0.03	U	U	0.01	U	0.02	0.03	U	U	0.02	U

U = Not detected
NA = Not analyzed
R = Data rejected

TABLE 5-3
Surface Water Laboratory Test Results
Summer, 1991 Sampling

	California Gulch				C. G. Tributaries			Arkansas River								Arkansas River Tributaries						
STATION	**CG-3**	**CG-4**	**CG-5**	**CG-6**	**OG-1**	**SD-1**	**SG-1**	**AR-1**	**AR-2**	**AR3E**	**AR3W**	**AR3A**	**AR-4**	**AR-5**	**EM-1**	**EM-2**	**EM-3**	**EM-4**	**HC-1**	**IG-1**	**LF-1**
TOTAL METALS (ug/L)																					
Aluminum	U	9	318	2.2	17	0.74	144	U	U	U	U	U	U	U	U	U	2.3	U	U	U	U
Antimony	922	3770	46100	1840	103000	322	65800	92.8	78.4	174	112	114	147	160	97.8	U	438	767	62	214	108
Arsenic	1.2	28.9	627	11.4	601	2.8	1130	U	U	U	U	U	U	U	U	U	1.8	1.6	U	U	U
Barium	47.3	96.6	1600	66.8	U	55.7	350	43.6	51.8	54.5	54.5	53.5	38.5	43	94.8	80.5	107	126	17.6	52.7	15.1
Cadmium	19.2	148	208	186	549	7	959	0.4	0.55	3.4	0.84	2.3	1.5	1.5	U	U	0.27	0.34	U	0.62	0.18
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	117	346	4210	16.9	2340	17	7970	5.2	2.4	11.2	3.5	6.4	8.9	9.7	4.6	2.6	5	2.9	1.5	5.8	4.3
Iron	707	26300	270000	8580	3710000	1060	1170000	245	171	479	206	305	486	515	171	0	873	1270	68.6	411	638
Lead	U	0.2	0.7	U	0.3	U	0.94	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	1440	15800	23200	6160	1260000	309	50000	49.1	45.2	460	75.3	228	182	159	14	0	161	138	U	126	85.2
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	22.4	1840	38800	451	3600	131	8990	1.8	1.9	11.2	2.2	6.3	8.2	14.2	1.4	U	12.3	15	U	21.3	U
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	2.5	NA	U	U	2.8	U	U	U	U	3.6	U	U	U	U	U	U	U	U
Zinc	4730	17900	43600	9690	559000	512	92800	85.4	258	957	311	604	298	329	U	U	30.3	30.6	U	113	25.4
DISSOLVED METALS (ug/L)																					
Aluminum	U	U	U	U	0	U	5.4	U	U	U	U	U	U	NA	U	U	U	U	U	U	U
Antimony	U	U	U	U	96200	U	52200	U	U	U	U	U	U	NA	U	95.6	U	U	U	U	U
Arsenic	1.2	U	U	U	268	U	1110	U	U	U	U	U	U	U	U	U	1.2	U	U	U	U
Barium	36.1	45.1	61.1	37.1	U	48.3	U	41.2	45.5	46.4	43.9	52.2	32.7	NA	83	86.3	76	87.2	13.7	40.3	U
Cadmium	U	78.4	88.6	9.1	664	4.7	934	0.16	0.18	1.2	0.32	1	1	NA	U	0.12	U	U	U	0.16	U
Chromium	U	U	U	U	U	U	U	U	U	U	U	10	U	NA	U	U	U	U	U	U	U
Copper	2	4.2	9.8	6.8	2270	2.8	7880	4.5	2	5.2	3.8	2.4	3.8	NA	U	U	1	1.3	1.4	2	U
Iron	U	65.1	U	U	3650000	236	1080000	124	67.2	44.1	63	45.1	139	NA	37.8	0	129	75.6	32.5	U	292
Lead	U	U	U	U	U	U	0.5	U	U	U	U	U	U	NA	U	U	U	U	U	U	U
Manganese	U	16400	11700	4310	1290000	348	50600	45.3	43.7	324	48.7	165	160	NA	U	0	28.6	21.8	U	28.6	58.8
Mercury	U	25.8	U	U	U	U	U	U	U	U	U	U	U	NA	U	U	U	U	U	U	U
Nickel	U	U	3.6	U	U	U	1420	U	U	U	U	U	U	NA	U	2.2	U	U	U	U	U
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	NA	U	U	U	U	U	U	U
Silver	U	7	U	U	U	U	U	U	1.1	U	U	U	U	NA	U	U	U	U	U	U	U
Zinc	U	9920	7770	114	0	177	94800	U	157	167	U	122	46.1	NA	U	U	U	U	U	U	U
MAJOR CONSTITUENTS																					
pH (Field)	11.61	7.43	6.76	8	2.55	8.14	2.52	8.14	7.87	8.15	8.18	8.08	8.14	8.23	8.33	8.29	8.4	8.07	8.61	8.16	7.48
Alkalinity (mg/L)	20	20	12	50	1	42	U	50	56	64	56	60	44	54	62	74	86	98	28	84	26
Calcium (mg/L)	358	240	189	163	442	24	275	15	17	28	18	23	151	23	16	19	22	26	8	66	8
Chloride (mg/L)	1	2	3	8	6	1	2	U	U	U	U	U	1	1	U	U	U	U	U	U	U
Cyanide	NA	NA	NA	NA	NA	NA	NA	U	NA	NA	NA	NA	U	U	U	U	U	U	U	U	U
Dissolved Organic Carbon (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7	5	9	9	9	7	8	7	10
Fluoride (mg/L)	0.4	0.3	0.2	0.3	0.1	U	U	0.1	0.2	0.3	0.2	0.3	0.2	0.2	0.4	0.4	0.4	0.5	U	0.2	0.2
Magnesium (mg/L)	1	37	34	23	1730	11	89	6	7	8	7	8	6	8	6	8	9	10	3	14	2
Nitrate + Nitrite (mg/L)as N	0.26	0.22	0.43	0.32	0.47	0.12	0.3	1.57	0.02	0.06	0.04	0.04	0.07	0.07	0.25	0.08	U	U	U	0.35	0.02
Potassium (mg/L)	2	2	3	4	6	U	3	U	U	1	U	U	U	U	U	U	U	U	U	U	U
Silica (mg/L)	4	6	5	8	81	4	7	6	6	6	6	6	7	8	4	5	7	8	5	5	7
Sodium (mg/L)	4	4	4	14	26	U	1	1	1	2	1	2	2	3	U	U	U	2	U	2	3
Specific Conductivity (umhos/cm)	1310	1050	842	878	12400	174	4170	98	118	172	125	147	19	147	105	118	140	161	50	336	59
Sulfate (mg/L)	0	0	0	0	0	0	0	U	0	0	0	0	19	49	10	16	23	14	12	154	U
Total Dissolved Solids (mg/L)	1240	1170	1100	898	9430	146	7060	78	86	136	88	110	86	126	84	88	100	120	38	344	54
Total Suspended Solids (mg/L)	106	148	2170	148	490	34	600	8	18	16	16	20	18	18	18	8	12	18	14	20	22
Total Phosphorus (mg/L) as P	U	0.35	0.51	0.83	0.88	U	7.64	U	U	0.04	U	U	U	U	U	U	U	U	U	U	U

U = Not detected
NA = Not analyzed
R = Data rejected

TABLE 5-4
Surface Water Laboratory Test Results
Summer Storm Sampling, August 24, 1991

STATION	AR-2	AR-2	AR-2	AR-2
SAMPLE NUMBER	1	2	3	4
TOTAL METALS (ug/L)				
Arsenic	1.1	U	1.1	NA
Cadmium	0.96	0.37	0.26	NA
Copper	1.1	U	U	NA
Iron	107	106	121	NA
Lead	U	U	U	NA
Manganese	45.9	44.1	44.1	NA
Silver	U	U	U	NA
Zinc	82.3	83.1	82.5	NA
MAJOR CONSTITUENTS				
pH (Field)	7.5	7.89	8.07	8.03
Calcium	23200	23100	23100	NA
Magnesium	8950	9020	8970	NA
Specific Conductivity (umhos/cm)	NA	NA	NA	NA
Total Suspended Solids (mg/L)	4	4	4	U

STATION	AR-3E	AR-3E	AR-3E	AR-3E
SAMPLE NUMBER	1	2	3	4
TOTAL METALS (ug/L)				
Arsenic	U	U	U	U
Cadmium	2	1.1	2	0.97
Copper	U	U	U	U
Iron	124	122	166	120
Lead	1.1	U	1.2	U
Manganese	511	510	441	340
Silver	U	U	U	U
Zinc	422	414	413	369
MAJOR CONSTITUENTS				
pH (Field)	7.97	8.02	8.03	8.09
Calcium	25000	25000	24800	24700
Magnesium	10100	10000	9950	9900
Specific Conductivity (umhos/cm)	NA	NA	NA	NA
Total Suspended Solids (mg/L)	U	4	4	18

STATION	AR-3A	AR-3A	AR-3A	AR-3A
SAMPLE NUMBER	1	2	3	4
TOTAL METALS (ug/L)				
Arsenic	U	U	U	U
Cadmium	3.1	1.6	1.6	0
Copper	8.9	3.2	U	U
Iron	122	108	122	132
Lead	U	U	1.3	1.3
Manganese	297	298	308	282
Silver	U	U	U	0.86
Zinc	326	327	330	330
MAJOR CONSTITUENTS				
pH (Field)	8.04	8	7.97	8.04
Calcium	25100	24500	24600	24300
Magnesium	9960	9720	9780	9600
Specific Conductivity (umhos/cm)	NA	NA	NA	NA
Total Suspended Solids (mg/L)	U	U	4	U

STATION	CG-6	CG-6	CG-6	CG-6
SAMPLE NUMBER	1	2	3	4
TOTAL METALS (ug/L)				
Arsenic	1.1	1.1	1.5	1.4
Cadmium	29.5	31.5	31.1	23.6
Copper	U	30.8	30.8	30.5
Iron	1440	2050	2270	2110
Lead	42.2	51	86.8	1.6
Manganese	9850	9880	7940	6100
Silver	U	U	U	U
Zinc	6840	7400	7200	5980
MAJOR CONSTITUENTS				
pH (Field)	7.98	8.02	8.07	8.09
Calcium	70300	67400	60900	55000
Magnesium	33500	32500	29000	25700
Specific Conductivity (umhos/cm)	NA	NA	NA	NA
Total Suspended Solids (mg/L)	14	20	20	20

U = Not detected
NA = Not analyzed
R = Data rejected

TABLE 5-5
Surface Water Laboratory Test Results
Summer Storm Sampling, August 30, 1991

STATION	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	1.9	U	U	U	U	U	U	U	U	U	U	U
Cadmium	0.26	0.18	0.14	0.12	0.12	0.16	0.12	U	U	0.11	0.25	0.18
Copper	0	0	0	0	999	0	0	0	0	0	0	0
Iron	88.4	87.6	87.4	U	96.4	112	97.6	88.4	94.5	93.6	89.3	93.8
Lead	2	U	U	U	U	U	U	U	U	U	U	U
Manganese	32	33.1	33.9	33.5	33.9	33.9	34.2	31.3	34.2	32	32.8	34.2
Silver	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	59.5	61.2	58.5	56.6	54.9	58.9	57	55.5	58	56.8	57	61
MAJOR CONSTITUENTS												
pH (Field)	*7.5*	*8*	*8.04*	*8.06*	*8.14*	*8.09*	*7.94*	*7.94*	*8.01*	*7.98*	*7.94*	*7.94*
Calcium	21800	21900	22300	22200	22500	22700	22700	22600	22700	22800	22700	23500
Magnesium	8540	8500	8530	8450	8550	8640	8600	8470	U	8610	8510	8830
Specific Conductivity (umhos/cm)	220	190	200	210	230	200	200	220	220	210	210	200
Total Suspended Solids (mg/L)	2	U	U	U	2	2	2	U	4	U	2	U

STATION	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	U	U	U	2.9	U	U	2.5	U	U	U	1.2	1.9
Cadmium	7	7.4	9	7.8	7.8	8.6	10.1	15.6	11.1	10	10	9.8
Copper	9.5	13	28.2	13.3	5.8	7.6	11.9	70.4	14.6	12	16.3	31.2
Iron	138	210	135	5300	589	158	213	1160	306	256	326	364
Lead	0	0	0	0	0	0	0	0	0	0	0	0
Manganese	828	792	1000	991	927	1010	1130	1310	1230	1130	1070	1090
Silver	U	U	U	U	U	U	7	U	U	U	U	U
Zinc	1430	1470	1940	1460	1520	1730	2110	3600	2380	2110	1980	1980
MAJOR CONSTITUENTS												
pH (Field)	7.23	7.66	7.56	7.56	7.64	7.6	7.58	7.6	7.64	7.72	7.78	7.8
Calcium	25800	25600	26100	26400	26200	26500	27100	28100	27900	27600	27000	27200
Magnesium	10600	10500	11000	11000	10900	11000	11400	11800	11600	11500	11300	11300
Specific Conductivity (umhos/cm)	297	297	339	298	300	333	327	291	327	291	278	272
Total Suspended Solids (mg/L)	2	4	6	12	10	10	6	12	6	6	4	U

STATION	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	1.3	U	U	U	U	U	U	U	U	U	U	U
Cadmium	5.5	4.4	4.7	5.2	5.6	5.1	5.5	6.6	8.8	7.5	7.8	6.9
Copper	3.5	3.5	3.8	10	6.9	5.1	5	5.1	25.4	5.7	6.4	8.9
Iron	103	113	122	153	139	127	119	132	443	99.5	162	153
Lead	U	1.3	1.4	2.2	2.4	2.1	1.4	2.1	4.6	1.8	2.6	4.7
Manganese	432	465	453	543	538	528	569	610	736	694	693	616
Silver	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	737	799	827	869	883	934	1030	1170	1800	1350	1360	1190
MAJOR CONSTITUENTS												
pH (Field)	7.68	7.72	7.72	7.82	7.88	7.89	7.94	7.98	7.87	7.79	7.55	7.73
Calcium	24500	24700	24800	24900	25000	25100	25500	25400	26400	26000	27300	25900
Magnesium	9640	9710	9800	9880	9870	9910	10100	10100	10500	10400	10900	10200
Specific Conductivity (umhos/cm)	230	230	240	240	230	274	288	292	305	279	274	272
Total Suspended Solids (mg/L)	U	U	2	U	2	8	2	6	4	4	4	6

STATION	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	U	U	2.1	U	U	U	U	6.8	4.1	4.3	5.1	9.7
Cadmium	71.8	74.4	90.1	86	85.9	88.8	96.8	127	112	99.9	96.6	95.6
Copper	0	0	747	0	0	0	0	620	0	0	0	400
Iron	2280	3290	7880	4000	2820	2980	4730	11200	6000	6940	7220	10900
Lead	45.3	93.8	152	103	60.9	49.9	119	478	305	298	287	418
Manganese	10200	10400	12700	11800	11700	12400	12100	14000	14200	12600	12700	13000
Silver	U	U	U	U	U	U	U	0	0	0	0	0
Zinc	18400	19300	25900	21800	22100	23100	26900	36300	29800	26000	25700	25800
MAJOR CONSTITUENTS												
pH (Field)	7.14	7.46	7.58	7.61	7.61	7.37	7.45	7.23	7.31	7.34	7.23	7.3
Calcium	72000	71900	77600	76800	77600	78400	78000	88700	89100	81700	81700	81700
Magnesium	35100	35900	41400	38800	38700	39500	39000	44100	44200	40100	40600	40700
Specific Conductivity (umhos/cm)	899	984	1020	99	99	1030	1060	1100	1110	1030	1060	1090
Total Suspended Solids (mg/L)	30	40	76	42	36	36	52	92	38	50	56	76

U = Not detected
NA = Not analyzed
R = Data rejected

TABLE 5-6
Surface Water Laboratory Test Results
Summer Storm Sampling, Sept. 11, 1991

STATION	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**	**AR-2**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	U	U	U	U	U	U	U	U	U	U	U	1.1
Cadmium	0.48	0.29	0.27	0.32	0.28	0.4	0.24	0.32	0.33	0.19	0.23	0.3
Copper	3.7	7.3	6.5	6.8	7.2	6.6	7.5	8.4	6.5	1.8	7.3	1.2
Iron	117	108	119	124	122	116	103	119	114	122	119	127
Lead	U	U	U	U	U	U	U	U	U	U	U	U
Manganese	48.5	48	48	49.4	48	48	42.5	46.2	46.2	48	47.5	48.9
Silver	U	U	13.5	U	5.7	U	U	U	U	U	U	U
Zinc	77.5	84.5	85	86.4	81.7	86.4	82.5	85.2	81.2	81.7	89.2	89.4
MAJOR CONSTITUENTS												
pH (Field)	7.01	7.34	7.58	7.779	7.87	7.91	7.96	8.01	8.03	8.1	8.05	8.1
Calcium	22400	22800	22300	23700	22300	22800	22200	22300	22600	22900	23000	22900
Magnesium	8600	8790	8570	9060	8460	8680	8510	8520	8740	8910	8890	8840
Specific Conductivity (umhos/cm)	262	259	260	194	191	192	192	194	196	199	201	197
Total Suspended Solids (mg/L)	4	6	8	4	4	12	6	4	4	6	8	2

STATION	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**	**AR-3E**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	1.2	U	U	U	U	U	U	U	U	150	59	5.8
Cadmium	6.4	4.4	6.4	3.8	2.7	5.7	5.6	5.4	6.8	251	85.2	25.1
Copper	44.5	46.4	27.7	25.7	21.1	46.8	38	35.5	26.7	687	333	92
Iron	420	314	285	287	194	460	695	577	372	58600	23000	4380
Lead	6.4	7.8	5.2	6.9	3.6	16	23.4	32.7	27.7	1200	1090	409
Manganese	466	379	409	341	300	409	344	553	608	5290	3170	1640
Silver	U	U	U	U	U	U	U	U	U	5.4	U	1.2
Zinc	1050	734	924	711	585	1040	1160	1160	1330	37900	15300	5170
MAJOR CONSTITUENTS												
pH (Field)	7.91	7.86	7.85	7.94	7.78	7.81	7.87	7.92	8.01	6.48	6.39	6.95
Calcium	24100	23200	23700	23400	23400	23700	23400	24400	25100	34400	33200	29300
Magnesium	9780	9420	9640	9440	9440	9630	9530	10100	10400	16400	14400	12400
Specific Conductivity (umhos/cm)	227	221	226	220	218	231	229	240	250	558	370	300
Total Suspended Solids (mg/L)	6	4	6	6	6	10	2	2	4	172	88	22

STATION	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**	**AR-3A**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	U	NA	U	U	U	U	U	U	U	U	44.4	27.7
Cadmium	2.6	NA	2.6	7.1	3.2	2.3	2.8	3.6	3.4	4.3	96.4	58.7
Copper	0	NA	3.2	6.7	2.9	3	5.9	8.8	6.9	8.6	254	213
Iron	204	NA	612	300	232	219	835	431	370	469	30000	19300
Lead	3.6	NA	3.6	15.6	4.6	3.9	8.7	13	14.7	26.9	813	452
Manganese	296	NA	255	301	243	208	266	236	326	334	3390	2370
Silver	U	NA	U	U	U	U	U	U	U	U	3.9	2.3
Zinc	543	NA	549	862	564	481	690	762	740	791	23400	11700
MAJOR CONSTITUENTS												
pH (Field)	7.88	7.82	7.9	8.01	8	8.2	8.16	8.2	8.17	8.13	7.22	7.29
Calcium	24100	NA	23000	23700	23600	23000	24000	23300	23600	24000	30000	29200
Magnesium	9550	NA	9070	9400	9400	9190	9740	9340	9590	9680	13000	12400
Specific Conductivity (umhos/cm)	222	219	214	217	214	213	218	219	222	224	383	331
Total Suspended Solids (mg/L)	4	4	2	6	4	2	2	2	2	6	98	76

STATION	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**	**CG-6**
SAMPLE NUMBER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
TOTAL METALS (ug/L)												
Arsenic	2.4	2.7	2.6	2.9	4	6.1	8.3	7.2	17.3	878	296	108
Cadmium	44.3	44.5	41.5	40.7	40.2	51.9	55.7	63.1	78.5	1530	698	227
Copper	96.8	107	104	128	139	306	270	227	360	6870	2910	764
Iron	2990	3540	3170	3720	4810	8010	8970	8170	14000	634000	195000	51300
Lead	66.6	111	102	130	169	363	397	483	1020	25300	10200	3470
Manganese	7120	6490	5970	5750	5290	5270	5270	8200	7300	52700	30100	21300
Silver	U	U	U	U	0.56	0.64	1.8	1.4	2.3	7.4	22.9	14.2
Zinc	11900	11500	11300	11000	11100	14900	16500	17300	21200	342000	143000	59100
MAJOR CONSTITUENTS												
pH (Field)	7.05	7.43	7.57	7.8	7.87	7.73	7.88	7.76	7.78	2.98	3.21	4.26
Calcium	58300	55000	52600	50500	48900	48900	50200	66700	61300	155000	131000	116000
Magnesium	27600	26200	24800	24000	23100	23300	23300	32000	30200	89500	63300	56500
Specific Conductivity (umhos/cm)	749	730	700	701	685	704	702	817	790	3450	219	146
Total Suspended Solids (mg/L)	34	36	38	42	48	50	74	54	110	436	250	230

U = Not detected
NA = Not analyzed
R = Data rejected

Table 5-7
Surface Water Laboratory Test Results
Fall, 1991 Sampling

	California Gulch[1]				Arkansas River							Arkansas River Tributaries											
STATION	**CG-3**	**CG-4**	**CG-5**	**CG-6**	**AR-1**	**AR-2**	**AR-3E**	**AR-3W**	**AR-3A**	**AR-4**	**AR-5**	**EF-1**	**EF-2**	**EG-1**	**EM-1**	**EM-2**	**EM-3**	**EM-4**	**HC-1**	**IG-1**	**LF-1**	**TC-01**
TOTAL METALS (ug/L)																						
Aluminum	116	2750	1830	93.3	U	U	66.4	66.5	U	U	U	U	U	U	62.4	U	73.1	55.3	U	U	64.6	58.2
Antimony	U	U	U	U	U	U	U	U	1.2	1.1	U	2.2	U	U	U	U	1.3	U	U	U	U	U
Arsenic	1.4	U	3.8	1.5	U	U	U	U	U	U	U	U	U	U	U	U	1.2	U	U	U	U	U
Barium	31.7	24	25.3	36	68.5	61.7	61.3	61.5	62.8	41.8	47.3	79.1	81.8	75.5	84.7	88.8	91.5	119	24.1	44.2	16.8	20.9
Cadmium	87.2	77.1	49.8	5.6	0.4	0.4	NA	0.59	1.1	0.8	0.99	U	0.56	0.48	U	0.13	U	U	U	0.33	0.14	0.23
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	13.6	102	66	11.4	U	1.2	5.1	2.1	5.1	5.6	5.1	U	U	U	5.6	4.1	6.3	4.8	5	3	2.4	U
Iron	1970	21800	15200	697	174	144	171	152	199	335	209	89.4	102	U	214	204	489	377	81.8	52.3	410	361
Lead	41.8	315	276	30.2	0	U	1.8	1.4	2.4	4.5	2.4	0	4.4	0	U	U	18.7	3.2	U	2.9	1.5	2.5
Manganese	11300	57300	19500	3530	72.3	50	187	88.1	120	123	68.9	17.4	86.9	U	16.3	22.5	68.9	39.2	U	19.1	30.2	29.1
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	36.2	88	40.8	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	0	0	0	0	0	0	0	0	U	U	U	U	1.2	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	0	U	U	U	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	37300	51100	27700	2840	145	97.3	229	139	198	200	186	U	176	60.9	19.7	16	14.9	28.7	U	243	20.7	33.5
DISSOLVED METALS (ug/L)																						
Aluminum	U	716	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Antimony	8.1	12.8	U	8.6	0	3.1	7.2	5.4	9.8	9.8	U	3.2	3.9	4.1	11.5	7.2	6.1	9.4	6	5.2	0	3.6
Arsenic	U	U	U	U	U	1.2	1.1	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Barium	33.3	24.2	25.8	20.1	63.4	63.3	60.1	63	59.8	36.1	43.1	75.5	77	69.3	65.6	85.6	87.3	107	16.7	44.1	10.9	11.5
Cadmium	98.2	83	46.9	2.9	0.38	0.11	0.49	0.14	0	U	0	U	0.22	0.32	0	0	0	U	0	0	U	U
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Copper	2.4	88.3	13.1	10.8	1	2.8	1.4	U	1	2.2	1	U	U	U	3.2	U	U	U	U	U	U	7.7
Iron	223	15700	140	U	U	92.3	78.7	72.9	41.8	92.9	57.1	U	U	U	29.1	U	89.6	59.5	U	U	206	169
Lead	0	199	0	U	U	U	0	0	U	U	U	U	U	U	U	U	U	U	U	U	U	1.6
Manganese	12800	59800	22600	3590	56.7	50	195	87.6	112	110	60.5	10.6	78.1	U	U	10.2	29.3	30.4	U	11.6	15.5	20.6
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	36.6	96.1	38.4	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Selenium	U	U	U	U	0	U	U	U	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	40500	55200	26500	35	17.4	U	14.9	11.2	10.6	10	U	U	U	U	U	U	U	U	U	U	U	10.6
MAJOR CONSTITUENTS																						
pH (Field)	7.5	5.23	7.69	8.26	8.3	7.21	8.25	8.02	8.13	8.5	7.87	8.7	8.37	8.46	8.38	8.48	8.49	7.94	8.48	8.49	8.42	7.56
Alkalinity (mg/L)	68	2	28	140	72	70	76	76	76	56	64	82	86	98	72	106	122	124	40	134	38	34
Calcium (mg/L)	146	195	132	48	23	24	25	24	23	18	23	22	28	24	18	24	26	32	10	113	10	8
Chloride (mg/L)	1	3	5	22	U	U	1	U	U	2	U	U	U	U	U	U	U	U	U	1	2	U
Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	53	5	U	NA	NA	NA	U	U	U	15	U	4	U	NA
Dissolved Organic Carbon (mg/L)	2	2	4	6	2	3	4	3	2	3	2	2	U	2	2	2	3	4	2	3	3	3
Fluoride (mg/L)	0.3	0.3	0.2	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.1	0.3	0.3	0.3	0.3	U	0.1	0.2	0.1
Magnesium (mg/L)	72	112	67	23	9	10	10	10	9	7	9	9	11	12	7	11	11	12	4	28	3	3
Nitrate + Nitrite (mg/L)as N	U	U	0.38	0.59	0.05	U	0.05	0.04	0.14	0.1	0.15	0.08	0.1	U	0.22	0.19	0.02	0.03	0.09	0.23	0.04	U
Potassium (mg/L)	3	4	4	7	U	U	1	U	1	U	1	U	U	U	U	U	U	U	U	2	U	U
Silica (mg/L)	15	22	15	14	U	7	8	7	5	6	7	2	2	1	4	5	5	6	4	5	6	3
Sodium (mg/L)	4	7	8	33	2	2	3	2	3	3	4	1	2	U	1	1	2	2	1	4	4	2
Specific Conductivity (umhos/cm)	994	1640	962	558	191	164	179	169	195	159	196	168	215	189	143	192	199	226	83	693	97	76
Sulfate (mg/L)	642	1200	617	117	14	51	74	23	12	21	14	U	25	U	U	20	10	17	23	274	U	U
Total Dissolved Solids (mg/L)	1010	1410	1120	478	100	120	128	124	152	128	148	96	130	96	106	164	156	168	64	594	80	44
Total Suspended Solids (mg/L)	142	208	138	32	U	20	24	22	38	18	20	U	U	U	20	22	34	42	18	140	18	U
Total Phosphorus (mg/L) as P	U	U	U	0.28	0.01	0.01	0.09	U	U	U	U	0.09	U	U	U	U	U	U	U	U	U	U

1. California Gulch tributaries were not sampled due to zero discharge

U = Not detected

NA = Not analyzed

R = Data rejected

Table 5-8
Surface Water Laboratory Test Results
Winter, 1992 Sampling

	California Gulch & Tributaries						Arkansas River							Arkansas River Tributaries				
STATION	**CG-2**	**CG-3**	**CG-4**	**CG-5**	**CG-6**	**SD-1**	**AR--1**	**AR--2**	**AR-3E**	**AR-3W**	**AR-3A**	**AR-4**	**AR-5**	**EF-2**	**EM-2**	**EM-4**	**LF-1**	**TC-01**
TOTAL METALS (ug/L)																		
Aluminum	56.9	80.4	1450	1150	486	17800	U	U	113	63.8	U	59.4	U	U	U	U	206	88.7
Antimony	U	U	U	U	U	12.8	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	U	U	2.4	3.5	52.8	U	U	U	U	U	U	U	U	U	U	U	U
Barium	24.7	53.9	41.6	44.3	47.8	400	72.4	74.8	69.4	71.4	72.9	46.6	50.6	99.6	93.8	148	26.6	46.2
Cadmium	4.3	10.1	27.1	32	11.7	13.3	U	0.42	1.7	0.76	0.93	0.85	U	U	U	U	U	U
Chromium	U	U	U	U	U	22.1	U	U	2.3	2.3	2.4	3.5	2.6	U	2.4	2.3	2.7	U
Copper	5.3	10.2	39.7	39.4	27.1	165	4	17.3	6.6	4.9	4.7	17.8	3.3	5.2	4.1	7.4	6.8	4.4
Iron	284	574	6740	5580	2320	24500	139	58.6	570	394	350	368	241	87.4	71.7	204	873	399
Lead	15	26.9	84.3	95	83.7	1480	U	U	15.2	9.1	8.4	4.6	3.6	U	U	U	U	2.2
Manganese	126	665	11900	11100	3850	1220	29	17.4	699	433	392	164	86.4	53	U	32.1	118	51.1
Mercury	U	U	U	U	U	0.4	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	5.6	5	19.4	20.8	8.8	19.5	6	U	2.5	U	U	2.4	U	9	U	3.6	U	2.7
Selenium	U	3.8	5.1	3.5	3.3	U	U	2.4	U	U	3	U	U	U	U	U	U	U
Silver	U	U	U	U	U	6.6	U	U	U	U	U	0.49	U	U	U	U	U	U
Zinc	349	2870	12400	14000	4820	2350	52.2	56.1	927	590	537	184	144	81	U	U	31	28.3
DISSOLVED METALS (ug/L)																		
Aluminum	U	U	U	U	U	71.1	68.3	U	U	U	U	U	U	U	U	U	U	U
Antimony	5.9	6	9.4	5.4	8.4	11.5	2.2	5.3	2.4	8.5	5.6	5.9	2.8	8.5	4.8	6.4	5.9	7.2
Arsenic	U	U	U	1.3	1.1	3.2	U	U	U	U	U	U	U	U	U	U	U	U
Barium	23.6	46.7	39.4	40.6	33.6	25.6	68.6	68.5	63.6	59	65.3	37.3	39.4	95.6	82.5	133	18.1	108
Cadmium	4.3	10.4	26.8	31.3	8	1.7	U	U	1.4	0.8	0.92	0.19	0.23	U	U	U	U	0.37
Chromium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	523
Copper	7.7	5.9	8.1	4.7	5.2	13.7	U	3.6	2.1	13.7	5.8	4.7	1.7	23.4	3.7	5.2	5.2	19.6
Iron	30.1	77.6	2470	413	U	26.2	75.6	24.2	U	U	U	54.5	58.1	U	U	54.1	152	106
Lead	U	1.7	U	U	U	4.6	U	U	U	U	U	U	U	U	U	U	U	2.4
Manganese	123	693	12500	11800	3980	138	22.9	14.9	699	426	387	143	62.3	47.3	U	31	77.3	16.4
Mercury	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel	8	5.2	24.7	17.5	8.7	3.5	2.9	2.2	3.4	3.1	3.3	1.6	2.2	8.1	1.8	2.6	U	37.5
Selenium	2	2.3	3.7	5.1	U	U	U	U	U	1.1	U	U	U	1.6	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc	353	2780	13400	14200	3090	56.8	U	U	399	116	32.3	U	U	U	U	U	U	U
MAJOR CONSTITUENTS																		
pH (Field)	7.35	7.97	7.32	7.65	7.77	8.49	8.32	8.19	8.29	8.37	8.78	8.35	8.57	8.3	8.55	7.83	7.6	7.72
Alkalinity (mg/L)	10	62	22	34	88	34	66	68	70	66	68	50	58	76	104	134	32	54
Calcium (mg/L)	114	74	103	99	57	25	32	32	34	33	34	20	23	49	25	36	10	16
Chloride (mg/L)	U	U	1	2	14	31	U	U	2	1	1	1	2	U	U	U	U	U
Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dissolved Organic Carbon (mg/L)	U	U	U	U	U	16	U	U	U	U	U	NA	U	1	U	U	U	4
Fluoride (mg/L)	0.5	U	U	0.5	U	U	0.3	U	0.5	U	U	U	U	0.4	0.5	0.5	U	0.3
Magnesium (mg/L)	41	29	49	48	26	4	13	14	15	14	14	8	9	20	11	12	3	6
Nitrate + Nitrite (mg/L) as N	0.19	0.1	0.15	0.31	0.45	0.66	0.13	U	0.15	U	0.16	U	0.19	0.19	U	U	U	0.07
Potassium (mg/L)	2	1	2	2	5	5	1	U	2	2	1	1	1	1	U	1	U	U
Silica (mg/L)	U	5	8	10	10	2	9	9	9	10	9	9	10	7	7	9	9	11
Sodium (mg/L)	3	2	4	5	19	25	7	6	8	7	7	5	6	12	1	2	4	3
Specific Conductivity (umhos/cm)	767	547	817	817	561	296	276	274	306	285	293	182	193	428	194	247	94	135
Sulfate (mg/L)	451	284	473	457	U	U	101	U	U	U	U	U	U	158	U	U	U	37
Total Dissolved Solids (mg/L)	614	400	342	664	376	189	178	184	202	188	190	110	118	286	110	150	68	92
Total Suspended Solids (mg/L)	U	U	12	U	U	586	8	U	U	U	U	U	U	4	U	U	6	8
Total Phosphorus (mg/L) as P	U	U	U	U	2.78	0.45	U	U	0.28	0.16	0.17	0.08	0.05	U	U	U	0.05	U

U = Not detected
NA = Not analyzed
R = Data rejected

Table 5-9
Stream Sediment Laboratory Test Results
Ice-Off, 1991 Sampling

	California Gulch					California Gulch Tributaries							Arkansas River						Arkansas River Tributaries							
STATION	CG-1	CG-3	CG-4	CG-5	CG-6	AG-1	GG-1	MG-1	OG-1	PG-1	SD-1	SG-1	AR-1	AR-2	AR-3	AR-3	AR-4	AR-5	EF-1	EF-2	EM-2	EM-3	EM-4	HC-1	IG-1	LF-1
TOTAL METALS (mg/kg)																										
Aluminum	14100	6630	7230	4870	10500	2560	7630	2220	2620	8210	5550	1710	1690	1980	4070	3750	3360	3540	1200	1180	5350	6260	1640	1780	2940	3760
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	346	290	146	111	156	81	144	25.4	152	88.9	147	99	8.7	4.3	67	R	29.2	13.3	2	2.9	11.7	13.4	15.3	1.3	24.7	4.2
Barium	293	119	230	375	324	66	186	56.4	125	426	221	71	56.3	64.3	197	143	115	133	38.5	32.7	218	259	69.4	29.3	181	155
Cadmium	17	26.9	17.3	11.3	114	3.7	9.2	6.7	1.5	24.5	438	21.7	2.1	2.9	17	17.8	11	10.2	U	U	U	U	4.9	U	12.2	3.1
Chromium	U	U	U	U	U	2.5	8.7	3.2	U	18.6	4.5	U	3	2.9	2.1	1.9	4.4	5.2	1.4	U	9.4	7	2.8	4.7	5.5	5.1
Copper	R	R	451	547	2120	R	R	84	R	R	R	R	11	8.5	289	R	73.6	56.8	8.4	5.1	R	9.6	19.5	7	54.8	14.3
Iron	104000	93500	75400	62700	82000	6050	18100	10900	53900	30100	44100	51000	6750	5400	29200	31000	16700	15400	4420	3930	16700	15100	8780	8260	15000	12600
Lead	R	R	2810	3400	5980	R	R	1350	R	R	R	R	219	45.2	1220	R	424	284	3.9	14.2	R	63.5	269	7.1	1080	32.9
Manganese	R	R	R	2090	2550	R	R	774	526	R	R	R	1000	921	2590	R	1290	2460	290	502	R	1270	650	138	483	3100
Mercury	0.8	2.2	0.36	0.29	1.1	0.11	R	0.19	0.09	0.6	0.22	0.13	U	U	0.12	0.13	0.33	0.21	U	U	R	U	0.1	U	0.21	U
Nickel	U	12.1	U	U	U	U	9.7	U	U	9.8	U	U	3.8	4.3	8.3	6	4.4	5.2	2.9	2.6	49.9	5.9	U	5.5	U	4.5
Selenium	R	R	R	3.2	2.8	R	R	0.3	R	R	R	U	0.29	U	1.4	0.43	U	0.55	U	U	R	U	U	U	U	0.19
Silver	R	R	R	R	24.3	R	R	2	R	R	R	R	U	U	1.9	R	R	U	U	U	R	R	U	R	R	U
Zinc	R	R	R	6080	23000	200	R	752	1820	R	R	R	685	576	4230	4520	1900	1970	68.2	351	R	133	731	23.6	1460	365
MAJOR CONSTITUENTS (mg/kg)																										
Calcium	1540	3330	11100	8800	5350	536	7110	601	3470	12300	20100	1760	1220	1760	2070	1830	2430	1620	1760	886	6140	6100	2950	552	3890	2220
Chloride	9	U	7	6	36	32	13	19	12	70	20	6	U	12	14	24	13	14	U	6	9	17	19	U	18	17
Cyanide	0.97	U	0.17	U	R	0.08	U	0.18	0.05	0.24	0.16	U	0.05	0.05	0.05	0.45	U	U	R	R	U	0.07	U	0.05	U	R
Magnesium	2320	2380	6700	1930	3140	586	2590	607	1290	5740	11000	1140	829	887	1550	875	1790	1350	1110	633	2970	2740	1530	871	2500	1630
Potassium	2430	993	1160	909	1460	517	1920	389	1060	2430	1460	651	293	389	605	539	582	978	248	230	1750	1690	447	618	810	902
Sodium	U	U	U	U	U	U	203	U	301	287	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sulfate	712	816	1690	650	396	159	148	233	3570	108	324	1250	177	U	140	133	78	U	115	129	213	36	92	63	147	53

U = Non-detect
R = Data rejected
NA = Not analyzed

Table 5-10
Stream Sediment Laboratory Test Results
Summer, 1991 Sampling

	California Gulch				C.G. Tributaries			Arkansas River								Arkansas River Tributaries										
STATION	CG-3	CG-4	CG-5	CG-6	OG-1	SD-1	SG-1	AR-1	AR-1	AR-2	AR-3E	AR-3W	AR-3A	AR-4	AR-5	EF-1	EF-2	EG-1	EG-2	EM-1	EM-2	EM-3	EM-4	HC-1	IG-1	LF-1
TOTAL METALS (mg/kg)																										
Aluminum	5000	3770	2710	4010	1690	3270	1990	1080	877	1540	1350	1560	703	1530	1140	1200	1510	1740	4250	1970	738	1010	1290	705	2130	1750
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	214	61.5	59.2	81.6	2.3	2.8	1.6	2.5	3.2	3.7	6.7	14.4	4.4	16	5.7	3.9	3.4	21.2	116	8.1	1.2	3.8	17.1	0.69	10.1	4.3
Barium	87.2	138	137	160	55.1	239	115	38.2	26.1	47.9	62.8	37.1	34.5	147	57.8	30.6	41.5	105	340	89.2	31.1	61.7	51.4	13.6	863	61.2
Cadmium	18	8.5	7	14.6	4.6	19.8	34	1.3	0.77	1.6	3.2	26.2	5.2	8.3	4.8	U	1.5	2.7	10.1	1.4	0.68	U	9.1	U	4.9	1.5
Chromium	U	8.1	U	U	U	8.7	U	U	U	2.1	U	2.7	U	1.4	1.8	1.4	1.5	U	7.2	3.1	U	U	1.2	7.3	U	2.3
Copper	1070	593	277	370	109	296	282	6.2	6.2	6.2	21.1	46.7	38.1	47.2	22.1	7.4	8.3	20.2	224	5.4	U	1.8	84.8	7.5	59.9	7.5
Iron	82700	31300	43100	45800	47000	46500	36700	3590	3380	4850	6470	8060	4260	13600	5780	6550	6600	10600	33000	7900	2880	3530	9940	8260	12100	5830
Lead	2130	1220	1210	1420	633	2380	3000	40	26.7	25.3	95.7	42.4	87.1	R	R	9.4	16.9	455	1690	R	15.6	13.9	R	5.3	R	10.4
Manganese	2310	1850	1190	1310	646	4100	4470	527	342	702	801	544	517	1480	1210	207	515	1070	2650	566	277	537	257	123	2660	1030
Mercury	0.46	0.18	U	U	U	0.42	0.24	U	U	0.27	U	0.24	0.36	U	U	U	U	0.12	0.25	U	U	U	U	U	0.45	U
Nickel	U	6.7	U	U	U	U	U	10.7	U	2.7	2.4	U	U	2.5	U	2.8	3.2	U	U	U	U	U	U	10.4	U	U
Selenium	0.13	1.7	1.3	4.3	0.15	5.7	U	U	U	0.14	U	U	0.29	0.2	U	U	U	U	8.4	U	U	U	U	U	1.7	U
Silver	12.6	6.5	U	8.8	U	17.5	13.1	U	U	U	U	U	4.1	R	R	U	U	1.3	U	R	R	R	R	U	R	U
Zinc	3710	2530	2780	7130	683	6410	4000	280	183	322	505	3340	756	1470	658	75.3	331	552	7420	95.6	27.2	23.6	1330	22.8	2510	115
MAJOR CONSTITUENTS (mg/kg)																										
Calcium	5090	6390	3610	11000	1720	12500	12300	983	604	1660	1040	2180	1200	3530	645	1070	1040	3270	16500	3020	842	1450	2430	412	28000	1040
Chloride	161	114	108	114	120	96	102	102	90	102	120	150	96	132	120	90	108	114	140	102	90	90	168	102	192	102
Cyanide	0.13	U	U	U	0.17	U	U	0.05	U	0.05	U	U	U	U	0.12	U	U	0.06	0.05	U	0.05	U	U	U	0.15	0.08
Magnesium	2630	2870	1020	2290	1270	2980	7010	519	410	851	479	606	361	976	435	719	793	1760	2930	1490	483	502	636	327	9750	701
Potassium	1140	826	679	938	1170	1020	788	213	278	388	448	442	140	371	269	280	386	252	1240	492	191	243	364	122	679	418
Sodium	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	663	U
Sulfate	1060	450	350	110	6920	100	1960	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	50	U

U = Non-detect
R = Data rejected
NA = Not analyzed

Table 5-11
Stream Sediment Laboratory Test Results
Fall, 1991 Sampling

	California Gulch				Arkansas River							Arkansas River Tributaries										
STATION	CG-3	CG-4	CG-5	CG-6	AR-1	AR-2	AR-3E	AR-3W	AR-3A	AR-4	AR-5	EF-1	EF-2	EG-1	EM-1	EM-2	EM-3	EM-4	HC-1	IG-1	LF-1	TC-1
TOTAL METALS (mg/kg)																						
Aluminum	2180	3200	4790	3430	1210	859	1770	972	1490	1520	741	1270	995	1420	1310	1280	2400	1260	1160	1550	1340	U
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	152	56.7	95	48.2	2.1	3.2	1.9	9.1	9.9	20.4	3.5	2	2	49.2	3	2.9	5.2	15.2	0.34	1.6	1.6	1.1
Barium	65.4	132	204	130	37.2	28.3	163	52	60.9	212	37.5	32.9	18.6	65.5	53.4	83.1	146	60.8	16.6	122	41.2	27.1
Cadmium	13.2	9.9	8.7	10.4	1.2	0.81	5.6	2.3	2.5	3.3	2.3	U	U	3.1	U	U	U	8.5	U	13.1	U	0.89
Chromium	U	7.1	U	U	U	U	U	U	U	U	U	2.1	1.5	1.6	1.3	1.2	1.8	1.2	4.6	5.6	1.6	2.5
Copper	1260	242	466	343	8.1	7.1	210	38.6	35.4	73	11.6	6.6	5.4	25.3	3	2.8	2.9	21.4	3.3	53.2	4.9	3.1
Iron	80000	30000	59200	29800	4050	5820	23100	6980	8030	13000	4110	4220	3300	10300	5570	5650	7120	9590	5820	12000	4510	4270
Lead	2180	1170	3200	1310	17.5	U	853	198	177	1020	75.1	9.2	13.2	605	18.9	19.2	23.3	216	3.4	444	14.2	6.7
Manganese	3010	1410	2140	1530	673	508	820	546	918	1470	833	236	245	964	332	510	1290	411	130	1460	527	544
Mercury	0.99	0.57	0.33	U	U	U	U	U	U	U	U	U	U	1.2	U	U	U	U	U	U	U	U
Nickel	U	U	U	U	2.7	3.3	U	U	U	U	U	3	2.5	2.9	U	U	U	U	4.4	4.3	U	U
Selenium	1.4	1.5	U	U	U	U	U	U	0.63	U	U	U	U	U	U	U	U	U	U	1.7	U	U
Silver	R	R	R	R	R	R	R	U	U	2.5	U	R	R	R	U	U	U	U	U	3.5	U	R
Zinc	5210	3040	3250	4380	402	273	2160	592	914	1680	546	59.7	154	746	68.6	62.9	59.6	1330	21.2	4530	87.2	104
MAJOR CONSTITUENTS (mg/kg)																						
Calcium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloride	18	18	42	28	24	36	21	12	12	14	14	18	24	12	18	18	21	12	12	21	18	24
Cyanide	U	U	0.11	0.11	0.18	U	U	0.05	0.07	0.05	0.12	U	U	U	0.06	0.05	0.09	U	U	0.11	0.07	U
Magnesium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Potassium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	270	410	440	30	U	U	U	U	U	U	U	U	U	U	U	U	U	300	120	420	240	U

U = Non-detect
R = Data rejected
NA = Not analyzed

Table 5-12
Stream Sediment Laboratory Test Results
Winter, 1992 Sampling

	California Gulch and Tributaries						Arkansas River							Arkansas River Tributaries					
STATION	CG-2	CG-3	CG-4	CG-5	CG-6	SD-1	AR-1	AR-2	AR-3E	AR-3W	AR-3A	AR-4	AR-5	EF-2	EF-2	EM-2	EM-4	LF-1	TC-1
TOTAL METALS (mg/kg)																			
Aluminum	8580	4570	4000	3980	3280	2850	1350	1540	2950	2770	1070	2150	1630	1240	1240	1380	1250	2320	1040
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	444	199	116	114	71.6	4805	2.8	2.8	58.8	39.5	8.1	20.5	9.3	1.7	1.7	3.2	9.9	2.9	1.1
Barium	140	121	163	182	149	148	45.3	49.4	147	90.9	36.6	235	57.5	28.5	28.5	63.2	48.3	84	41.6
Cadmium	36.1	24.8	11.3	10.8	20.1	7.6	1.3	1.4	14.3	7.9	2.3	6	6.2	0.77	0.77	U	12.7	1.6	1.4
Chromium	13.9	U	10.5	7.6	6.5	6.3	1.9	2.8	4.4	4.5	2	4.6	3.1	1.8	1.8	2.3	2.9	4.3	2.5
Copper	368	895	319	406	315	91.9	7	6	226	164	12	51.3	30.7	5.8	5.8	U	160	4.7	2.4
Iron	107000	84700	47300	47300	39400	17500	4710	4880	32400	23400	4230	16100	8910	4760	4760	5950	8620	9550	2960
Lead	4310	2620	2150	1780	1450	578	32.4	21.8	854	795	R	0.999	R	10.3	10.3	R	R	R	25.1
Manganese	3110	4040	2920	1280	1030	1230	774	1020	890	1080	1060	1830	1350	469	469	451	171	1320	536
Mercury	0.8	0.68	0.19	0.27	0.27	U	U	U	0.32	0.13	U	0.28	0.26	U	U	U	0.13	U	U
Nickel	U	U	6.5	7.3	U	4.1	2.7	2.7	6.8	5.8	3	3.6	4.2	U	U	U	U	3.5	U
Selenium	0.65	1.3	2.4	2.6	1.2	2	0.19	U	0.63	1.1	U	0.6	U	U	U	0.2	0.17	0.14	U
Silver	23.8	15	9.5	6.3	4.2	1.8	U	U	2.6	2.8	U	2.7	U	U	U	U	1.4	U	U
Zinc	7500	6100	4190	4380	5570	1680	407	486	3850	2750	570	1810	981	333	333	52.3	1870	141	123
MAJOR CONSTITUENTS (mg/kg)																			
Calcium	26000	6000	5680	3450	2090	7570	1120	1030	3610	1610	734	4690	949	990	990	1510	2140	896	565
Chloride	22	15	17	18	23	25	13	34	23	34	10	19	17	15	15	47	17	31	17
Cyanide	U	U	U	0.24	U	U	U	U	0.36	13.8	4.7	0.5	0.8	U	U	U	U	U	U
Magnesium	17000	3690	1920	973	746	2640	633	762	1940	808	519	1150	798	655	655	676	524	728	327
Potassium	1880	1080	827	798	524	720	372	351	508	462	260	584	302	316	316	342	321	555	232
Sodium	U	U	U	U	U	183	U	U	U	U	U	U	U	U	U	U	U	U	U
Sulfate	2550	362	262	302	94	49	U	U	78	81	26	23	26	40	40	U	U	41	U

U = Non-detect
R = Data rejected
NA = Not analyzed

TABLE 5-13

PERCENTAGE OF ANALYTE DETECTIONS IN SURFACE WATER; ICE-OFF, SPRING, SUMMER, FALL AND WINTER SAMPLING EVENTS

Analyte	Sampling Locations							
	California Gulch[1]		California Gulch Tributaries[2]		Arkansas River[3]		Arkansas River Tributaries[4] (not including California Gulch)	
	% Detects	% > CRDL	% Detects	% > CRDL	% Detects	% > CRDL	% Detects	% > CRDL
TOTAL METALS								
Aluminum	100%	84%	100%	100%	65%	19%	66%	23%
Antimony	0%	0%	7%	0%	7%	0%	5%	0%
Arsenic	64%	36%	100%	86%	13%	0%	27%	0%
Barium	100%	12%	86%	50%	97%	0%	100%	0%
Cadmium	100%	96%	100%	93%	93%	0%	70%	0%
Chromium	0%	0%	29%	29%	16%	0%	7%	0%
Copper	100%	80%	100%	93%	94%	3%	89%	0%
Iron	100%	100%	100%	100%	100%	97%	98%	72%
Lead	100%	100%	100%	100%	83%	60%	67%	37%
Manganese	100%	100%	100%	100%	100%	100%	80%	73%
Mercury	24%	24%	57%	57%	0%	0%	0%	0%
Nickel	58%	17%	43%	29%	10%	0%	7%	0%
Selenium	47%	20%	0%	0%	24%	0%	7%	0%
Silver	40%	16%	100%	43%	7%	0%	3%	0%
Zinc	100%	100%	100%	100%	100%	100%	77%	59%
MAJOR CONSTITUENTS								
pH								
Alkalinity (mg/L)	72%		50%		97%		100%	
Calcium (mg/L)	100%	100%	100%	79%	100%	100%	100%	98%
Chloride (mg/L)	60%		43%		42%		7%	
Cyanide	8%	8%	14%	0%	25%	19%	14%	3%
Dissolved Organic Carbon (mg/L)	43%		55%		76%		89%	
Fluoride (mg/L)	80%		29%		81%		82%	
Magnesium (mg/L)	100%	96%	79%	64%	100%	84%	98%	70%
Nitrate + Nitrite (mg/L) as N	92%		93%		68%		70%	
Potassium (mg/L)	96%	4%	57%	7%	48%	0%	23%	2%
Silica (mg/L)	96%		100%		97%		100%	
Sodium (mg/L)	96%	40%	57%	21%	90%	19%	66%	2%
Specific Conductivity (umhos/cm)								
Sulfate (mg/L)	95%		57%		74%		80%	
Total Dissolved Solids (mg/L)	100%		100%		100%		100%	
Total Suspended Solids (mg/L)	72%		100%		58%		66%	
Total Phosphorus (mg/L) as P	60%		93%		52%		30%	

1. Sampling Stations CG-1 through CG-6
2. Sampling Stations SD-1, SG-1, OG-1, GG-1, PG-1, AG-1 and MG-1
3. Sampling Stations AR-1 through AR-5
4. Sampling Stations TC-1, EF-1, EF-2, EG-1, EG-2, LF-1, HC-1, IG-1, and EM-1 through EM-4
5. % Detects = Percentage of detections per total number of tests performed (rejected data is not included in number of tests)
6. % > CRDL = Percentage of detections greater than the Contract Required Detection Limit per total number of tests performed.

TABLE 5-14
CONCENTRATION RANGE IN SURFACE WATER SAMPLES WHERE ANALYTE DETECTED; ICE-OFF, SPRING, SUMMER, FALL AND WINTER SAMPLING EVENTS

Analyte	CRDL	Sampling Locations			
		California Gulch[1]	California Gulch Tributaries[2]	Arkansas River[3]	Arkansas River Tributaries[4] (not including California Gulch)
TOTAL METALS (ug/L)					
Aluminum	200	56.9 - 46,100	322 - 381,000	53 - 1010	55.3 - 1620
Antimony	60		12.8	1.1 - 1.2	1.3 - 2.2
Arsenic	10	1.2 - 627	2.1 - 1130	1.1 - 2.1	1.2 - 5.7
Barium	200	14 - 1600	31.8 - 2610	32.4 - 74.8	12.5 - 148
Cadmium	5	4.3 - 290	4.6 - 959	0.4 - 3.6	0.13 - 2.6
Chromium	10		17.1 - 55.8	2.3 - 3.5	2.3 - 2.7
Copper	25	5.3 - 4210	17 - 12,900	1.2 - 36.1	1.2 - 17
Iron	100	284 - 270,000	1060 - 8,130,000	58.6 - 1680	52.3 - 2520
Lead	3	15 - 38,800	131 - 55,900	1.4 - 27.5	1.2 - 103
Manganese	15	126 - 61,900	309 - 2,510,000	17.4 - 699	13.8 - 410
Mercury	0.2	0.2 - 2.3	0.3 - 9		
Nickel	40	5-88	19.5 - 1600	2.4 - 6	2.7 - 9
Selenium	5	2.5 - 11.8		1.9 - 4.1	1.2 - 4.5
Silver	10	1.2 - 318	0.74 - 381	0.49 - 0.55	2.3
Zinc	20	349 - 61,200	512 - 1,110,000	52.2 - 957	10.2 - 689
MAJOR CONSTITUENTS					
pH (Field)		2.9 - 11.6	2.3 - 8.5	7.2 - 8.8	7.4 - 8.7
Alkalinity (mg/L)		2 - 140	1 - 42	27 - 84	14 - 134
Calcium (mg/L)	5	37 - 358	2 - 442	9 - 151	4 - 113
Chloride (mg/L)		1 - 22	1 - 31	1 - 2	1 - 2
Cyanide	10	38	3	5 - 53	4 - 15
Dissolved Organic Carbon (mg/L)		2 - 14	4 - 24	2 - 19	1 - 54
Fluoride (mg/L)		0.1 - 0.7	0.1 - 0.4	0.1 - 0.5	0.1 - 0.5
Magnesium (mg/L)	5	1 - 112	2 - 1730	4 - 15	2 - 34
Nitrate + Nitrite (mg/L) as N		0.1 - 1.16	0.02 - 5.36	0.02 - 4.14	0.02 - 1.35
Potassium (mg/L)	5	2 - 7	2 - 6	1 - 2	1 - 5000
Silica (mg/L)		2 - 55	2 - 81	5 - 10	1 - 11
Sodium (mg/L)	5	3 - 33	1 - 26	1 - 8	1 - 12
Specific Conductivity (umhos/cm)		307 - 1640	21 - 13,300	19 - 306	32 - 693
Sulfate (mg/L)		70 - 1200	6 - 7480	12 - 101	8 - 274
Total Dissolved Solids (mg/L)		208 - 1640	48 - 29,600	60 - 202	38 - 594
Total Suspended Solids (mg/L)		10 - 2170	12 - 2480	4 - 44	2 - 140
Total Phosphorus (mg/L) as P		0.02 - 2.78	0.14 - 7.64	0.02 - 0.28	0.01 - 0.14

1. Sampling Stations CG-1 through CG-6
2. Sampling Stations SD-1, SG-1, OG-1, GG-1, PG-1, AG-1 and MG-1
3. *Sampling Stations AR-1 through AR-5*
4. Sampling Stations TC-1, EF-1, EF-2, EG-1, EG-2, LF-1, HC-1, IG-1, and EM-1 through EM-4

TABLE 5-15
PERCENTAGE OF ANALYTE DETECTIONS IN SEDIMENT; ICE-OFF, SUMMER, FALL AND WINTER SAMPLING EVENTS

Analyte	Sampling Locations							
	California Gulch[1]		California Gulch Tributaries[2]		Arkansas River[3]		Arkansas River Tributaries[4] (not including California Gulch)	
	% Detects[5]	% > CRDL[6]	% Detects[5]	% > CRDL[6]	% Detects[5]	% > CRDL[6]	% Detects[5]	% > CRDL[6]
TOTAL METALS								
Aluminum	100%	100%	100%	100%	100%	100%	97%	97%
Antimony	0%	0%	0%	0%	0%	0%	0%	0%
Arsenic	100%	100%	100%	86%	100%	96%	100%	64%
Barium	100%	100%	100%	100%	100%	75%	100%	61%
Cadmium	100%	100%	100%	100%	100%	93%	56%	44%
Chromium	33%	33%	64%	64%	61%	43%	83%	47%
Copper	100%	100%	100%	100%	100%	100%	94%	63%
Iron	100%	100%	100%	100%	100%	100%	100%	100%
Lead	100%	100%	100%	100%	96%	96%	100%	100%
Manganese	100%	100%	100%	100%	100%	100%	100%	100%
Mercury	83%	83%	77%	69%	39%	39%	17%	14%
Nickel	22%	6%	29%	14%	68%	7%	44%	6%
Selenium	87%	73%	67%	44%	43%	7%	17%	3%
Silver	90%	90%	83%	50%	29%	24%	8%	0%
Zinc	100%	100%	100%	100%	100%	100%	100%	100%
MAJOR CONSTITUENTS								
Calcium	100%	100%	100%	85%	100%	76%	100%	65%
Chloride	94%	No CRDL	100%	No CRDL	96%	No CRDL	94%	No CRDL
Cyanide	35%	0%	57%	0%	61%	7%	38%	0%
Magnesium	100%	86%	100%	85%	100%	24%	100%	35%
Potassium	100%	43%	100%	46%	100%	0%	100%	12%
Sodium	0%	0%	38%	0%	0%	0%	0%	0%
Sulfate	100%	No CRDL	100%	No CRDL	32%	No CRDL	39%	No CRDL

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[1] Sampling Stations CG-1 through CG-6

[2] Sampling Stations SD-1, SG-1, OG-1, GG-1, PG-1, AG-1 and MG-1

[3] Sampling Stations AR-1 through AR-5

[4] Sampling Stations TC-1, EF-1, EF-2, EG-1, EG-2, LF-1, HC-1, IG-1, and EM-1 through EM-4

[5] % Detects = Percentage of detections per total number of tests performed (rejected data is not included in number of tests)

[6] % > CRDL = Percentage of detections greater than the Contract Required Detection Limit per total number of tests performed.

TABLE 5-16

CONCENTRATION RANGE IN SEDIMENT SAMPLES WHERE ANALYTE DETECTED ICE-OFF, SUMMER, FALL AND WINTER SAMPLING EVENTS

Analyte	CRDL	Sampling Locations			
		California Gulch [1]	California Gulch Tributaries [2]	Arkansas River [3]	Arkansas River Tributaries [4] (not including California Gulch)
TOTAL METALS (mg/kg)					
Aluminum	40	2180-14100	1550-8210	703-4070	705-6260
Antimony	12				
Arsenic	2	48.2-444	1.6-4805	1.9-67	0.34-116
Barium	40	65.4-375	55.1-863	26.1-235	13.6-340
Cadmium	1	7-114	1.5-438	0.77-26.2	0.68-12.7
Chromium	2	6.5-13.9	2.5-18.6	1.4-5.2	1.2-9.4
Copper	5	242-2120	53.2-296	6-289	1.8-224
Iron	20	29800-107000	6050-53900	3380-32400	2860-33000
Lead	0.6	1170-5980	444-3000	0.999-1220	3.4-1690
Manganese	3	1030-4040	483-4470	342-2590	123-3100
Mercury	0.1	0.18-2.2	0.09-0.6	0.12-0.36	0.1-1.2
Nickel	8	6.5-12.1	4.1-9.8	2.4-10.7	2.5-49.9
Selenium	1	0.13-4.3	0.15-5.7	0.14-1.4	0.14-8.4
Silver	2	4.2-24.3	1.8-17.5	1.9-4.1	1.3-1.4
Zinc	4	2530-23000	200-6410	183-4520	21.2-7420
MAJOR CONSTITUENTS (mg/kg)					
Calcium	1000	1540-26000	536-28000	604-4690	412-16500
Chloride		6-161	6-192	10-150	6-168
Cyanide	2	0.11-0.97	0.05-0.24	0.05-13.8	0.05-0.09
Magnesium	1000	746-17000	586-1000	361-1940	284-2970
Potassium	1000	524-2430	389-2430	140-978	122-1750
Sodium	1000		183-663		
Sulfate		30-2550	49-6920	23-177	36-300

[1] Sampling Stations CG-1 through CG-6

[2] Sampling Stations SD-1, SG-1, OG-1, GG-1, PG-1, AG-1 and MG-1

[3] Sampling Stations AR-1 through AR-5

[4] Sampling Stations TC-1, EF-1, EF-2, EG-1, EG-2, LF-1, HC-1, IG-1, and EM-1 through EM-4

TABLE 5-17
SUMMARY OF DISSOLVED/TOTAL METAL RATIOS ARKANSAS RIVER AND CALIFORNIA GULCH

SAMPLING EVENT/ SAMPLING STATION	DISSOLVED/TOTAL METAL RATIO[1]												
	AG	*AL*	*AS*	*BA*	*CD*	*CR*	*CU*	*FE*	*HG*	*MN*	*PB*	*SE*	*ZN*
ICE-OFF, 1991													
AR-1					0.5		0.7	0.7		>=1.0			
AR-2				>=1.0	>=1.0		0.6	0.7		>=1.0			0.2
AR-3				>=1.0	>=1.0		>=1.0	0.6					0.5
AR-4				0.5	0.4		0.4	0.2		0.9	0.0		
AR-5	>=1.0		>=1.0	0.5	>=1.0		>=1.0	0.2		0.6	>=1.0	>=1.0	
CG-1	0.1	0.3		0.4	>=1.0		0.3	0.0		>=1.0	0.2	>=1.0	>=1.0
CG-2		0.0		0.2	>=1.0	>=1.0	0.1	0.2		>=1.0	0.0		>=1.0
CG-3				0.9	>=1.0		0.1	0.1		>=1.0	0.0		>=1.0
CG-4		0.3	0.0	0.1	>=1.0		0.4	0.4		0.9	0.2		0.8
CG-5		0.8		0.5	>=1.0		0.8	0.6		>=1.0	0.4		>=1.0
CG-6				0.1	0.8		0.0			1.0			0.8
SPRING, 1991													
AR-1				0.5	0.5		0.5	0.1		0.3			0.4
AR-2				0.4	>=1.0		>=1.0	0.1		0.2			0.3
AR-3				0.5	0.5		0.6	0.1		0.6			0.7
AR-4				0.8	0.9		>=1.0	0.2		0.7			0.6
AR-5				>=1.0	0.7		>=1.0	0.1		0.5			0.5
CG-1		>=1.0		>=1.0	>=1.0		>=1.0	0.8		>=1.0	>=1.0		>=1.0
CG-2		>=1.0		0.7	>=1.0		>=1.0	0.3		>=1.0	0.8		>=1.0
CG-3		0.2		>=1.0	>=1.0		>=1.0	0.9		>=1.0	0.6		>=1.0
CG-4		0.9	>=1.0	>=1.0	>=1.0		>=1.0	0.7		>=1.0	>=1.0		>=1.0
CG-5		0.1		>=1.0	>=1.0		>=1.0	0.6		>=1.0	0.5		>=1.0
CG-6				0.9	1.0		0.1			>=1.0	0.0		>=1.0
SUMMER, 1991													
AR-1				0.9	0.4		0.9	0.5		0.9			
AR-2				0.9	0.3		0.8	0.4		>=1.0		>=1.0	0.6
AR3E				0.9	0.4		0.5	0.1		0.7			0.2
AR3W				0.8	0.4		>=1.0	0.3		0.6			
AR3A				>=1.0	0.4	>=1.0	0.4	0.1		0.7			0.2
AR-4				0.8	0.7		0.4	0.3		0.9			0.2
AR-5													
CG-3			>=1.0	0.8			0.0						
CG-4				0.5	0.5		0.0	0.0		>=1.0		>=1.0	0.6
CG-5				0.0	0.4		0.0			0.5	0.0		0.2
CG-6				0.6	0.0		0.4			0.7			0.0
FALL, 1991													
AR-1				0.9	>=1.0		>=1.0			0.8			0.1
AR-2			>=1.0	>=1.0	0.3		>=1.0	0.6		>=1.0			
AR3E			>=1.0	>=1.0	>=1.0		0.3	0.5		>=1.0			0.1
AR3W				>=1.0	0.2			0.5		>=1.0			0.1
AR3A				1.0			0.2	0.2		0.9			0.1
AR-4				0.9			0.4	0.3		0.9			0.1
AR-5				0.9			0.2	0.3		0.9			
CG-3				>=1.0	>=1.0		0.2	0.1		>=1.0			>=1.0
CG-4		0.3		>=1.0	>=1.0		0.9	0.7		>=1.0	0.6		>=1.0
CG-5				>=1.0	0.9		0.2	0.0		>=1.0			>=1.0
CG-6				0.6	0.5		0.9			>=1.0			0.0
WINTER, 1992													
AR-1		>=1.0		0.9				0.5		0.8			
AR-2				0.9			0.2	0.4		0.9			
AR3E				0.9	0.8		0.3			>=1.0			0.4
AR3W				0.8	>=1.0		>=1.0			>=1.0		>=1.0	0.2
AR3A				0.9	>=1.0		>=1.0			>=1.0			0.1
AR-4				0.8	0.2		0.3	0.1		0.9			
AR-5				0.8	>=1.0		0.5	0.2		0.7			
CG-2				>=1.0	>=1.0		>=1.0	0.1		>=1.0		>=1.0	>=1.0
CG-3				0.9	>=1.0		0.6	0.1		>=1.0	0.1	0.6	>=1.0
CG-4				0.9	>=1.0		0.2	0.4		>=1.0		0.7	>=1.0
CG-5			0.5	0.9	1.0		0.1	0.1		>=1.0		1.5	>=1.0
CG-6			0.3	0.7	0.7		0.2			>=1.0			0.6

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[1] Appendix D-3, Data Usability and Data Gaps, discusses possible explanations for dissolved metal concentrations exceeding total metal concentrations.

TABLE 5-18
BACKGROUND METALS IN SOILS
ESTIMATED STUDY AREA VALUES & LITERATURE REPORTED VALUES

Metal	Estimated Background Metals in Soils on Site[1] Range (ppm)	Soils of the Western United States[2] Range (ppm)	Soils of the United States[3] Range (ppm)	Worldwide[4] Range (ppm)
Sb		<1 - 2.6	0.25 - 0.6	--
As	0.7 - 120	<0.1 - 97	1.9 - 16.0	1 - 50
Ba		70 - 5,000	200 - 1,500	100 - 3,000
Cd	0.5 - 8	--	--	0.01 - 0.70
Cr		3 - 2,000	10 - 100	1 - 1,000
Cu	8 - 190	2 - 300	7 - 100	2 - 100
Pb	80-870	<10 - 700	10 - 30	2 - 200
Mn		30 - 5,000	50 - 1,500	20 - 3,000
Hg		<0.01 - 4.6	0.01 - 0.38	0.01 - 0.3
Ni		<5 - 700	5 - 30	5 - 500
Ag		2-5	--	0.01 - 5
Se		--	--	--
Zn	37 - 660	10 - 2,100	20 - 109	10 - 300

[1] Alluvial landscape estimated background concentration (Walsh & Associates, 1994).

[2] Schacklette & Boerngen, 1984.

[3] Loess and soils on silt deposits (Kabota-Pendias & Pendias, 1984).

[4] Lindsay, 1979.

TABLE 5-19
SEDIMENT TRANSPORT SUMMARY

Reach	2-yr Event (tons/event)	Erosional Process	10-yr Event (tons/event)	Erosional Process	100-yr Event (tons/event)	Erosional Process
1	1,440	Aggrading	2,080	Aggrading	3,470	Aggrading
2	2,090	Degrading	4,080	Aggrading	7,910	Aggrading
3	1,440	Aggrading	12,840	Degrading	36,400	Degrading
4	2,240	Aggrading	400	Aggrading	490	Aggrading
5	3,190	Degrading	3,180	Transition	5,310	Aggrading
6	1,680	Transition	3,600	Degrading	7,050	Degrading
7	1,740	Aggrading	2,280	Transition	5,630	Aggrading
8	2,200	Transition	2,860	Transition	13,860	Degrading
9	1,940	Degrading	2,480	Degrading	1,480	Aggrading
10	970	Transition	950	Aggrading	11,170	Degrading
11	960	Transition	1,280	Transition	170	Degrading
12	1,160	Degrading	1,560	Degrading	90	Aggrading
13	910	--	840	--	530	--

Source: Woodward Clyde Consultants, Draft Surface Water RI

TABLE 5-20

Comparison of Total Metal Concentrations at Stations AR-2 and AR-3E

ANALYTE	CRDL	ICE-OFF			SPRING			SUMMER			FALL			WINTER		
		AR-2	AR-3	AR-3/AR-2	AR-2	AR-3	AR-3/AR-2	AR-2	AR3E	AR-3/AR-2	AR-2	AR3E	AR-3/AR-2	AR-2	AR3E	AR-3/AR-2
TOTAL METALS (ug/L)																
Aluminum	200	U	U		1010	934	<1	78.4	174	2*	27.5	66.4	2*	27.5	113	4*
Antimony	60	U	U		U	U		U	U		U	U		U	U	
Arsenic	10	U	U		U	U		U	U		U	U		U	U	
Barium	200	63.9	61.6	<1	46	47.3	1	51.8	54.5	1	61.7	61.3	<1	74.8	69.4	<1
Cadmium	5	0.62	0.88	1	0.94	3	3*	0.55	3.4	6*	0.4	NA		0.42	1.7	4*
Chromium	10	U	U		U	U		U	U		U	U		1.1	2.3	2*
Copper	25	4.7	5.3	1	8	8.8	1	2.4	11.2	5*	1.2	5.1	4*	17.3	6.6	<1
Iron	100	493	561	1	1230	1520	1	171	479	**3**	144	171	1	58.6	570	**10**
Lead	3	1.1	4.5	**4**	12.2	16.6	1	1.9	11.2	**6**	0.55	1.8	3*	1.1	15.2	**14**
Manganese	15	89.6	R		150	322	**2**	45.2	460	**10**	50	187	**4**	17.4	699	**40**
Mercury	0.2	U	U		U	U		U	U		U	U		U	U	
Nickel	40	U	U		U	U		U	U		U	U		1.1	2.5	2*
Selenium	5	0.55	1.9	3*	R	R		U	U		R	R		2.4	1.1	<1
Silver	10	0.275	0.55	2*	U	U		U	U		U	U		U	U	
Zinc	20	198	276	1	166	570	**3**	258	957	**4**	97.3	229	**2**	56.1	927	**17**

NOTES:

* = Although AR-3/AR-2 is greater than 1, concentrations at both stations are less than the CRDL.
U = Non-detect (for purposes of numerical comparisons, non-detects were reported as half the detection limit)
R = Data rejected
NA = Not analyzed

TABLE 5-21
COMPARISON OF TOTAL METAL LOADS AT STATIONS AR-2 AND AR-3E/W

ANALYTE	ICE-OFF			SPRING			SUMMER			FALL			WINTER		
	AR-2	AR-3	AR-3/AR-2	AR-2	AR-3	AR-3/AR-2	AR-2	AR-3[1]	AR-3/AR-2	AR-2	AR-3[1]	AR-3/AR-2	AR-2	AR-3[1]	AR-3/AR-2
TOTAL METALS (lbs/day)															
Aluminum	U	U		1625	1458	<1	29.6	57.6	2*	4.5	8.9	2*	1.6	5.2	3*
Antimony	U	U		U	U		U	U		U	U		U	U	
Arsenic	U	U		U	U		U	U		U	U		U	U	
Barium	5.9	8.0	1	74	74	1	19.6	23	1	10.0	8.2	<1	4.4	4.6	1
Cadmium	0.06	0.11	2*	1.5	4.7	3*	0.2	0.8	4*	0.1	NA		0.02	0.07	3*
Chromium	U	U					U	U		U	U		0.07	0.15	2*
Copper	0.4	0.7	2*	12.9	13.7	1	0.9	2.8	3*	0.2	0.4	2*	1.0	0.4	<1
Iron	45	73	**2**	1979	2372	1	65	132	**2**	23	21	<1	3.5	29.5	**8**
Lead	0.1	0.6	**6**	19.6	25.9	1	0.7	2.4	**3**	0.1	0.2	2*	0.07	0.7	**11**
Manganese	8.2	R		241	503	**2**	17	96	**6**	8	17	**2**	1	34	**33**
Mercury	U	U		U	U		U	U		U	U		U	U	
Nickel	U	U		U	U		U	U		U	U		0.07	2.5	38*
Selenium	0.1	0.2	5*	R	R		U	U		R	R		0.1	1.1	8*
Silver	0.03	0.1	3*	U	U		U	U		U	U		U	U	
Zinc	18.2	35.8	**2**	267	890	**3**	98	239	**2**	15.8	23.4	1	3.3	45.8	**14**

NOTES:

[1] Load at AR-3E/W for Summer, Fall and Winter calculated as: (Conc[AR-3E] * Discharge [AR-3E]) + (Conc[AR-3W] * Discharge [AR-3W])

* = Although AR-3/AR-2 is greater than 1, concentrations at both stations are less than the CRDL.

U = Non-detect (for purposes of numerical comparisons, non-detects were reported as half the detection limit)

R = Data rejected

NA = Not analyzed

Figure 5-1

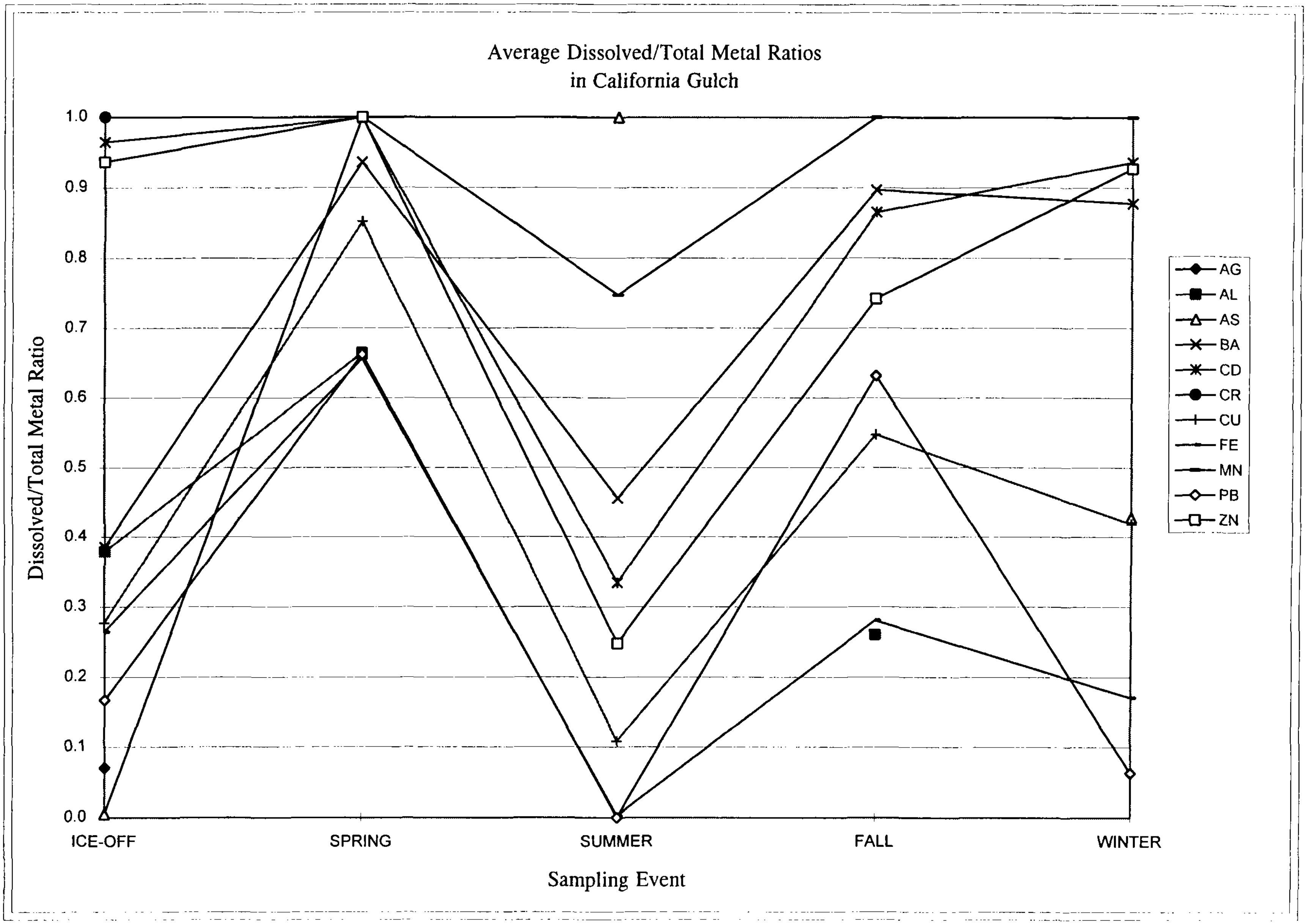

Average Dissolved/Total Metal Ratios
in California Gulch
Dissolved/Total Metal Ratio
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ICE-OFF
SPRING
SUMMER
FALL
WINTER
Sampling Event
AG
AL
AS
BA
CD
CR
CU
FE
MN
PB
ZN

Figure 5-2
California Gulch Discharge, pH, and Total Suspended Solids

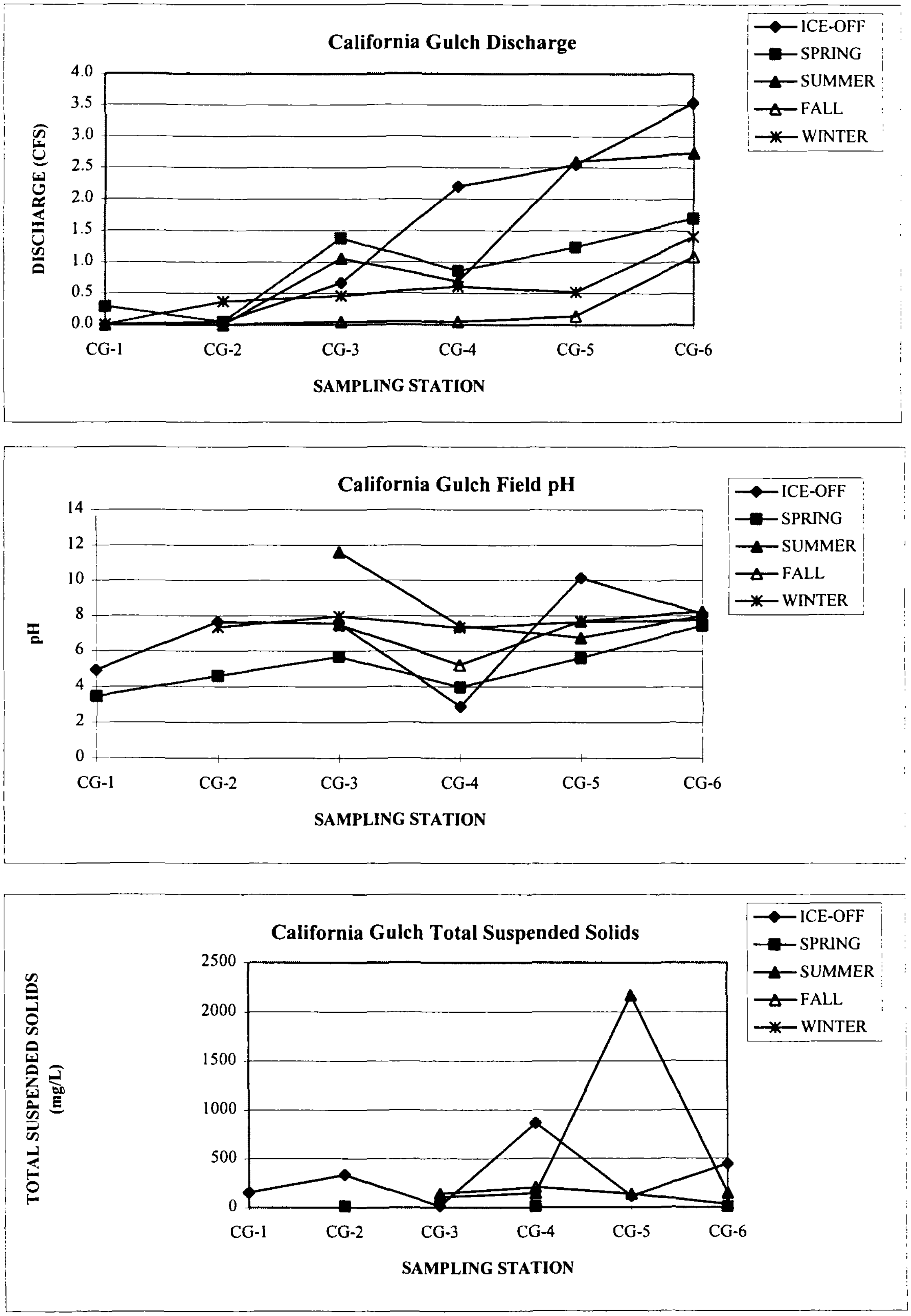


Figure 5-3
California Gulch Aluminum Summary

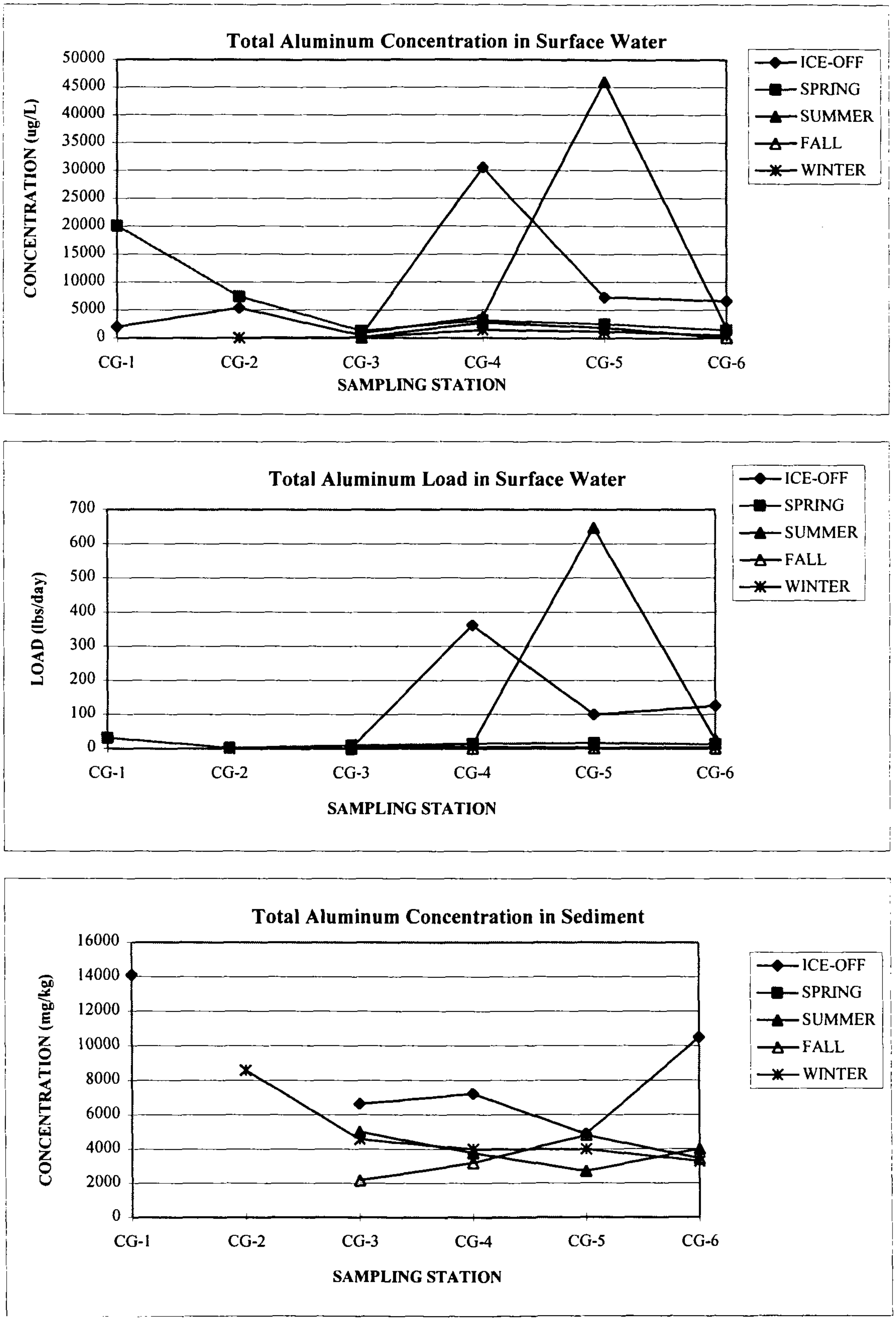


Figure 5-4
California Gulch Arsenic Summary

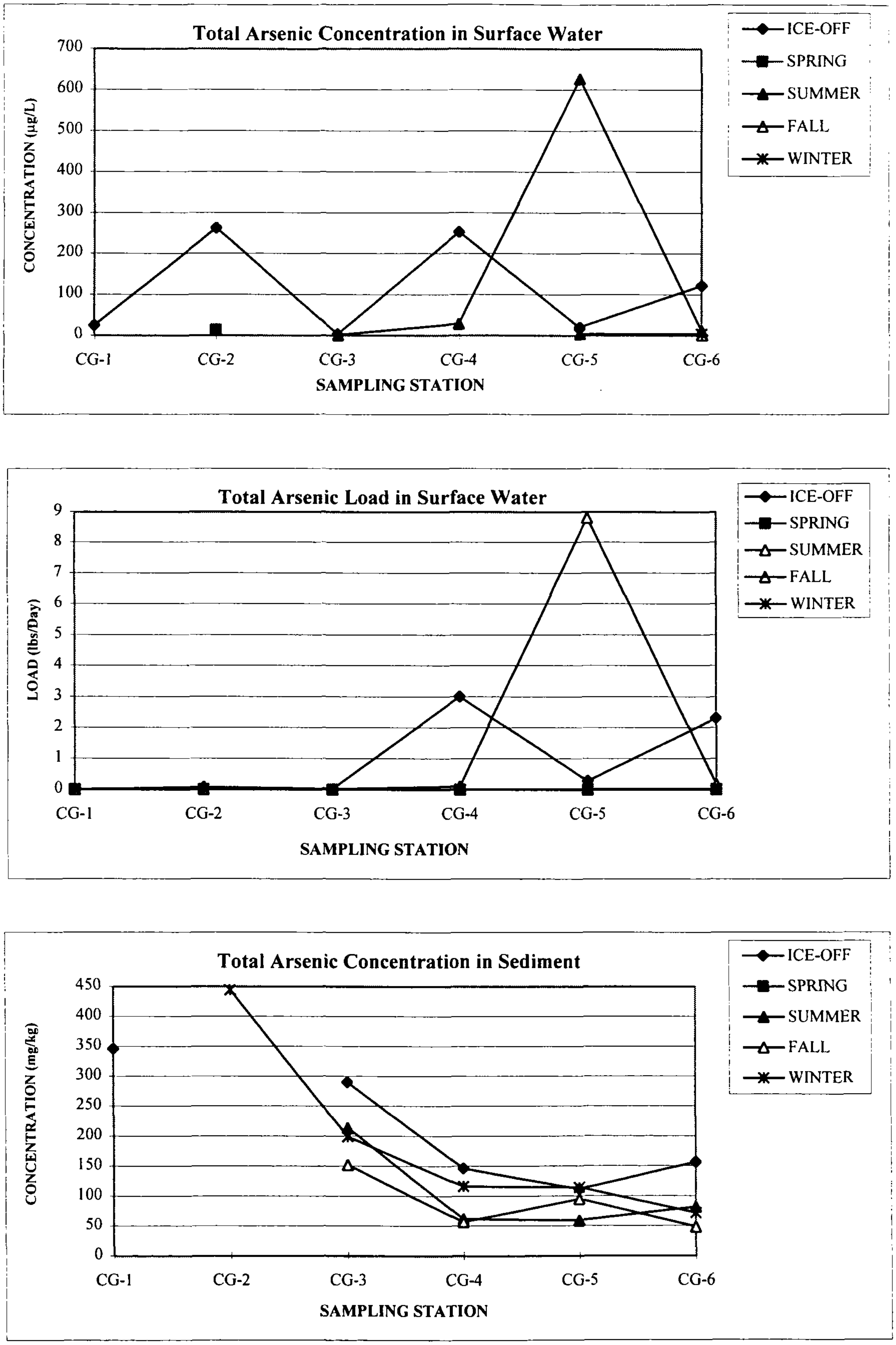
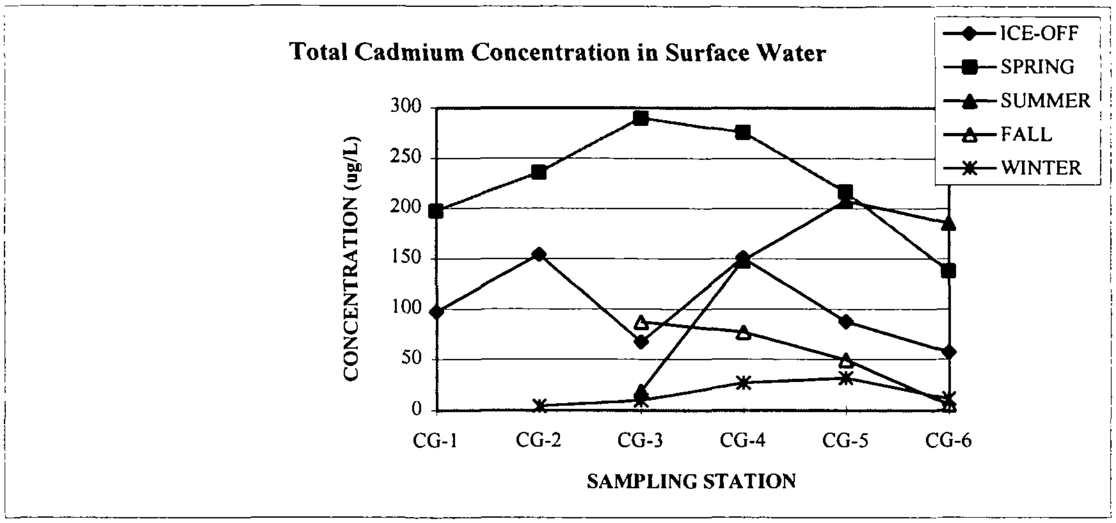
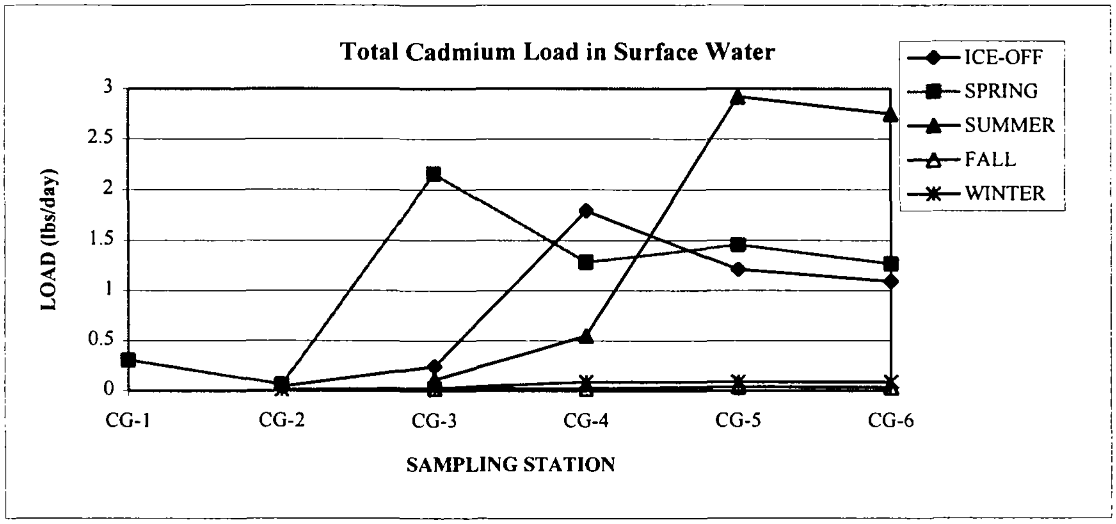


Figure 5-5
California Gulch Cadmium Summary





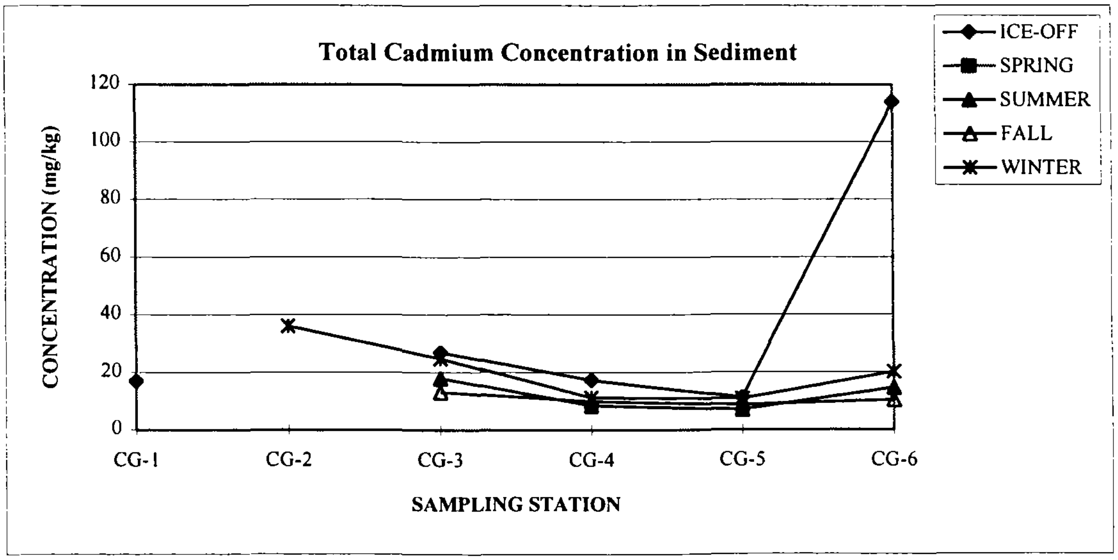
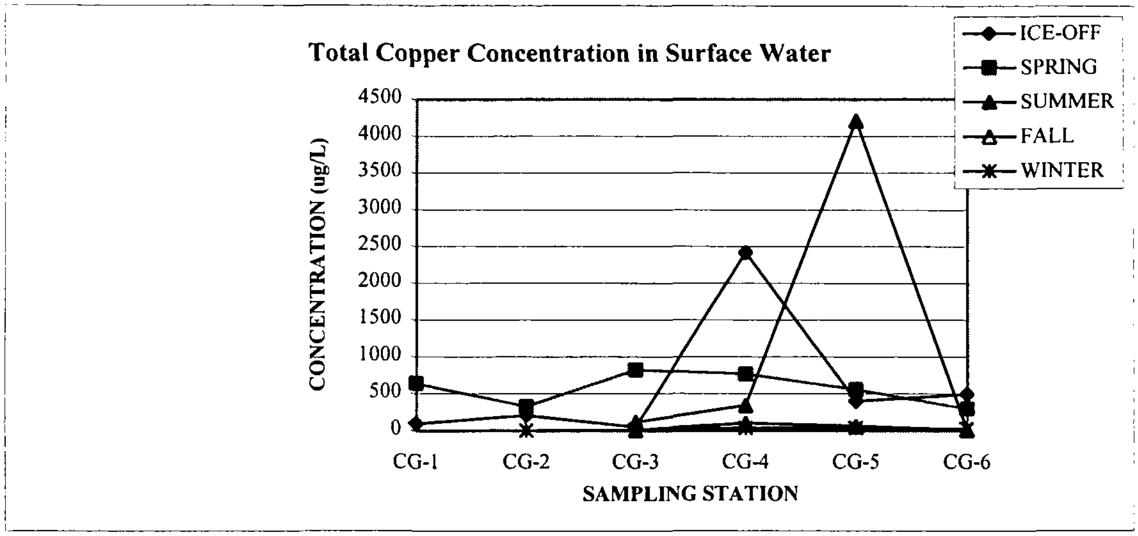
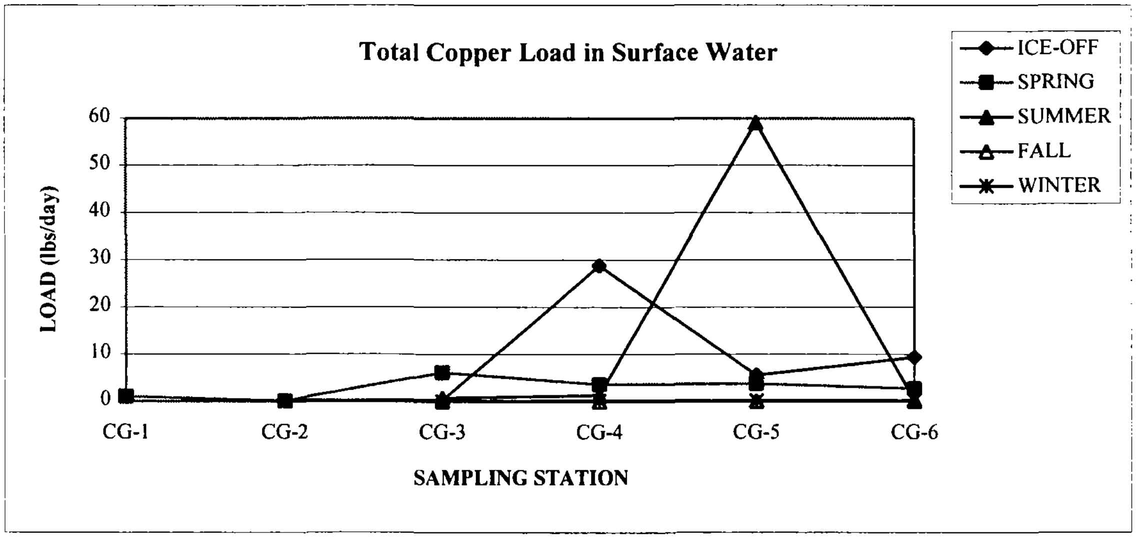


Figure 5-6
California Gulch Copper Summary


Total Copper Concentration in Surface Water


Total Copper Load in Surface Water

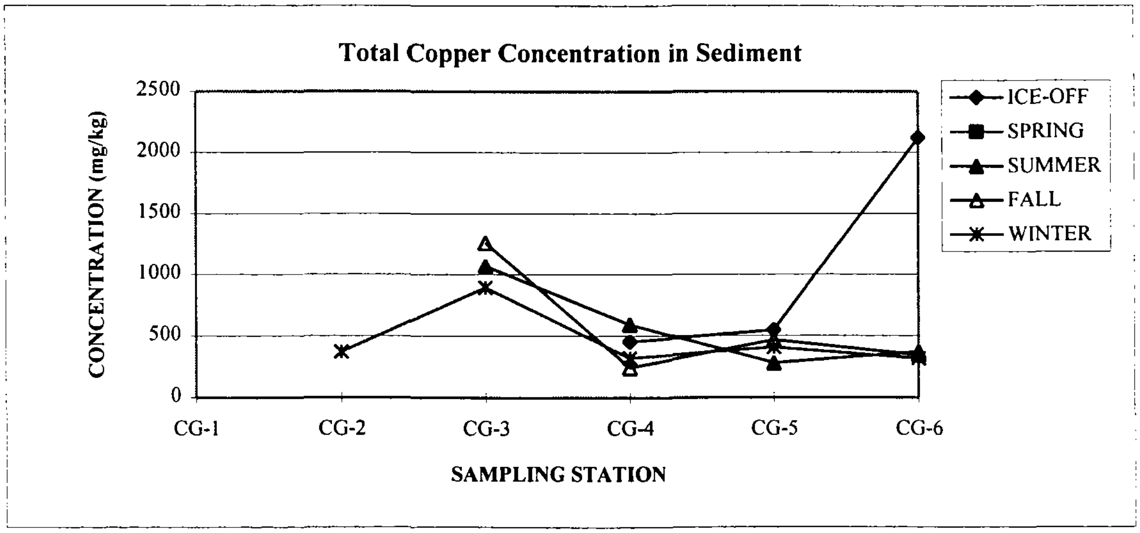
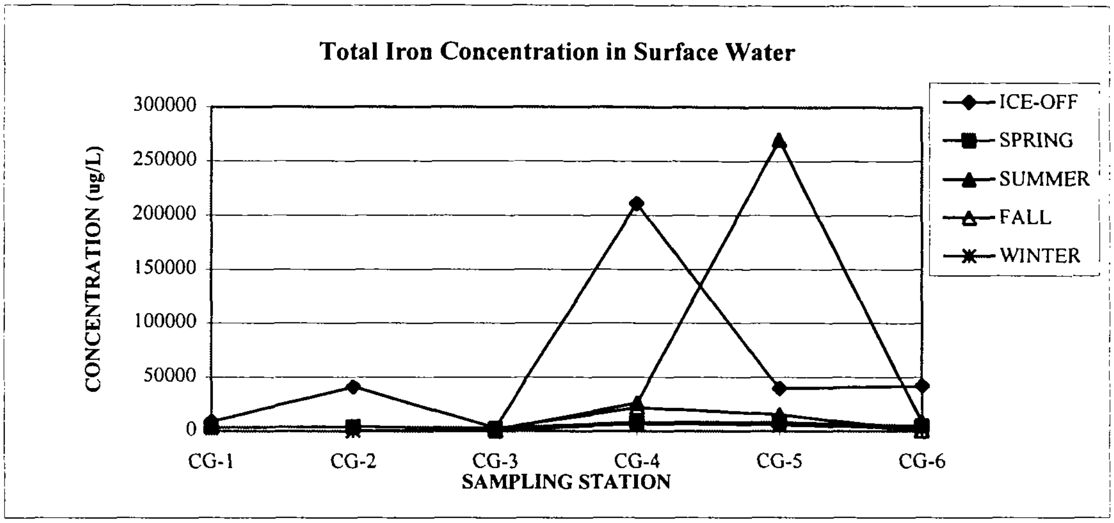
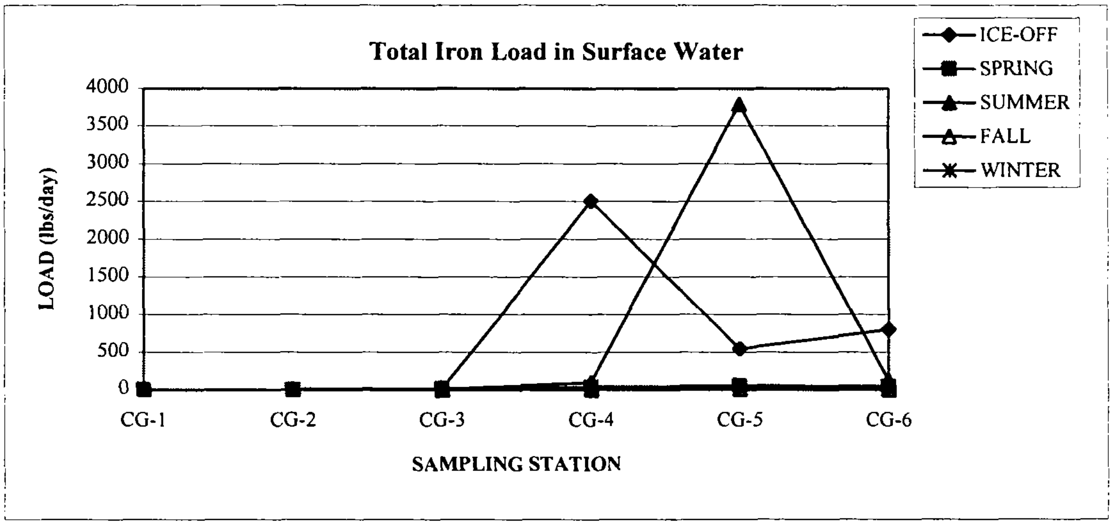

Total Copper Concentration in Sediment

Figure 5-7
California Gulch Iron Summary





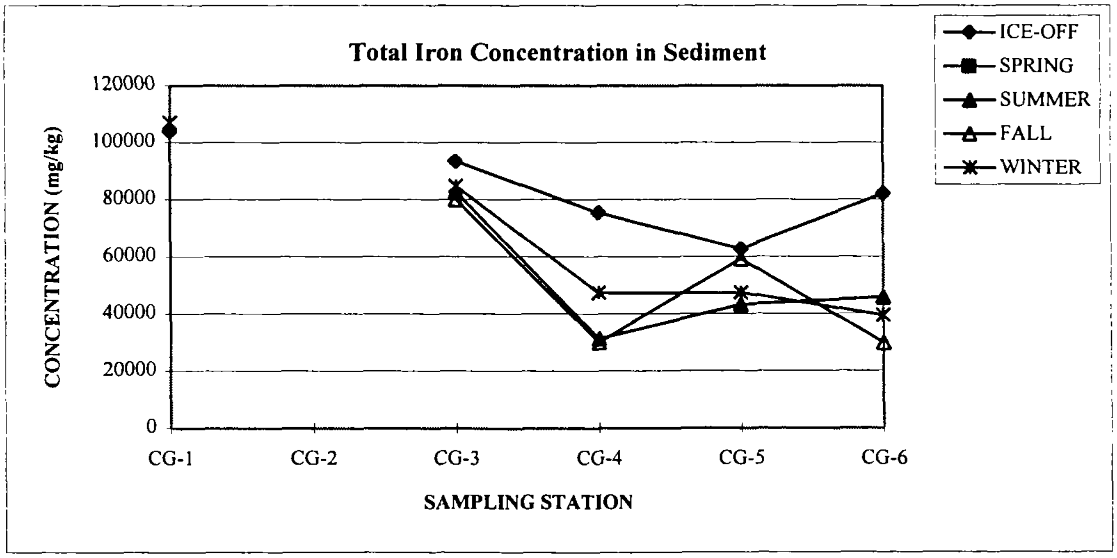
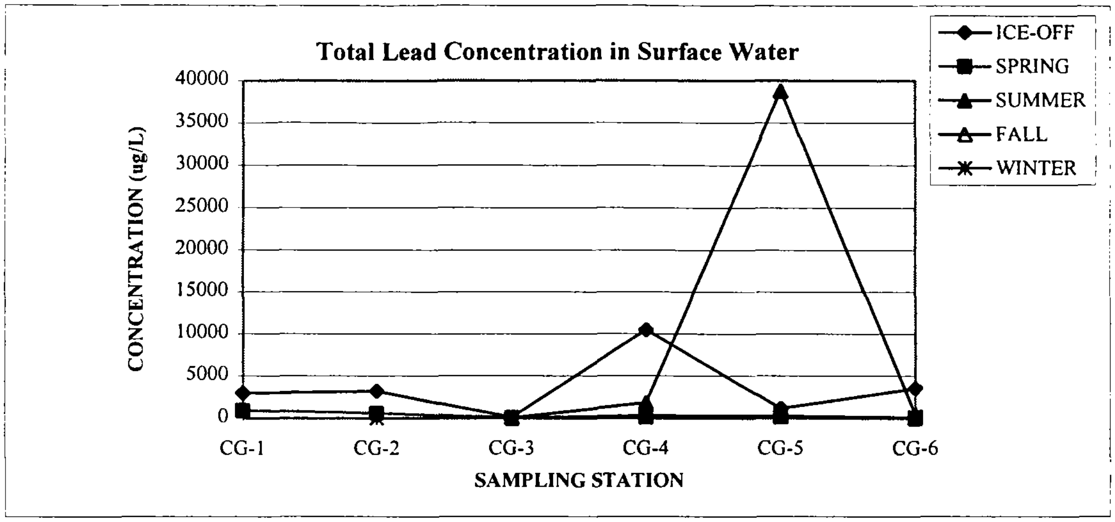
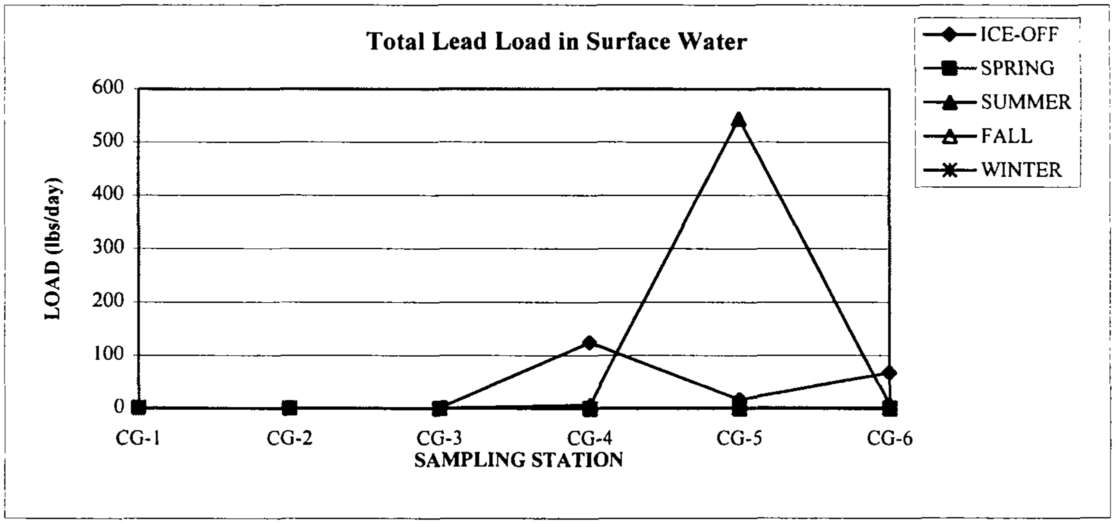


Figure 5-8
California Gulch Lead Summary





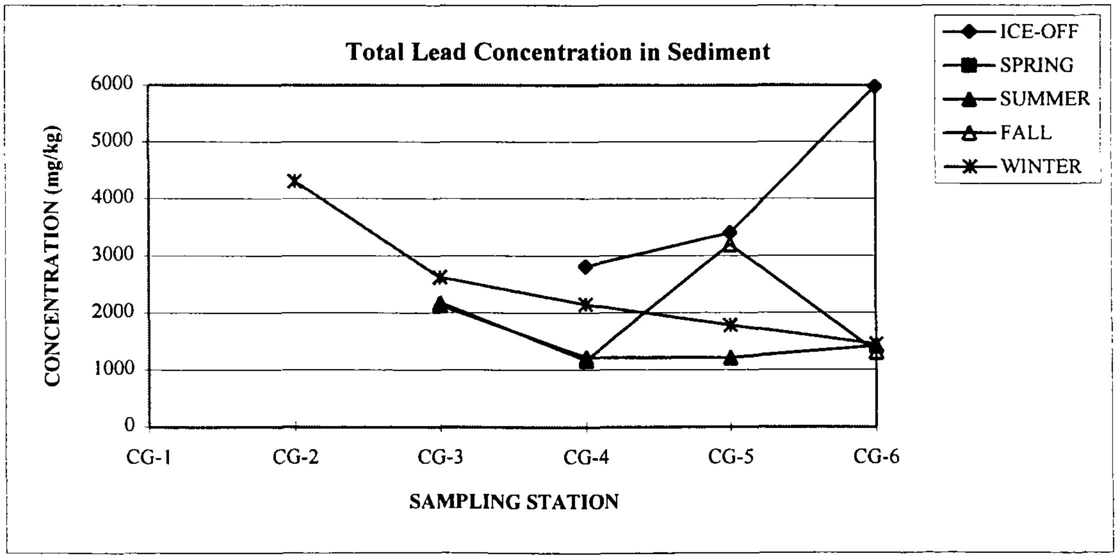
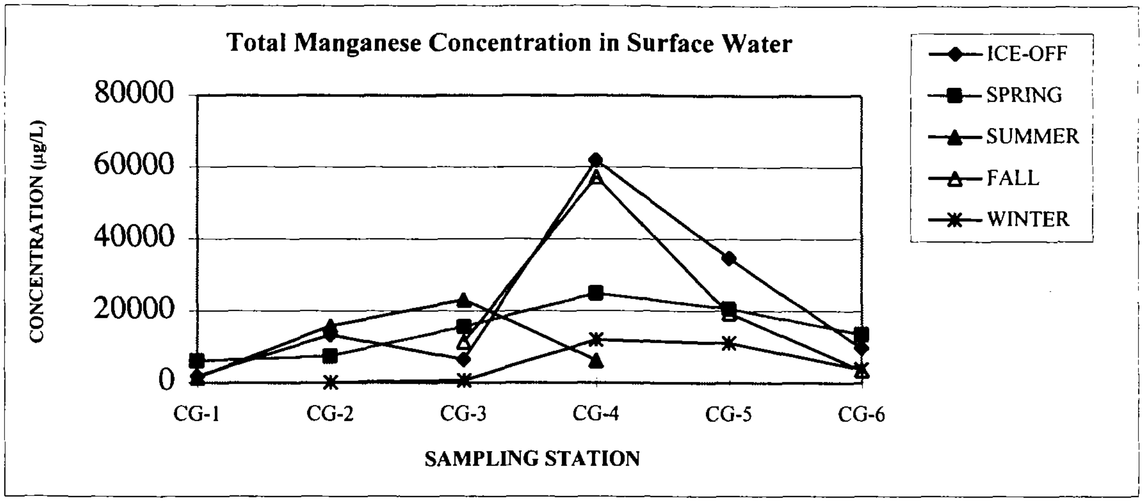
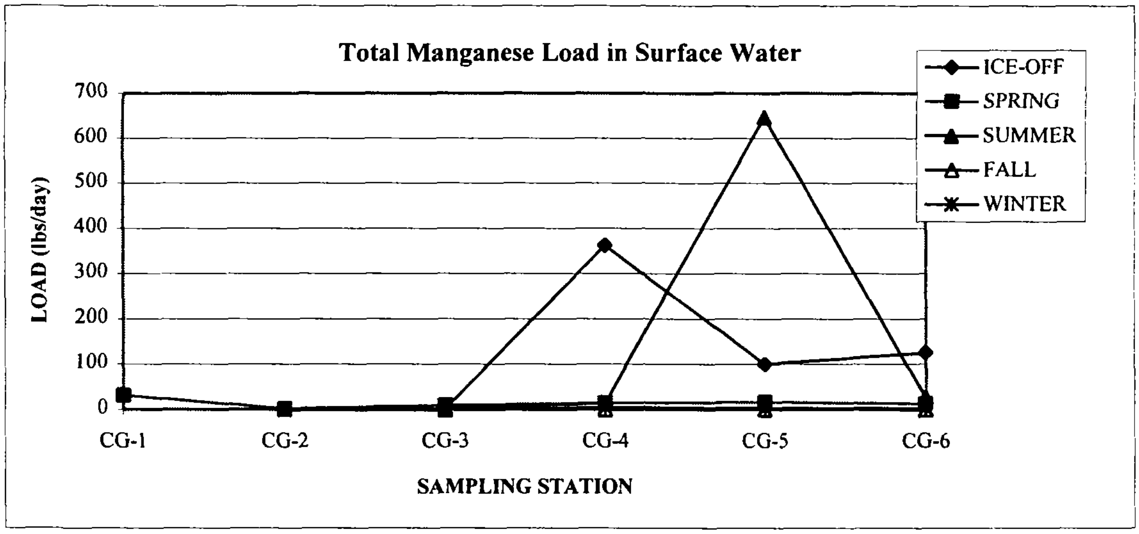


Figure 5-9
California Gulch Manganese Summary





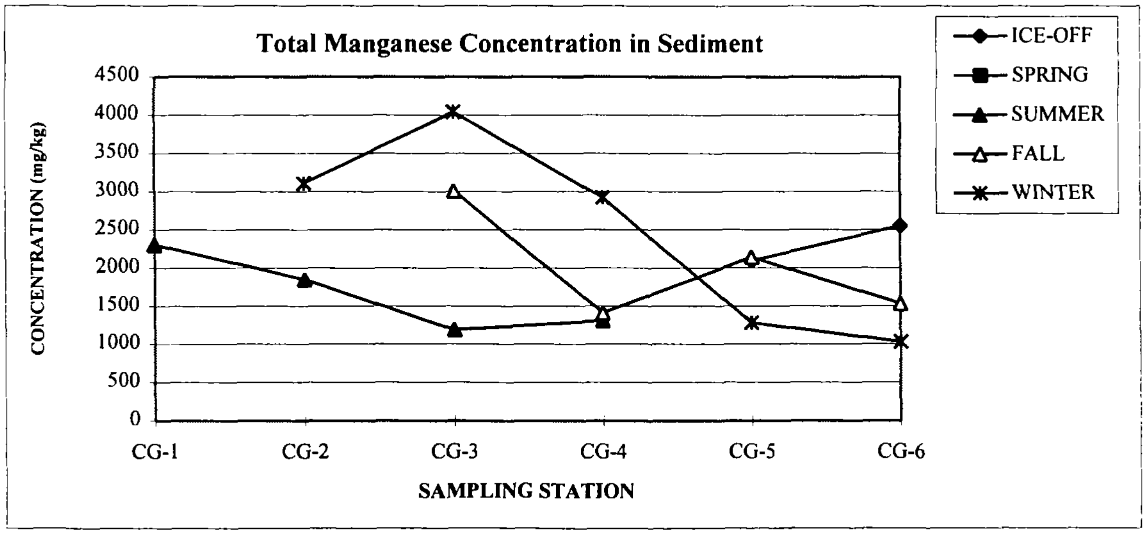
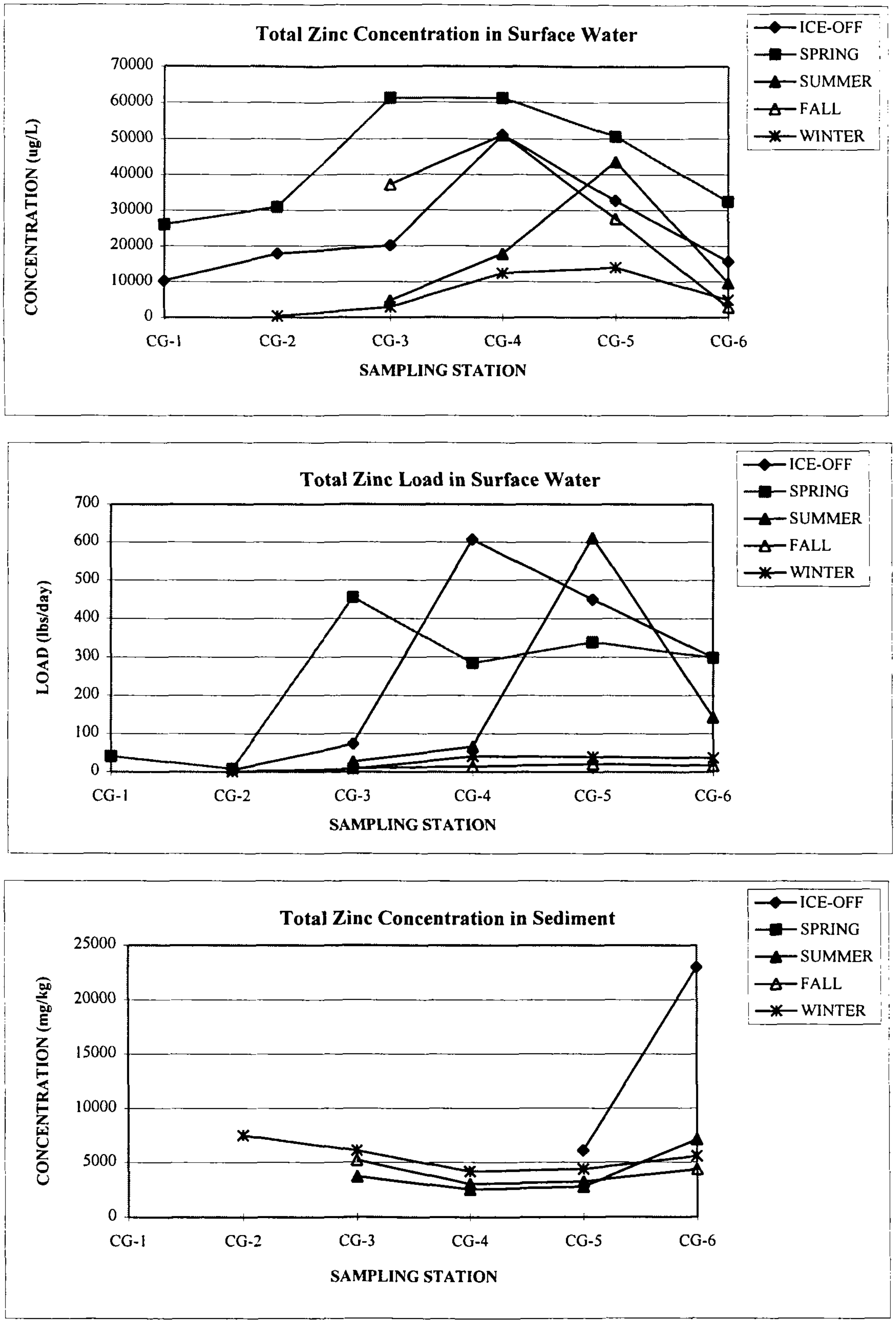
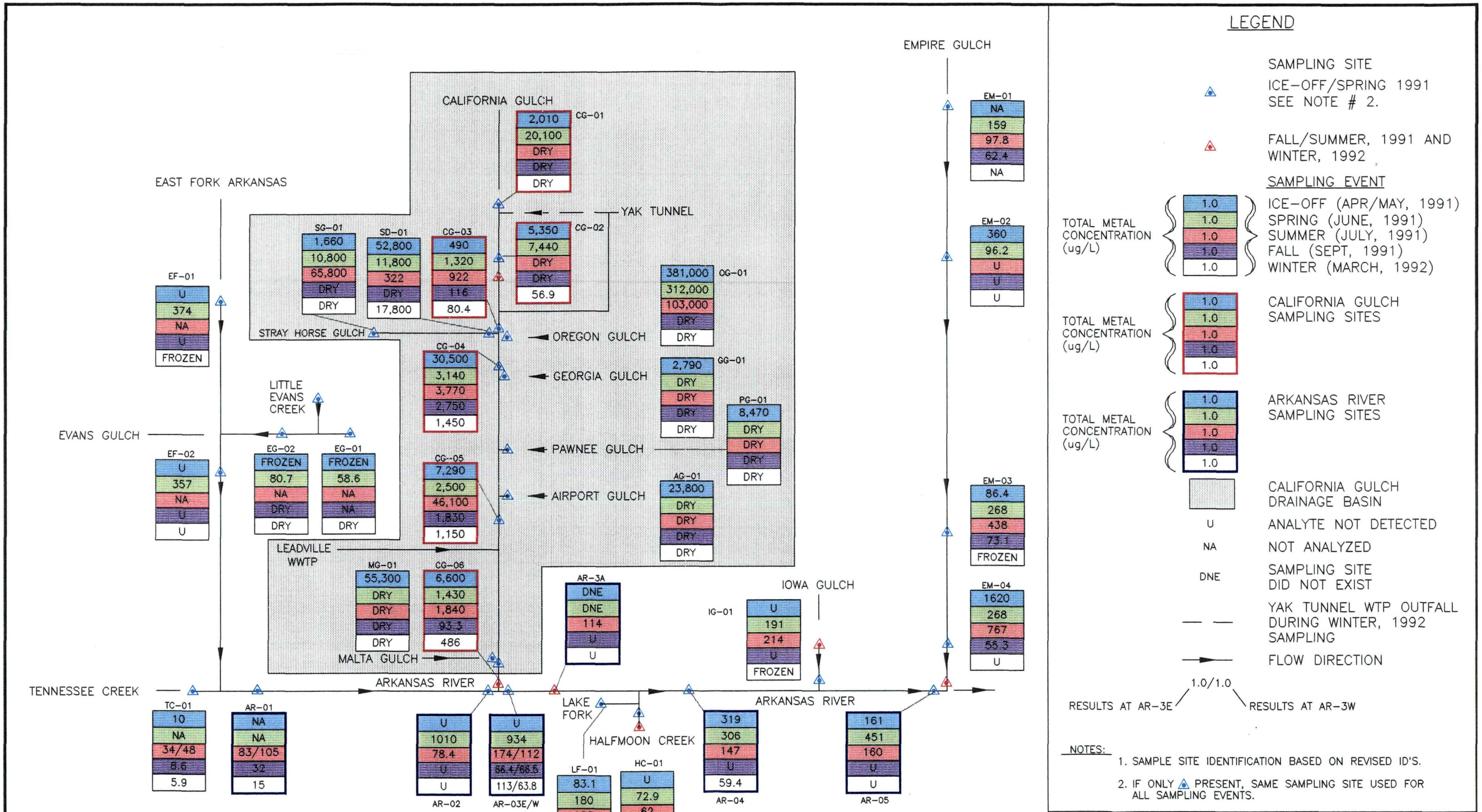


Figure 5-10
California Gulch Zinc Summary





NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates Denver, Colorado

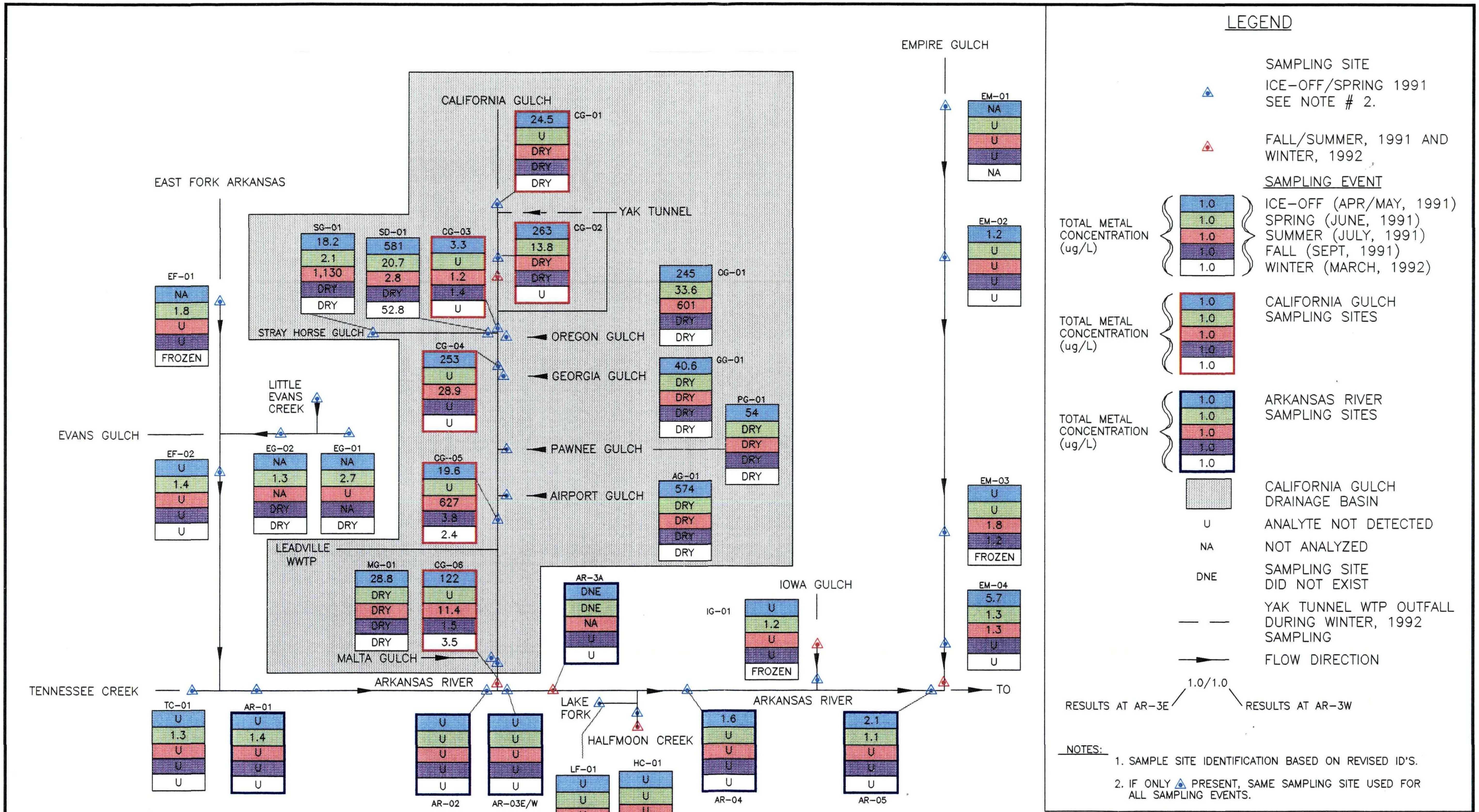
CLIENT/PROJECT

ASARCO
SURFACE WATER RI REPORT

TITLE

SCHEMATIC OF TOTAL ALUMINUM CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
CHECKED	ABR	SCALE	NO SCALE	DWG. NO./REV. NO.	
REVIEWED	BDP	FILE NO.	2819B014	FIGURE NO.	5-11



DATA SOURCE : ROY F. WESTON, INC.

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CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF TOTAL ARSENIC CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
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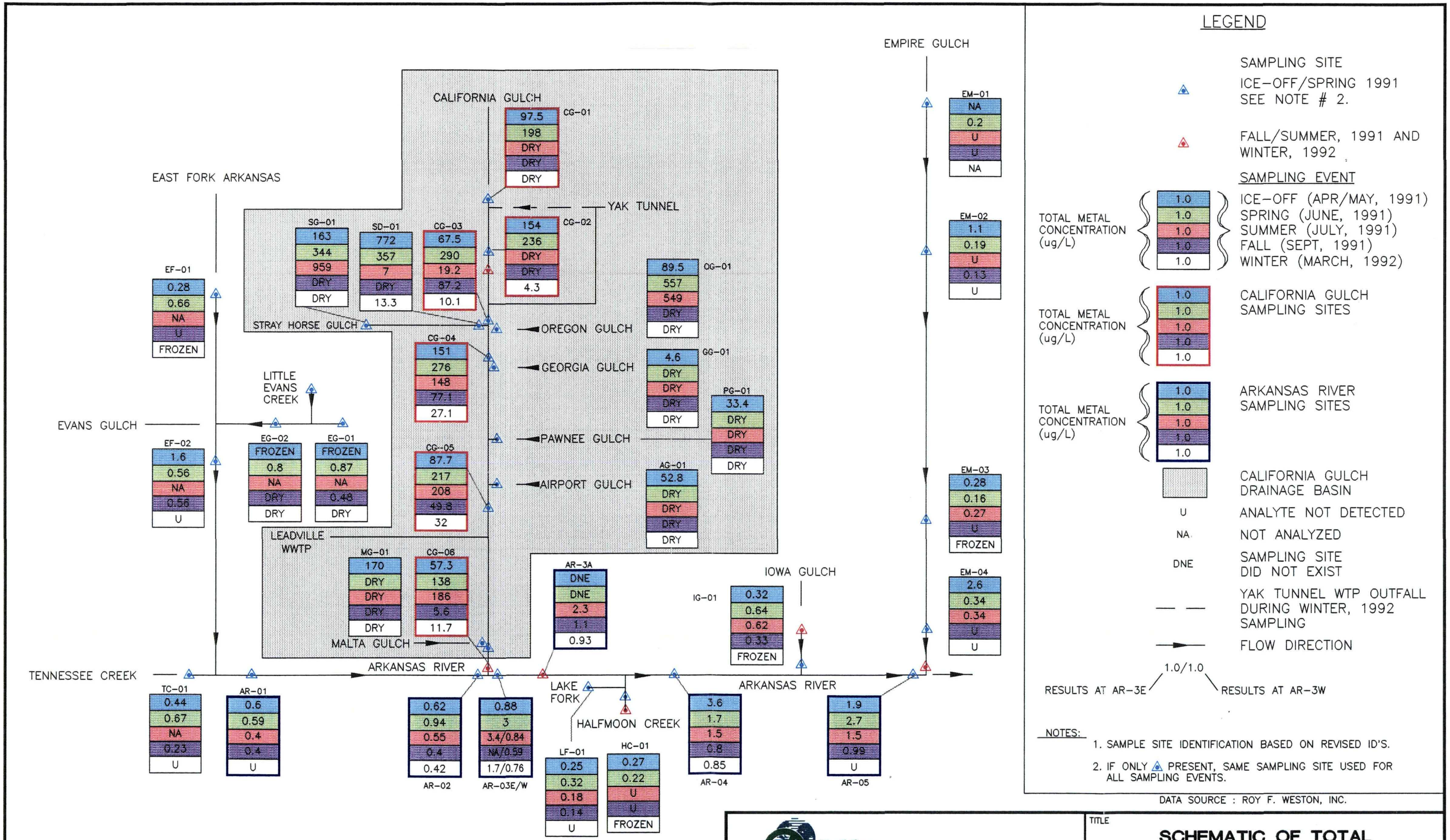

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates
Denver, Colorado

CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF TOTAL CADMIUM CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
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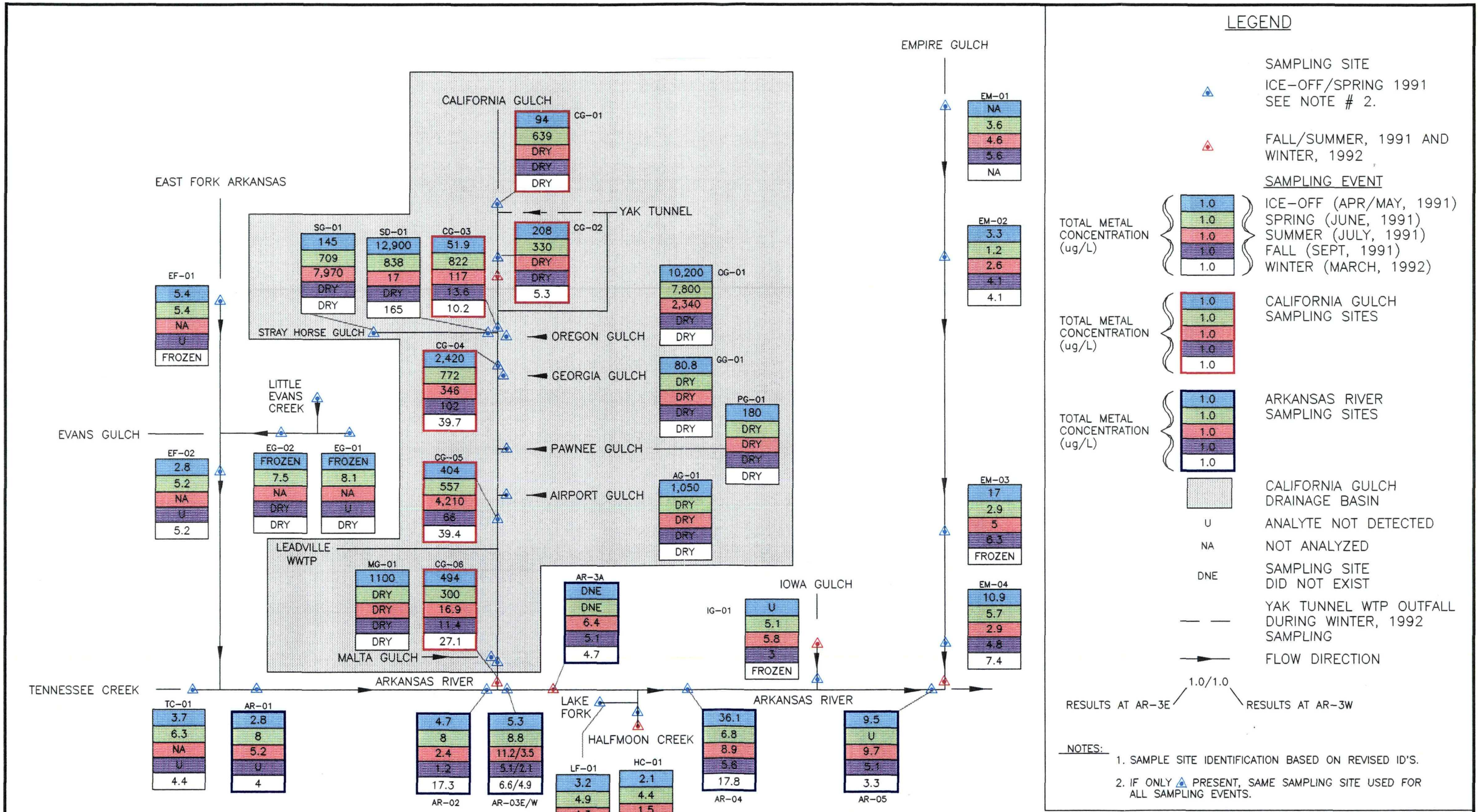

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates Denver, Colorado

CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF TOTAL COPPER CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
CHECKED	ABR	SCALE	NO SCALE	DWG. NO./REV. NO.	
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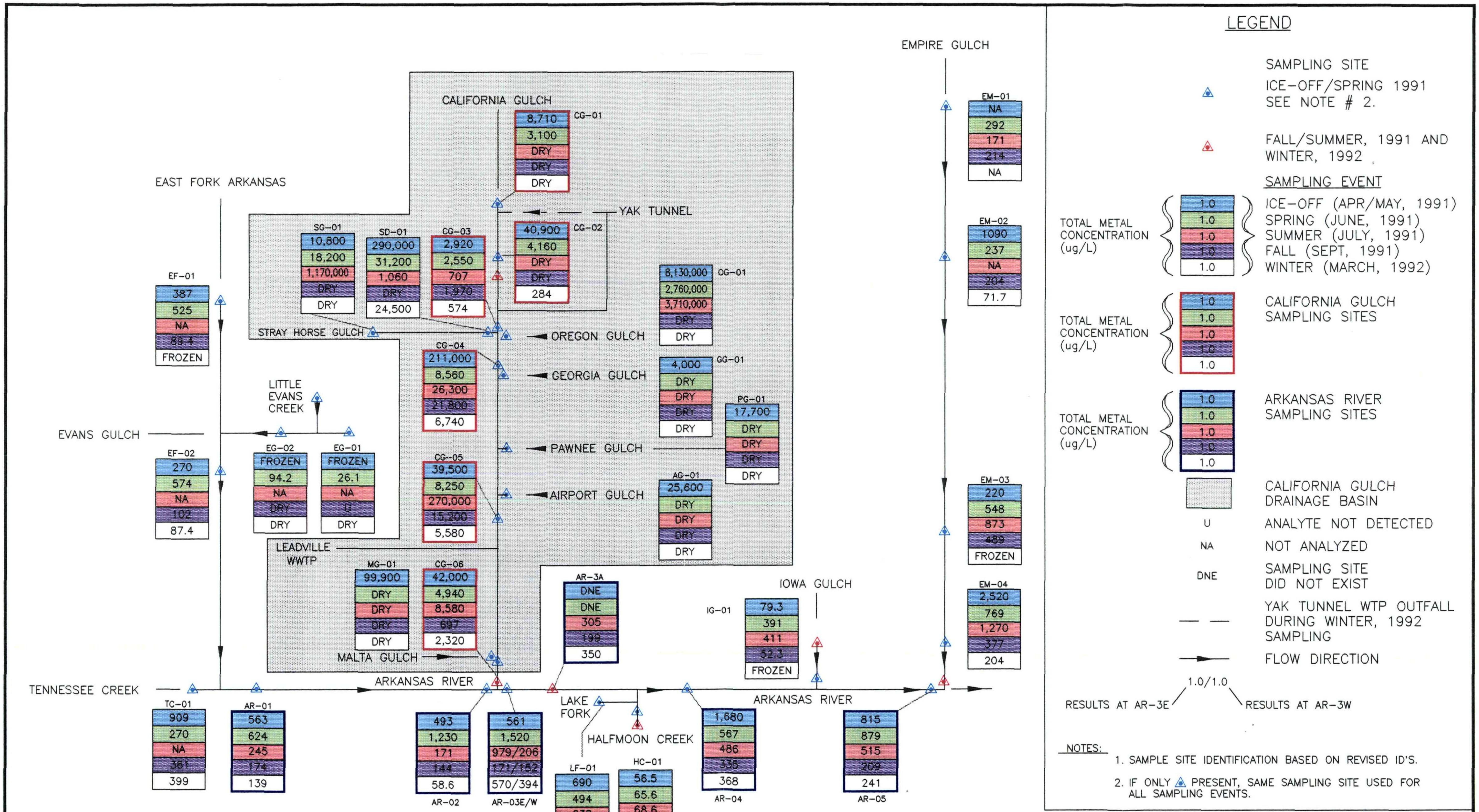

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

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CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF TOTAL IRON CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
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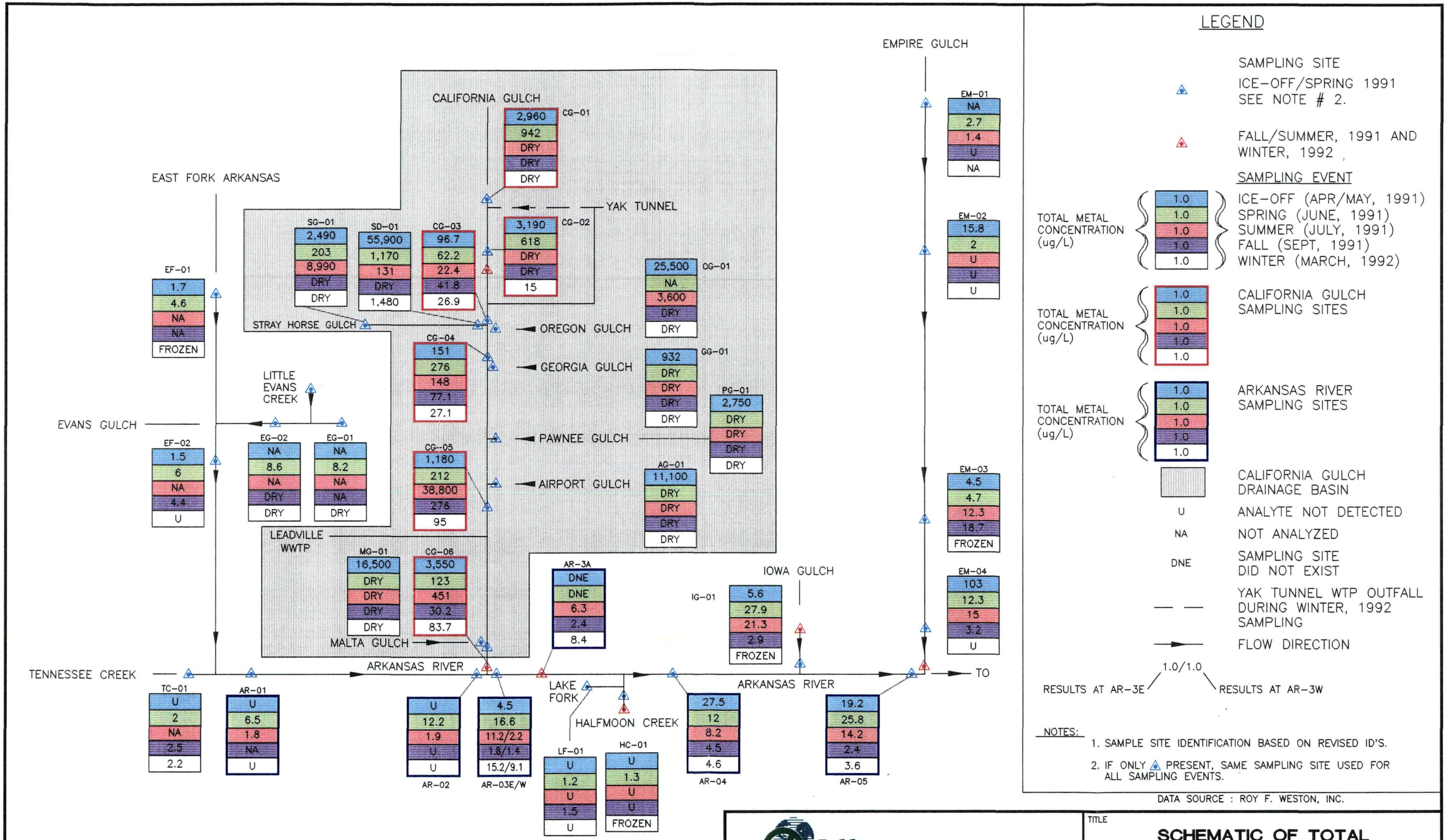

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates
Denver, Colorado

CLIENT/PROJECT
ASARCO
SURFACE WATER RI REPORT

TITLE
SCHEMATIC OF TOTAL LEAD CONCENTRATIONS

DRAWN	RB	DATE	MAY 1996	JOB NO.	943-2819
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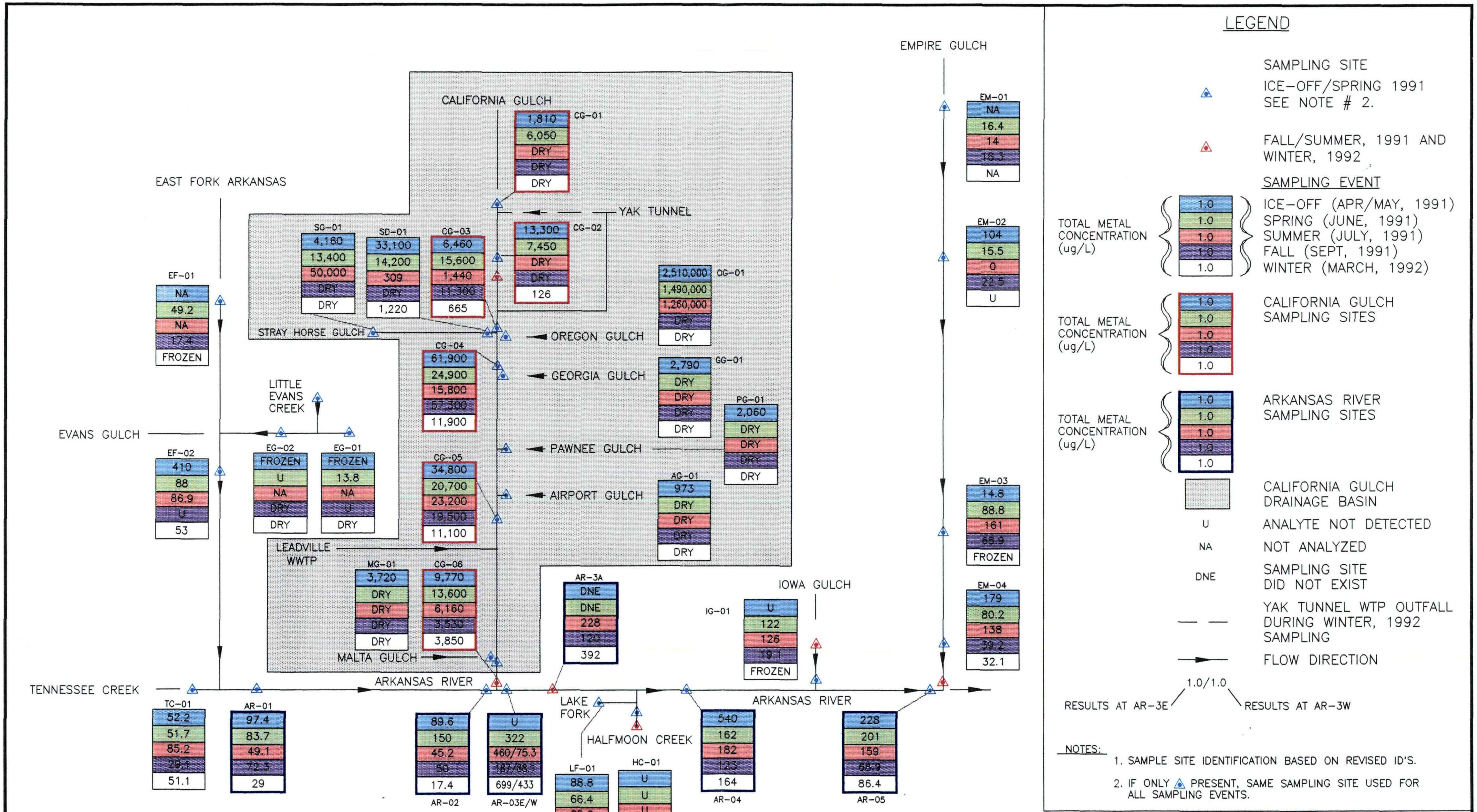

NOTES:

1. SAMPLE SITE IDENTIFICATION BASED ON REVISED ID'S.
2. IF ONLY ▲ PRESENT, SAME SAMPLING SITE USED FOR ALL SAMPLING EVENTS.

DATA SOURCE : ROY F. WESTON, INC.

Golder Associates Denver, Colorado	TITLE	**SCHEMATIC OF TOTAL MANGANESE CONCENTRATIONS**			
CLIENT/PROJECT **ASARCO SURFACE WATER RI REPORT**	DRAWN RB	DATE MAY 1996	JOB NO. 943-2819		
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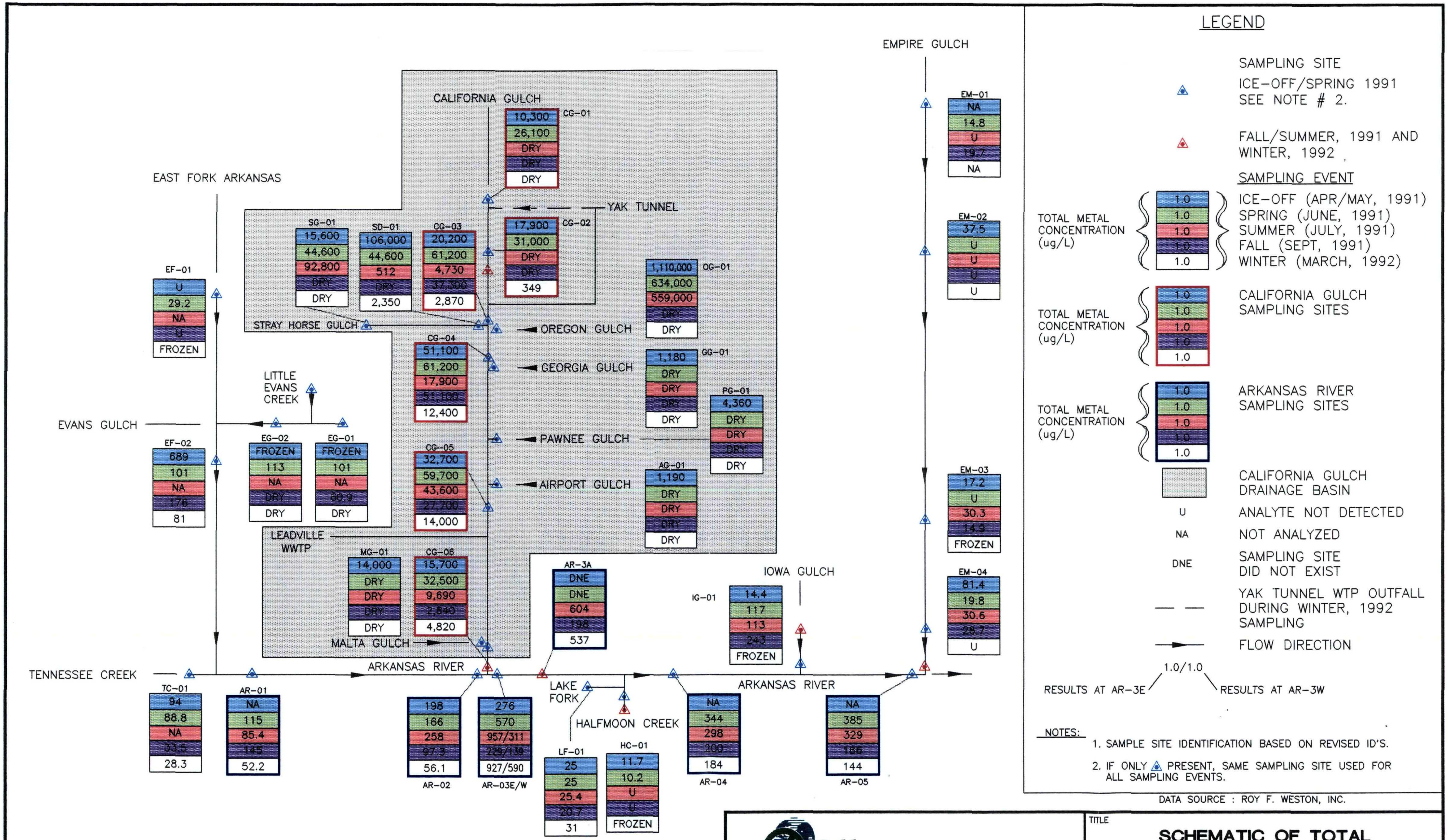
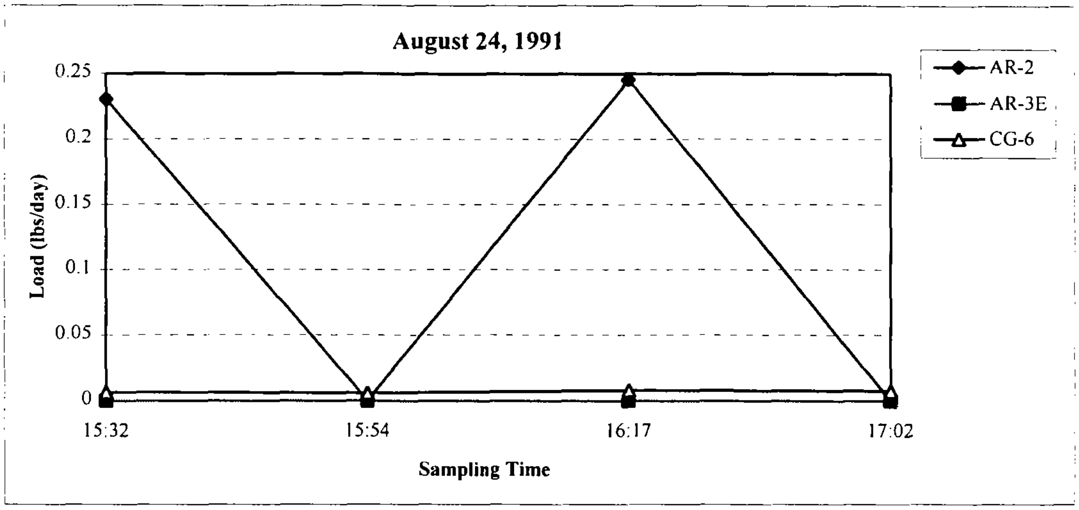
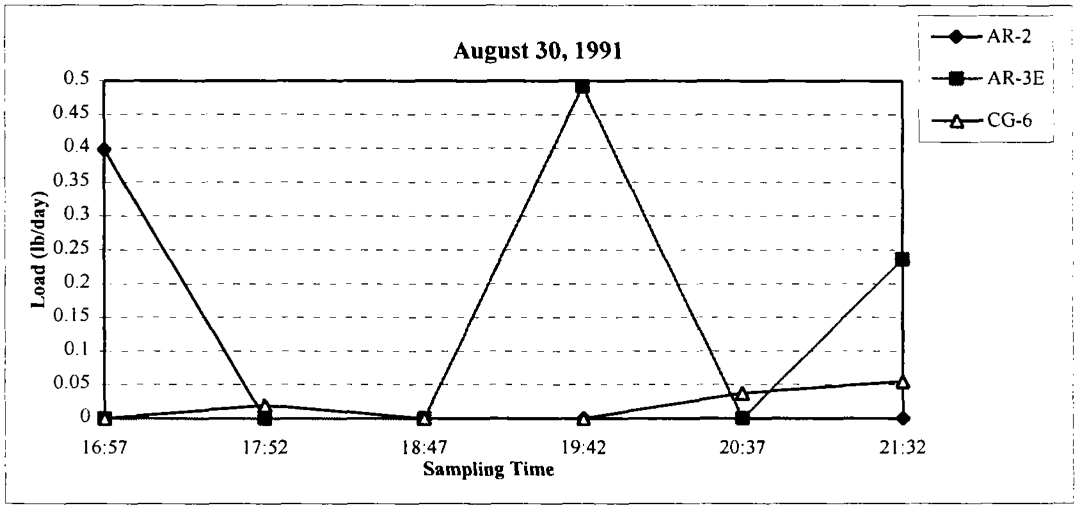


DATA SOURCE : ROY F. WESTON, INC.

Golder Associates Denver, Colorado		TITLE	**SCHEMATIC OF TOTAL ZINC CONCENTRATIONS**		
CLIENT/PROJECT **ASARCO SURFACE WATER RI REPORT**	DRAWN RB	DATE MAY 1996		JOB NO. 943-2819	
	CHECKED ABR	SCALE NO SCALE		DWG. NO./REV. NO.	
	REVIEWED BDP	FILE NO. 2819B019		FIGURE NO. **5-18**	

Figure 5-19
Summer Storm Loading Hydrograph
Total Arsenic





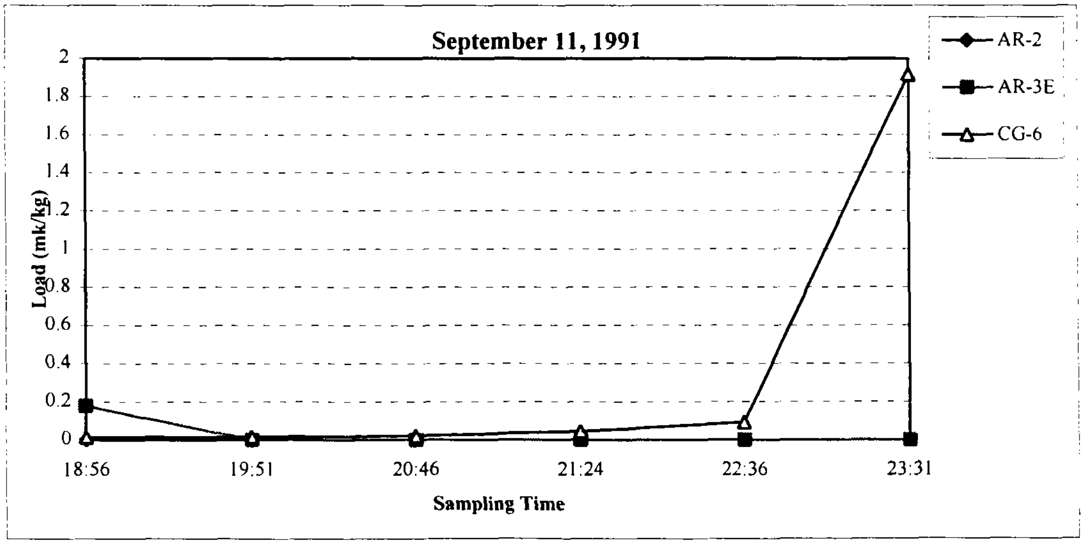
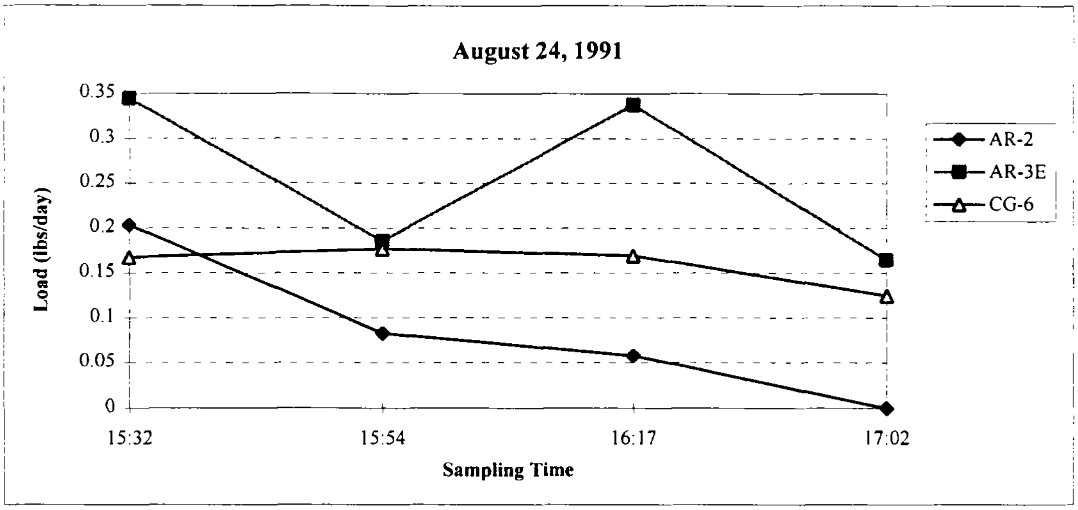
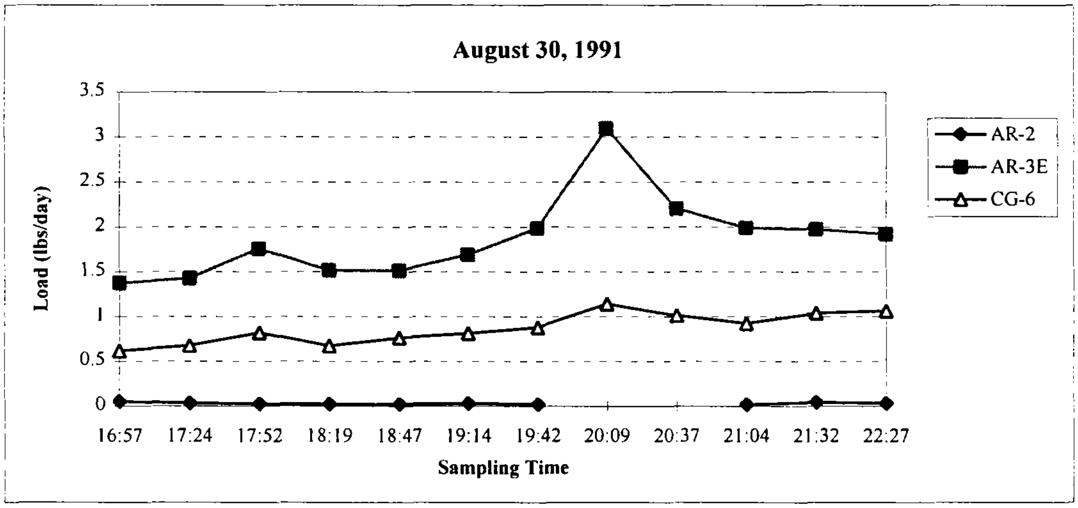


Figure 5-20
Summer Storm Loading Hydrograph
Total Cadmium





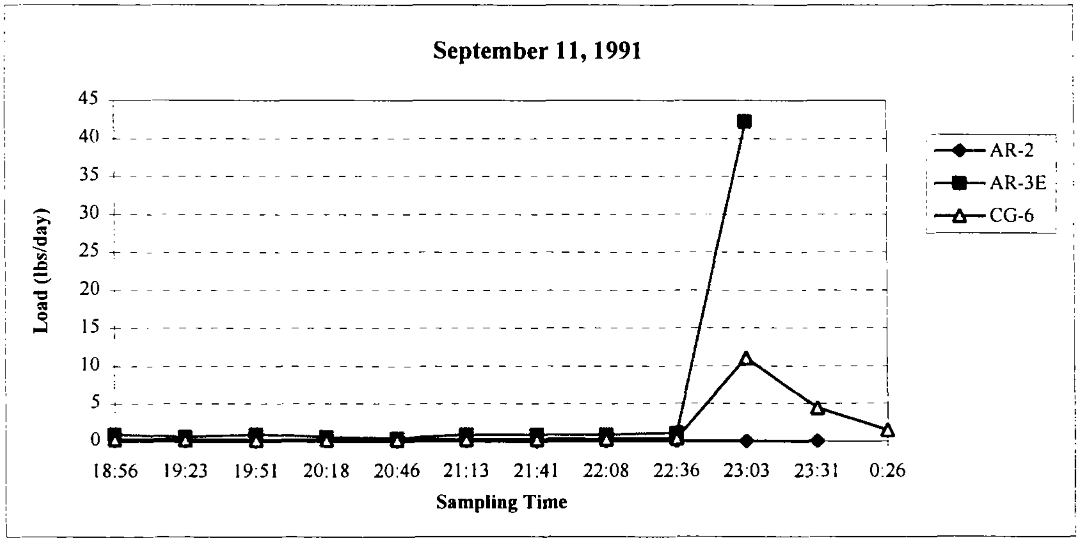
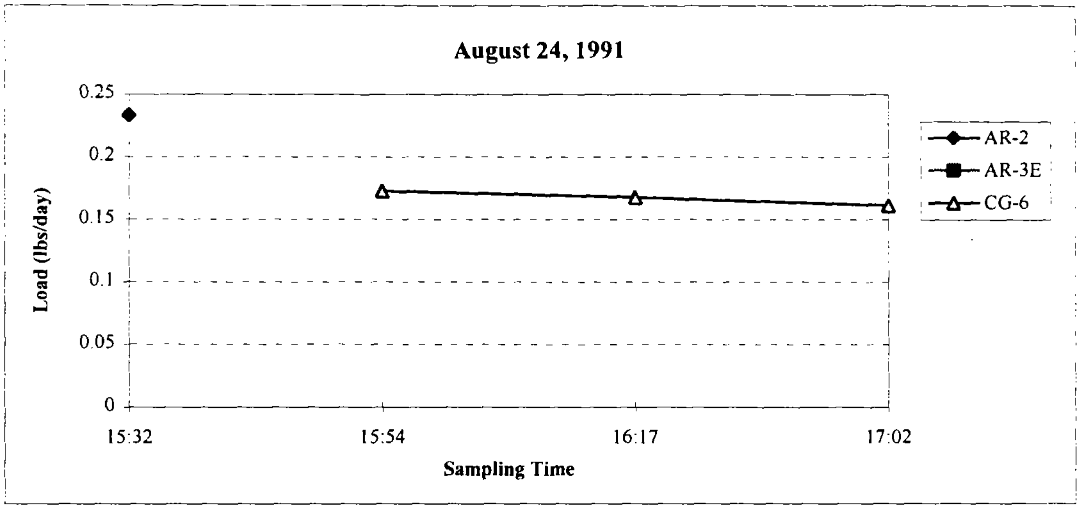
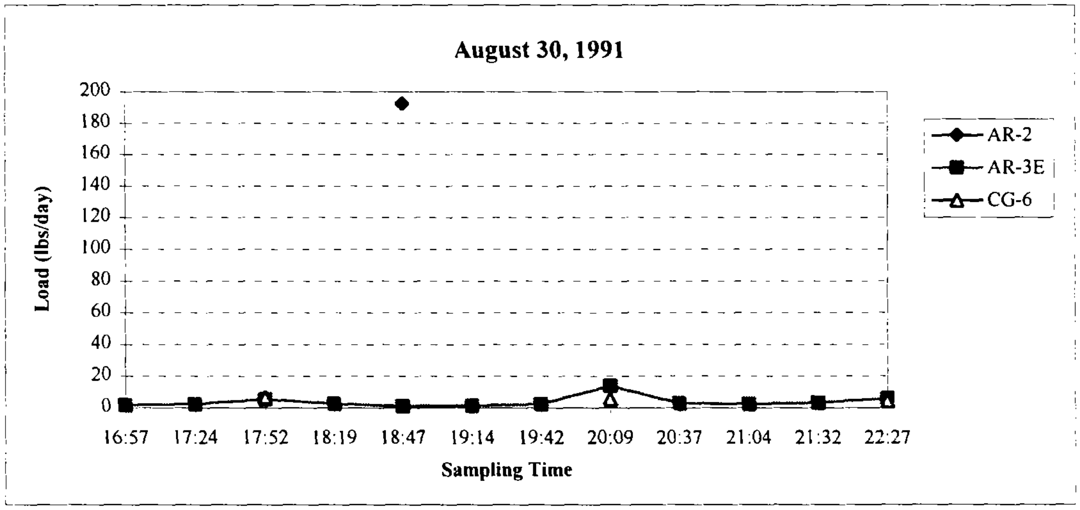


Figure 5-21
Summer Storm Loading Hydrograph
Total Copper





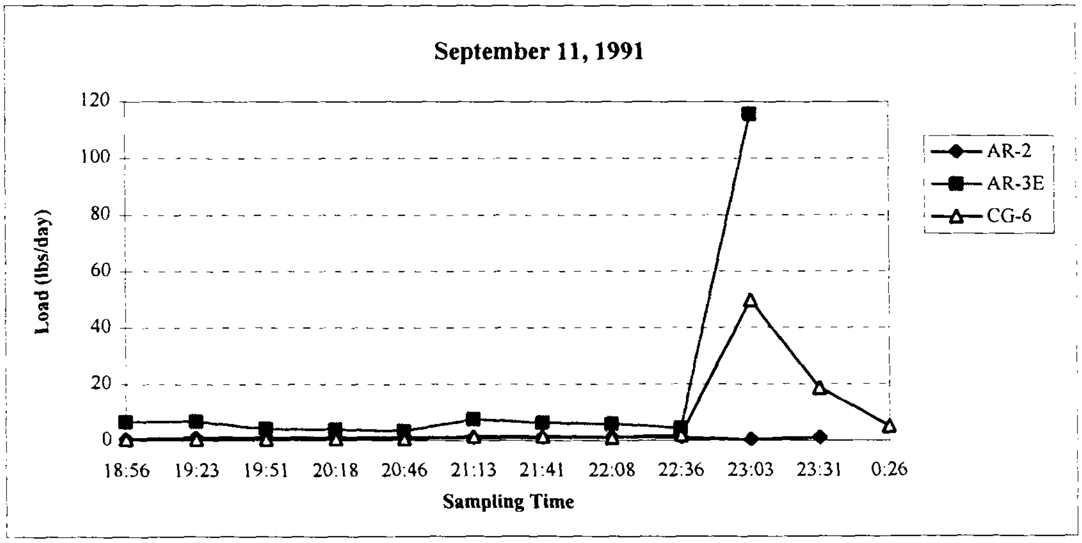
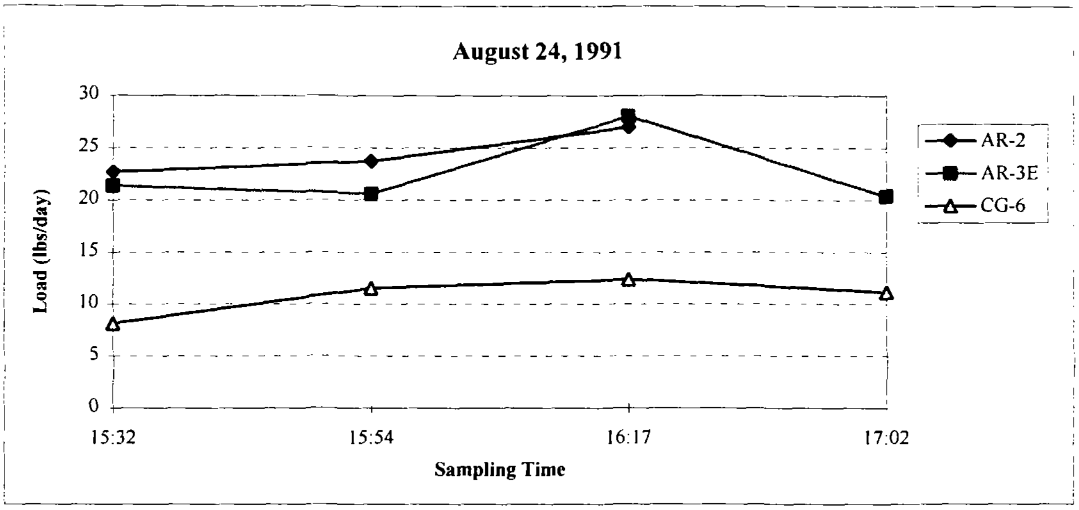
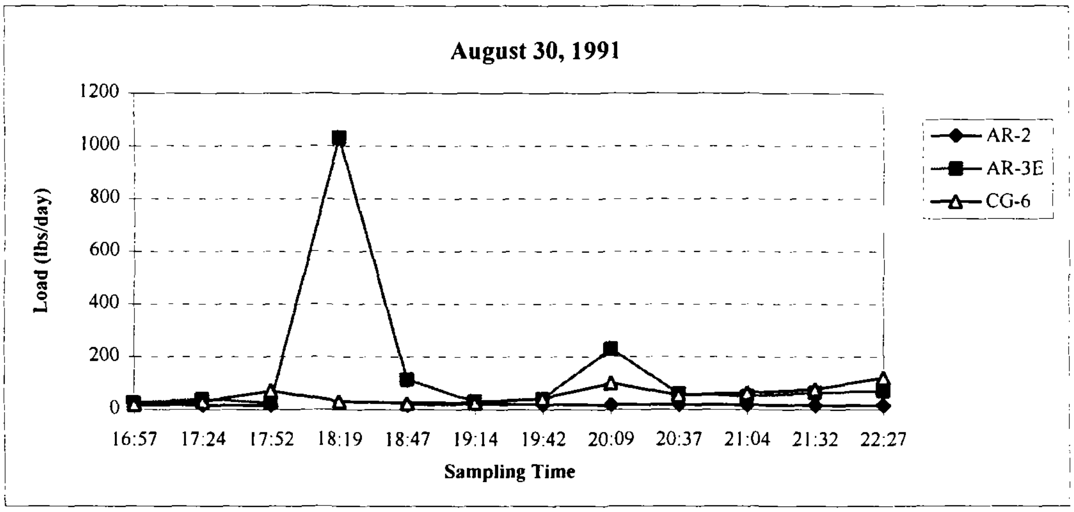


Figure 5-22
Summer Storm Loading Hydrograph
Total Iron





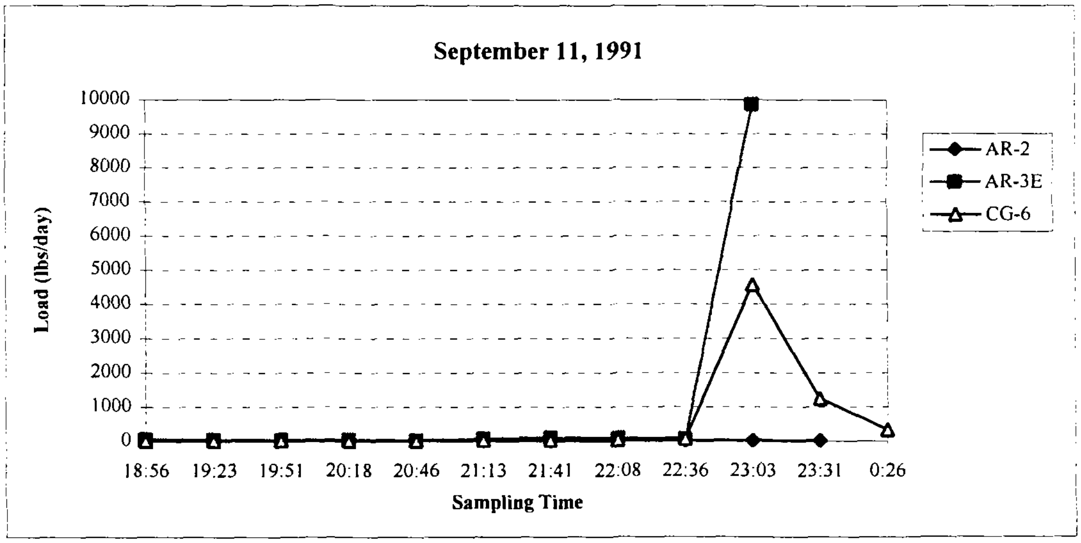


Figure 5-23
Summer Storm Loading Hydrograph
Total Lead

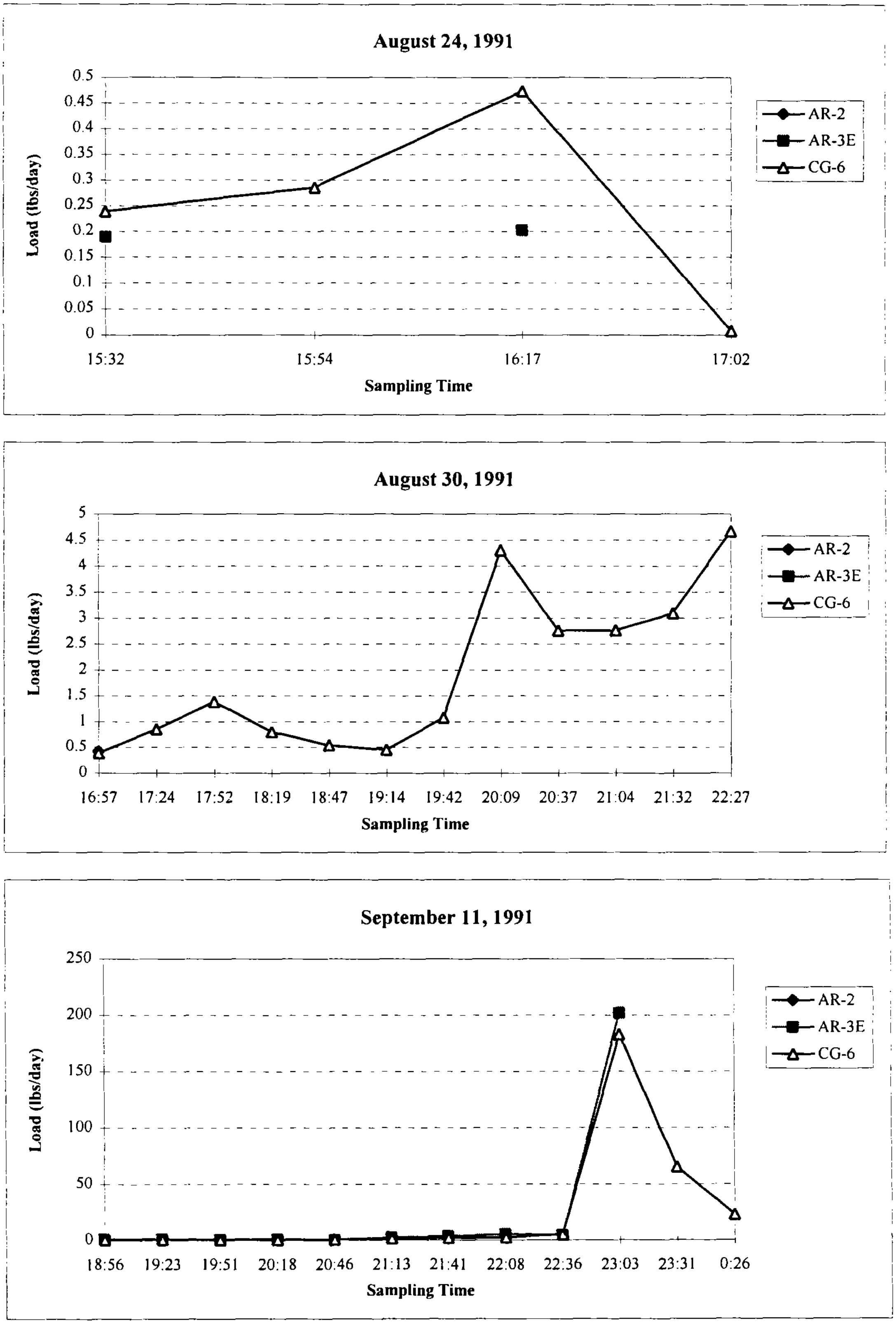


Figure 5-24
Summer Storm Loading Hydrograph
Total Manganese

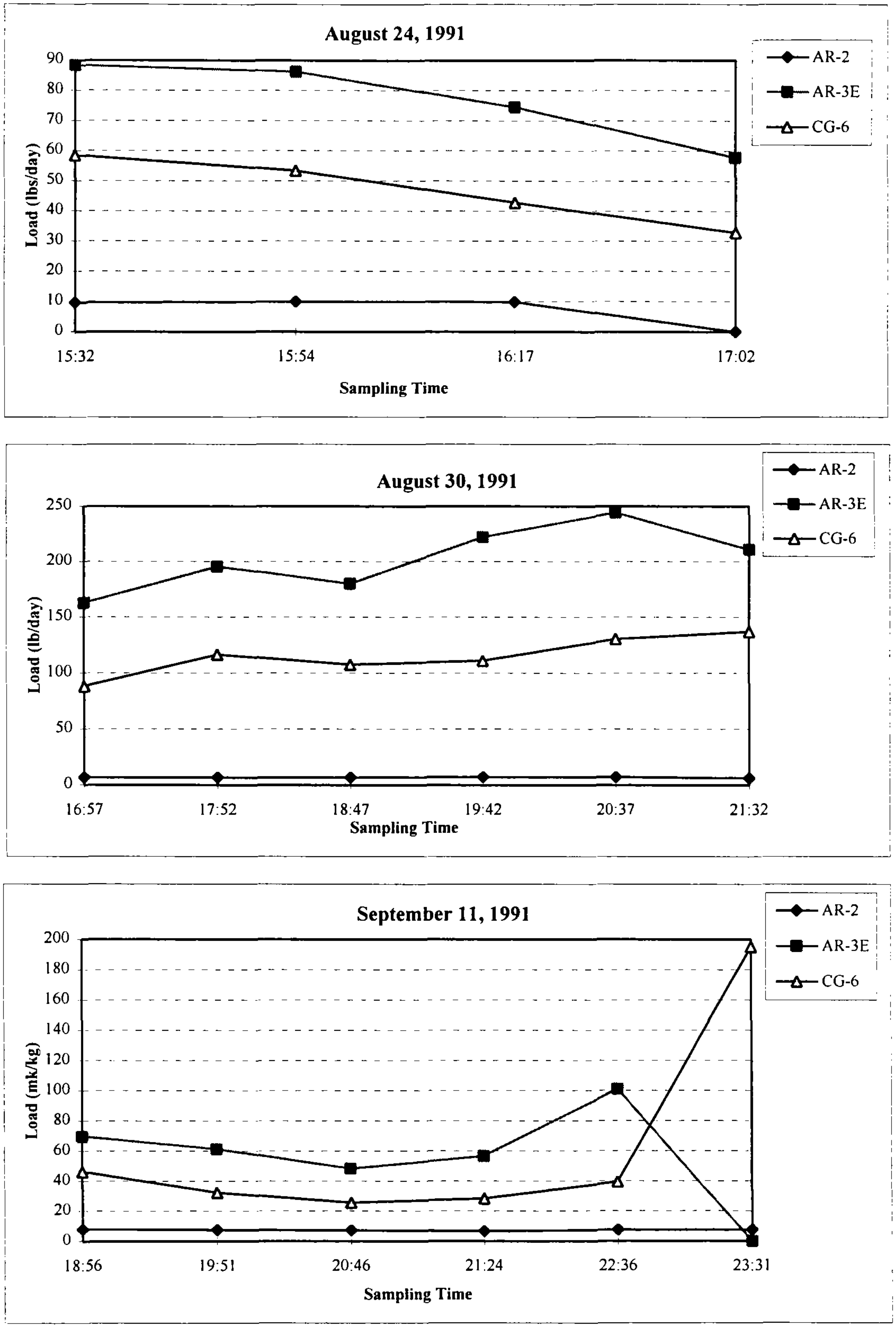
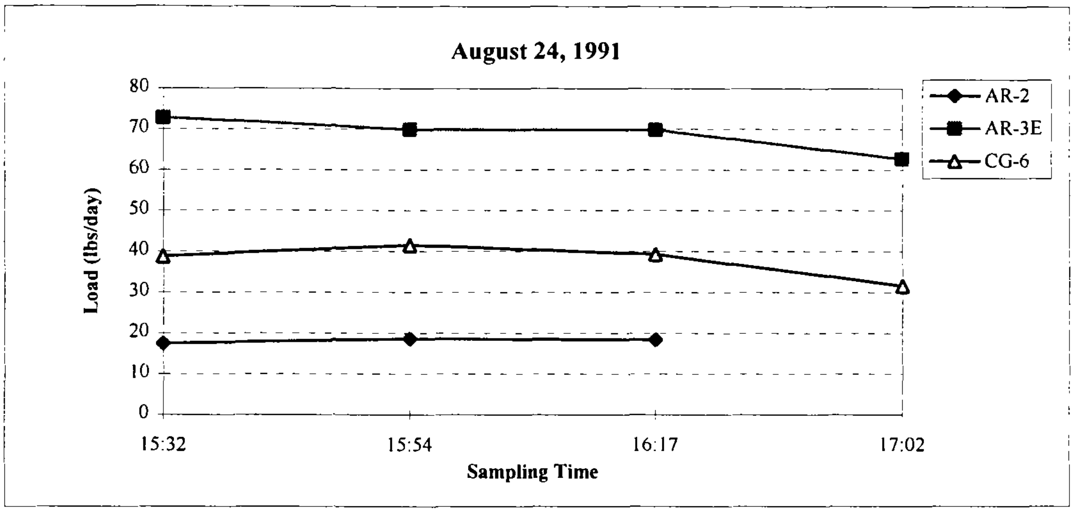
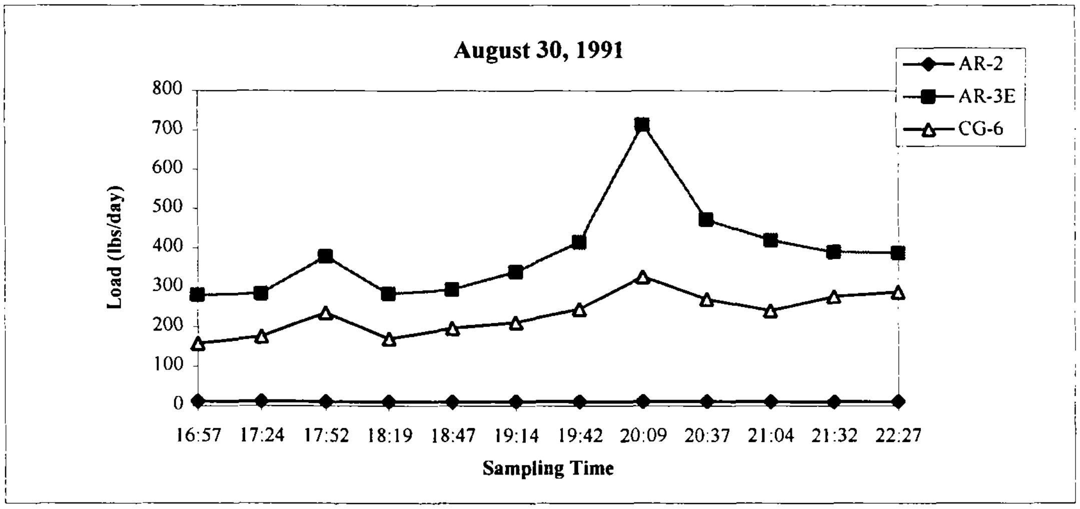
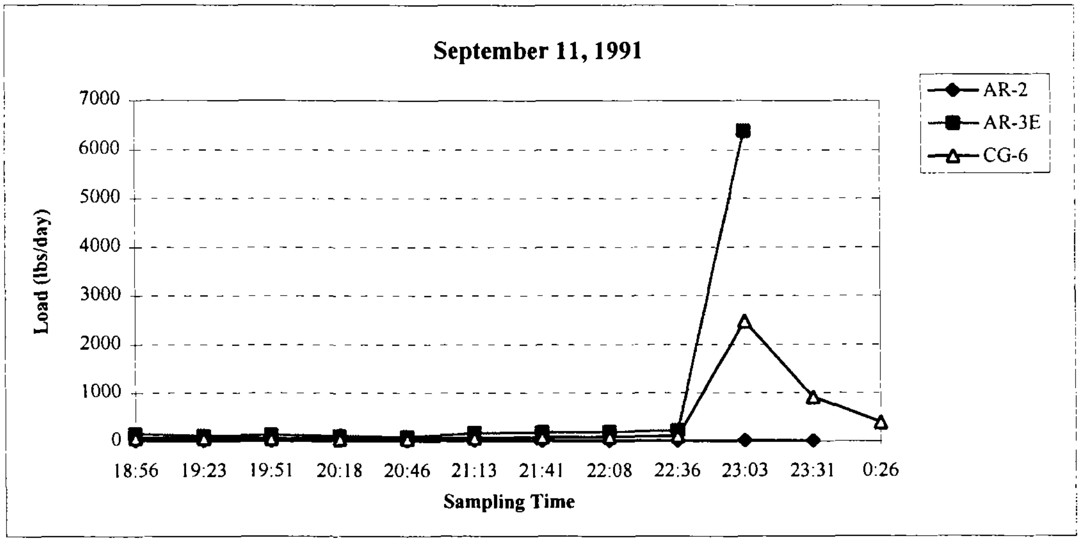


Figure 5-25
Summer Storm Loading Hydrograph
Total Zinc







Section 6

6.0 BACKGROUND SURFACE WATER QUALITY

Background surface water quality is defined as the chemical composition of water interacting with natural and undisturbed mineralized materials, prior to mining activities. In a naturally mineralized area such as California Gulch, both surface water and groundwater chemically interact with undisturbed sulfide minerals and their associated weathering products. This interaction can result in the oxidation of sulfide minerals, leaching of metals, increased acidity, and ultimately, the discharge of naturally degraded waters into local streams.

California Gulch is located in an area with a world-class ore body. Mining activities, which occurred in California Gulch from the late 1880s until the mid 1900s, have resulted in changes to local groundwater elevations and weathering patterns of the ore body. Background contributions of metals and acidity to the surface water in California Gulch and the Arkansas River continue today, even with mining-related impacts.

This section presents a discussion of background surface water quality in California Gulch and the potential influence of background surface water quality on the overall stream water quality of California Gulch and the Arkansas River. The following subjects are presented:

- Factors influencing background water quality;
- Methods available to estimate background water quality in disturbed areas;
- Review of previous studies in the California Gulch area and other similar mineralized areas in Colorado; and,
- Preliminary background water quality evaluation for California Gulch.

6.1 Factors Influencing Background Water Quality in California Gulch

The natural factors which influence the interaction of surface water and groundwater with mineralized rock, resulting in metals loads to surface water or groundwater include:

- ***Topography*** plays a significant role in exposing mineralization, due to mechanical erosion and exposed surface area;
- ***Mineralization*** type and morphology control the reactivity of the material;
- ***Geology*** provides control on weathering, source of buffering, permeability, and physical stability;
- ***Climate*** affects depth of weathering, erosion rates, and dictates the availability of water for transport of constituent loads; and,
- ***Hydrology*** controls the reaction and movement of waters through the mineralized rock as well as mixing with other waters.

These factors are summarized in the following paragraphs:

Topography

California Gulch topography ranges from steep mountainous terrain to relatively gentle topography near the town of Leadville. The mountainous terrain has resulted in erosion and exposure of the mineralized rock throughout the district.

Mineralization

California Gulch mineralization is primarily comprised of massive sulfide deposits in a limestone host. The sulfide mineralization includes pyrite, galena, sphalerite, and chalcopyrite. The mineralized zones are generally composed of massive sulfides, which in general tend to be less reactive to weathering than vein-controlled or disseminated sulfides.

However, in California Gulch extensive weathering and oxidation of the sulfide mineralization has occurred to depths of 500 feet below ground surface, indicating that the breakdown of sulfide minerals in California Gulch is a natural process which has occurred throughout recent geologic time. Early hardrock mining activities in the district focused on the oxidized sulfide zones.

Geology

The geology of California Gulch is complex and includes Precambrian metamorphic and intrusive rocks overlain by Paleozoic sedimentary rocks. The Paleozoic section includes both dolostone and limestone which provide buffering capacity. The entire sequence has been intruded and altered by Cretaceous and Tertiary igneous rocks. Glaciation during the Wisconsin period, created many of the topographic features.

Climate

The climate is typical of mountainous areas in Colorado with high precipitation from thunderstorm events occurring in July and August. Additionally, precipitation accumulates during the winter months as snowpack, resulting in high stream flow during the spring runoff event. Freeze/thaw cycles increase mechanical erosion of the exposed bedrock. Seasonal variations in temperature and precipitation result in similar fluctuations in stream flow, causing high erosion rates and increased depth of weathering.

Hydrology

Surface water and groundwater hydrology in California Gulch is complex between the alluvial hydrogeologic unit which overlies the bedrock hydrogeologic unit. Surface water flow is ephemeral above the Yak Tunnel.

These interrelated factors result in the natural oxidation and weathering of mineralized rock. Surface water infiltrating through the weathered and oxidized rock is acidified and leaches out metals, which are subsequently discharged, as background constituent load to surface water streams.

6.2 Estimating Background Surface Water Quality in Disturbed Areas

Several approaches can be used to estimate pre-mining surface water quality. Each approach has distinct advantages and disadvantages, but the resulting calculated background water quality values represent estimates based on assumptions. As discussed during the March 14, 1995 TAC meeting, approaches for estimating background water quality are presented in the following sections. Summaries are presented which demonstrate the use of the approaches in estimating background water quality for California Gulch and the Arkansas River.

Background water quality can be addressed through several methods, all of which rely on the extent of available data and whether the data represent the complex interaction between mineralogy, topography, climate, and hydrology. None of these methods will give unique results and none are definitive. Selection of potential methods for evaluation of background water quality is site specific. Potential approaches and applications to the California Gulch site are discussed below.

6.2.1 Analog Approach

The analog approach consists of locating a non-mined drainage area with similar characteristics that can be used as an analog for background water quality in the mined basin. Since no two drainages are exactly alike, selection of an analog basin can be accomplished by assigning similarity factors to each basin characteristic. Each characteristic can also be assigned a weighting factor, based on the characteristic's importance in influencing water quality. Determination of an analog basin can be made by comparing the similarity and weighting factors. Characteristics to consider include the topography, mineralization, geology, climate, and hydrology of the region. As an example, geologic characteristics such as average grain size, relative abundance, and average zinc content of pyrite grains in rocks within the mined basin could be compared with the candidate analog basins.

Advantages of the analog approach include allowing: direct observation of conditions in the analog basins; use of many different factors; selection of the degree of complexity by limiting the number of characteristics to be considered.

Disadvantages include the difficulty in locating data obtained from mineralized, but non-mined regions, difficulty in determining and quantifying characteristics influencing water quality, and the inability to quantify the relative precision of the estimation. An analog approach should concentrate on nearby basins and would weight the factors more appropriately.

Miller and McHugh (1994) estimated background water quality in the vicinity of the Summitville mine by examining five non-developed mineralized drainages within the Alamosa River basin. Three of the drainages contain calcium-bicarbonate type waters and two acid-sulfate waters. Dissolved zinc concentrations ranged from 4 to 1800 µg/L in the non-developed mineralized zones. This study also provided a description of the steps involved in an analog approach to background water quality determination.

6.2.2 Analytical Approach

The analytical approach calculates background surface water quality by use of theoretical weathering reaction stoichiometries and estimated reaction rates, coupled with the amount of exposed area within the mined basin. These factors are used to estimate the theoretical flux of each element into basin surface waters per unit area. Surface water concentration of each element then can be calculated by combining the theoretical flux with water balance information. Increased accuracy can be obtained by considering differential mineral weathering rates, secondary mineral formation (such as oxides or clays), and groundwater/surface water interactions.

Advantages of the analytical approach include allowing: application of the theoretical models to remediation planning; the concentration of data collection efforts on one basin; and calibration of the model using water quality data. Additionally, several computer predictive models exist that can assist in calculations.

Disadvantages of this approach include the difficulty in assigning rates to chemical weathering reactions, and difficulties in simulating processes controlling trace metal concentrations.

An analytical approach to pre-mining water quality determination for California Gulch would require detailed geologic, hydrologic and climatic data for the entire basin. Groundwater flow paths, travel times and recharge/discharge relationships would have to be well defined, possibly with the use of a flow modeling software package such as MODFLOW. A geochemical model (e.g., MINTEQA2 or PHREEQE) can be used to model rock/water interactions and establish a predicted water quality.

The analytical modeling method was used in two separate studies for predicting zinc concentrations in water in equilibrium with area minerals. A Hydrometrics (1987) report estimated two sets of trace metal values, based on equilibrium with site-specific sulfide and carbonate ore zone minerals under conditions found in shallow groundwater. The Hydrometrics report used the computer model PHREEQE and predicted concentrations of dissolved zinc in waters from sulfide and carbonate ores at 67,000 and 10,000 µg/L, respectively. A U.S.G.S. (1979) report used the SOLMNEQ model and predicted a zinc concentration of 13,000 µg/L in waters from carbonate ores.

The values generated by these two reports are not intended to represent background surface water quality, but represent the quality of water (i.e., groundwater) that is in complete equilibrium with ore minerals. The reports do not account for any dilution effects from non-mineralized zone waters or the likelihood of partial equilibrium, both of which would act to lower the predicted trace metal concentrations.

6.2.3 Direct Measurement Approach

The direct measurement approach involves locating areas or bodies of water that are of pre-mining age and that have not been exposed to mining activities within (or very near) the mined area. It is important to ensure that water quality data are derived from water that has come in contact with mineralized rock; this requires that flow paths and lithologies be well defined. It also is important to consider geochemical factors before using the data to define background water quality. Isotopic dating techniques such as C_{14} can be used to verify that the groundwater samples are of pre-mining age.

Advantages of this approach are that it allows direct and conclusive measurement of chemical quality in water samples representative of pre-mining conditions. The disadvantage is that it may be difficult to locate waters or stream reaches within a mined area that have not been disturbed. Other difficulties exist in extrapolating surface water background chemistry from groundwater samples, and ensuring that the sampled water has had sufficient contacted with mineralized rock to be considered representative of background conditions. It also may be difficult to prove that a given sample has not been influenced by mining activities.

A direct measurement approach in the California Gulch basin would require locating a region of groundwater that has contacted significant amounts of mineralized rock under oxidizing conditions, but that has not been affected by mining activities. This would be difficult because dewatering associated with the Yak Tunnel and Leadville Drainage Tunnel has significantly altered upgradient groundwater compared to background conditions. Groundwater downgradient of the drainage tunnels may not have been impacted by mining, but it may not have been in contact with significant ore bearing minerals.

Natural and anthropogenic sources of acidity and metals were examined in the vicinity of the Summitville mine (Kirkham, 1995). In this study, several active and fossilized ferricrete and iron bog deposits that were unrelated to mining activity were sampled and analyzed. Dissolved zinc in active iron bogs was reported to range from 100 to 900 µg/L. It was estimated that less than 1 percent of mining related metals (Cu, Mn and Zn) were contributed to the Alamosa River above the confluence of Wightman Fork by Summitville mining activities. About 18 percent of the aluminum in the Alamosa River was estimated to be from mining activities. These estimates were based on total metals loads observed in surface water emanating from mined areas. The estimates did not include contributions to surface water from groundwater affected by mining.

Miller et al. (1994) discussed surface waters affected by natural acid drainage (NAD) along the Colorado Mineral Belt in which Leadville is located. The authors state that many NAD-influenced waters have zinc contents usually less than 1,000 µg/L, but can reach several thousand µg/L. Geneva Gulch was cited as an example of a basin influenced by NAD.

6.2.4 Empirical Approach

The empirical approach consists of measuring trace metal contents of chemical precipitates in iron bogs or ferricrete deposits from streams that are in pre-mining areas. The most common precipitate is iron oxyhydroxide, but other precipitates could be measured. The basis for this approach is the assumption that the measured trace metal content of the precipitate is dependent on the trace metal content and pH of the water in which the precipitate is formed.

The primary method of trace metal incorporation into an iron oxide is assumed to be sorption (or co-precipitation). The amount of sorbed material in a sample is compared to the trace metal content of water and is expressed as an empirical constant (Kd) value. Many Kd values can be found in literature or can be measured in active iron bog or stream deposits.

A disadvantage of the empirical approach is that Kd values are pH-dependent. The pH of pre-mining water must be determined (estimated) using other methods.

An empirical approach in the California Gulch basin would require identifying pre-mining stream or ferricrete deposits, extracting and analyzing samples, and interpreting the analytical results. Multiple samples from the same deposit would add a level of confidence to the results. Ideally, the sample(s) would be collected from California Gulch and not from a tributary stream. Active stream deposits and water quality samples collected in California Gulch would be analyzed to provide data for calculating site-specific Kd values. Due to fluvial dredging along the length of California Gulch, undisturbed samples may be difficult to obtain.

6.2.5 Historical Records Review Approach

A review of historical water quality records can be useful, particularly if waters were analyzed before mining began. Anecdotal evidence, including descriptions of stream appearance, descriptions of fish or wildlife, or records of consumptive use may confirm results from other methods. An historical-records search may not find quantitative water quality data, but may provide qualitative water quality information.

6.2.6 Review of Previous Studies Approach

Several studies have estimated background or pre-mining water quality in California Gulch and in other similar mineralized areas. These studies show variability in predicted trace metal concentrations of up to three orders of magnitude. The previous studies are summarized on Table 6-1 and discussed below.

6.2.7 Combined Methods Approach

A report by Runnells (1988), includes a discussion of several background water quality approaches: 1) a review of historical records; 2) an analog approach; and, 3) an overview of the Hydrometrics (1987) and U.S.G.S. (1979) analytical methods. This report combined results from the three approaches and made a qualitative estimate of background water quality conditions. The results of this study predicted a range of 1,000 to 70,000 μg/L in the background levels of dissolved zinc.

6.3 Low-Flow Background Surface Water Quality Evaluation

This section presents a preliminary evaluation of background surface water quality contributions to California Gulch, and subsequent contribution to the Arkansas River. Given the existing database and the metal loading to the surface water from mining-related disturbances, it is difficult to separate the comparatively small background contribution.

The existing low-flow concentrations of zinc in California Gulch and the Arkansas River are reviewed. Zinc was selected as the indicator species because zinc is an excellent predictor of the geochemical behavior of copper, lead, cadmium, manganese, and iron. In addition, current surface water concentrations of zinc are relatively high compared to these metals.

Baseflow (low flow) zinc concentrations were selected for comparison with predicted water quality in the Arkansas River. Calculating the percentage of the zinc concentration in the Arkansas River contributed as background zinc from California Gulch is particularly important in the evaluation. Surface water baseflow represents a period when surface runoff is at a minimum. Surface water baseflow in California Gulch occurs during low precipitation periods, generally late Fall or during the Winter when precipitation is held in the snowpack. Groundwater discharge is the primary source of surface water flow during baseflow conditions. During baseflow conditions, direct runoff from the mine waste facilities into California Gulch are at a minimum; consequently, concentrations of zinc in streams are generally at the seasonal fluctuation low. Figure 6-1 presents a plot of total and dissolved zinc concentration, and flow in California Gulch versus time. In general the low-flow period of October through April has the corresponding lowest zinc concentrations with dissolved values reaching a low of 1,000 µg/L. During periods of higher flow (May through September), dissolved zinc values exceed 10,000 µg/L.

The zinc concentration during baseflow conditions in California Gulch includes zinc from the following sources:

- Background contribution;
- Sediment bedload;
- Residual seepage from mine waste piles; and,
- Groundwater.

To evaluate the potential significance of the background contribution, it is assumed that the entire zinc concentration presented on Figure 6-1 is related to background. This is a simplification and is clearly an overestimation of the background zinc concentrations because there are several other potential sources in the gulch. It is also assumed that the baseflow dissolved zinc concentration is 1,000 µg/L. By using these assumptions it is possible to evaluate the effect of a likely maximum background contribution on water quality in the Arkansas River downstream of California Gulch, and decide whether more detailed background water quality evaluations are warranted.

Figure 6-2 presents the predicted dissolved zinc concentrations in the Arkansas River at AR-3, below the confluence with California Gulch. Calculations shown in Figure 6-2 were based on zinc loads determined from measured zinc concentration and flow in the Arkansas River at AR-2 (upstream of the confluence with California Gulch), added to a load determined from flow measured in California Gulch at CG-6 and the assumed background concentration of 1000 µg/L. The load calculated at AR-3 was then converted to concentration using predicted flow rates. Figure 6-2 presents a bar graph showing the zinc contribution of the assumed background from California Gulch and the upstream load from the Arkansas River (AR-2). The majority of the zinc concentration predicted at AR-3, using a background contribution from California Gulch, is from other sources on the Arkansas River. This indicates that, using an assumed background value of 1,000 µg/L, the California Gulch contribution at AR-3 ranges from 2.5 to 98 percent of the total zinc concentration. This range is dependent on flow rate; California Gulch background contributions are the lowest during high flow and highest during low flow conditions. A summary of the flow and concentration data is presented on Table 6-2.

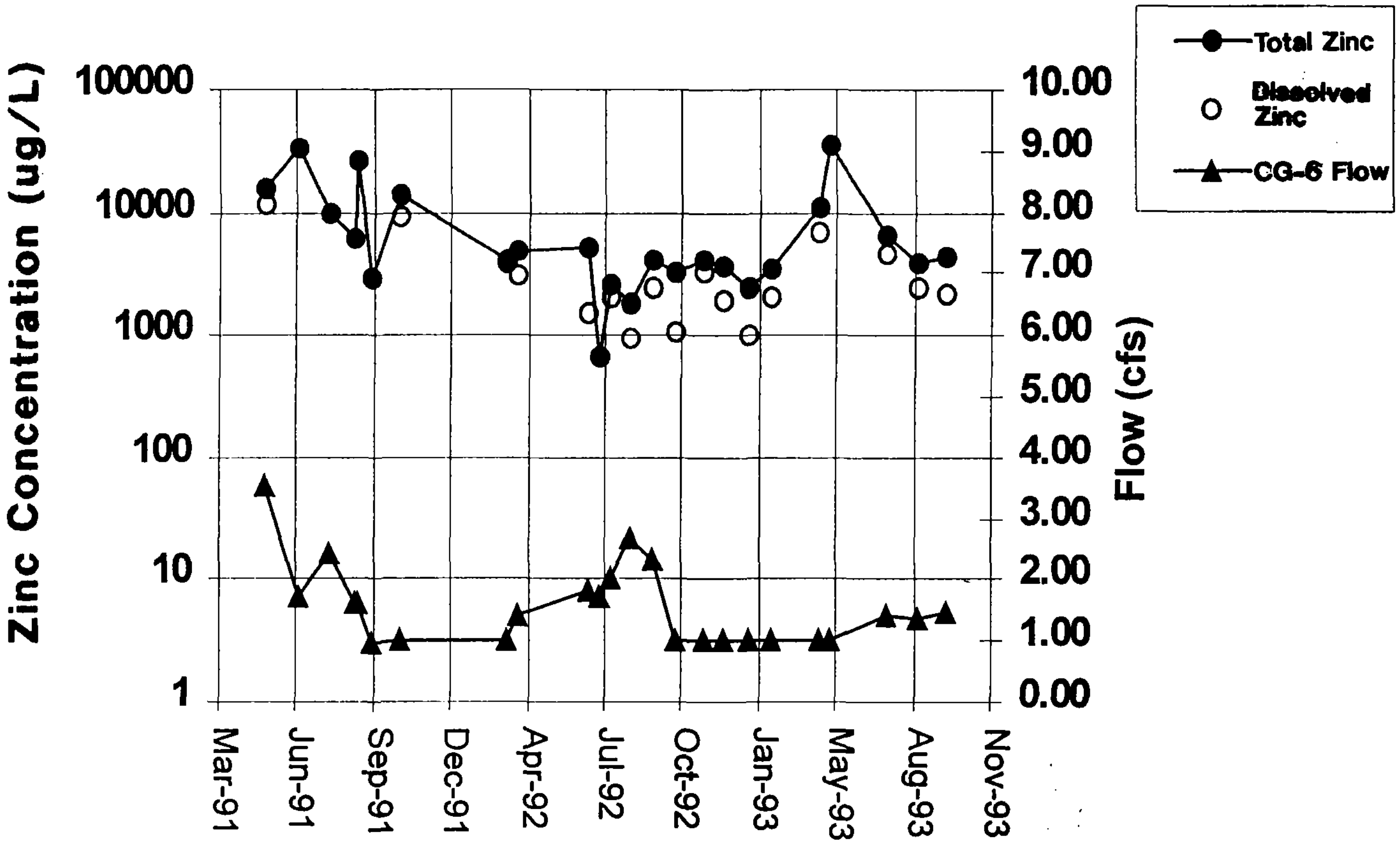
Figure 6-2 shows an aquatic life reference line at 120 µg/L using the Colorado Water Quality Control Commission, Table Values of Acute Standards for zinc at a hardness of 100 mg/L). The aquatic life reference was added for comparison with potential background contributions. The aquatic life reference is **not** intended to represent either a remedial objective or imply a regulatory standard. The predicted background zinc contribution from California Gulch averages 26.0 µg/L, 22 percent of the aquatic life reference.

TABLE 6-1
SUMMARY OF PREVIOUS WORK

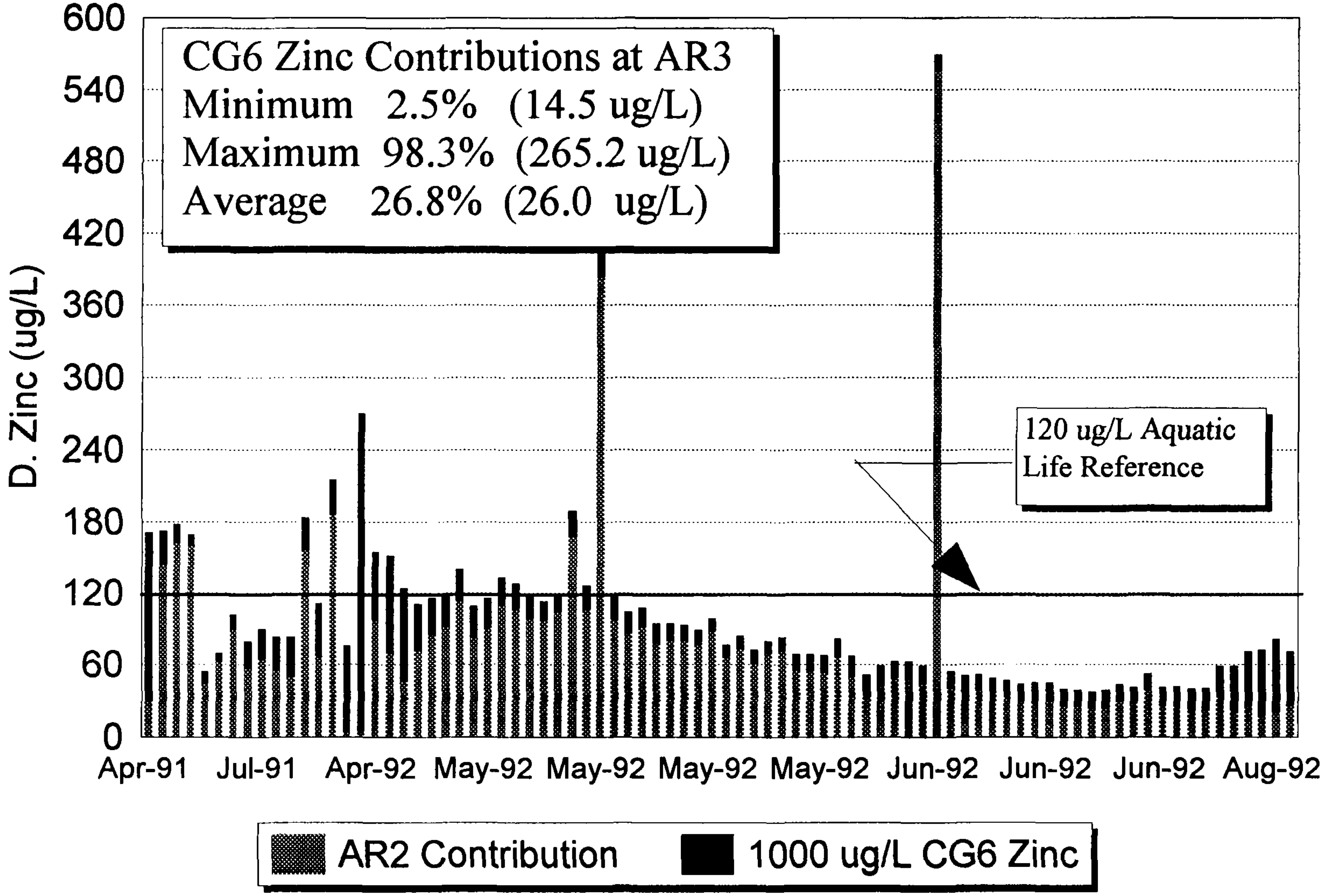
Author	Approach	Result (Dzn)	Location
USGS 1979	Analytical	13 mg/L	Leadville Area Carbonate Ore
Hydrometrics, Inc. 1987		10 mg/L	Leadville Area Carbonate Ore
Hydrometrics, Inc. 1987		67 mg/L	Leadvill Area Sulfide Ore
Runnells, 1988	Analytical and Analog	1 to 70 mg/L	California Gulch
Woodward and Clyde SWRI 1993	Analog	0.15 to 1.35 mg/L	California Gulch
USGS 1994 (Miller and McHugh)	Analog	> 1.0 mg/L	Summitville Area
Colorado Geol. Survey (Kirkham et al, 1995)	Direct	1% Dzn in Alamosa River is Mining Related about Wightmon Fork	Summitville Area

TABLE 6-2
CONCENTRATION AND FLOW DATA SUMMARY
SITE SURFACE WATERS 1991-1992

Station	Dissolved Zinc Concentration (ug/L)			Flow (cfs)		
	Min	Max	Ave	Min	Max	Ave
CG-6	35	33,500	9,160	1.09	2.74	1.74
AR-2	< 10	157	52	11	298	102
AR-3	13	376	183	6	289	99.5



CLIENT/PROJECT							TITLE		
ASARCO SURFACE WATER RI REPORT			Golder Associates Denver, Colorado				ZINC CONCENTRATIONS AND FLOW IN CALIFORNIA GULCH		
DRAWN AM	CHECKED	REVIEWED	DATE MAY 1996	SCALE N/A	FILE NO. 2819A214		JOB NO. 943-2819	DWG NO./REV.NO.	FIGURE 6-1



CLIENT/PROJECT

ASARCO
SURFACE WATER RI REPORT

Golder Associates
Denver, Colorado

TITLE

PREDICTED ZINC CONCENTRATIONS
IN THE ARKANSAS RIVER
BELOW CALIFORNIA GULCH

DRAWN AM	CHECKED	REVIEWED	DATE MAY 1996	SCALE N/A	FILE NO. 2819A213	JOB NO. 943-2819	DWG NO./REV.NO.	FIGURE 6-2

Section 7

7.0 SUMMARY AND CONCLUSIONS

This section summarizes the findings of the surface water Remedial Investigation and presents conclusions based on analysis of the findings. The nature and extent of metals loading, chemical fate and transport are summarized below.

7.1 Nature and Extent of Metals Loading

The nature and extent of contamination was evaluated using chemical data collected as part of the Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Workplan (Res-Asarco, 1991a). Analysis of these data indicates that California Gulch surface water contributes iron, lead, manganese, and zinc to the Arkansas River. Sediments in California Gulch, California Gulch tributaries, the Arkansas River, and Arkansas River tributaries contain aluminum, arsenic, cadmium, copper, iron, lead, manganese, and zinc.

California Gulch contributed total metals to the Arkansas River surface water during a Winter sampling event, which was during a period of relatively low flow. During the higher Spring flow event, loading of total metals from California Gulch to the Arkansas River did not appear to be significant. However, during summer storms, particularly a September 11, 1991 storm, California Gulch contributed to metals loadings in the Arkansas River.

7.2 Sources, Fate and Transport

Metals concentrations and movement within the system vary seasonally. Source areas with the greatest potential for increasing metals content in California Gulch appear to be Stray Horse Gulch/Starr ditch and Oregon Gulch. Other potential point source areas identified In the Tailings and Mine Waste RI include Colorado Zinc Lead Tailings, Fluvial Tailings Site No. 2, Fluvial Tailings Site No. 3, Fluvial Tailings Site No. 4, Fluvial Tailings Site No. 6 and Fluvial Tailings Site No. 8.

The primary mode of metals transport within the California Gulch surface water system is by metals adsorbed onto or attaching to sediment suspended in the water column and/or bed material. However, some seasonal variations in dissolved concentrations occurred, apparently as a result of generally or locally depressed pH values.

Groundwater and surface water interactions (gaining and losing stream reaches) are complex and some reaches vary seasonally. It is possible that the surface water interaction with groundwater is effecting the water quality of the two systems. Further discussion of this interaction is presented in the Hydrogeologic RI report.

7.3 Risk Assessment

The results of the risk assessment evaluation for human exposure to metals in fish fillets are presented under separate cover.

7.4 Recommended Remedial Action Objectives for Feasibility Study

Based on the findings of the Surface Water RI, it appears that metals enter the surface water at the California Gulch from many sources. Loading is high during periods of storm runoff suggesting that erosional processes contribute to elevated concentrations of metals in California Gulch and the Arkansas River. Remedial action objectives should address metals loading by control of erosional processes and runoff.

Section 8

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Appendix A

APPENDIX A

TECHNICAL MEMORANDA REGARDING SAMPLING

APPENDIX A.1

ICE-OFF,
1991 SAMPLING EVENT

TO: Gary Slifka
Res-ASARCO

FROM: Michelle Rehmann
Woodward-Clyde
OFFICE: Denver

DATE: May 15, 1991

Re: Samples collected during the week of April 29 to May 3, 1991
Project No. 22443E (Task 3100)

This listing is a compilation of field note information and chain-of-custody records concerning this sampling event:

Monday, 4/29/91

GW, DH TEAM

AR-1	W-AR01W-01-910429	Water Sample
	W-AR01T-01-910429	Toxicity
	W-AR01W-02-910429	Duplicate Sample
	W-AR01S-01-910429	Sediment
AR-2	W-AR02W-01-910429	Water Sample
	W-AR02T-01-910429	Toxicity
	W-AR02S-01-910429	Sediment

DN, JC TEAM

IG-1	W-IG01W-01-910429	Water Sample
	W-IG01S-01-910429	Sediment
EM-1	W-EM01W-01-910429	Water Sample
	W-EM01S-01-910429	Sediment
	W-EM01W-MS-910429	Matrix Spike-20 bottles
	W-EM01S-MS-910429	Sediment MS-4 bottles
	W-IG01W-01-910429	Toxicity
	W-EM01W-01-910429	Toxicity
	W-EM01W-MS-910429	Toxicity MS-4 containers

Tuesday, 4/30/91

JAC, DN TEAM
MS and Field Blank

HC1	W-HC01W-01-910430	Water
	W-HC01W-MS-910430	MS & dupe
	NO MS on Sediments	No MS on sed?
	W-HC01S-01-910430	Sediment
	W-EM02S-01-910430	Sediment
	W-EM02S-MS-910430	Sed MS

Wednesday, 5/1/91

DH, GW TEAM

AR03 and AR04	W-AR03W-01-910430	Water
	W-AR03W-01-910430	Water
	W-AR03S-01-910430	Sed.
	W-AR03S-01-910430	Sed.
	W-AR03T-01-910430	Tox.
	W-AR0tW-01-910430	Water
	W-AR04S-01-910430	Sed.
	W-OR04T-01-910430	Tox.
ARO5	W-AR05W-01-910430	
	W-AR05S-01-910430	
	W-AR03T-02-910430	
	W-AR04T-01-910430	

GW, DH TEAM

EF01	W-EF01W-01-910501	Water
	W-EF01S-01-910501	Sediment
	W-EF02S-01-910501	Sediment
EF02	W-EF02W-01-910501	Water
	W-EF02W-04-910501	Water Rinsate
	W-EF02S-04-910501	Sed. Rinsate
	W-EF02T-01-910501	Toxicity
CG01	W-CG01W-01-910501	Water
	W-CG01T-01-910501	Toxicity
	W-CG01S-01-910501	Sediment

<u>DN, JC TEAM</u>		
TC01	W-TC01W-01-910501	Water
	W-TC01S-01-910501	Sediment
	W-TC01W-02-910501	Water Duplicate
	W-TC01S-02-910501	Sediment Duplicate
	W-TC01T-01-910501	Toxicity
LF01	W-LF01W-01-910501	Water
	W-LF01W-MS-910501	MS & Water Duplicate
	W-LF01W-03-910501	Field Blank
	W-LF01S-01-910501	Water
	W-LF01S-MS-910501	MS & Duplicate Sed.
	W-LF01S-03-910501	Sed. Field Blank
	W-LF01T-01-910501	Toxicity
MG01	W-MG01W-01-910501	Water
	W-MG01S-01-910501	Sediment

Thursday, 5/2/91

GW, DHH TEAM		
CG-2	W-CG02W-01-910502	Water
	W-CG02W-MS-910502	Matrix Spike-Water
	W-CG02T-01-910502	Toxicity
	W-CG02S-01-910502	Sediment
	W-CG02S-MS-910502	Matrix Spike-Seds.
PG-1	W-PG01W-01-910502	Water
	W-PG01W-03-910502	Field Blank
	W-PG01S-01-910502	Sediment
GG-1	W-GG01W-01-910502	Water
	W-GG01S-01-910502	Sediment
OG-1	W-OG01W-01-910502	Water
	W-OG01S-01-910502	Sediment
JC, DKN TEAM		
AG-1	W-AG01S-01-910502	Sediment
	W-AG01S-02-910502	Sediment Duplicate
	W-AG01W-01-910502	Water
	W-AG01W-02-910502	Duplicate Water
CG-3	W-CG03W-01-910502	Water
	W-CG03S-01-910502	Sediment
SD-1	W-SD01W-01-910502	Water
	W-SD01S-01-910502	Sediment
SHG-1	W-SG01W-01-910502	Water
	W-SG015-01-9105021	Sediment

Friday, 5/3/91

GJW, DHH TEAM

CG-4	W-CG04W-01-910503	Water
	W-CG04S-01-910503	Sediment
	W-CG04T-01-910503	
CG-5	W-CG05W-01-910503	Water
	W-CG05T-01-910503	Toxicity
	W-CG05W-02-910503	Water - Duplicate
	W-CG05T-02-910503	Toxicity - Duplicate
	W-CG05W-MS-910503	Matrix Spike-Water
AR-3	W-AR03S-01-910503	Sediment
	W-AR03S-02-910503	Sediment - Duplicate

JAK, DKN TEAM

EM-3	W-EM03W-01-910503	Water
	W-EM03W-03-910503	Field Blank
	W-EM03S-01-910503	Sediment
	W-EM03T-01-910503	
CG-6	W-CG06W-01-910503	Water
	W-CG06S-01-910503	Sediment
	W-CG-6S-MS-910503	Matrix Spike Sediment
	W-CG06T-01-910503	Toxicity

APPENDIX A.2

SPRING,
1991 SAMPLING EVENT

WATER
WASTE
& LAND
INC.

2629 Redwing Rd. Suite 200, Fort Collins, Colorado 80526
(303) 226-3535
fax (303) 226-6475

June 21, 1991

WWL #102

Mr. Gary Slifka
Project Chemist
ASARCO Incorporated
1019 Eighth Street, Suite 304
Golden, CO 80401

RE: California Gulch CERCLA Site, Leadville, CO
June 1991 Surface Water Sampling Episode

Dear Gary,

Included with this letter are the documents pertaining to the surface water site investigation which took place in the Leadville area during the time period from June 11 to June 13, 1991. The sampling field work was performed by Water, Waste and Land, Inc. (WWL) on behalf of ASARCO. WWL personnel were accompanied during the sampling by employess of Roy F. Weston Inc., who provided oversite for the EPA.

Table 1 presents a summary of the field data collected, including discharge measurements and field parameter measurements. A list of all water quality samples and QA/QC samples collected by WWL, and split samples collected by Weston from each sample location is included in Table 2. Table 3 presents the bottle filling order agreed upon with Weston. The bottle filling order is dependant upon the number of chemical analysis samples and QA/QC samples to be collected by WWL and Weston at a sample location. It covers each situation encountered during the June 1991 sampling episode, and should be utilized by field personnel during future sampling events.

A list of field equipment and supplies to be purchased prior to the sampling event in August 1991 is provided in Table 4. The field equipment listed was provided by WWL during the June event. The quantities listed for field supplies are minimum quantities required for one sampling event.

It should be noted that backup pH, EC and DO meters as well as a second Marsh-McBirney velocity meter and portable adjustable cutthroat flume will be provided by WWL. If WWL's Marsh Mc-Birney meter is not available, one will be rented.

Repairs are required on the cigarette lighter DC power cords for the two peristaltic pumps. Repairs can be made by WWL personnel prior to the next sampling event.

We have specified that tygon tubing rather than silicone tubing be used for future sampling events. Tygon is about half the cost of silicone tubing, and our experience indicates it does not effect the water quality of the samples. Literature states that metallic contamination (i.e. iron and zinc) from silicone tubing can be a problem at the ppb level. This may not be a problem with the short contact time involved.

Attachment A contains the original field data sheets and copies of the field notebooks containing the information recorded by the WWL personnel during the surface water site investigation. Attachment B provides the calibration documentation for the two Marsh-McBirney velocity meters, one a rental from Flow Instrumentation and Consulting Service, Englewood, Colorado and the other owned by WWL, used during the June 1991 sampling episode. It shows that both meters are in good working order and well within factory specifications. The attachments are included in a notebook for easy reference.

Labeled photographs and the negatives from the June sampling episode will be sent to you as soon as they are complete. We are sending copies of the field data sheets and field notebooks to Don Polla of ASARCO under separate cover. Signed site access agreement forms from the Denver and Rio Grande Railroad were given to Don Polla after the site visit to MG01.

If you have any questions or comments on the information submitted please give me or Sherm Worthington a call.

Sincerely,

WATER, WASTE & LAND, INC.

Phil Leonhardt

Phil Leonhardt
Project Engineer
Environmental Division

Attachments

TABLE 3
SAMPLE BOTTLE FILLING ORDER FOR WATER QUALITY SAMPLING

Churn	Analysis	Total Number of Bottles	Total Volume (liter)	Filter	ASARCO Samples	EPA Samples
ASARCO Sample Only						
A	Total Metals	1	250	No	X	
	Total CN	1	500	No	X	
	NO_2, NO_3	1	500	No	X	
	pH, TSS	1	500	No	X	
		Subtotal	1,750			
	Diss. Metals	1	250	Yes	X	
	DOC	1	250	Yes	X	
	Diss. Anions	1	500	Yes	X	
		TOTAL	2,750			
ASARCO Sample, Duplicate Sample & Spike Sample						
A	Total Metals	3	750	No	X	
	Total CN	3	1,500	No	X	
	NO_2, NO_3	3	1,500	No	X	
		Subtotal	3,750			
	Diss. Metals	3	750	Yes	X	
	Diss. Anions	3	1,500	Yes	X	
		TOTAL	6,000			
B	pH, TSS	3	1,500	No	X	
		Subtotal	1,500			
	DOC	3	750	Yes	X	
		TOTAL	2,250			
ASARCO Sample; EPA Split						
A	Total Metals	1	250	No	X	
		1	1,000	No		X
	Total CN	1	500	No	X	
		1	1,000	No		X
	Total Anions	2	2,000	No		X
		Subtotal	4,750			
	Diss. Metals	1	250	Yes	X	
		1	1,000	Yes		X
	Diss. Anions	1	500	Yes	X	
		TOTAL	6,500			

TABLE 3 (cont.)
SAMPLE BOTTLE FILLING ORDER
FOR WATER QUALITY SAMPLING

Churn	Analysis	Total Number of Bottles	Total Volume (liter)	Filter	ASARCO Samples	EPA Samples
ASARCO Sample; EPA Split (Cont.)						
B	NO_2, NO_3	1	500	No	X	
		2	2,000	No		X
	pH, TSS	1	500	No	X	
		Subtotal	3,000			
	DOC	1	250	Yes	X	
		TOTAL	3,250			
ASARCO Sample; EPA Split & Duplicate						
A	Total Metals	1	250	No	X	
		2	2,000	No		X
	Total CN	1	500	No	X	
		2	2,000	No		X
		Subtotal	4,750			
	Diss. Metals	1	250	Yes	X	
		2	2,000	Yes		X
		TOTAL	7,000			
B	NO_2, NO_3	1	500	No	X	
		4	4,000	No		X
		Subtotal	4,500			
	DOC	1	250	Yes	X	
		TOTAL	4,750			
C	Total Anions	4	4,000	No		X
	pH, TSS	1	500	No	X	
		Subtotal	4,500			
	Diss. Anions	1	500	Yes	X	
		TOTAL	5,000			

TABLE 3 (cont.)
SAMPLE BOTTLE FILLING ORDER
FOR WATER QUALITY SAMPLING

Churn	Analysis	Total Number of Bottles	Total Volume (liter)	Filter	ASARCO Samples	EPA Samples
ASARCO Sample; EPA Sample, MS & MSD						
A	Total Metals	1	250	No	X	
		3	3,000	No		X
		Subtotal	3,250			
	Diss. Metals	1	250	Yes	X	
		3	3,000	Yes		X
		TOTAL	6,500			
B	Total CN	1	500	No	X	
		3	3,000	No		X
		TOTAL	3,500			
C	Total Anions	2	2,000	No		X
	NO_2, NO_3	1	500	No	X	
		2	2,000	No		X
	pH, TSS	1	500	No	X	
		Subtotal	5,000			
	DOC	1	250	Yes	X	
	Diss. Anions	1	500	Yes	X	
		TOTAL	5,750			

TABLE 4
ADDITIONAL FIELD EQUIPMENT AND FIELD SUPPLIES REQUIRED FOR SURFACE WATER SAMPLING EPISODES

Equipment/Material	Quantity Required	Item No.	Cost/ Item	Vender
Water Quality Equipment				
Beckman ϕ11 pH Meter ✓	2 ea			
Field Altimeter	2 ea			
Spare pH Probe	1 ea			
Spare EC Probe	1 ea			
500 ml Wide-mouth LDPE Wash Bottle	6 ea			
Quick Release Peristaltic Pump Heads	2 ea			
Stream Gaging Equipment				
—Marsh-McBirney Velocity Meter	1 ea			
Wading Staff Gage for Velocity Meter (top setting), 5 foot length	2 ea*			
Fiberglass Measuring Tape (200 ft)	1 ea			
1-Liter HDPE Wide-mouth Bottle	2 ea			
1-Gallon HDPE Wide-mouth Bottle	2 ea			
2-inch PVC pipe (3 feet length)	2 ea			
Portable Adjustable Cutthroat Flume (2-inch/8-inch width)	1 ea			
Level for use with Flume	1 ea			
Shovel	2 ea			
Miscellaneous Field Supplies				
Conductivity Standard,10,000 µmhos/cm	1 gal			
Disposable Gloves (medium/large)	2 bx			
Tubing, Tygon 0.19 in. ID, 3/8 in. OD, thick walled	300 ft			
Tubing, Tygon 3/8 in. ID, to make connections with filters	10 ft			
Extra NaOH preservative	? ?			
ill Kim Wipes	2 bx			
[illegible] —First Aid Kit	2 ea			
Waterproof Ultra Fine Point Marker	1 bx			

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* Possibly trade two wading rods that are for use with the Price and Pygmy velocity meters for the Marsh McBirney top setting wading rods.

APPENDIX A.3

SUMMER,
1991 SAMPLING EVENT

WATER
WASTE
& LAND
INC.

2629 Redwing Rd. Suite 200, Fort Collins, Colorado 80526
(303) 226-3535
fax (303) 226-6475

August 20, 1991 WWL #102

Mr. Gary Slifka
Project Chemist
ASARCO Incorporated
1019 Eighth Street, Suite 304
Golden, CO 80401

RE: California Gulch CERCLA Site, Leadville, CO
July 1991 Surface Water Sampling Episode

Dear Gary:

Included with this letter are two copies of the documents pertaining to the surface water site investigation which took place in the Leadville area during the week of July 22, 1991. The sampling field work was performed by Water, Waste and Land, Inc. (WWL) on behalf of ASARCO. WWL personnel were accompanied during the sampling by employees of Roy F. Weston Inc., who provided oversite for the EPA.

Contained in this letter are two tables. Table 1 presents a summary of the field data collected during the July sampling event, including discharge measurements and field parameter measurements. Table 2 contains a list of all water quality samples and Quality Assurance/Quality Control (QA/QC) samples collected by WWL, and duplicate samples collected by Weston from each sample location.

Detailed field notes pertaining to the sampling event are included as attachments organized in a notebook for easy reference. The first attachment contains the surface water data collection field notes. The sediment sample field data sheets are contained in the second attachment. The third attachment includes copies of the field notebooks containing the information recorded by the WWL personnel during the surface water site investigation. The fourth attachment provides the equipment calibration documentation for the two Marsh-McBirney velocity meters used during the July 1991 sampling episode, one a rental from Flow Instrumentation & Consulting Services, Inc., Englewood, Colorado and the other owned by WWL. It also contains the original daily master calibration control sheets for the field parameter instruments (pH, EC and DO). Labeled photographs and the negatives from the July sampling episode are included in the final attachment of the notebook containing the original surface water data collection field notes only.

Water quality and sediment samples were collected, and surface water data collection field notes and discharge measurements were completed for sampling locations AR01 and TC01 on both 7/23/91 and 7/25/91. The locations were sampled the second time on 7/25/91 at the request of ASARCO personnel.

We are sending copies of the field data sheets and field notebooks to Don Polla of ASARCO under separate cover. Signed site access agreement forms from the Denver and Rio Grande Railroad for sample location MG01 are at the end of the Surface Water Notes Attachment.

If you have any questions or comments on the information submitted please give me or Sherm Worthington a call.

Sincerely,

WATER, WASTE & LAND, INC.

Phil Leonhardt

Phil Leonhardt, P.E.
Project Engineer
Environmental Division

Attachments

APPENDIX A.4

SUMMER STORMS,
1991 SAMPLING EVENT

WATER
WASTE
& LAND
INC.

2629 Redwing Rd. Suite 200, Fort Collins, Colorado 80526
(303) 226-3535
fax (303) 226-6475

DUPLICATE

ASARCO INC.
California Gulch CERCLA Site

SEP 11 1991

RECEIVED

WWE #102

September 9, 1991

Mr. Gary Slifka
Project Chemist
ASARCO Incorporated
1019 Eighth Street, Suite 304
Golden, CO 80401

RE: California Gulch CERCLA Site, Leadville, CO
August 1991 Surface Water Field Work

Dear Gary:

Included with this letter are two copies of the documents pertaining to the surface water field work performed in the Leadville area during August 1991 by Water, Waste & Land, Inc. (WWL) on behalf of ASARCO. The field work pertained to the ongoing surface water sampling program, according to Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Workplan, California Gulch Site, Leadville, Colorado, (the Workplan), Woodward-Clyde, June 1991.

The field work performed in August was: 1) Installation of automatic water sampling equipment at stations AR3A, AR3E, AR02 and CG06; 2) Measurement of stream flow at all sample locations according to the monthly schedule presented in the Workplan; 3) Additional measurement of stream flows at the stations where automatic sampling equipment was installed; and 4) Installation and survey of staff gages at appropriate sample stations. Automatic sampling equipment was installed according to Minimum Requirements for a Storm Event Sampling Program for Surface Water at the California Gulch Site, (letter by Denise Link, EPA to Gary Slifka, ASARCO, July 26, 1991.)

Included with this letter are three tables. Table 1 contains a summary of the sampling station locations. Table 2 presents a list of all staff gage readings and discharge measurements performed at the site under the current program through August 1991. Table 3 contains the results of a staff gage survey. The purpose of the staff gage survey is to allow the replacement of staff gages at the proper location and elevation if a gage is washed out during the course of the study. As shown on Table 3 staff gages in low-flow locations were not surveyed.

Detailed field notes pertaining to the field work are included as attachments organized in a notebook for easy reference. The first attachment contains the discharge measurement field notes. The second attachment includes copies of the field notebooks containing the information recorded by the WWL personnel during the field work. Also contained in the second attachment are equipment calibration documentation for the Marsh-McBirney velocity meter used during the August 1991 field work and signed site access agreement forms from the Denver and Rio Grande Railroad for sample location MG01.

If you have any questions or comments on the information submitted please give me or Sherm Worthington a call.

Sincerely,

WATER, WASTE & LAND, INC.

Phil Leonhardt

Phil Leonhardt, P.E.
Project Engineer
Environmental Division

Attachments

cc: Don Polla

MEMORANDUM

To: Gary Slifka, ASARCO

From: Phil Leonhardt, Water, Waste & Land, Inc.

Date: October 29, 1992

Subject: 1991 Storm Event Sampling

We have received a request from John Sikora of Woodward Clyde Corporation (WCC) for information on the 1991 storm sampling program. The enclosed letter to Ms. Denise Link of the EPA, from Glenn Anderson of ASARCO dated September 11, 1991, describes the storm sampling conducted in August and September, 1991 using ISCO automatic samplers. Also enclosed is a copy of a memorandum from yourself to Don Polis dated August 19, 1991 describing sample numbering and QA/QC requirements. John also requested copies of the chain of custody forms from the three sampling events. Please forward this information and a copy of this memorandum, which provides a brief summary of the storm sampling program, to John Sikora of WCC.

Four ISCO automatic samplers were installed in August 1991 to monitor chemical loading of metals to the Arkansas River from California Gulch during storm events. The ISCO automatic sampling equipment was installed by personnel of Water, Waste & Land, Inc. Maintenance of the samplers and sample collection from the automated equipment was performed by personnel of ASARCO.

Three storm events, occurring on August 24, August 30 and September 11, 1991, were sampled with the automated equipment. Samples were collected at 30 minute intervals. Each ISCO sampler contained 24, 1000 ml, polypropylene sample bottles. During the August 24 storm event, six bottles were filled at each 30 minute interval resulting in four sample sets spanning 90 minutes. Laboratory parameters analyzed were total metals, total suspended solids and acute toxicity.

Following the August 24 storm event it was determined that the 90 minute sampling period was not adequate to characterize the runoff from a storm event occurring in the area of the Surge Pond. The samplers were re-programmed, and during the August 30 and September 11 storm events, two bottles were filled at each 30 minute interval resulting in 12 sample sets spanning 5.5 hours. Acute toxicity was dropped from the analyte list for the August 30 and September 11 sampling event.

#102 file

ASARCO

Leadville Unit

Michael G. Lee
Unit Manager

September 11, 1991

Ms. Denise Link
EPA Remedial Project Manager
Hazardous Waste Management Division
EPA Region VIII
999 18th Street, Suite 500
Denver, CO 80202-2405

RE: California Gulch CERCLA Site, Leadville, CO
Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Work Plan, California Gulch Site, Leadville, Colorado

Dear Ms. Link:

The purpose of this letter is to submit an addendum for a storm event sampling program for surface water at the California Gulch Site. The storm event sampling program will be incorporated into the ongoing Surface Water Sampling program as described in the Surface Water, Bed Material and Aquatic Ecosystem Data Collection Program Work Plan, California Gulch Site, Leadville, Colorado (Work Plan).

The storm event sampling program has been designed to conform to EPA Draft Minimum Requirements For A Storm Event Sampling Program For Surface Water at the California Gulch Site, July 26, 1991.

Purpose
As stated in the Minimum Requirements, the storm event sampling program is designed to determine the chemical loading of metals to the Arkansas River from the California Gulch during storm event. Water samples will be collected at 30 minute intervals by automatic water sampling equipment after actuation by a precipitation gage located near the suspected sources of storm-caused metal loading to the system. Analysis of storm precipitation data, the storm runoff hydrograph in California Gulch and the sample collection times will be required to ensure that sampled water was storm runoff and that water samples were collected that bracket the peak of the storm runoff hydrograph from California Gulch. If these conditions are not met the sample collection times or analysis parameters will be adjusted to ensure sample collection at appropriate times. If necessary, during subsequent sampling events analysis of acute toxicity may be eliminated to provide more

frequent sample intervals and a longer total period of sampling. This is due to the relatively large sample volume required (two gallon) for acute toxicity testing.

Based on the chemical analysis of the storm runoff water and flow data, an estimate of the peak and average metal loading values caused by storm runoff will be calculated. These storm produced loading values will be compared with appropriate metal loading values calculated from data representative of flows in the Arkansas River and California Gulch to the Arkansas River due to storm events will be calculated.

Sample Locations
Automatic water sampling and water level measuring equipment will be installed at the following locations:

CG06	California Gulch at the Parshall flume above the confluence with the Arkansas River.
AR02	Arkansas River approximately 150 feet upstream of California Gulch,
AR3E	East bank of the Arkansas River approximately 375 feet downstream of California Gulch,
AR3A	Arkansas River approximately one-half mile downstream of California Gulch and above the confluence with Lake Fork.

Equipment and Installation
The major components to be used in the Storm Event Program will be ISCO 3700 Automatic Samplers , ISCO 3230 Flow Meters and radio receivers installed at each sampler and one radio transmitter installed at the meteorologic station maintained by ASARCO at the Surge Pond in California Gulch. Electrical power will be supplied by 12 V batteries at each sample location. Equipment will be housed in a plywood shelter located adjacent to the channel. Tubing running from the sampler and the flow meter to the water will be contained in PVC conduit. Equipment mounted in the channel will be fastened to steel fence posts driven into the stream bed.

Sample water intake is through a length of thin-walled stainless-steel tubing set in the channel horizontally, with the inlet pointed upstream. The stainless-steel tube is attached to three-eighths inch I.D. vinyl tubing ranging in length from 20 to 30 feet depending on sampler location. The vinyl tubing is attached to silicon tubing running through a peristaltic pump at the sampler. Inlet elevation of the stainless steel tube from the stream bed was set at four-tenths of the total depth at the time of installation. Total depth will be monitored and sampler inlet elevation may be adjusted if necessary. The three AR stations will be sampled from a point in the channel approximately eight to ten feet from the East bank. At CG06 the sampler inlet is positioned just downstream of the flume outlet, approximately centered. At each of the stations the sampler inlet location is approximately representative of typical flow conditions at that cross-section.

Flow Measurement
The flow meter uses the bubble method of stage measurement. One-eighth inch O.D. vinyl tubing transmits the bubble from the meter to the channel. At the AR stations the bubble tubing outlet is positioned in the channel just downstream of the sampler inlet and fastened in a stilling well, consisting of perforated PVC. A continuous stage record will be recorded on strip chart and on electronic data base. Flow at the AR stations will be computed from a stage-discharge relationship which will be developed during the course of the study. At CG06 an existing Parshall flume will be used in conjunction with the stage data to be collected. The bubble outlet is positioned directly opposite the stage gage in the flume at CG06.

Sample Collection
The samplers will be automatically activated by radio signal originating from software connected to the rain gage at the meteorologic station at the Surge Pond when a storm event resulting in a minimum of 0.1 inches of continuous rain is recorded. To facilitate computer programming for automatic sampler actuation the storm event will be defined as 0.1 inch of rain within a three hour period. Each ISCO Sampler contains 24, specially designed, one-liter bottles. Currently, the automatic sampler is programed to collect a sample set at sampling activation and at the end of three, 0.5 hour intervals. Based on the analysis parameters, a sample set will consist of six, one-liter bottles.

After the four sample sets from each of the four samplers have been automatically filled, the 16 sets of water samples will be dispensed into the appropriate laboratory-supplied bottles with pre-dispensed preservation where necessary. Decontaminated sampler bottles will then be replaced in the sampler and the system will be prepared to sample again. The stage and sample collection record on the flow meter strip charts will be examined and stage data will be down-loaded from the flow meters and compared with the precipitation data to determine the appropriateness of the sample collection times.

Sampler inlet tubing is automatically rinsed with stream water three times prior to collecting each sample set. One-liter ISCO bottles have been dedicated to each sampler to eliminate cross contamination between sample locations. Decontamination of the ISCO bottles will consist of a dilute nitric acid rinse followed by two rinses with deionized water.

Analysis Parameters
Laboratory parameters analyzed will consist of the total concentrations of: arsenic, cadmium, calcium, copper, iron, lead, magnesium, manganese, silver, zinc; total suspended solids and acute toxicity. Field parameters measured will consist of pH and electrical conductivity from each of the 16 sample sets. Detection limits, sample volumes, EPA laboratory analysis methods, QC Sampling, and sample holding times are specified in the Work Plan. Due to the limitations of the automatic sampler a composite of the first and second, third and forth sample sets of will be used for the acute toxicity samples.

Sampler Maintenance
Each of the four automatic sampler stations will be inspected periodically for proper operation. At a minimum, daily inspection of the precipitation record produced at the meteorologic stationis required to determine if a storm event has occurred.

Weekly inspection will consist of:

- checking all tubing, wiring and hardware for proper positioning and connection;
- filling one sample bottle with the automatic sampler through the tubing to ensure that the tubing is not plugged and to check equipment operation and sample volume;
- check flow meter strip chart and ribbon;
- check flow meter stage record, compare with staff gage reading and adjust flow meter stage reading if necessary.

In addition to the weekly inspection, batteries will be changed every two weeks or after two sampling episodes have occurred.

Schedule of Operation
To date, two storm events have been sampled. The dates being on August 24, 1991 and August 31, 1991 respectively.

After the first event the samplers were reprogrammed to collect twelve sets of two samples. One being for total metals and the other for total suspended solids (TSS). This change was confirmed with Denise Link on August 28, 1991.

Should you have any questions regarding this matter please contact me at (303) 279-2646.

Sincerely,

Glenn L. Anderson
Environmental Superintendent

GLA/pl
(3 copies sent)

lc: Mr. Ken Wangerud; EPA
Mr. Russ Allen; CDH
Ms. Mary Capdeville; Colorado Department of Law
Mr. Jeff Lewis; ASARCO Incorporated, Golden, CO
Ms. Janet Campbell; Roy F. Weston
Mr. Earl Madsen; Badley, Campbell, Carney, Madsen
Mr. John Shepherd; Holland & Hart
Mr. Ron Eddy; Sherman & Howard
Mr. Mac Deguire; Resurrection Mining
Mr. Alan Tapp; Resurrection Mining
Mr. M.G. Lee; ASARCO Incorporated, Leadville CO
Mr. Larry Drew; HECLA
Ms. Kathleen Snead; Denver & Rio Grande Western
Ms. Betsy Temkin; Davis, Graham & Stubbs
Ms. Charlotte Neitzel; Holme, Robert & Owens
Mr. Sherman Worthington; Water, Waste & Land
Mr. Verle Martz; Woodward Clyde Consultants
Central File

102

MEMORANDUM

TO: Don Polla

FROM: Gary A. Slifka

DATE: August 19, 1991

SUBJECT: Storm Water Sampling Program

The ISCO Automatic Samplers will collect a set of six sample containers every half hour up to four sets. Each set of six samples shall to be assigned a specific sample identification and will be identified as such on the sample label and Chain of Custody. The Automatic Samplers themselves are numbered according to their location as follows:

LOCATION	UNIT IDENTIFICATION
California Gulch at the confluence	CG06
Arkansas River above the confluence	AR02
Arkansas River below the confluence	AR3E
Arkansas River past mixing zone (below)	AR3A

The following is a list of sample ID's that can be used to record each sample:

UNIT IDENTIFICATION	IDENTIFIER
CG06	R-CG06W1-01-YYMMDD
	2
	3
	4
AR02	R-AR02W1-01-YYMMDD
	2
	3
	4
AR3E	R-AR3EW1-01-YYMMDD
	2
	3
	4
AR3A	R-AR3AW1-01-YYMMDD
	2
	3
	4

The field consisting of 1,2,3,4 in the ID stands for the time interval in which the sample is cut (i.e. 1 stands for time = 0 hours, 2 stands for time = 0.5 hours, etc.).

For each set of six samples (four per automatic sampler) use the following list of sample containers and their appropriate volumes for QA/QC.

1. -Composite four bottles into a 1-gallon container for TOXICITY TESTING.

TOTAL VOLUME 4000ml

2. -Use one bottle for:
   A). TOTAL METALS PRIMARY-01 250ml.
   B). TOTAL METALS DUPLICATE-02 250ml.
   * C). TOTAL METALS MATRIX SPIKE/DUPLICATE-MS 250ml.
   D). FIELD PARAMETERS; temperature,pH,EC, and DO 250ml.

TOTAL VOLUME 1000ml

3. -Use one bottle for:
   A). TOTAL SUSPENDED SOLIDS PRIMARY-01 500ml.
   * B). TOTAL SUSPENDED SOLIDS DUPLICATE-02 500ml.

TOTAL VOLUME 1000ml

* NOTE: ONLY ONE STATION REQUIRES A DUPLICATE AND MATRIX SPIKE IS REQUIRED. THE OTHER STATIONS DO NOT REQUIRE SUCH SAMPLING.

1C: Glenn L. Anderson, ASARCO
Phil Leonhardt, WWL
File

APPENDIX A.5

FALL,
1991 SAMPLING EVENT

WATER
WASTE
& LAND
INC.

2629 Redwing Rd. Suite 200, Fort Collins, Colorado 80526
(303) 226-3535
fax (303) 226-6475

October 2, 1991 WWL #102

Mr. Gary Slifka
Project Chemist
ASARCO Incorporated
1019 Eighth Street, Suite 304
Golden, CO 80401

RE: California Gulch CERCLA Site, Leadville, CO
September 1991 Surface Water Sampling Episode

Dear Gary:

Included with this letter are two copies of the documents pertaining to the surface water site investigation which took place in the Leadville area during the week of September 16, 1991. The sampling field work was performed by Water, Waste and Land, Inc. (WWL) on behalf of ASARCO. WWL personnel were accompanied during the sampling by employees of Roy F. Weston Inc., who provided oversite for the EPA.

Contained in this letter are two tables. Table 1 presents a summary of the field data collected during the September sampling event, including discharge measurements and field parameter measurements. Table 2 contains a list of all water quality samples and Quality Assurance/Quality Control (QA/QC) samples collected by WWL, and duplicate samples collected by Weston from each sample location.

Detailed field notes pertaining to the sampling event are included as attachments organized in a notebook for easy reference. The first attachment contains the surface water data collection field notes. The sediment sample field data sheets are contained in the second attachment. The third attachment includes copies of the field notebooks containing the information recorded by the WWL personnel during the surface water site investigation. The fourth attachment provides the equipment calibration documentation for the two Marsh-McBirney velocity meters used during the September 1991 sampling episode, one the property of ASARCO and the other owned by WWL. It also contains the original daily master calibration control sheets for the field parameter instruments (pH, EC and DO). Labeled photographs and the negatives from the September sampling episode are included in the final attachment of the notebook containing the original surface water data collection field notes only.

We are sending copies of the field data sheets and field notebooks to Don Polla of ASARCO. Signed site access agreement forms from the Denver and Rio Grande Railroad for sample location MG01 are at the end of the Surface Water Notes Attachment.

As requested by the EPA, sampled water was tested for the presence of sulfide using lead acetate test paper. The presence of sulfide was not indicated by the test paper in any of the sampled waters.

If you have any questions or comments on the information submitted please give me or Sherm Worthington a call.

Sincerely,

WATER, WASTE & LAND, INC.

Phil Leonhardt

Phil Leonhardt, P.E.
Project Engineer
Environmental Division

Attachments

cc: Don Polla

APPENDIX A.6

WINTER,
1991 SAMPLING EVENT

WATER
WASTE
& LAND
INC.

2629 Redwing Rd. Suite 200, Fort Collins, Colorado 80526
(303) 226-3535
fax (303) 226-6475

April 3, 1992

WWL #102

Mr. Gary Slifka
Project Chemist
ASARCO Incorporated
1019 Eighth Street, Suite 304
Golden, CO 80401

RE: California Gulch CERCLA Site, Leadville, CO
March 1992 Surface Water Sampling Episode

Dear Gary:

Included with this letter are two copies of the documents pertaining to the surface water site investigation which took place in the Leadville area during the week of March 22, 1992. The sampling field work was performed by Water, Waste and Land, Inc. (WWL) on behalf of ASARCO. WWL personnel were accompanied during the sampling on March 23 by Denise Link of the EPA. During the sampling on March 24 and 25 employees of Roy F. Weston Inc. provided oversite for the EPA.

Contained in this letter are two tables. Table 1 presents a summary of the field data collected during the March 1992 sampling event, including discharge measurements and field parameter measurements. Table 2 contains a list of all water quality samples and Quality Assurance/Quality Control (QA/QC) samples collected by WWL, and duplicate samples collected by Weston from each sample location.

Detailed field notes pertaining to the sampling event are included as attachments organized in a notebook for easy reference. The first attachment contains the surface water data collection field notes. The sediment sample field data sheets are contained in the second attachment. The third attachment includes copies of the field notebooks containing the information recorded by WWL personnel during the surface water site investigation. The fourth attachment provides the equipment calibration documentation for the two Marsh-McBirney velocity meters used during the March 1992 sampling episode, one the property of ASARCO and the other owned by WWL. It also contains the original daily master calibration control sheets for the field parameter instruments (pH, EC and DO). Labeled photographs from the March sampling episode are included in the final attachment of the notebook containing the original surface water data collection field notes only.

We are sending copies of the field data sheets and field notebooks to Don Polla of ASARCO. Signed site access agreement forms from the Denver and Rio Grande Railroad for sample location MG01 are at the end of the Surface Water Notes Attachment.

If you have any questions or comments on the information submitted please give me or Sherm Worthington a call.

Sincerely,

WATER, WASTE & LAND, INC.

Phil Leonhardt

Phil Leonhardt, P.E.
Project Engineer
Environmental Division

Attachments

cc: Don Polla